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TRENDS IN NUMBERS OF MIGRANT LANDBIRDS AT LESSER SLAVE LAKE BIRD OBSERVATORY (1994-1999), BEAVERHILL BIRD OBSERVATORY (1992-1999) AND INGLEWOOD BIRD SANCTUARY (1995-1999)

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by

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EXECUTIVE SUMMARY

This report presents trends in numbers of migratory landbirds at three Canadian Migration Monitoring stations in Alberta, Canada. Spring and fall trend estimates for 40 bird species at Lesser Slave Lake Bird Observatory were calculated using six years (1994-1999) of daily estimated total (DET) data. Spring and fall trend estimates for 14 bird species at Beaverhill Bird Observatory were calculated using eight years (1992-1999) of DET data and trend estimates for Inglewood Bird Sanctuary were derived from five years of fall DET data.

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

Based on combined spring/fall trend estimates, three species (Least Flycatcher, Swamp Sparrow, Ruby-crowned Kinglet) declined significantly and three species (Pine Siskin, White-crowned Sparrow, Ovenbird) increased significantly from 1994-1999 at Lesser Slave Lake. The decline in numbers of Swamp Sparrows at Lesser Slave Lake is likely the result of wet seasons from 1994-1996 followed by dry seasons in 1997 and 1998. At Beaverhill, three species (Alder Flycatcher, Chipping Sparrow, Myrtle Warbler) declined significantly and no species increased significantly based on combined spring/fall trend estimates for the period 1992-1999. Fall population indices for the period 1995-1999 at Inglewood showed significant increases for two species (Yellow Warbler and Gray Catbird) and no species are showed significant population declines.

Population indices and trend estimates presented in this report should be considered very preliminary for several reasons. First, the short time frame of this study may result in high variance in annual population indices, and thus only very large changes in population indices will be detected. However, as more years of data become available, the reliability and precision of trend estimates will increase. Second, possible changes in protocol, habitat conditions, personnel, and observer skill at the migration monitoring stations may have a large influence on population trends, especially for stations with few years of data. Third, the set of weather variables used for trend analyses in this report are identical to those used at Long Point Bird Observatory, but have not been critically evaluated to determine whether they are appropriate for use at all CMMN stations. Finally, the selection of species was based mainly on sample size so, some of these species may be inappropriate for trend analysis (e.g. irruptive species, diurnal migrants, early or late migrants).

There was a strong correlation between spring and fall trends at Lesser Slave Lake and Beaverhill, which suggests that at least some of the variation in population indices reflects true population change. Trend estimates at the three Alberta stations were not correlated. However, with few years of data and a small number of species available for comparison, the power for detecting a significant correlation is low. Furthermore, due to differences in geography and habitat, the three Alberta stations may actually be monitoring different populations of migrant landbirds. It is important to emphasize that the value of these data for monitoring long-term trends will continue to increase as additional data are collected.

Trends in numbers of migrant landbirds at Lesser Slave Lake Bird Observatory (1994-1999), Beaverhill Bird Observatory (1992-1999), and Inglewood Bird Sanctuary (1994-1999)

by

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INTRODUCTION

This report presents the results of an analysis of trends in population indices for selected migratory landbirds at three Canadian Migration Monitoring Network (CMMN) stations in Alberta, Canada: Lesser Slave Lake Bird Observatory, Beaverhill Bird Observatory and Inglewood Bird Sanctuary. This document briefly describes data collection and statistical methodology used to obtain population indices from raw field data, and presents trend estimates derived from simple linear regression. Trend estimates for 40 species at Lesser Slave Lake for the period 1994-1999, 14 species at Beaverhill for the period 1992-1999, and 32 species at Inglewood for the period 1995-1999 are derived from daily estimated total data. Spring and fall trends are compared for those species monitored adequately in both seasons at a station, and trend estimates are also compared among stations.

Trend estimates presented in this report should be considered preliminary for several reasons. First, trends were calculated using essentially the same methods as at Long Point Bird Observatory. However, these methods have not been critically evaluated to determine whether they are the best methods for use at all CMMN stations. Because of differences in geography, habitat, and the number of years of data, the set of weather variables used at Long Point may not be the most appropriate variables for use at all migration monitoring stations. It is possible that the use of alternate, additional, or fewer weather variables at Alberta stations may provide more reliable population indices. Second, the selection of species for trend analyses is based largely upon sample sizes. The behaviour of some of these species (e.g., irruptive species, diurnal migrants) may make them less suitable than others for estimating trends. Third, we have assumed that data collection procedures and methods for deriving daily estimated totals have not changed over time. If any of the CMMN stations considered in this report have changed their migration monitoring protocol over time, this may obscure true population trends. Finally, because of the short time time-scale of this study (Lesser Slave Lake: N=6 years, Beaverhill: N=8 years, Inglewood: N=5 years), it is likely that only very large changes in population indices will be detected.

A complication of migration monitoring is that migration counts may include a high proportion of individuals that breed in the area (Dunn and Hussell 1995). Counts of these species may reflect changes in the local breeding population but not accurately reflect changes in the larger population, breeding north of the station, that we are hoping to sample. Furthermore, an assumption of standard trend analysis methods is that, most of the time, the same individuals are not being counted each day. This assumption would be violated if birds remain through the season around the sampling area. Consequently, only species classified as primarily migrant at a station are included in trend analyses.

The procedures used to derive population indices and estimate trends are similar to those currently in use for analysing data from other CMMN stations (e.g. Francis 1998) and are based upon statistical procedures described by Hussell *et al.* (1992) and Francis and Hussell (1999). In simple terms, they are equivalent to the means of the log-transformed daily counts within the migration period for each species, after using multiple regression approaches to correct for some of the daily variation in counts due to weather variables.

Note that in this report we have analysed only data for landbirds that are primarily nocturnal migrants. However, many species of waterfowl, shorebirds and raptors, as well as some smaller landbirds that frequently migrate during the day (e.g., blackbirds, swallows) are also counted regularly. It is likely that data from at least some of those species are also useful for monitoring, but we have not considered them in the current report.

METHODS

Daily Estimated Totals

For all three stations, annual population indices and trends were calculated based on daily estimated totals (DET).

At Lesser Slave Lake, DETs are based on banding totals, a visual migration count of diurnal migrants, a standardized daily census and casual observations (Beaverhill Bird Observatory 1995). DETs at Lesser Slave Lake are calculated by summing the above components, and there is little extrapolation involved. DETs are only recorded when a visible migration count, a census, and several hours of casual observations and/or banding are done. Lesser Slave Lake Bird Observatory operates in both spring and fall.

At Beaverhill, the DET is comprised of three components: banding, a 40-minute standardized daily census, and casual observations collected throughout the day (Beaverhill Bird Observatory 1994). The DET value is usually equal to the sum of the above components, except when it is known that the same individual was observed on more then one occasion. Like Lesser Slave Lake, little extrapolation is involved in deriving the DET. The minimum requirements for a DET to be recorded are daily census, plus several hours of incidental observations and/or banding. Beaverhill Bird Observatory operates in spring, summer and fall.

Inglewood uses a slightly different method for calculating DETs (Collister et al. 2000). The DET at Inglewood incorporates banding data, a standardized census, and casual observations, but is not necessarily equal to the sum of these components. The presence of probable known stopovers (PKS) is also considered when calculating the DET. If a large number of birds are caught and/or there is a personnel shortage, a census is not performed and a DET is not recorded. Inglewood Bird Sanctuary operates in fall only.

Species Selection

Species were included in trend analyses if an average of at least ten individuals were recorded per season per year, on an average of at least five days, and at least one individual of a species was recorded in every year of coverage. Species that met this abundance criterion were further classified according to their breeding status. Each CMMN station was asked to classify species into one of the following categories:

a) majority of individuals of this species are passage migrants, and few or none of the birds recorded in DETs breed within 1 km of the station.

b) majority of individuals of this species counted in daily totals are local breeders (summer or permanent residents), such that migratory individuals cannot be readily distinguished from migrants in the daily totals.

c) there are local breeders but the number of individuals recorded increases significantly during migration due to the presence of passage migrants and numbers drop off following migration.

