Trends in numbers of migrant birds at Long Point Bird Observatory (1961-2002)

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EXECUTIVE SUMMARY

In 2002, migration monitoring at Long Point Bird Observatory (LPBO) was carried out at three stations (Tip, Breakwater, Old Cut) on the following dates: Tip: 8 April-8 June, 12 August-11 November; Breakwater 21 April-3 June, 20 August-23 September; Old Cut: 1 April-9 June, 19 July-15 November. This represents the 42th consecutive year of coverage at LPBO.

Annual population indices, based upon migration counts, were computed with the same methods as in previous years, using multiple regression to reduce the variance in daily counts associated with variation in weather and time of the season. These annual indices were then used to estimate population trends with polynomial and linear regression methods. Graphs of annual indices and population trajectories for each species, along with tables of the long-term trends, are included in appendices.

During spring 2002, there was a higher percentage of species showing decreases relative to 2001 than there were increases. Fifty-two percent (33/64) of species declined and 48% (31/64) increased relative to 2001. In fall, the majority of species also had lower population indices in 2002 than in 2001. Seventy-eight percent (49/63) of fall migrants showed population declines relative to 2001, and only 22% (14/63) showed an increase. In addition, 26 species showed declines in both seasons. Only eight species (Baltimore Oriole, Brown Thrasher, Lincoln's Sparrow, Northern Waterthrush, Red-headed Woodpecker, Song Sparrow, White-crowned Sparrow, Winter Wren) increased in both spring and fall.

Combined spring/fall population trends were calculated for 47 migrants at LPBO. Twenty-five of these species (53%) were increasing and 22 (47%) were declining, based on combined spring/fall indices. Seventeen species had statistically significant population increases ($P<0.05$) between 1961-1963 and 2000-2002. Chipping Sparrow and Eastern Phoebe showed the largest increases (4.3%/year and 5.0%/year respectively). Ten species showed statistically significant declines for the same time period (Brown Thrasher, Eastern Towhee, Vesper Sparrow, Fox Sparrow, Black-billed Cuckoo, Yellow-bellied Flycatcher, Veery, Swainson's Thrush, Tennessee Warbler, Cape May Warbler). Eastern Towhee and Vesper Sparrow showed the largest average annual declines (-3.4%/year and -2.7%/year respectively).

Trends in numbers of migrant birds at Long Point (1961-2002)

by

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INTRODUCTION

This report presents the results of analyses of trends in population indices for 64 species of migrant birds at Long Point Bird Observatory (LPBO) from 1961-2002. These indices were calculated from daily estimated totals of birds passing through the designated area at the three stations of Long Point Bird Observatory.

This document describes field methods used to collect the data, statistical methods used to obtain population indices from raw field data, and results of trend analyses using polynomial regression (the latter only for Long Point) for various time periods at each station.

For LPBO, trend estimates are based mainly upon polynomial regression methods (see Francis and Hussell 1998) to compare the predicted mean for the first three years (1961-1963) with the predicted mean of the most recent three years (2000-2002). For the sake of comparison with other studies, trend estimates based upon log-linear regression are also presented for the entire period, for 1991-2002 as well as for the same time periods as the Breeding Bird Survey (1968-2002).

METHODS

The following methods are the same as those used in previous reports (Francis and Hussell 1998), but are repeated here for the benefit of those who have not seen those reports.

Daily estimated totals

Population indices are based on daily "estimated totals" (ETs) which are an estimate of the numbers of migrants present, or passing through a designated area on a given day. ETs are an observer's best estimate of the number of birds in the designated area. At Long Point, ETs were collected from three different stations (Old Cut, Breakwater, Tip).

At Long Point, ETs are derived from: a standardized daily census (in which all birds seen or heard on a specific route within the census area are counted over a one-hour period), banding totals (based on non-standardized banding), and general observations. Details of the methods, and justifications for using ETs, are given in McCracken *et al.* (1993).

Abundance indices

The number of birds detected in a census area on a given day reflects many different factors, including population level (the factor to be indexed), seasonal variation, weather conditions, phase of the moon, and additional (error) variation. Factors such as time in the season or certain weather variables (e.g., the passage of cold fronts in autumn) affect the number of birds migrating on a given day, whereas factors such as cloud cover, rain, or phase of the moon affect

the number of birds that stop at the station.

By modelling variation in these additional factors, variation in the counts can be reduced, which results in indices that more closely reflect true population changes for each species (see Hussell *et al.* 1992). This may increase the sensitivity of the analyses for detecting changes in the populations. For the present analyses, we used multiple regression to estimate relationships between daily estimated totals and various external factors, such as weather and time of year, and then used these relationships to adjust the counts and produce a population index. Factors included in the equation include date (within a season), cloud cover, wind speed and direction, temperature, and phase of the moon. Some of these variables were adjusted using only linear terms, while for others second or higher order polynomial terms were included as well. All variables were assumed to interact additively on a log scale (multiplicatively on the original scale), but to have independent effects in each of the areas.

At Long Point, area effects were modelled using dummy variables so that data from all three areas could be included together (see Hussell *et al.* 1992, Francis and Hussell 1998 for further details). Indices were calculated separately for spring and fall data. For each species, analyses were restricted to the period when most of that species migrates (migration window). Migration windows were determined by excluding isolated occurrences of the species (early or late records separated by more than 4 days from the next record), then determining the middle 98% of occurrence days. In addition, for species with small breeding populations at a particular site, the late spring cut-off and the early fall cut-off were selected to exclude periods when more than half of individuals detected were probably resident in the area. This involved a judgement call in many cases, but analyses of the data using a variety of different cut-offs suggest that the results were not strongly affected by the precise cut-off dates.

Weather data

Weather data for the analyses at Long Point were obtained from the U. S. meteorological station for Erie, PA. BSC now has complete hourly data for that station from 1961-2002 for several weather variables, including cloud cover, horizontal visibility, wind speed and direction, temperature, relative humidity, station pressure and ceiling height. In 1995, the wind measurement changed from a 1-minute mean to a 2-minute mean, but this likely had little effect on measurements. In late 1995, the weather station became automated. This likely had little effect on most measurements, with the exception of Total Sky Cover (i.e. cloud cover). When the station became automated, opaque sky cover was no longer recorded, and any type of sky cover is only recorded up to a height of 12000' (about 3600 m). This means that total cloud cover above this height will be recorded as clear sky. An analysis of ceiling height and cloud cover from earlier years suggests that total cloud cover over that height was not common, but occasionally occurred. This change likely had little effect on our analyses, but this has not yet been critically evaluated.

Population trends

Because most of the population changes evident at Long Point have not been linear (see Appendix 4), polynomial regression provides a better approximation to the true population trajectory than does linear regression. For each season, polynomial models were fitted ranging from 1st order (linear) to 7th order on the log-transformed indices. The most parsimonious model (model with the lowest order that adequately fits the data) was then selected using the Akaike's

Information Criterion (AIC).

There are two components to testing significance of population changes based upon polynomial regression models. The first is considering whether there is any evidence for population change. For this test, if the AIC selects a non-linear model there is evidence for significant changes in the population indices for the species. If a linear model was selected, it is necessary to examine the tables in Appendix 1 to determine whether the slope differs significantly from zero. A quick glance at the graphs in Appendix 4 indicates that all species showed at least some population change in one season or the other. The second component is testing whether the population levels in recent years are similar to those in the early 1960s when monitoring began. To test this, a transformation was used to estimate the difference in the predicted values during the first three years (1961-1963) compared with the most recent three years (1999-2001), and to test whether these were significantly different based upon the chosen polynomial model. The main comparison is made based upon 3-year averages rather than the end-points so that the results would be less sensitive to poor estimates of the shapes of the curves at the end-points. These tests were carried out for both seasons separately. To estimate a combined trend for spring and fall together, models were fitted allowing the population trajectories to differ, but assuming the overall trend was the same in each season. If this model was a significantly worse fit than a model allowing the trends to differ, then the combined trend is not presented.

Although the polynomial population change estimates provide a more representative picture of population trends than does linear analyses, the latter are also presented for two reasons (Appendix 2). First, they are most comparable to the method used by other programs such as the Breeding Bird Survey. Second, for shorter time periods (e.g., ≤ 10 years), linear trends are all that can reliably be fitted, because additional years of data are required to get useful estimates for higher order models.

With linear regression, the slope of the regression represents an estimate of the annual percentage increase or decrease in the population, assuming the population had changed by a constant proportion each year. Trends were calculated separately for spring and fall, and then jointly for both periods using analysis of covariance (ANCOVA), assuming that changes were parallel in the two time periods. The latter assumption was tested by re-running the ANCOVA, including a separate interaction term in the equation and testing the significance of the interaction term. In the tables, the joint trend estimate is presented only if the seasons were not significantly different.

For LPBO, log-linear trends were calculated separately for the following time periods: 1961-2002 (all available data), 1968-2002 (the time period over which corresponding Breeding Bird Survey data are available for Ontario), 1991-2002 (as an indication of recent trends, and for comparison with the Thunder Cape data).

All analyses were performed using SAS computer programs.

RESULTS

Summaries of population trends for each species, based on polynomial regression comparing estimated population levels in 2000-2002 with 1961-1963 are presented in Appendix 1. Population trend estimates derived from linear regression for 1961-2002, 1968-2002, and 1991-2002 are presented in Appendix 2. Appendix 3 compares mean population levels for 1988-2002

with population levels for 1961-1987 using polynomial regression. Graphs showing annual population indices for all species, along with the best-fit polynomial regression models are presented in Appendix 4. Species were included in trend analyses if an average of at least 10 individuals were recorded per season per year, on an average of at least 5 days, and at least one individual of a species was recorded in every year of coverage.

During spring 2002, there was a higher percentage of species showing decreases relative to 2001 than there was increases. Fifty-two percent (33/64) of species declined and 48% (31/64) increased relative to 2001. In fall, the majority of species also had lower population indices in 2002 than in 2001. Seventy-eight percent (49/63) of fall migrants showed population declines relative to 2001, and only 22% (14/63) showed an increase. In addition, 26 species showed declines in both seasons. Only eight species (Baltimore Oriole, Brown Thrasher, Lincoln's Sparrow, Northern Waterthrush, Red-headed Woodpecker, Song Sparrow, White-crowned Sparrow, Winter Wren) increased in both spring and fall.