We excluded species classified as summer or permanent residents (category B) from trend analyses because fluctuations in local population indices may obscure population changes in the migratory population. Species classified as category C were included.

Annual Population Indices

The numbers of birds detected by a DET reflects many different factors, including the true population level, seasonal variation in numbers migrating on a particular date, weather conditions, phase of the moon, and other sources of variation. Some of these factors, such as time in the season or certain weather variables (e.g. the passage of cold fronts in autumn) affect the numbers of birds migrating on a given day. Other factors, such as cloud cover, rain, or the phase of the moon, may affect the number of birds stopping at the monitoring station.

By modelling variation in these additional factors, variation in counts can be reduced. Hopefully this will result in population indices that more closely reflect true population changes and increase the sensitivity of analyses for detecting population change (Hussell et al. 1992). 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 counts and produce population indices. Factors included in the equation were date (within a season), cloud cover, wind speed and direction, temperature, and phase of the moon. Some of these variables were adjusted using linear terms, while for others second or higher order polynomial terms were included as well. All variables were assumed to act additively on a log scale (multiplicatively on the original scale). Population indices were calculated separately for spring and fall.

Analyses were restricted to the period when most individuals of a given species migrate (migration windows). Migration windows were determined by examining a chart of the total number of each species recorded by DETs each day (summed across years) and picking the earliest and latest dates for the species, after excluding outliers. Birds were considered outliers if only one or a few individuals were recorded after a gap of four or more days.

Weather Data

Weather data for Lesser Slave Lake were obtained from the Environment Canada weather station at Fort McMurray because some weather variables (e.g. cloud cover) were not available from the weather station at Slave Lake. Weather data for Beaverhill and Inglewood were obtained from Environment Canada weather stations at Edmonton and Calgary respectively.

Population Trends

Trend estimates presented in this report are based on simple linear regression of the log-transformed indices for the selected time periods. With a linear regression on logs, the slope of the regression (after back-transformation) represents an estimate of the annual percentage increase or decrease in the population, assuming the population has 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) and assuming 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. Combined spring/fall trend estimates are presented in Appendices 1-3 only if the difference between spring and fall trend estimates was non-significant ($P>0.10$).

Station Comparison
To test whether similar trends in migratory bird numbers were being detected at the three Alberta CMMN stations, trends were compared among stations using simple correlation. If population trends are strongly correlated among stations, this is a good indication that trend estimates may reflect true population trends.

All analyses were performed using SAS computer programs.

RESULTS

LESSER SLAVE LAKE BIRD OBSERVATORY

There were adequate data to calculate spring trends for 37 species, fall trends for 29 species, and combined spring/fall trends for 27 species of migratory landbirds at Lesser Slave Lake Bird Observatory. American Robin and American Tree Sparrow were excluded from trend analyses because spring migration for these species begins before the start of migration monitoring, and fall migration continues after the station has closed (S. Jungkind pers. comm.). Annual population indices and population trend estimates derived from log-linear regression of the population indices are presented in Appendices 1 and 4. Trend estimates for each species represent percentage change in population indices per year.

Spring trends. Based on spring population indices, 14 species declined and 23 species increased from 1994-1999 at LSLBO (Appendices 1 & 3). However, Yellow-bellied Sapsucker (*Syphyrapicus varius*) is the only species that showed a significant decline ($P<0.05$) in spring population indices. Spring numbers of Evening Grosbeak (*Coccothraustes vespertinus*), White-crowned Sparrow (*Zonotrichia leucophrys*) and Rose-breasted Grosbeak (*Pheucticus ludovicianus*) recorded by DETs showed marginally significant increases ($P<0.10$) whereas population indices for Pine Siskin (*Carduelis spinus*), Tennessee Warbler (*Vermivora peregrina*), and Ovenbird (*Seiurus aurocapillus*) increased significantly ($P<0.05$).

Fall trends. Based on fall population indices, 18 species declined and 11 species increased during the period 1994-1999. Fall trend estimates for White-throated Sparrow (*Zonotrichia albicollis*), Swamp Sparrow (*Melospiza georgiana*), Cedar Waxwing (*Bombycilla cedrorum*), and Common Yellowthroat (*Geothlypis trichas*) showed marginally significant declines ($P<0.10$) and Least Flycatcher (*Empidonax minimus*) declined significantly ($P<0.01$). Ovenbird is the only species that increased significantly in the fall at Lesser Slave Lake from 1994-1999.

Combined spring/fall trends. Lesser Slave Lake spring and fall population indices were significantly, positively correlated ($r=0.38$, $P<0.05$). However, trend estimates for Tennessee

Warbler, Yellow Warbler (*Dendroica petechia*), Common Yellowthroat, and White-throated Sparrow differed significantly between spring and fall. Based on combined spring/fall trend estimates, 9 species decreased and 13 species increased. Three species (Least Flycatcher, Swamp Sparrow, and Ruby-crowned Kinglet (*Regulus calendula*)) declined significantly and three species (Pine Siskin, White-crowned Sparrow, and Ovenbird) increased significantly ($P<0.10$, $P<0.05$ and $P<0.0001$ respectively) from 1994-1999.

BEAVERHILL BIRD OBSERVATORY

Based on our selection criteria, there were adequate data to calculate spring trends for 11 species, fall trends for 12 species, and combined spring/fall trends for 6 species. Although several other species met the abundance criteria, they were excluded from analyses because they were classified as summer or permanent residents at Beaverhill. Annual population indices and trend estimates derived from log-linear regression of the population indices are presented in Appendices 2 and 5. Trend estimates for each species represent percentage change in population indices per year.

Spring trends. Based on spring population indices, nine species declined and two species are increased at Beaverhill Bird Observatory for the period 1992-1999. Spring population indices for Alder Flycatcher (*Empidonax alnorum*), Brown-headed Cowbird (*Molothrus ater*) and Blackpoll Warbler (*Dendroica striata*) showed significant declines ($P<0.10$, $P<0.01$, $P<0.01$ respectively). Cedar Waxwing is the only species that increased significantly in the spring at Beaverhill ($P<0.01$).

Fall trends. Eight species showed declines in fall population indices and four species showed increases. All fall population increases were non-significant ($P>0.10$), but two species (Alder Flycatcher, Myrtle Warbler (*Dendroica coronata*) declined significantly from 1992-1999.

Combined spring/fall trends. Beaverhill spring and fall population trends were positively, but non-significantly correlated ($r=0.61$, $P=0.15$, $N=6$). However, lack of significance can be attributed to small sample size. There was no detectable difference between spring and fall population trends for the six species monitored adequately in both seasons. All species for which combined spring/fall trends were produced declined over the period 1992-1999 and declines were significant for three species (Alder Flycatcher, Myrtle Warbler, Chipping Sparrow (*Spizella passerina*)).

INGLEWOOD BIRD SANCTUARY

There were sufficient data to calculate fall trends for 30 species at Inglewood. Annual population indices and population trend estimates derived from log-linear regression of the population indices are presented in Appendices 3 and 6. Trend estimates for each species represent percentage change in fall population indices per year.

Fall trends. Based on fall population indices from 1995-1999, 50% (15/30) of the species monitored at Inglewood declined, and 50% (15/30) increased. All declining trends were non-significant ($P>0.10$), whereas two species (Gray Catbird (*Dumetella carolinensis*) and Yellow Warbler (*Dendroica petechia*) increased significantly.

COMPARISON OF TRENDS AMONG STATIONS

Trend estimates from the three Alberta stations were not significantly correlated. Spring population trend estimates for Beaverhill and Lesser Slave Lake for the period 1994-1999 were weakly correlated (r_s=0.21, P=0.59, N=9), but fall trends and combined spring/fall trends were negatively correlated (r_f=-0.44, P=0.12, N=11; $r_{s/f}$=-0.65, P=0.24, N=5). Beaverhill and Inglewood fall trend estimates for the period 1995-1999 were negatively correlated (r_f=-0.50, P=0.11, N=11), as were Inglewood and Lesser Slave Lake fall trends for the period 1995-1999 were not correlated (r_f=-0.063, P=0.80, N=18).

DISCUSSION

When only a small number of years are included in a trend analysis, it is very difficult to distinguish real population trends from random fluctuations in population indices due to sampling variation. Trend estimates presented in this report are quite high, and are therefore likely inflated by sampling variation. These trend estimates should not be interpreted as true population change because it is unlikely that species considered in this report are experiencing such significant changes in population size (e.g.-42% per year change in Ruby-crowned Kinglet numbers at Lesser Slave Lake). Furthermore, the observed annual variation in population indices may be due to short-term population fluctuations, as opposed to population trends. Nevertheless, species showing statistically significant changes in population indices may well be undergoing 'true' population change and concern for these species is appropriate. As more years of data become available, trend estimates will more accurately reflect real population change.

Fall and spring population indices are influenced by different biological factors. High spring population indices suggest that overwinter mortality rates, and/or mortality rates on spring migration were low. Fall population indices, on the other hand, not only reflect adult mortality during the breeding season, but also annual productivity. High fall population indices suggest favourable breeding ground conditions and thus high breeding success in the areas being monitored by the station. Spring and fall trend estimates for Lesser Slave Lake were significantly positively correlated, and Beaverhill spring and fall trends were also strongly correlated. Positive correlation between spring and fall trends suggests that trend estimates presented in this report may at least partly reflect true population change. If trend estimates were merely the result of sampling variation, we would not expect to see a strong correlation between spring and fall indices.

Although we attempted 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 weather conditions that influence the number of birds migrating are different from those that influence the proportion that stop. 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 of favourable weather in a row). It is not possible to correct for this type of variation with the models currently in use. For example, population indices for Swamp Sparrow declined significantly and population indices for Wilson's Warbler declined non-significantly from 1994-1999 at Lesser Slave Lake. However, populations of

Swamp Sparrow and Wilson's Warbler were impacted regionally by wet seasons in 1994-1996 followed by dry seasons in 1997-1998.

There was significant correlation between fall trend estimates at Beaverhill and Lesser Slave Lake. This correlation is encouraging, and suggests that at least some of the trends in population indices over the period 1994-1999 reflect true changes in populations of migrant landbirds in Alberta. As more years of data become available, the precision of trend estimates should increase, provided that current migration monitoring protocols remain standardized.

Lack of correlation in trend estimates among the three Alberta CMMN stations is somewhat disappointing, however, it is possible that because of differences in geography and habitat, Lesser Slave Lake, Beaverhill, and Inglewood are monitoring different source populations of migrant birds. Lack of correlation may also be due to the small number of species for which there were adequate data to calculate trends at all stations, as well as the short time frame involved. Another complication is that due to their northerly location, many of the bird species monitored at Lesser Slave Lake and Beaverhill breed at the station (although there are significantly more migrant individuals than local breeders). Thus, changes in the local breeding population may have a strong effect on trend estimates.

Changes in protocol that are typically associated with opening new migration monitoring station may also bias trend estimates and obscure correlations among stations. For example, variation in mist-net use (e.g. fluctuations in capture rate, changes in personnel) at Lesser Slave Lake may have biased trends for species that are mainly recorded by mist-net capture (S. Jungkind pers. comm.). In addition, trend estimates for species that are mainly recorded by observations (e.g. swallows, blackbirds) are likely influenced by variation in observer skill over the years. This type of variation will average out over the long-term but could possibly have a large influence on short-term population trends.

It is important to emphasize that, despite problems with interpreting indices from individual years due to annual variation in weather, observer skill and phenology, the data are still valuable for monitoring long-term trends in individual species. Although major weather patterns such as global warming could cause some bias, most of the annual variation in weather involves year-to-year fluctuations that will average out over time. As more years of data become available, the precision and reliability of estimated trends will increase, provided that current migration monitoring protocols remain standardized.

FUTURE ANALYSES

There are several issues that still need to be examined more closely regarding analysis methods. As noted earlier, a more detailed assessment of weather effects on counts could be very worthwhile, to improve our ability to interpret indices from individual years. This would be most informative if additional data such as radar data were available to provide information on numbers of birds migrating over a station. Given that current analysis methods may not adequately correct for annual variation in weather, it is also worth considering whether the weather data are even necessary to improve the annual population indices. Although there is obviously much daily variation in weather through a season, which has a significant effect on the numbers of birds detected, adjusting for this variation may not have a large effect on seasonal average counts. If it were possible to develop population indices that were not dependent upon weather data, then the cost of analysing trends from stations across the country would be substantially reduced, because it would not be necessary to select and acquire all of the relevant weather data. Furthermore, analyses would be less vulnerable to changes in the weather station that could potentially bias trend estimation.

Weather data for Lesser Slave Lake Bird Observatory were obtained from Fort McMurray, which is not in close proximity to Slave Lake. Weather data are also collected at the Lesser Slave migration monitoring station, so it would be useful to compare the weather data collected at the station to data obtained from Fort McMurray. Using station specific weather data may help to reduce variation in daily counts and increase the precision of trend estimates.

Another possible future analysis is a comparison of Alberta trend estimates with trend estimates from the Breeding Bird Survey. At Long Point Bird Observatory, trends from migration monitoring are significantly correlated with BBS trends, which suggests that some of the variation measured by migration monitoring at LPBO and BBS represents real changes in the underlying population (Francis and Hussell 1998). However, there are many differences between the two monitoring programs that may obscure a significant correlation. Migration monitoring and BBS differ in methodology, analysis methods, and the two programs may be monitoring different bird populations. In fact, one of the main goals of migration monitoring is to monitor bird populations that are not adequately covered by BBS.

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Appendix 1 – Estimated annual percentage change in numbers of migratory birds passing through Lesser Slave Lake Bird Observatory between 1994-1999, based on linear regression on indices derived from daily estimated totals. The combined spring/fall trend estimates are only presented if the seasons were not significantly different. These analyses match the graphs in Appendix 4.

Species	Spring	Fall	Combined spring/fall	Difference between spring and fall trends
Yellow-bellied Sapsucker	-19.89 *	-	-	
Yellow-shafted Flicker	25.54	-	-	
Alder Flycatcher	-9.1	-12.78	-11.03	n.s
Least Flycatcher	-4.71	-17.31 **	-11.51 *	n.s
Blue Jay	-	11.08	-	
Brown-headed Cowbird	17.88	-	-	
Red-winged Blackbird	2.96	-	-	
Evening Grosbeak	38.80 +	-	-	
Pine Siskin	59.25 *	13.36	33.92 +	n.s
White-crowned Sparrow	22.21 +	23.96	23.11 **	n.s
White-throated Sparrow	-1.83	-15.81 +		0
Chipping Sparrow	28.34	-	-	
Clay-colored Sparrow	17.29	-	-	
Lincoln's Sparrow	1.13	-14.76	-7.42	n.s
Swamp Sparrow	-24.74	-35.63 +	-30.90 *	n.s
Rose-breasted Grosbeak	20.20 +	19.32	19.74	n.s
Western Tanager	1.62	12.54	7.27	n.s
Tree Swallow	-8.4	-	-	
Cedar Waxwing	-11.98	-18.53 +	-15.45	n.s
Red-eyed Vireo	4.64	-0.63	1.89	n.s
Warbling Vireo	-2.45	-	-	
Black-and-White Warbler	19.67	-0.84	8.27	n.s
Orange-crowned Warbler	-5.18	-2.12	-3.69	n.s
Tennessee Warbler	29.73 *	-29.40 *	-	***
Yellow Warbler	5.04	-13.71	-	0
Myrtle Warbler	-2.97	22.68	9.80	n.s
Magnolia Warbler	10.61	-2.40	3.81	n.s
Ovenbird	14.47 **	13.74 **	14.08 ****	n.s
Northern Waterthrush	4.61	3.80	4.18	n.s
Mourning Warbler	8.24	-2.40	2.42	n.s
Common Yellowthroat	5.91	-18.15 +		0
Wilson's Warbler	-11.42	-10.22	-10.81	n.s
Canada Warbler	16.46	-13.52		0
American Redstart	-0.15	-16.84	-9.02	n.s
American Pipit	-	50.02	-	
Red-breasted Nuthatch	22.12	2.49	11.75	n.s
Ruby-crowned Kinglet	-41.88	-10.70	-27.98 +	n.s
Swainson's Thrush	4.64	5.60	5.14	n.s

+ $P < 0.10$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; **** $P < 0.0001$; n.s.=non-significant difference

Appendix 2 – Estimated annual percentage change in numbers of migratory birds passing through Beaverhill Bird Observatory between 1994-1999, based on linear regression on indices derived from daily estimated totals. The combined spring/fall trend estimates are only presented if the seasons were not significantly different. These analyses match the graphs in Appendix 5.