POPULATION TRENDS

Spring population trends (1961-2002). Sixty-one percent (39/64) of spring migrants showed increasing population trends between 1961-1963 and 2000-2002, based on polynomial regressions (Appendix 1). Of these species, 23 showed a statistically significant ($P<0.10$) increase. Yellow Warbler, Eastern Phoebe and Chipping Sparrow have shown the largest increases in spring population indices between 1961-1963 and 2000-2002 (5.2%/year, 5.0%/year and 4.9%/year respectively). Twenty-five species had negative spring population trends, but declines were significant for only seven species (Black-billed Cuckoo, Gray Catbird, Brown Thrasher, Eastern Towhee, Fox Sparrow, Vesper Sparrow and White-throated Sparrow). Eastern Towhee and Black-billed Cuckoo and showed the largest average annual population declines (-3.8%/year and -3.2%/year respectively).

When spring migrants were separated into migration class (i.e., temperate vs. tropical), tropical migrants showed a preponderance of population increases (70%, 28\40), but the same was not true for temperate migrants. Only 42% of temperate migrants are now showing population increases. There are now fewer species showing population increases than in previous years (Badzinski 2000: 67% of temperate migrants and 82% tropical migrants had increasing spring trends).

Fall population trends (1961-2002). Compared to spring, fewer fall migrants had increasing population trends. Forty-three percent (27/62) of fall migrants increased and 57% (35/61) decreased between 1961-1963 and 2000-2002 (Appendix 1). Sixteen species of fall migrants showed statistically significant increases ($P<0.05$) and 12 showed statistically significant declines ($P<0.10$). Eastern Phoebe and Golden-crowned Kinglet showed the largest increases (4.7% and 4.6% respectively) and Vesper Sparrow and Bay-breasted Warbler showed the largest average annual declines (-2.9%/year and -2.6%/year respectively).

A higher percentage of temperate migrants showed increasing fall population trends than did tropical migrants. Fifty-eight percent (14/24) of temperate migrants had increasing population trends whereas only 32% of tropical migrants (12/38) showed increasing fall population trends.

Combined spring/fall trends (1961-2002). Combined spring/fall population trends were calculated for 47 migrants at LPBO. Twenty-five of these species (53%) were increasing and 22

were declining, based on combined spring/fall indices (Appendix 1). Seventeen species had statistically significant population increases ($P<0.05$) between 1961-1963 and 2000-2002. Chipping Sparrow and Eastern Phoebe showed the largest increases (4.3%/year and 5.0%/year respectively). Ten species showed statistically significant declines for the same time period (Brown Thrasher, Eastern Towhee, Vesper Sparrow, Fox Sparrow, Black-billed Cuckoo, Yellow-bellied Flycatcher, Veery, Swainson's Thrush, Tennessee Warbler, Cape May Warbler). Eastern Towhee and Vesper Sparrow showed the largest average annual declines (-3.4%/year and -2.7%/year respectively).

Based on combined spring/fall population indices, the percentages of tropical and temperate migrants with increasing population trends were approximately equal. Forty-eight percent of temperate migrants (10/21) and 46% of tropical migrants (12/26) showed population increases between 1961-1963 and 2000-2002.

Recent population change (1991-2002). Population trends for the period 1991-2002 were also generated using linear regression. These trends were calculated for comparison with Thunder Cape Bird Observatory and to allow examination of recent population trends in migratory birds. Over the past decade, the majority of bird species have shown declining population trends, particularly in fall. Fifty-two percent of spring migrants, and 77% of fall migrants declined between 1991-2002 at LPBO. In addition, many more bird species showed statistically significant decreases than did increases. In spring, 12 migrants showed statistically significant population declines compared to only five species with statistically significant population increases. In fall, there were 17 species showing significant declines and there were no species with significant increases over the same period. In spring, Cape May Warbler showed the largest decline (-10.4%/year) and Gray Catbird the largest increase (+9.3%/year). In fall, Bay-breasted Warbler showed the largest decline (-10.2%/year) and Blue-headed Vireo showed the largest increase (+5.2%/year).

DISCUSSION

Population indices for most migratory landbirds species monitored at LPBO were lower in 2002 than in 2001. This effect was most pronounced in fall, with 78% of fall migrants showing declines relative to 2001. Fall population indices, not only reflect fall weather conditions and adult mortality during the breeding season, but also annual productivity. Because the majority of migrants banded during fall migration at LPBO are hatch-year birds, differences in annual productivity can potentially have a large impact on annual population indices.

Although we attempt to correct for variation in daily weather through multiple regression techniques, the relationships between weather and bird migration are more complex than can be modelled with multiple regression on a limited suite of weather variables with a single measure for each day. This is particularly true because the weather conditions that influence the numbers of birds migrating are different from those that influence the proportion that stop. For example, weather conditions early in the night may influence numbers migrating, whereas conditions in the early morning may have a greater impact on the proportion that stop. Furthermore, numbers are likely influenced by weather conditions on preceding nights (e.g., on a night of favourable weather, migration volume might be higher following several nights of poor weather when birds could not migrate, rather than after several nights in a row of favourable weather). Correcting for this type of variation is not possible with the models currently in use. Further research into the effects of weather on bird migration is needed.

Although long-term population trends show that the majority of landbird populations are stable or increasing, there are a number of species that are undergoing persistent long-term population declines in both spring and fall. Analyses showed that there are 10 species showing long-term population declines based on combined spring/fall population indices. Many of these declining species breed in early successional shrubland habitat or grassland. Data collected from a variety of sources, including migration monitoring, Breeding Bird Survey, and bird atlases show that grassland and early-successional bird species are showing declines throughout North America.

Shrubland birds such as Eastern Towhee, Brown Thrasher, and Black-billed Cuckoo depend on disturbance (e.g., logging, fire) to create appropriate habitat. In the absence of disturbance or active management, species that rely on early- or mid-successional seral stages will inevitably decline as the forest matures. Further, some shrubland species may only be able to occupy a site for a few years after disturbance before the habitat becomes unsuitable. Powerline right-of-ways and certain silviculture treatments such as shelterwood and patch cuts have the potential to create appropriate habitat for shrubland birds.

Over the past few years, data have been collected using similar methods from a number of other nearby Canadian Migration Monitoring Network stations. These include Whitefish Point Bird Observatory near Sault Ste. Marie, as well as Haldimand Bird Observatory, Prince Edward Point Bird Observatory, and Innis Point Bird Observatory in southern Ontario. Trend analyses have been preformed using data from Haldimand Bird Observatory and Prince Edward Point Bird Observatory. Results of these analyses are available on BSC's website (http://www.bsc-eoc.org/national/migmain.jsp). Once more years of data are available from these stations, it will be interesting to compare trends in migratory bird numbers across Ontario. This should provide a more complete picture of bird population trends across the province.

ACKNOWLEDGMENTS

All analyses in these reports were carried out using programs written in SAS. These programs and their associated algorithms were mostly derived from models originally developed by David Hussell and various co-workers including Lucille Brown and Monica Mather, and were revised by Charles Francis. Field data were gathered by the hard work of many volunteers at LPBO. Data collection and data entry for 2002 was coordinated by Jody Allair, Matt Hindel and Keith Larson. Bird Studies Canada thanks the Ontario Ministry of Natural Resources and our numerous individual supporters for financial support of LPBO. Thanks to Bryan Smith (Atmospheric Environment Branch, Environment Canada) for providing weather data for TCBO and Jon McCracken (Bird Studies Canada) for editing this report. Thanks also to David Hussell and Charles Francis for their advice and leadership in this project.

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Appendix 1 – Estimated annual percentage change in numbers of migrant landbirds passing through LPBO between 1961-1963 and 2000-2002 based on polynomial regressions (1st to 7th order as selected by A.I.C) on indices derived from daily estimated totals. The combined spring/fall analysis is only present if the seasons were not significantly different.

		Spring			Fall			Combined	
Species	Winter Range	Trend		Order	Trend		Order	Trend	
Black-billed Cuckoo	Tropical	-3.2	**	(3)	-1.1		(4)	-2.3	**
Red-headed Woodpecker	Temperate	-1.2		(5)	-0.2		(6)	-0.7	
Northern Flicker	Temperate	-0.6		(7)	1.8	*	(7)		
Yellow-bellied Sapsucker	Temperate	-0.2		(5)	0.0		(4)	-0.1	
Eastern Wood-Pewee	Tropical	0.0		(3)	1.7	***	(7)		
Yellow-bellied Flycatcher	Tropical	-0.3		(7)	-2.2	*	(7)	-1.2	
Least Flycatcher	Tropical	0.5		(3)	-1.6	+	(5)	-0.3	+
Eastern Phoebe	Temperate	5.0	****	(1)	4.7	****	(6)	5.0	****
Great-crested Flycatcher	Tropical	0.9		(6)	-1.4		(6)		
Blue-headed Vireo	Tropical	1.1	*	(4)	2.1	***	(1)	1.8	
Red-eyed Vireo	Tropical	2.0	**	(3)	-0.2		(1)		
Philadelphia Vireo	Tropical	0.7		(3)	-0.4		(1)	-0.1	
Warbling Vireo	Tropical	3.8	****	(7)	2.6	***	(7)	3.3	****
Brown Creeper	Temperate	-1.1		(4)	2.2	**	(6)		
House Wren	Temperate	0.2		(4)	1.1		(4)	0.7	
Winter Wren	Temperate	-0.2		(5)	2.1	*	(6)	1.0	+
Golden-crowned Kinglet	Temperate	-0.1		(7)	4.6	**	(7)	3.0	+
Ruby-crowned Kinglet	Temperate	1.5	+	(5)	2.6	*	(7)	2.6	**
Blue-gray Gnatcatcher	Tropical	3.5	***	(3)	2.8	***	(6)	3.2	****
Wood Thrush	Tropical	-0.5		(1)					
Veery	Tropical	-0.9		(2)	-0.5		(2)	-0.7	*
Gray-cheeked Thrush	Tropical	0.9	+	(1)	-2.0	*	(3)		
Swainson's Thrush	Tropical	-0.5		(1)	-1.4	*	(3)	-0.7	*
Hermit Thrush	Temperate	1.2	**	(1)	-0.2		(6)	0.9	*
American Robin	Temperate	3.3	***	(5)	2.6	*	(4)	3.0	****
Gray Catbird	Tropical	1.5	**	(6)	0.6		(6)	1.0	*
Brown Thrasher	Temperate	-1.7	*	(4)	-2.3	**	(1)	-2.1	****
Tennessee Warbler	Tropical	-1.0	+	(4)	-2.4	**	(7)	-1.6	**
Nashville Warbler	Tropical	0.4		(4)	-0.4		(6)	0.0	
Chestnut-sided Warbler	Tropical	1.4	*	(5)	-0.3		(3)	0.5	+
Cape May Warbler	Tropical	-1.1		(3)	-0.9		(4)	-1.0	+
Magnolia Warbler	Tropical	1.3	*	(3)	0.7		(3)	1.0	+
Yellow-rumped Warbler	Temperate	2.1	**	(4)	2.0	*	(3)	2.0	***
Black-and-white Warbler	Tropical	1.3	*	(4)	0.8	*	(1)	0.9	**
Black-throated Blue Warbler	Tropical	1.3	*	(6)	2.0	**	(5)	1.7	***
Blackburnian Warbler	Tropical	0.3		(4)	-0.9		(4)	-0.3	
Black-throated Green Warbler	Tropical	1.4	***	(1)	0.9	*	(1)	1.2	***
Bay-breasted Warbler	Tropical	-0.3		(3)	-2.6	**	(5)		
Blackpoll Warbler	Tropical	2.8	**	(4)	2.1	***	(1)	2.3	****
Palm Warbler	Tropical	2.0	***	(5)	-0.6		(7)		
Yellow Warbler	Tropical	5.2	****	(7)	1.0		(3)		
Mourning Warbler	Tropical	-0.3		(6)	-0.9		(3)	-0.6	
Canada Warbler	Tropical	-0.1		(1)	-2.6	**	(7)		
Wilson's Warbler	Tropical	0.3		(7)	-0.3		(3)	0.0	
Ovenbird	Tropical	0.5		(1)	-1.3	**	(1)		
Northern Waterthrush	Tropical	2.1	*	(6)	-1.7	+	(3)		
Common Yellowthroat	Tropical	0.7		(3)	0.3		(2)	0.4	
American Redstart	Tropical	1.0		(3)	0.6		(4)	0.8	+
Scarlet Tanager	Tropical	0.5		(5)	-1.0		(1)	-0.6	
Eastern Towhee	Temperate	-3.8	***	(4)	-2.3		(6)	-3.4	****
Field Sparrow	Temperate	0.0		(6)	1.2		(7)	0.5	
Chipping Sparrow	Temperate	4.9	****	(5)	3.7	**	(6)	4.3	****
Fox Sparrow	Temperate	-2.6	***	(1)	-1.4		(3)	-2.3	****
Savannah Sparrow	Temperate	0.1		(1)	-2.2	**	(1)		
Lincoln's Sparrow	Tropical	0.5		(1)	-0.9		(5)	0.12	
Song Sparrow	Temperate	-0.23		(5)	-1.4		(6)	-0.9	
Vesper Sparrow	Temperate	-2.2	*	(5)	-2.9	***	(2)	-2.7	****
Swamp Sparrow	Temperate	-0.6		(1)	-0.8		(6)	-0.6	
White-throated Sparrow	Temperate	-0.8	*	(1)	0.3		(6)	-0.5	
White-crowned Sparrow	Temperate	0.4		(2)	1.3		(6)	0.6	
Dark-eyed Junco	Temperate	-1.1		(4)	-0.2		(4)	-0.7	
Rose-breasted Grosbeak	Tropical	-0.1		(1)	-2.2	**	(3)		
Indigo Bunting	Tropical	2.0	+	(6)					
Baltimore Oriole	Tropical	2.1	***	(5)	-1.9		(3)		

+ P < 0.10; * P < 0.05; ** P < 0.01; *** P < 0.001; **** P < 0.0001

Appendix 2 – Estimated annual percentage change in numbers of migrant landbirds passing through LPBO over various periods based on log-linear regression on indices derived from daily estimated totals. Combined spring/fall indices are presented only if spring and fall trend estimated were not significantly different. Note that linear trends over long periods are not reliable for species with non-linear population trajectories (Appendix 1,4).

a) Percentage change in population index per year assuming log-linear change from 1961-2002.

Species	Winter Range	Spring Trend		Fall Trend		Combined trend	
Black-billed Cuckoo	Tropical	-1.1		1.8	*	0.3	*
Red-headed Woodpecker	Temperate	-2.9	****	-2.2	**	-2.6	****
Northern Flicker	Temperate	0.0		0.6		0.3	
Yellow-bellied Sapsucker	Temperate	0.6		0.0		0.3	
Eastern Wood-Pewee	Tropical	2.1	****	2.4	****	2.3	****
Yellow-bellied Flycatcher	Tropical	1.7	**	0.1			
Least Flycatcher	Tropical	1.6	**	0.0			
Eastern Phoebe	Temperate	5.0	****	5.3	****	5.2	****
Great Crested Flycatcher	Tropical	1.2	**	0.0		0.6	+
Blue-headed Vireo	Tropical	0.9	**	2.1	***		
Red-eyed Vireo	Tropical	2.9	****	-0.2			
Philadelphia Vireo	Tropical	1.6	***	-0.5			
Warbling Vireo	Tropical	4.0	****	4.1	****	4.0	****
Brown Creeper	Temperate	-0.1		2.2	***		
House Wren	Temperate	1.0	+	2.5	***	1.8	***
Winter Wren	Temperate	0.2		3.0	***		
Golden-crowned Kinglet	Temperate	0.7		4.8	****		
Ruby-crowned Kinglet	Temperate	1.3	*	2.4	***	1.9	****
Blue-gray Gnatcatcher	Tropical	5.5	****	6.1	****	5.8	****
Wood Thrush	Tropical	-0.5					
Veery	Tropical	-0.7		-0.9	+	-0.8	*
Gray-cheeked Thrush	Tropical	0.9	+	-0.6			
Swainson's Thrush	Tropical	-0.5		-0.6		-0.5	+
Hermit Thrush	Temperate	1.2	**	1.4	*	1.3	***
American Robin	Temperate	3.6	****	4.1	****	3.8	****
Gray Catbird	Tropical	1.1	*	0.7		0.9	*
Brown Thrasher	Temperate	-2.3	****	-2.3	**	-2.3	****
Tennessee Warbler	Tropical	-0.8	+	-1.6	**	-1.2	**
Nashville Warbler	Tropical	1.1	*	0.8	*	1.0	**
Chestnut-sided Warbler	Tropical	1.9	****	1.0	*	1.5	****
Cape May Warbler	Tropical	-0.4		0.1		-0.1	
Magnolia Warbler	Tropical	2.6	****	1.8	***	2.2	****
Yellow-rumped Warbler	Temperate	3.9	****	3.4	****	3.7	****
Black-and-White Warbler	Tropical	2.1	****	0.8	*		
Black-throated Blue Warbler	Tropical	1.8	****	2.7	****	2.3	****
Blackburnian Warbler	Tropical	1.4	***	-0.3			
Black-throated Green Warbler	Tropical	1.4	***	0.9	*	1.2	***
Bay-breasted Warbler	Tropical	-0.2		-2.4	**		
Blackpoll Warbler	Tropical	2.9	****	2.1	***	2.5	****
Palm Warbler	Tropical	4.2	****	0.9			
Yellow Warbler	Tropical	5.7	****	3.7	****		
Mourning Warbler	Tropical	0.9	+	0.6		0.7	*
Canada Warbler	Tropical	-0.1		-1.3	**		
Wilson's Warbler	Tropical	1.1	*	1.2	*		
Ovenbird	Tropical	0.5		-1.3	**		
Northern Waterthrush	Tropical	1.5	*	0.0			
Common Yellowthroat	Tropical	2.1	****	0.5			
American Redstart	Tropical	2.1	****	1.7	****	1.9	****
Scarlet Tanager	Tropical	-0.1		-1.0		-0.6	
Eastern Towhee	Temperate	-3.4	****	-0.2			
Field Sparrow	Temperate	0.4		1.8	**		
Chipping Sparrow	Temperate	7.0	****	4.2	****		
Fox Sparrow	Temperate	-2.6	***	0.7			
Savannah Sparrow	Temperate	0.1		-2.2	**		
Lincoln's Sparrow	Tropical	0.5		-0.8			
Song Sparrow	Temperate	0.6		-0.2		0.2	
Vesper Sparrow	Temperate	-1.8	*	-2.3	*	-2.0	***
Swamp Sparrow	Temperate	-0.6		-1.0		-0.8	+
White-throated Sparrow	Temperate	-0.8	*	0.7			
White-crowned Sparrow	Temperate	0.8		0.8		0.8	+
Dark-eyed Junco	Temperate	-0.2		0.9	+	0.4	
Rose-breasted Grosbeak	Tropical	-0.1		-1.7	**		
Indigo Bunting	Tropical	3.8	****				
Baltimore Oriole	Tropical	1.9	***	0.5		1.3	**

+ P < 0.10; * P < 0.05; ** P < 0.01; *** P < 0.001; **** P < 0.0001

Appendix 2 continued

b) Percentage change in population index per year assuming log-linear change from 1968-2002.