Species	Spring	Fall	Combined spring/fall	Difference between spring and fall trends
Alder Flycatcher	-12.72+	-20.64**	-16.93***	n.s.
Brown-headed Cowbird	-14.98**	-	-	
Pine Siskin	-	-7.57	-	
White-throated Sparrow	-9.97	-	-	
Chipping Sparrow	-7.38	-28.49	-19.19+	n.s.
Cedar Waxwing	31.86**	-	-	
Orange-crowned Warbler	-0.11	-3.15	-1.60	n.s.
Tennessee Warbler	-5.73	-3.70	-4.73	n.s.
Myrtle Warbler	-12.95	-28.07+	-20.81*	n.s.
Magnolia Warbler	-	6.05	-	
Blackpoll Warbler	-17.69+	-0.46	-9.61	n.s.
Wilson's Warbler	-	6.6	-	
American Redstart	-	7.22	-	
Red-breasted Nuthatch	-	2.33	-	
Ruby-crowned Kinglet	-	-9.34	-	
Swainson's Thrush	-6.61	-	-	
American Robin	5.24	-	-	

+ P < 0.10; * P < 0.05; ** P < 0.01; *** P < 0.001; **** P < 0.0001; n.s.=non-significant

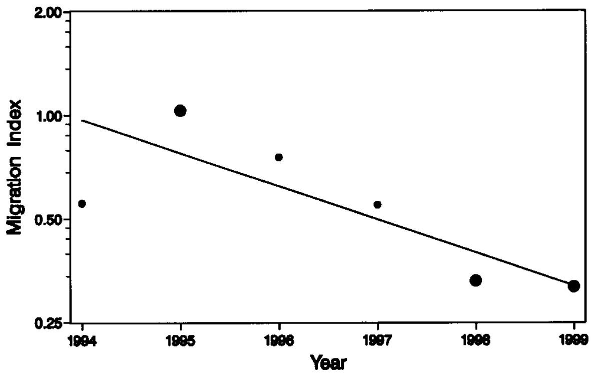
Appendix 3 – Estimated annual percentage change in numbers of migratory birds passing through Inglewood Bird Sanctuary between 1995-1999, based on linear regression on indices derived from daily estimated totals. These analyses match the graphs in Appendix 6. Inglewood only operates during the fall

Species	Fall
Belted Kingfisher	5.09
Eastern Kingbird	10.94
Western Wood Pewee	17.26
Trails Flycatcher	-4.54
Least Flycatcher	-1.89
Baltimore Oriole	-6.53
White-crowned Sparrow	3.57
White-throated Sparrow	7.47
Chipping Sparrow	15.79
Dark-eyed Junco	-5.69
Song Sparrow	22.94
Lincoln's Sparrow	3.15
Cedar Waxwing	-14.65
Warbling Vireo	-7.35
Orange-crowned Warbler	-6.33
Tennessee Warbler	19.45
Yellow Warbler	19.31+
Myrtle Warbler	12.88
Blackpoll Warbler	-8.90
Ovenbird	1.34
Northern Waterthrush	3.65
Mourning Warbler	-3.61
MacGillivray's Warbler	-8.38
Wilson's Warbler	-6.55
American Redstart	4.97
Gray Catbird	66.47*
House Wren	-1.23
Red-breasted Nuthatch	-14.17
Swainson's Thrush	-9.03
American Robin	-9.77

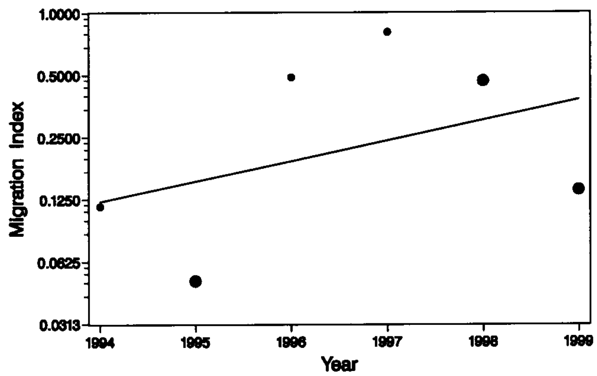
+ $P < 0.10$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Appendix 4 - Graphs showing annual population indices for spring and fall, and estimated population trajectories for each species at Lesser Slave Lake (1994-1999). The solid circles represent spring indices, while hollow triangles represent fall indices. The 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 similar 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 based on linear regression for the period 1994-1999, for both seasons separately. Significance of the trends can be determined from the tables in Appendix 1.