Species	Winter Range	Spring Trend		Fall Trend		Combined Trend	
Black-billed Cuckoo	Tropical	0.6		3.7	***		
Red-headed Woodpecker	Temperate	-3.4	****	-3.1	***	-3.3	****
Northern Flicker	Temperate	0.8		0.4		0.6	
Yellow-bellied Sapsucker	Temperate	1.2	+	0.1		0.7	
Eastern Wood-Pewee	Tropical	2.5	***	2.8	****	2.7	****
Yellow-bellied Flycatcher	Tropical	2.6	***	1.0	+		
Least Flycatcher	Tropical	2.0	**	0.4			
Eastern Phoebe	Temperate	5.2	****	6.1	****	5.6	****
Great Crested Flycatcher	Tropical	1.6	**	0.5		1.0	*
Blue-headed Vireo	Tropical	1.2	**	2.1	**	1.7	****
Red-eyed Vireo	Tropical	2.9	****	0.0			
Philadelphia Vireo	Tropical	1.7	**	-0.5			
Warbling Vireo	Tropical	4.8	****	4.7	****	4.7	****
Brown Creeper	Temperate	-0.3		1.6	*	0.6	
House Wren	Temperate	1.8	*	2.9	**	2.4	****
Winter Wren	Temperate	-0.4		2.6	**		
Golden-crowned Kinglet	Temperate	0.2		4.5	**		
Ruby-crowned Kinglet	Temperate	1.7	**	2.3	*	2.0	***
Blue-gray Gnatcatcher	Tropical	6.5	****	7.4	****	6.9	****
Wood Thrush	Tropical	-0.5					
Veery	Tropical	-0.3		-0.9		-0.6	
Gray-cheeked Thrush	Tropical	0.7		0.2		0.5	
Swainson's Thrush	Tropical	-0.6		-0.4		-0.5	
Hermit Thrush	Temperate	1.3	*	1.7	*	1.5	**
American Robin	Temperate	3.8	****	4.8	****	4.3	****
Gray Catbird	Tropical	1.9	**	2.7	***	2.3	****
Brown Thrasher	Temperate	-1.9	**	-1.8	+	-1.9	***
Tennessee Warbler	Tropical	-1.4	*	-2.2	**	-1.8	***
Nashville Warbler	Tropical	1.4	*	1.5	**	1.4	***
Chestnut-sided Warbler	Tropical	2.2	****	1.5	*	1.9	****
Cape May Warbler	Tropical	-1.1		-0.4		-0.8	
Magnolia Warbler	Tropical	3.2	****	2.3	**	2.7	****
Myrtle Warbler	Temperate	4.3	****	3.5	****	3.9	****
Black-and-White Warbler	Tropical	2.6	****	0.7			
Black-throated Blue Warbler	Tropical	2.2	****	3.5	****	2.9	****
Blackburnian Warbler	Tropical	1.6	**	-0.7			
Black-throated Green Warbler	Tropical	1.5	**	0.9		1.2	**
Bay-breasted Warbler	Tropical	-0.8		-3.8	***		
Blackpoll Warbler	Tropical	3.4	***	2.6	**	3.0	****
Palm Warbler	Tropical	5.2	****	2.3	**		
Yellow Warbler	Tropical	7.1	****	4.2	****		
Mourning Warbler	Tropical	1.1	+	1.3	+	1.2	**
Canada Warbler	Tropical	-0.4		-1.4	*	-0.9	*
Wilson's Warbler	Tropical	1.7	*	1.9	**	1.8	***
Ovenbird	Tropical	0.7		-1.1	+		
Northern Waterthrush	Tropical	1.6	*	0.4		1.0	+
Common Yellowthroat	Tropical	2.8	****	1.8	**	2.2	****
American Redstart	Tropical	2.7	****	2.2	***	2.5	****
Scarlet Tanager	Tropical	0.0		-1.0		-0.5	
Eastern Towhee	Temperate	-3.2	****	-0.3			
Field Sparrow	Temperate	0.9		2.5	**	1.7	**
Chipping Sparrow	Temperate	8.5	****	4.6	****		
Fox Sparrow	Temperate	-2.5	**	1.9	**		
Savannah Sparrow	Temperate	0.5		-1.7	*		
Lincoln's Sparrow	Tropical	0.6		-0.4		0.1	
Song Sparrow	Temperate	1.3		0.4		0.9	
Vesper Sparrow	Temperate	-0.7		-0.7		-0.7	
Swamp Sparrow	Temperate	-0.2		-0.5		-0.4	
White-throated Sparrow	Temperate	-0.5		1.3	+		
White-crowned Sparrow	Temperate	1.2	+	1.4		1.3	*
Dark-eyed Junco	Temperate	-0.1		1.2		0.6	
Rose-breasted Grosbeak	Tropical	0.0		-1.9	**		
Indigo Bunting	Tropical	5.3	****				
Baltimore Oriole	Tropical	2.9	****	1.6	+	2.2	****

+ P < 0.10; * P < 0.05; ** P < 0.01; *** P < 0.001; **** P < 0.0001

Appendix 2 continued

c) Percentage change in population index per year assuming log-linear change from 1991-2002.

Species	Winter Range	Spring Trend		Fall Trend		Combined Trend	
Black-billed Cuckoo	Tropical	1.4		0.1		0.7	
Red-headed Woodpecker	Temperate	-4.5		-0.1		-2.3	
Northern Flicker	Temperate	-3.4		-1.5		-2.5	
Yellow-bellied Sapsucker	Temperate	3.3		-0.5		1.4	
Eastern Wood-Pewee	Tropical	-4.9	*	-0.9			
Yellow-bellied Flycatcher	Tropical	-0.9		-0.1		-0.5	
Least Flycatcher	Tropical	-1.7		-5.5	**		
Eastern Phoebe	Temperate	2.9		-1.5		0.7	
Great Crested Flycatcher	Tropical	-0.5		1.1		0.3	
Blue-headed Vireo	Tropical	2.3		5.2		3.7	+
Red-eyed Vireo	Tropical	-1.1		-3.0		-2.1	
Philadelphia Vireo	Tropical	-1.8		-2.2		-2.0	
Warbling Vireo	Tropical	6.0	+	2.4		4.2	*
Brown Creeper	Temperate	-7.3	*	-5.8	*	-6.6	**
House Wren	Temperate	-1.8		-10.0	*		
Winter Wren	Temperate	-5.6	+	-9.1	**	-7.3	***
Golden-crowned Kinglet	Temperate	-4.9		-4.7		-4.8	+
Ruby-crowned Kinglet	Temperate	-3.4	+	-3.5		-3.4	*
Blue-gray Gnatcatcher	Tropical	2.1		0.9		1.5	
Wood Thrush	Tropical	1.6					
Veery	Tropical	1.2		-3.0		-0.9	
Gray-cheeked Thrush	Tropical	0.1		-3.3		-1.6	
Swainson's Thrush	Tropical	0.0		-5.1	+		
Hermit Thrush	Temperate	-0.7		-3.7		-2.2	
American Robin	Temperate	-3.5		-2.2		-2.9	
Gray Catbird	Tropical	9.3	****	3.3			
Brown Thrasher	Temperate	0.3		-3.1		-1.4	
Tennessee Warbler	Tropical	-4.4	*	-7.8	**	-6.1	***
Nashville Warbler	Tropical	0.3		-1.3		-0.5	
Chestnut-sided Warbler	Tropical	-1.7		-4.2		-3.0	+
Cape May Warbler	Tropical	-10.4	**	-9.0	*	-9.7	***
Magnolia Warbler	Tropical	1.1		-3.7		-1.3	
Myrtle Warbler	Temperate	-1.1		-3.1		-2.1	
Black-and-White Warbler	Tropical	0.8		-2.9		-1.1	
Black-throated Blue Warbler	Tropical	2.7		1.9		2.3	
Blackburnian Warbler	Tropical	-1.0		-6.4	+	-3.7	+
Black-throated Green Warbler	Tropical	0.8		-4.2		-1.7	
Bay-breasted Warbler	Tropical	-4.5	+	-10.2	**		
Blackpoll Warbler	Tropical	2.9		-0.9		0.9	
Palm Warbler	Tropical	0.0		-2.1		-1.1	
Yellow Warbler	Tropical	6.0	**	-5.3	*	0.2	**
Mourning Warbler	Tropical	0.1		-3.3	+	-1.6	
Canada Warbler	Tropical	-2.8	+	-6.1	**	-4.4	***
Wilson's Warbler	Tropical	1.5		-3.7		-1.1	
Ovenbird	Tropical	2.9		-2.0		0.4	
Northern Waterthrush	Tropical	4.7		-8.1	*	-1.9	**
Common Yellowthroat	Tropical	-0.5		1.5		0.5	
American Redstart	Tropical	0.7		-3.4	+	-1.4	
Scarlet Tanager	Tropical	-1.6		-3.2		-2.4	
Eastern Towhee	Temperate	-5.3	+	0.2		-2.6	
Field Sparrow	Temperate	-6.3	****	-0.2			
Chipping Sparrow	Temperate	-0.5		-3.0		-1.7	
Fox Sparrow	Temperate	-0.6		4.0		1.6	
Savannah Sparrow	Temperate	-2.4		-0.6		-1.5	
Lincoln's Sparrow	Tropical	1.3		-3.9		-1.3	+
Song Sparrow	Temperate	-6.4	**	-9.8	***	-8.1	****
Vesper Sparrow	Temperate	-7.2		2.3		-2.6	+
Swamp Sparrow	Temperate	-2.9		-5.6	+	-4.2	*
White-throated Sparrow	Temperate	0.2		0.6		0.4	
White-crowned Sparrow	Temperate	4.5	+	3.7		4.1	
Dark-eyed Junco	Temperate	-5.8	+	-1.2		-3.6	
Rose-breasted Grosbeak	Tropical	1.4		-5.9	*	-2.3	*
Indigo Bunting	Tropical	3.8					
Baltimore Oriole	Tropical	3.2	+	3.5		3.4	*

+ P < 0.10; * P < 0.05; ** P < 0.01; *** P < 0.001; **** P < 0.0001

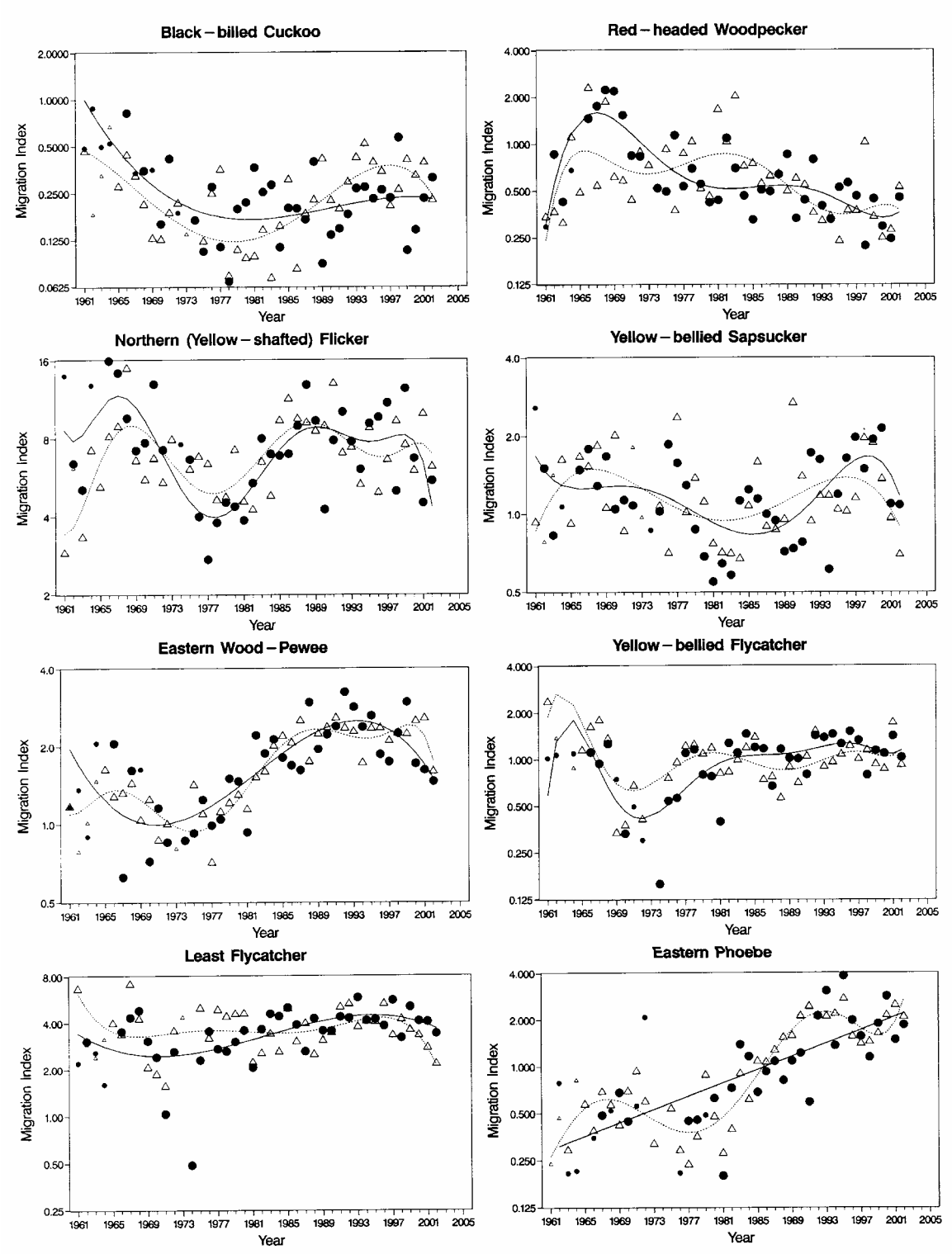
Appendix 3 – Estimated percent change in mean population indices of migrants passing through LPBO between the periods 1961-1987 and 1988-2002. Estimates are derived from polynomial models described in Appendix 1 for spring, fall, and both seasons combined.

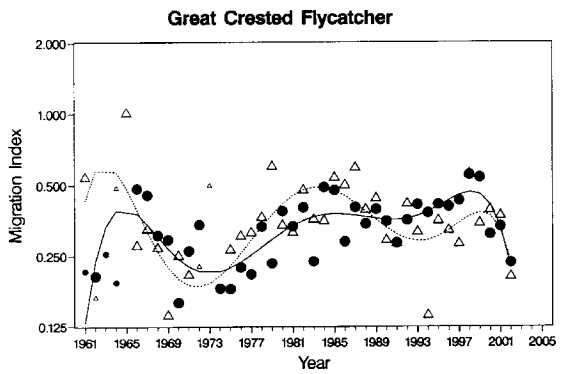
		Mean % change 1961-1987 to 1988-2002					
Species	**Winter Range**	**Spring**		**Fall**		**Combined**	
Black-billed Cuckoo	Tropical	-4.2		56.6	****	37.4	*
Red-headed Woodpecker	Temperate	-35.9	**	-44.2	***		
Northern Flicker	Temperate	17.2		13.8			
Yellow-bellied Sapsucker	Temperate	16.7		10.7			
Eastern Wood-Pewee	Tropical	63.4	****	56.6	****		
Yellow-bellied Flycatcher	Tropical	42.0	**	2.2			
Least Flycatcher	Tropical	37.7	**	3.3			
Eastern Phoebe	Temperate	155.7	****	228.5	****		
Great-crested Flycatcher	Tropical	22.1	*	-11.0		4.0	
Blue-headed Vireo	Tropical	23.6	**	48.9	**		
Red-eyed Vireo	Tropical	74.3	****	6.2			
Philadelphia Vireo	Tropical	31.6	**	-7.9			
Warbling Vireo	Tropical	127.8	****	98.1	****	112.1	****
Brown Creeper	Temperate	6.6		81.5	****	39.6	***
House Wren	Temperate	37.0	*	101.6	****	66.1	****
Winter Wren	Temperate	-2.9		102.8	****		
Golden-crowned Kinglet	Temperate	24.8		208.9	****		
Ruby-crowned Kinglet	Temperate	48.6	***	90.6	****		
Blue-gray Gnatcatcher	Tropical	169.3	****	204.6	****		
Wood Thrush	Tropical	-10.7					
Veery	Tropical	-10.2		-14.9			
Gray-cheeked Thrush	Tropical	25.7	*	6.9			
Swainson's Thrush	Tropical	-15.8	*	-11.0			
Hermit Thrush	Temperate	25.3	**	62.4	****		
American Robin	Temperate	114.6	****	140.7	****		
Gray Catbird	Tropical	27.9	*	39.1	*		
Brown Thrasher	Temperate	-31.0	**	-33.3	*		
Tennessee Warbler	Tropical	-26.1	**	-33.4	**		
Nashville Warbler	Tropical	21.8	+	17.3	+		
Chestnut-sided Warbler	Tropical	59.0	****	28.2	*		
Cape May Warbler	Tropical	-13.0		-6.8			
Magnolia Warbler	Tropical	70.2	****	49.6	***	59.3	****
Yellow-rumped Warbler	Temperate	114.3	****	98.4	****		
Black-and-White Warbler	Tropical	55.4	****	17.3	*	34.6	****
Black-throated Blue Warbler	Tropical	46.7	****	79.8	****		
Blackburnian Warbler	Tropical	30.1	**	-15.9			
Black-throated Green Warble	Tropical	27.9	**	20.9	+	24.3	**
Bay-breasted Warbler	Tropical	-15.4	+	-51.0	****		
Blackpoll Warbler	Tropical	107.3	****	55.5	**		
Palm Warbler	Tropical	134.4	****	42.4	**		
Yellow Warbler	Tropical	249.7	****	117.2	****		
Mourning Warbler	Tropical	19.8	+	9.4			
Canada Warbler	Tropical	3.5		-23.1	*	-11.0	+
Wilson's Warbler	Tropical	28.6	*	29.8	*		
Ovenbird	Tropical	-0.5		-19.4	*		
Northern Waterthrush	Tropical	3.8		6.5			
Common Yellowthroat	Tropical	58.1	****	16.9			
American Redstart	Tropical	56.0	****	44.4	****	49.9	****
Scarlet Tanager	Tropical	10.4		-16.2			
Eastern Towhee	Temperate	-43.4	***	28.6			
Field Sparrow	Temperate	21.9	+	55.9	**		
Chipping Sparrow	Temperate	384.6	****	180.8	****		
Fox Sparrow	Temperate	-38.0	**	41.0	**		
Savannah Sparrow	Temperate	4.8		-38.8	**		
Lincoln's Sparrow	Tropical	-0.8		-13.0			
Song Sparrow	Temperate	31.6	+	38.3	*		
Vesper Sparrow	Temperate	-17.4		-20.6			
Swamp Sparrow	Temperate	-13.1		2.9			
White-throated Sparrow	Temperate	-13.9		44.5	**		
White-crowned Sparrow	Temperate	28.0	*	44.1	*		
Dark-eyed Junco	Temperate	8.8		49.5	***		
Rose-breasted Grosbeak	Tropical	-1.1		-30.7	**		
Indigo Bunting	Tropical	114.4	****				
Baltimore Oriole	Tropical	60.3	***	15.8			

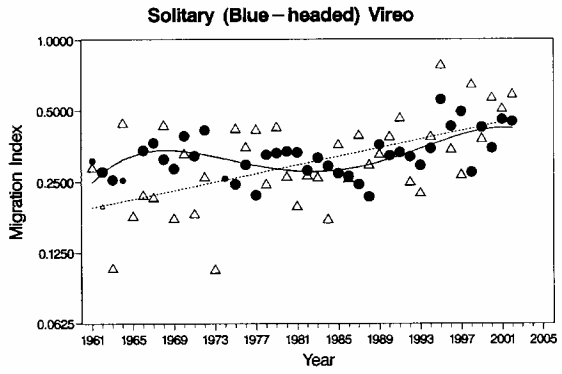
+ P < 0.10; * P < 0.05; ** P < 0.01; *** P < 0.001; **** P < 0.0001

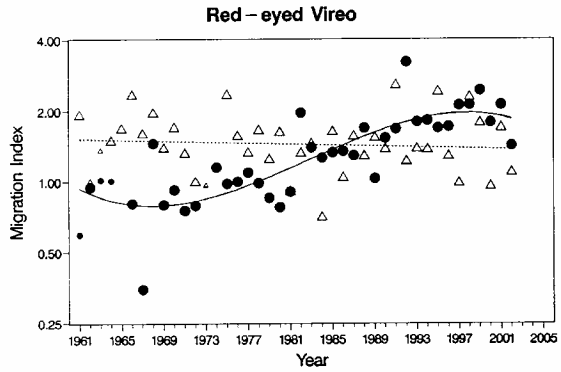
Appendix 4 - Graphs showing annual population indices for spring and fall, and estimated population trajectories for each species at LPBO (1961-2002). Solid circles represent spring indices, while hollow triangles represent fall indices. Smaller symbols represent seasons with reduced coverage (less than 30 station days). Seasons in which there were fewer than 10 station-days during the migration window for a species were excluded from the analyses. Solid curves represent estimated population trajectories for spring indices, while dotted lines represent curves for fall indices. On the graphs, indices for spring and fall have been adjusted to the same mean value, thus it is not possible to tell from the graph whether a species was more abundant in spring or in fall. Some species, although recorded in adequate numbers in one season, were rarely detected in the other season and hence are graphed only for one season.

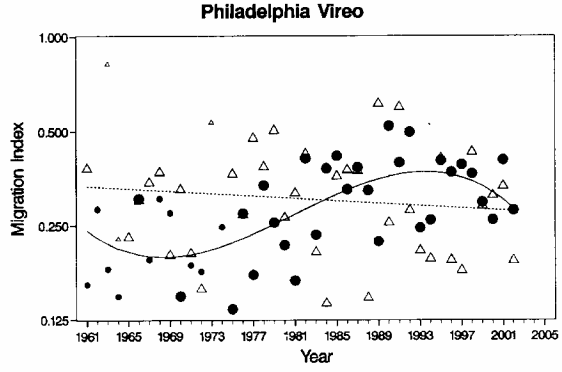
Population trajectories were estimated using the lowest order polynomial (maximum 7th order) that adequately fit the data based upon AIC. These represent the same order curves as were used to generate the values in Appendix I. If there are no significant changes, then the linear curve is printed to show the general trend. All non-linear curves are significantly different from no population change. The significance of linear population change can be determined from the significance levels in Appendix 1. All species at LPBO exhibit significant population change in at least some years for at least one season.