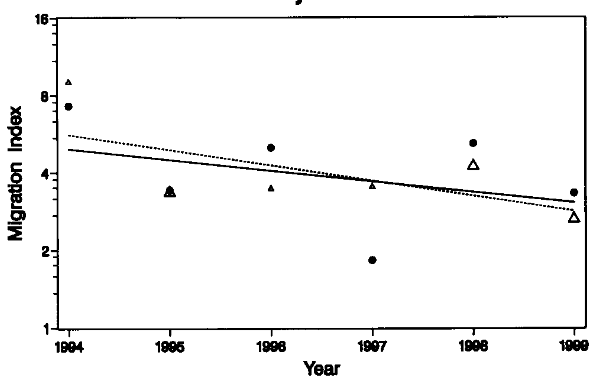
Yellow-bellied Sapsucker



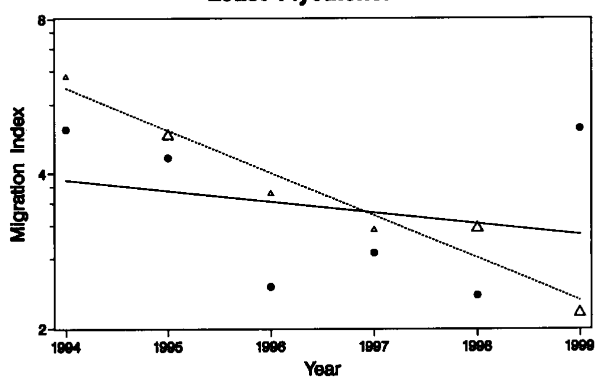
Yellow-shafted Flicker



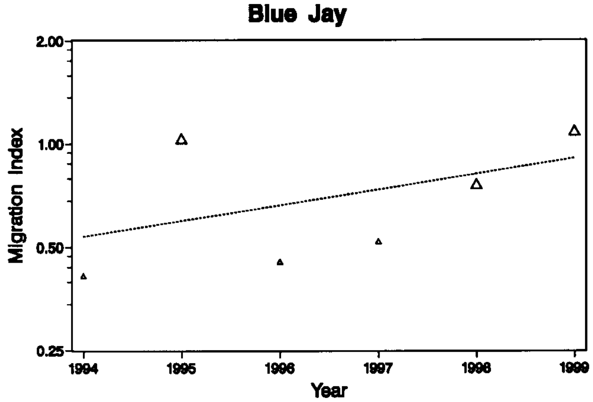
Alder Flycatcher



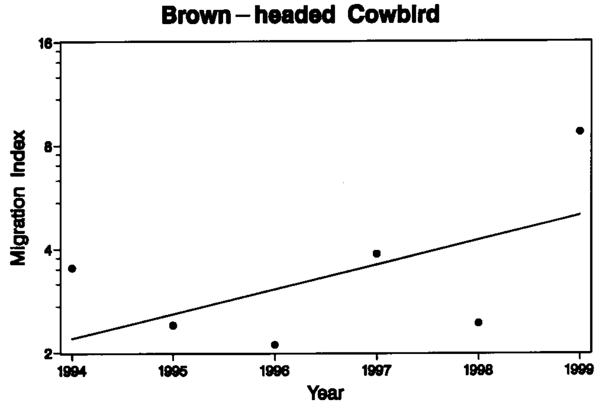
Least Flycatcher



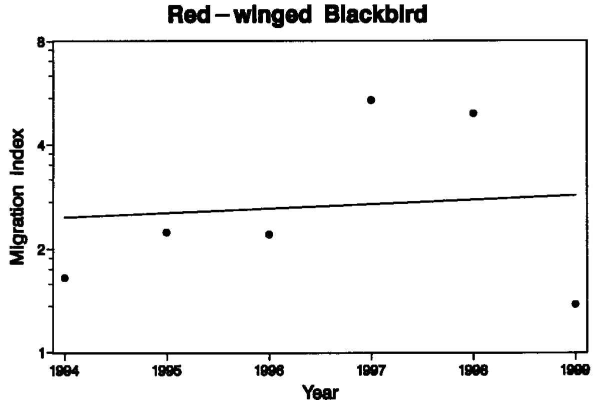
Blue Jay



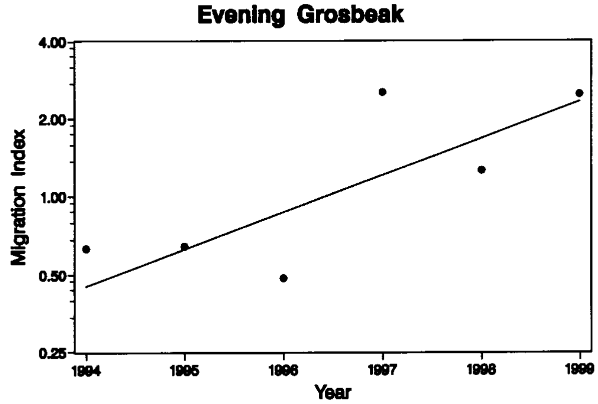
Brown-headed Cowbird

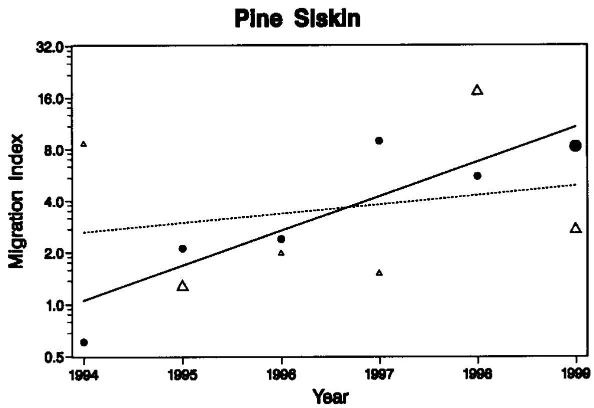


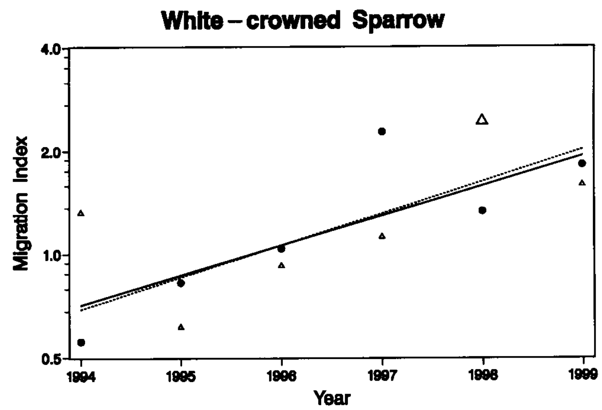
Red-winged Blackbird

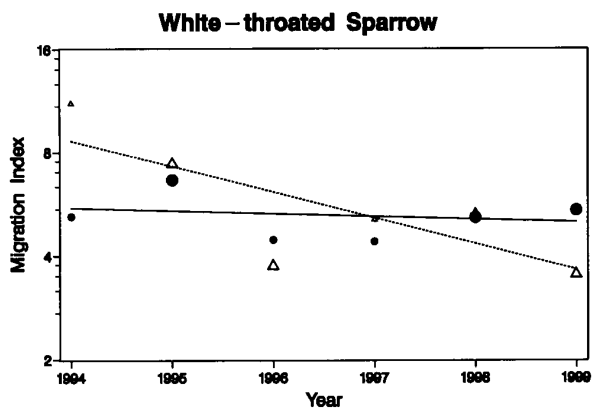


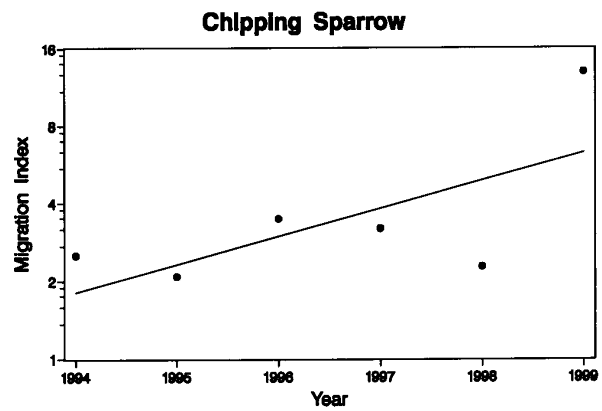
Evening Grosbeak

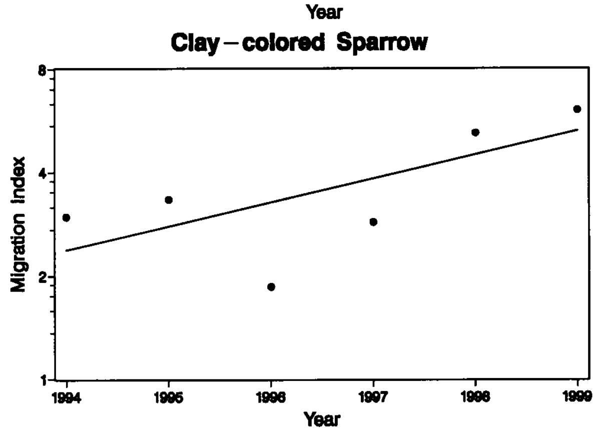


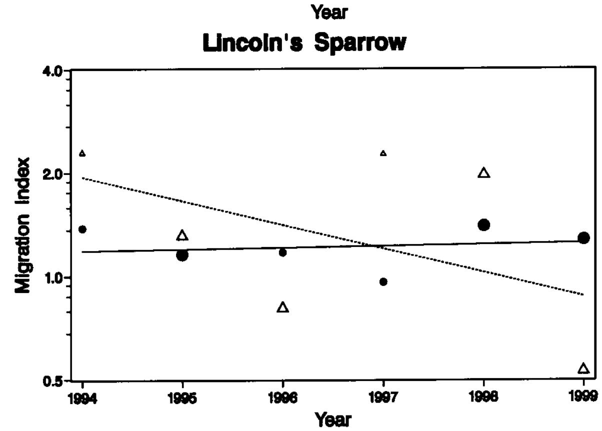

Pine Siskin
Migration Index
32.0
16.0
8.0
4.0
2.0
1.0
0.5
1994 1995 1996 1997 1998 1999
Year

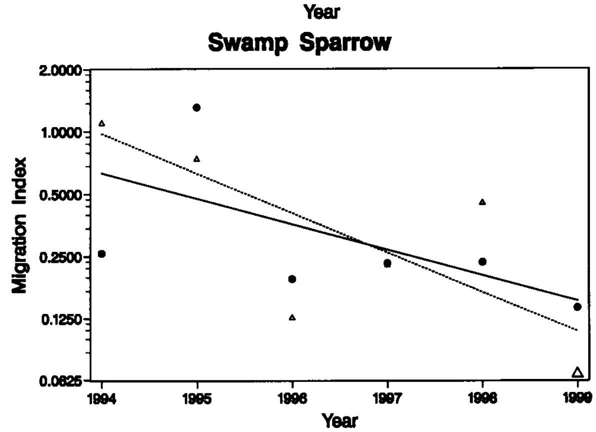

White – crowned Sparrow
Migration Index
4.0
2.0
1.0
0.5
1994 1995 1996 1997 1998 1999
Year

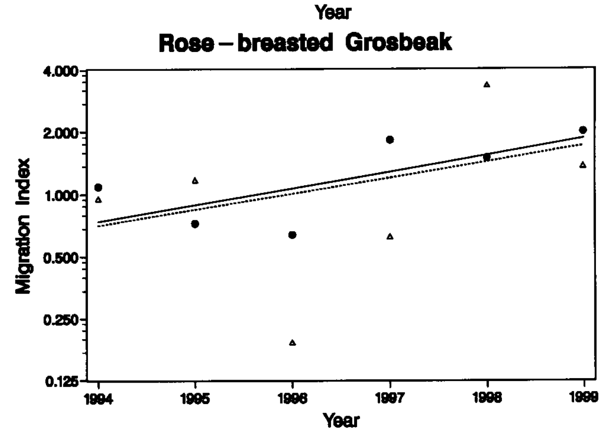

White – throated Sparrow
Migration Index
16
8
4
2
1994 1995 1996 1997 1998 1999
Year


Chipping Sparrow
Migration Index
16
8
4
2
1
1994 1995 1996 1997 1998 1999
Year

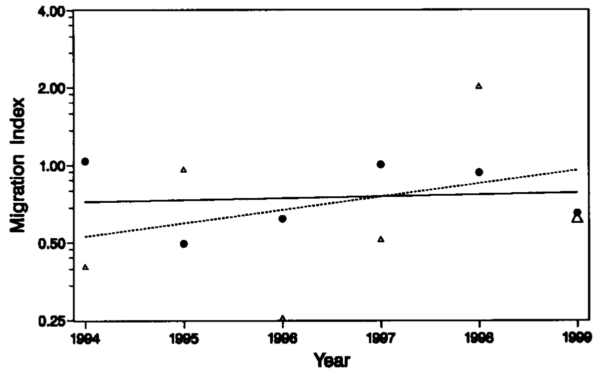

Clay – colored Sparrow
Migration Index
8
4
2
1
1994 1995 1996 1997 1998 1999
Year


Lincoln's Sparrow
Migration Index
4.0
2.0
1.0
0.5
1994 1995 1996 1997 1998 1999
Year

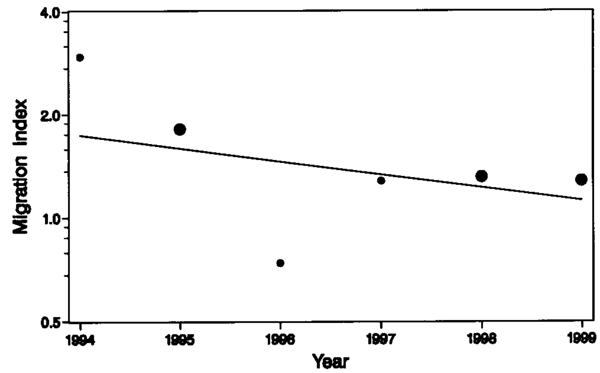

Swamp Sparrow
Migration Index
2.0000
1.0000
0.5000
0.2500
0.1250
0.0625
1994 1995 1996 1997 1998 1999
Year


Rose – breasted Grosbeak
Migration Index
4.000
2.000
1.000
0.500
0.250
0.125
1994 1995 1996 1997 1998 1999
Year