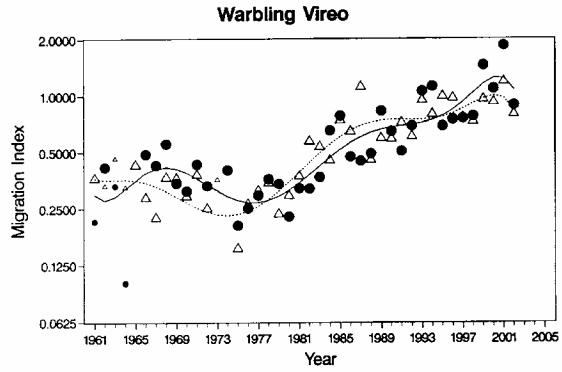

Black – billed Cuckoo
Red – headed Woodpecker
Northern (Yellow – shafted) Flicker
Yellow – bellied Sapsucker
Eastern Wood – Pewee
Yellow – bellied Flycatcher
Least Flycatcher
Eastern Phoebe
Migration Index
Year

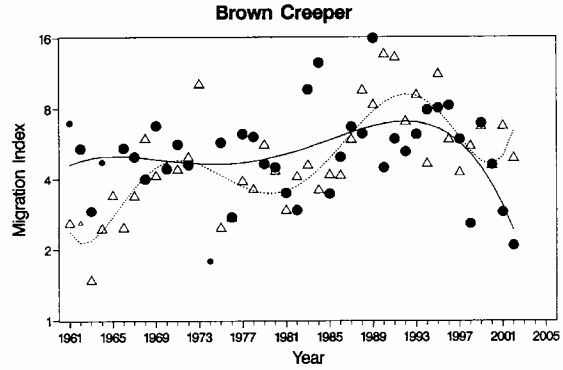

Great Crested Flycatcher
Migration Index
Year

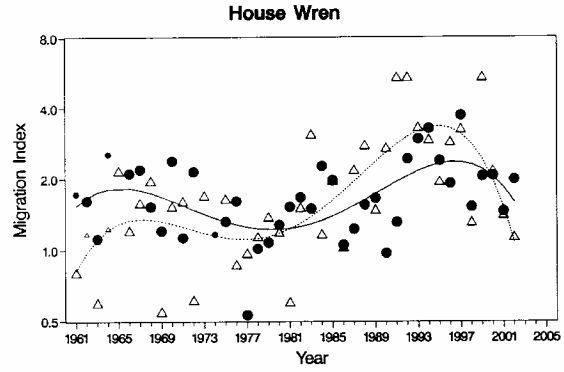

Solitary (Blue-headed) Vireo
Migration Index
Year

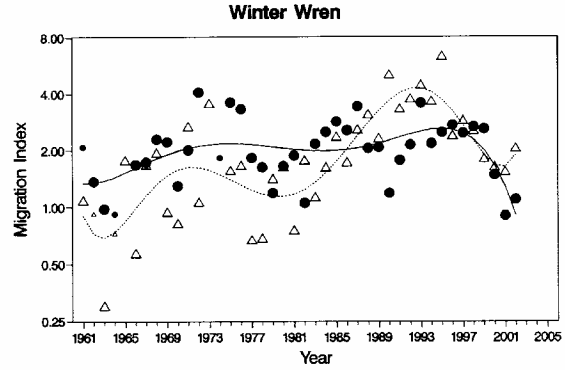

Red-eyed Vireo
Migration Index
Year

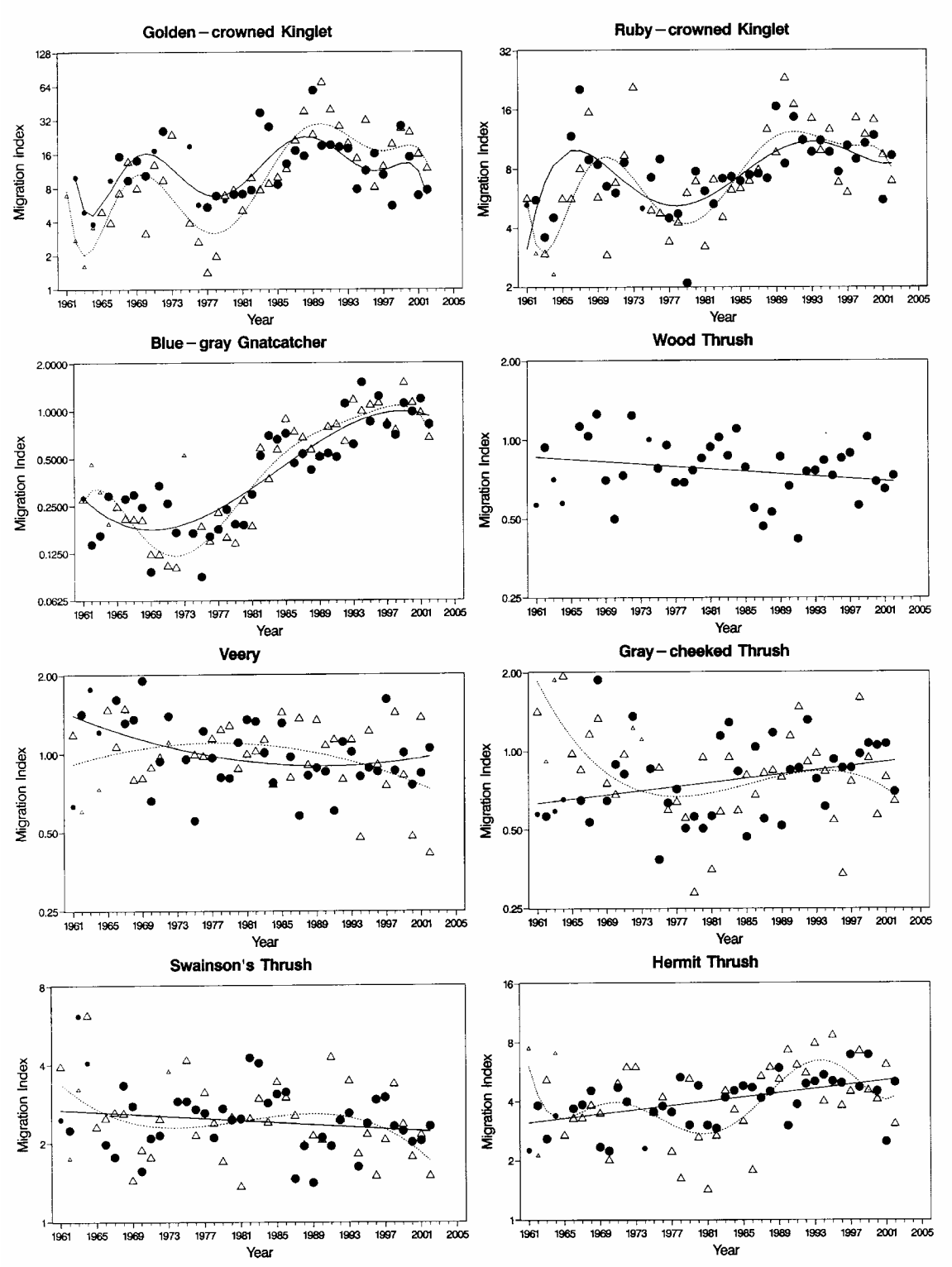

Philadelphia Vireo
Migration Index
Year

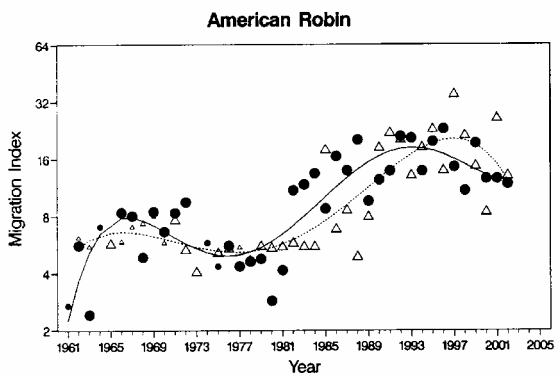

Warbling Vireo
Migration Index
Year

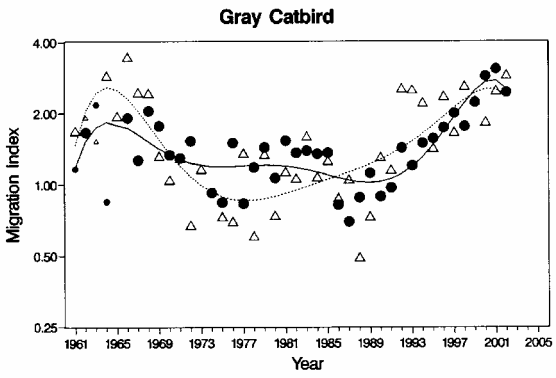

Brown Creeper
Migration Index
Year

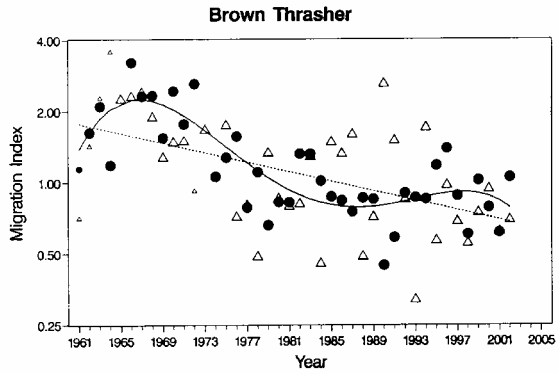

House Wren
Migration Index
Year

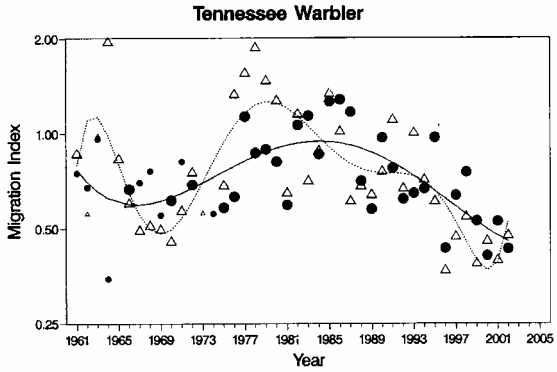

Winter Wren
Migration Index
Year

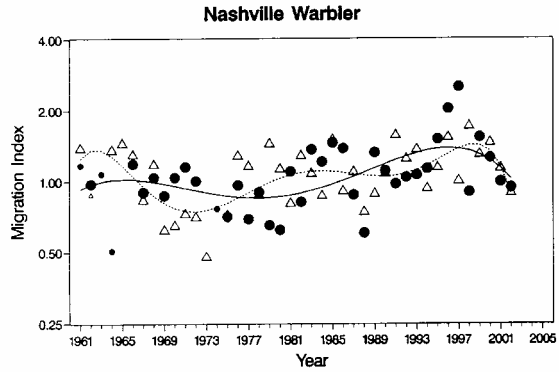

Golden – crowned Kinglet
Ruby – crowned Kinglet
Blue – gray Gnatcatcher
Wood Thrush
Veery
Gray – cheeked Thrush
Swainson's Thrush
Hermit Thrush
Migration Index
Year

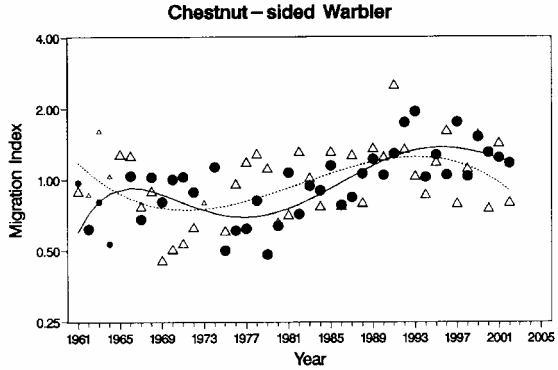

American Robin
Migration Index
Year

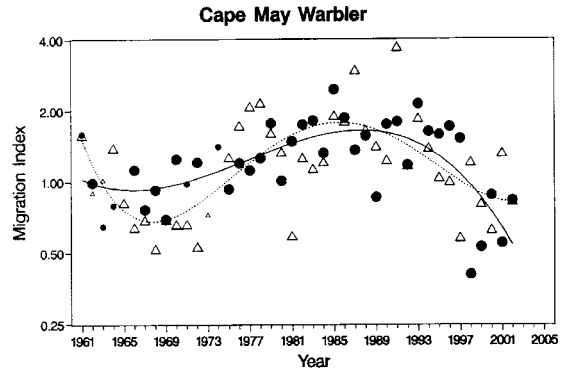

Gray Catbird
Migration Index
Year

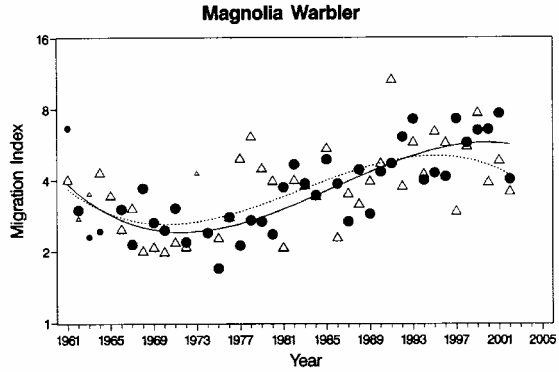

Brown Thrasher
Migration Index
Year

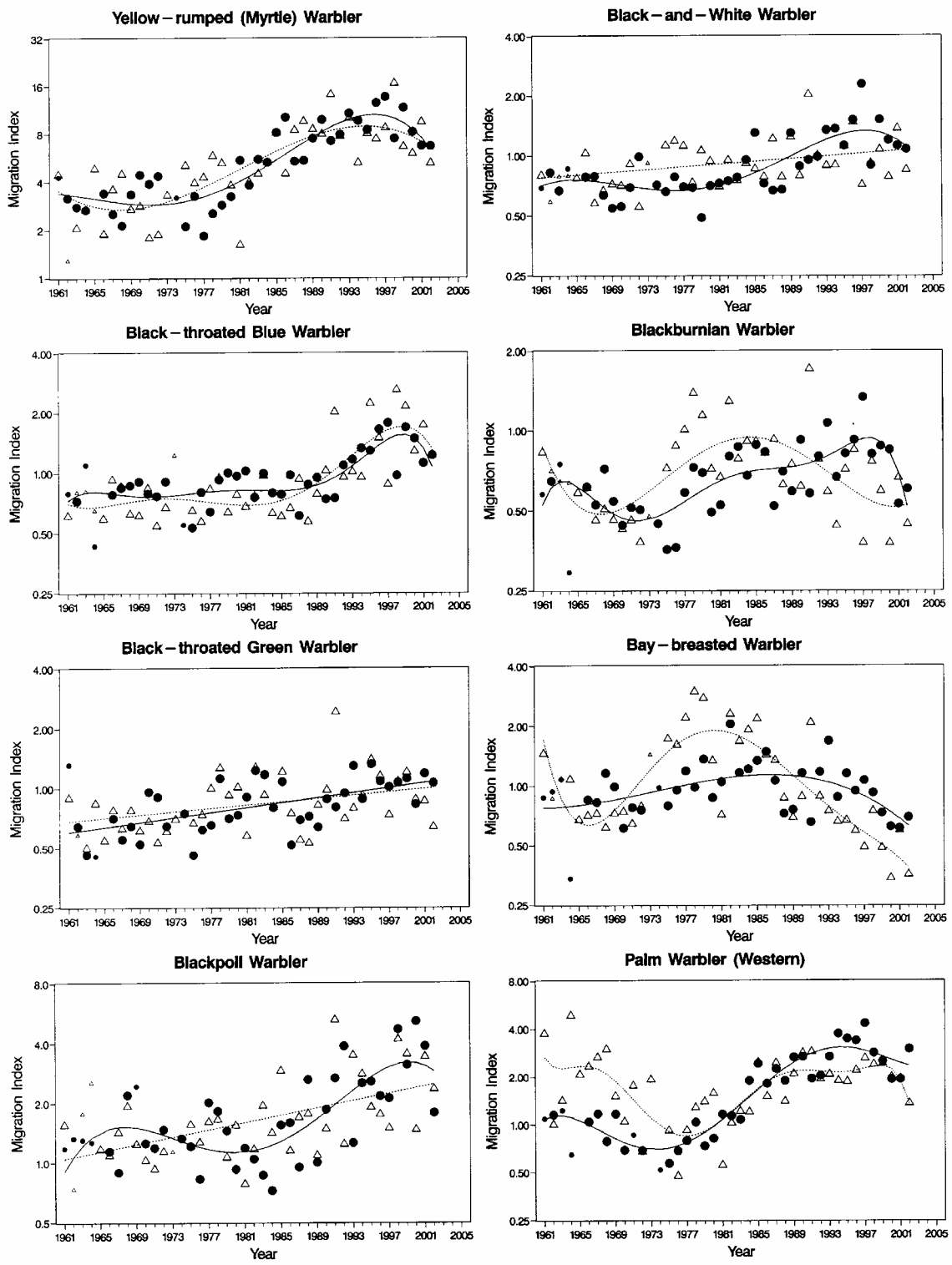

Tennessee Warbler
Migration Index
Year

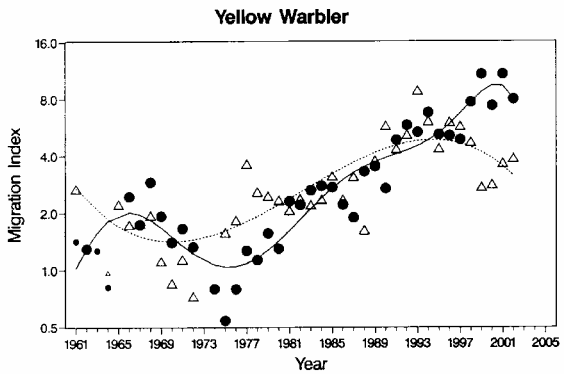

Nashville Warbler
Migration Index
Year

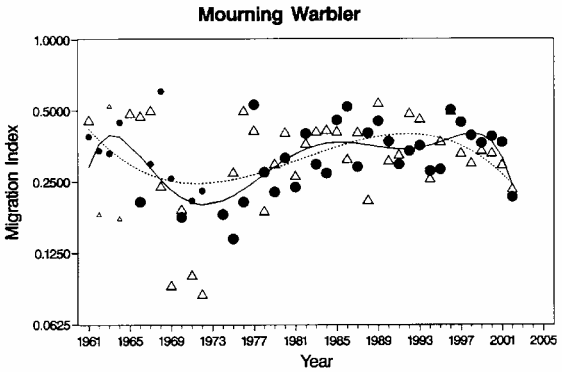

Chestnut-sided Warbler
Migration Index
Year

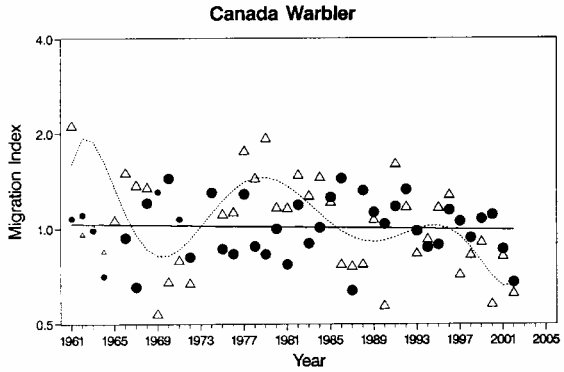

Cape May Warbler
Migration Index
Year

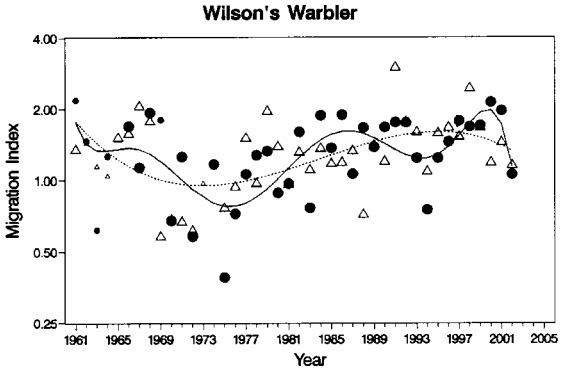

Magnolia Warbler
Migration Index
Year

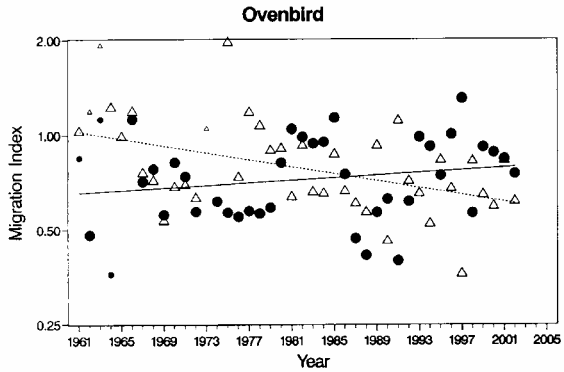

Yellow – rumped (Myrtle) Warbler
Black – and – White Warbler
Black – throated Blue Warbler
Blackburnian Warbler
Black – throated Green Warbler
Bay – breasted Warbler
Blackpoll Warbler
Palm Warbler (Western)
Migration Index
Year