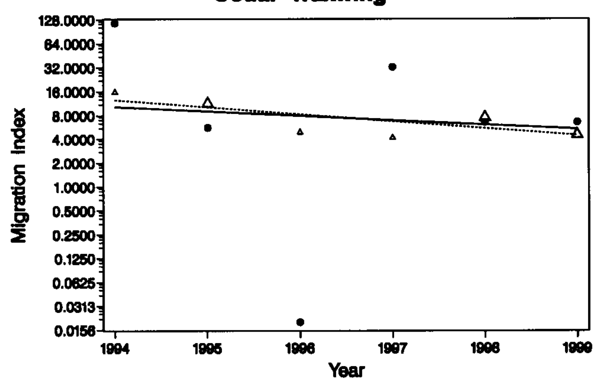
Western Tanager



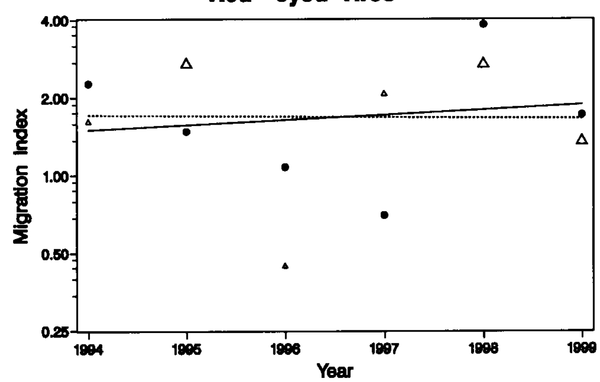
TRES



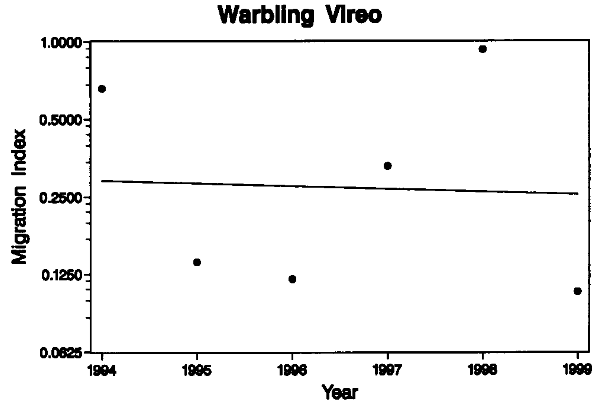
Cedar Waxwing



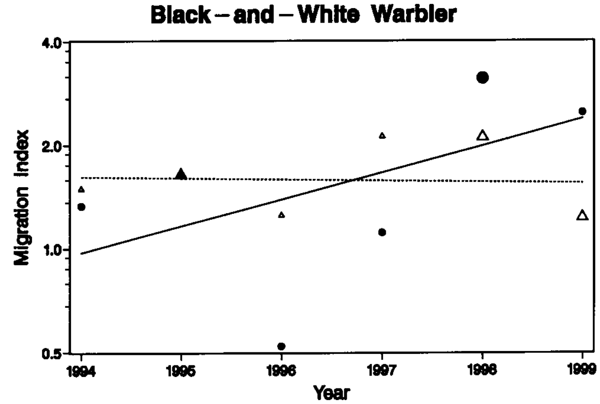
Red-eyed Vireo



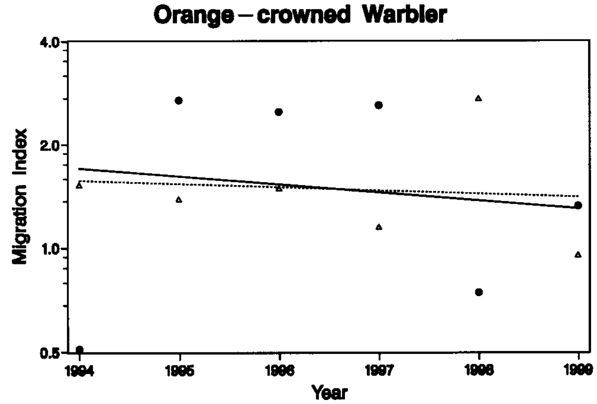
Warbling Vireo



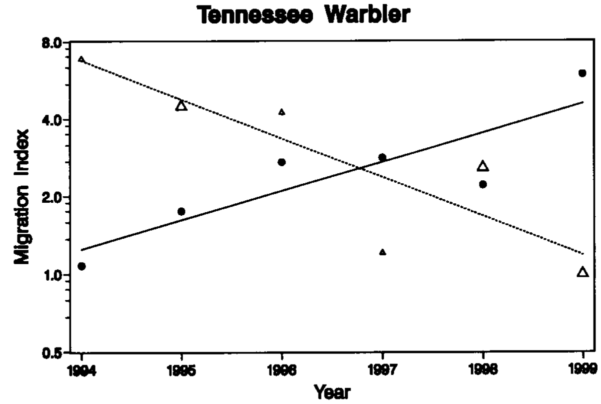
Black-and-White Warbler



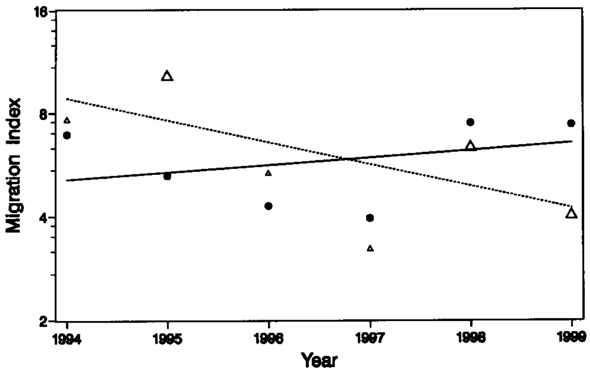
Orange-crowned Warbler



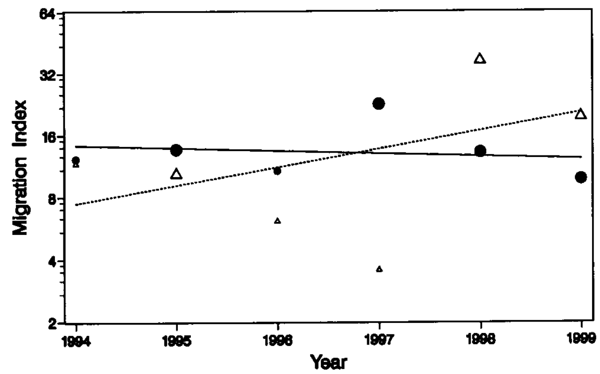
Tennessee Warbler



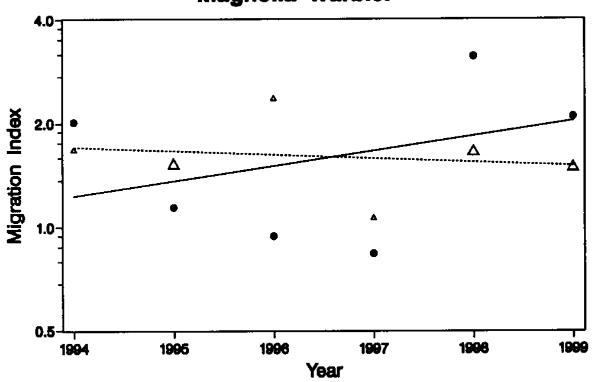
Yellow Warbler



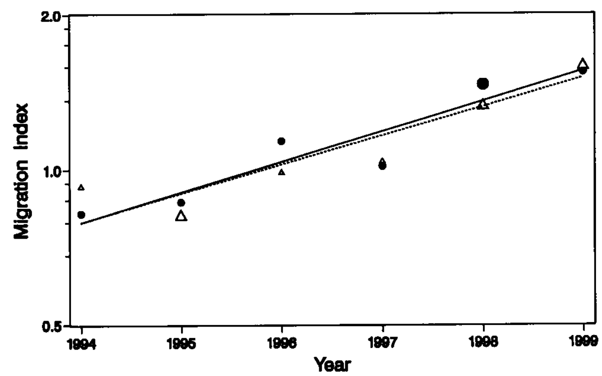
Myrtle Warbler



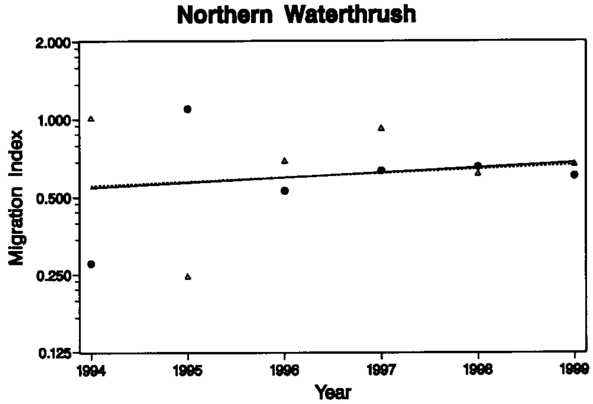
Magnolia Warbler



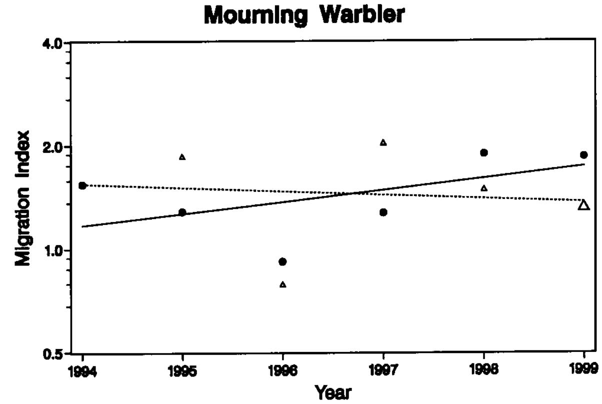
Ovenbird