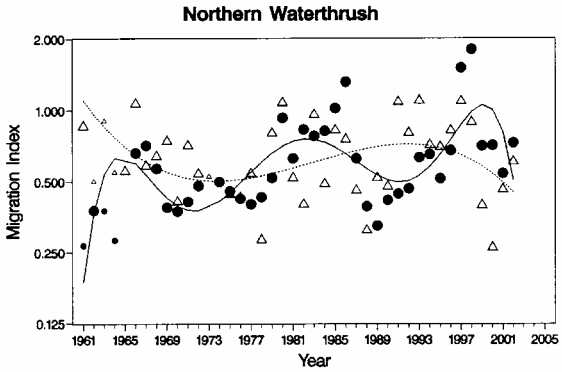

Yellow Warbler
Migration Index
Year

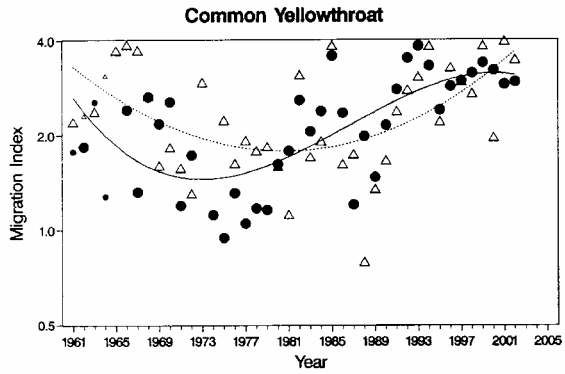

Mourning Warbler
Migration Index
Year

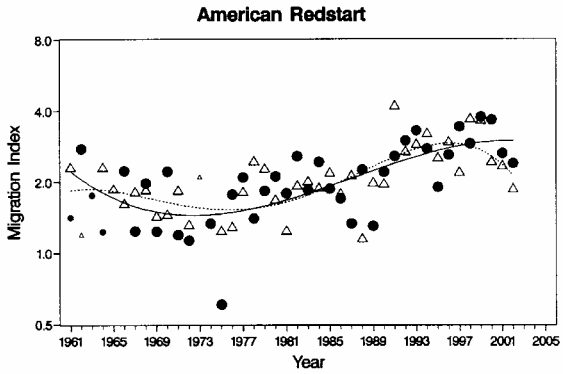

Canada Warbler
Migration Index
Year

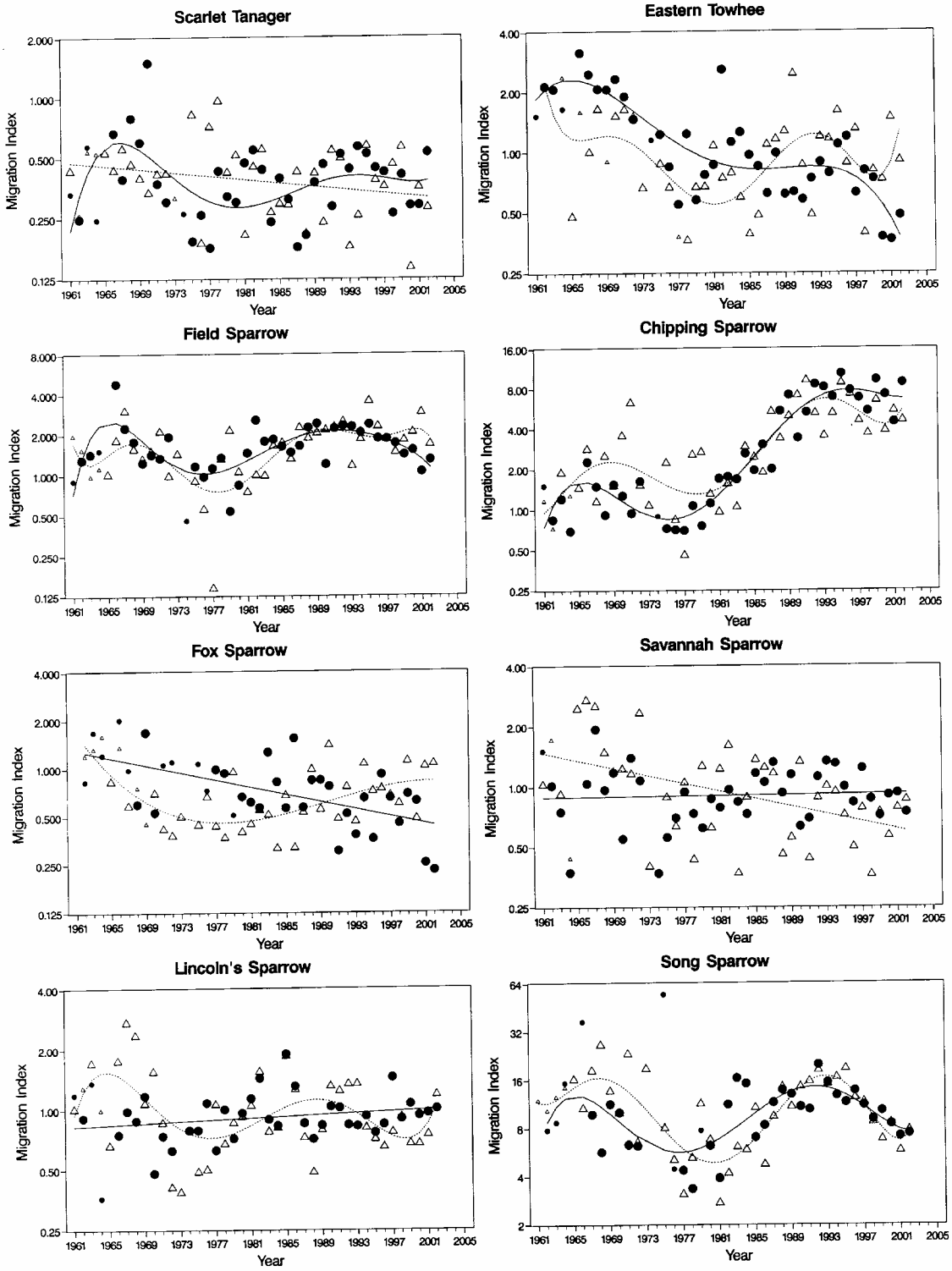

Wilson's Warbler
Migration Index
Year

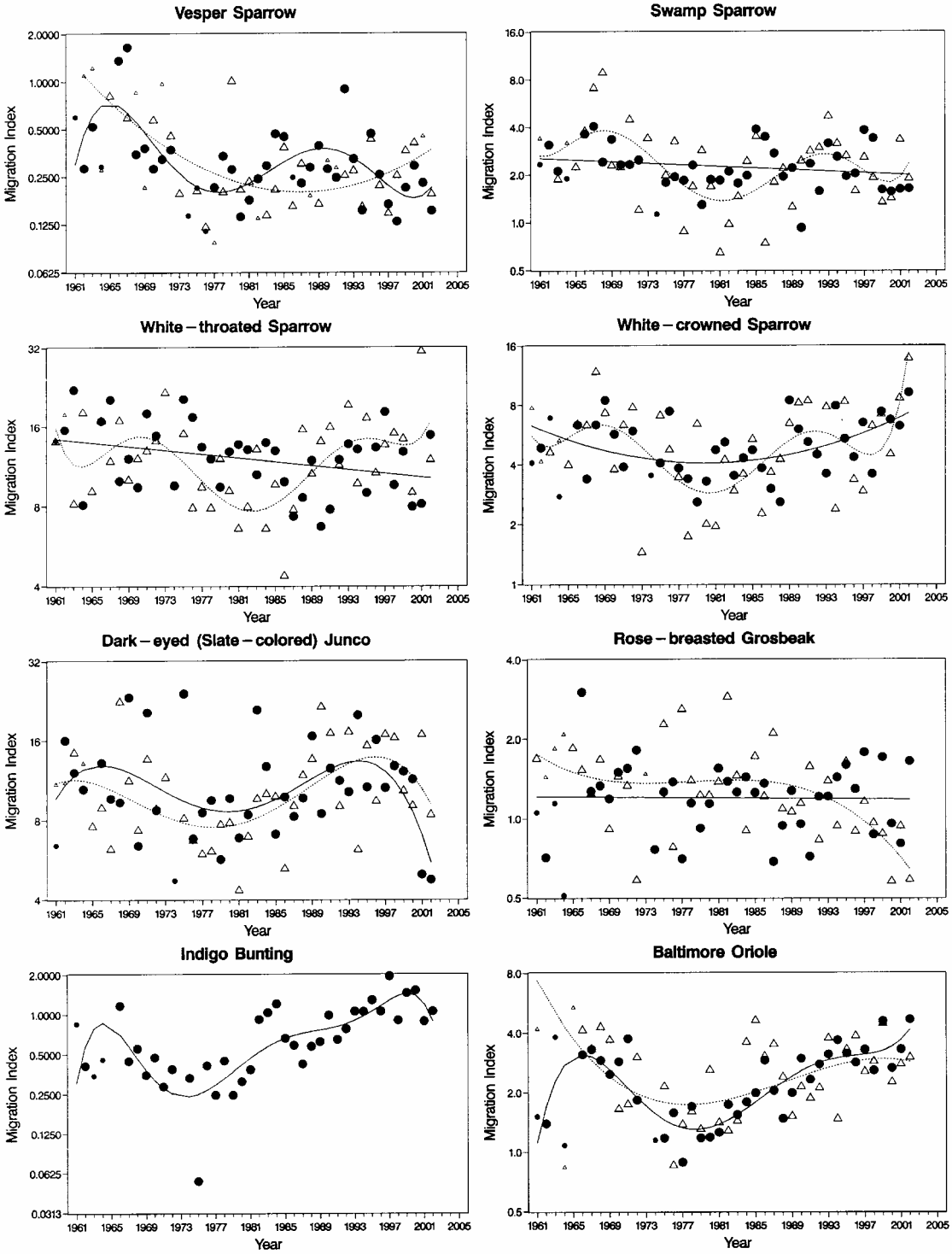

Ovenbird
Migration Index
Year


Northern Waterthrush
Migration Index
Year


Common Yellowthroat
Migration Index
Year


American Redstart
Migration Index
Year


Scarlet Tanager
Eastern Towhee
Field Sparrow
Chipping Sparrow
Fox Sparrow
Savannah Sparrow
Lincoln's Sparrow
Song Sparrow
Migration Index
Year


Vesper Sparrow
Swamp Sparrow
White – throated Sparrow
White – crowned Sparrow
Dark – eyed (Slate – colored) Junco
Rose – breasted Grosbeak
Indigo Bunting
Baltimore Oriole
Migration Index
Year