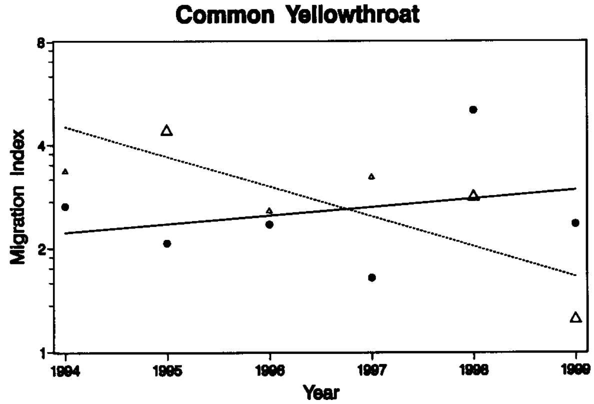
Northern Waterthrush



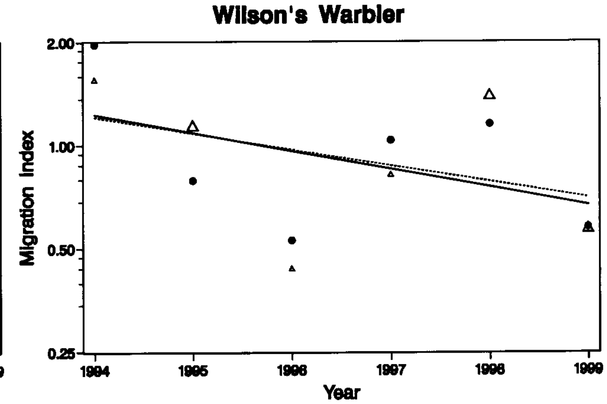
Mourning Warbler



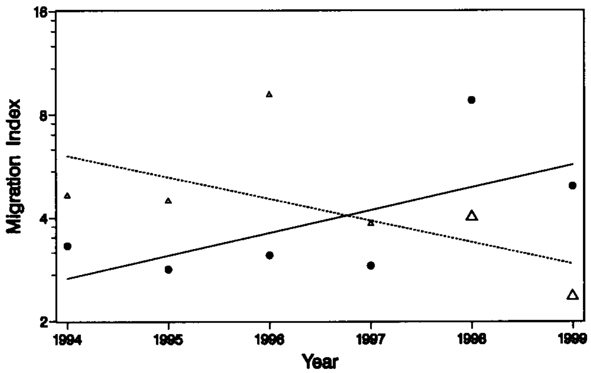
Common Yellowthroat



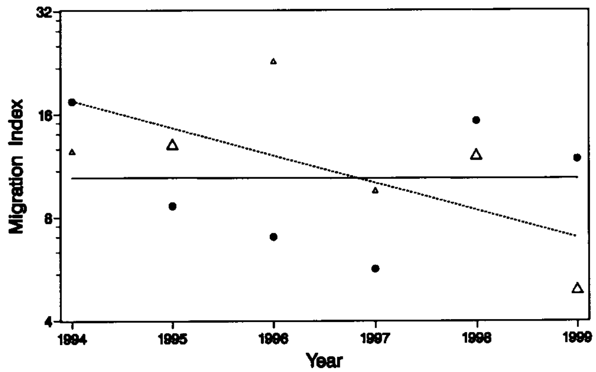
Wilson's Warbler



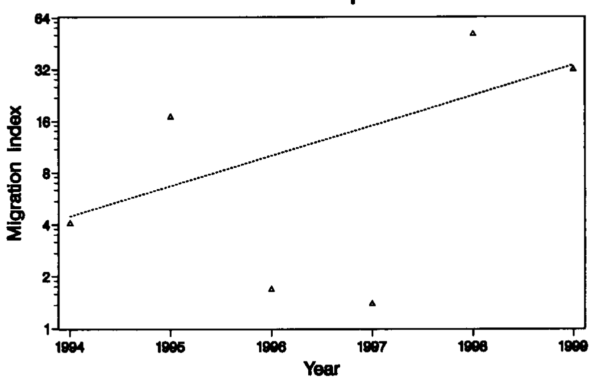
Canada Warbler



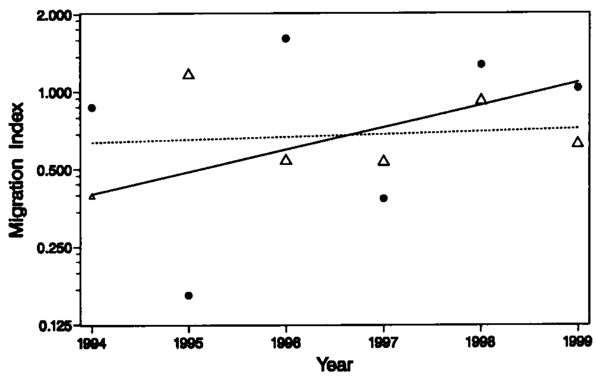
American Redstart



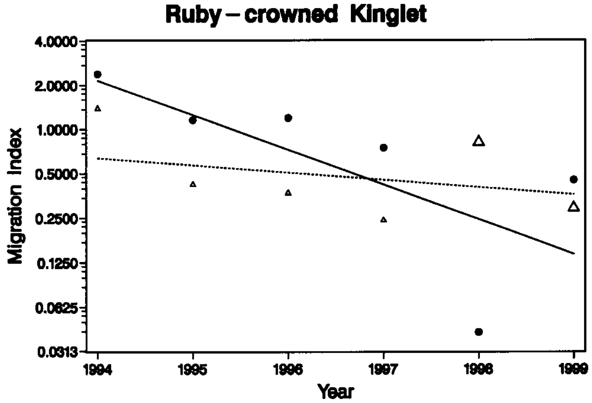
American Pipit



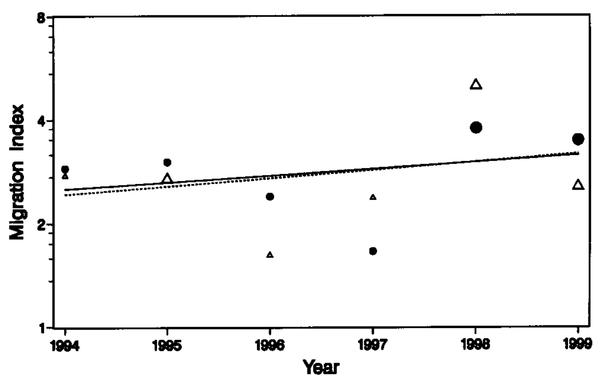
Red-breasted Nuthatch



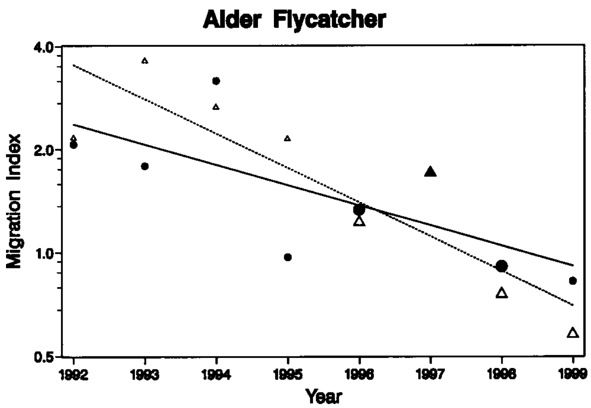
Ruby-crowned Kinglet

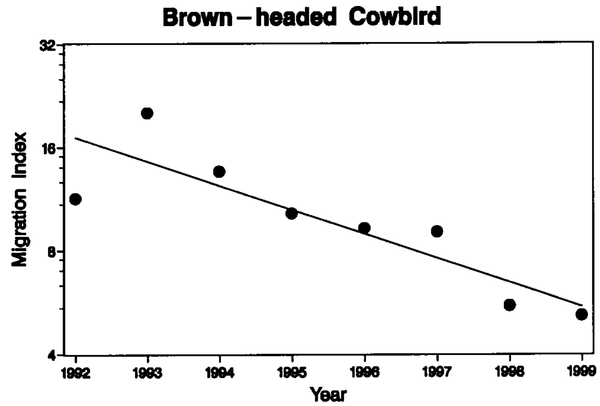


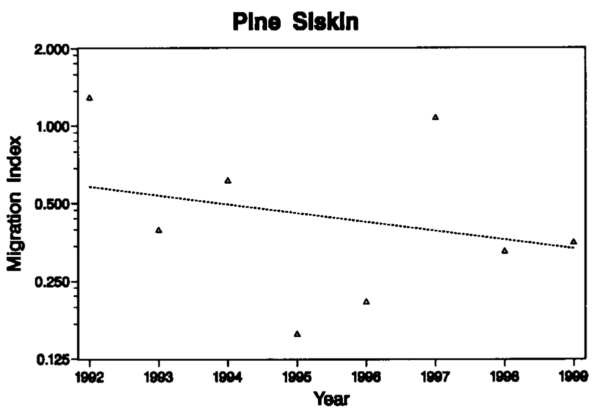
Swainson's Thrush

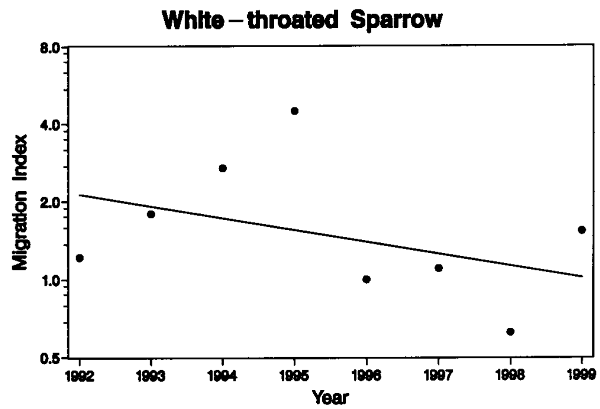


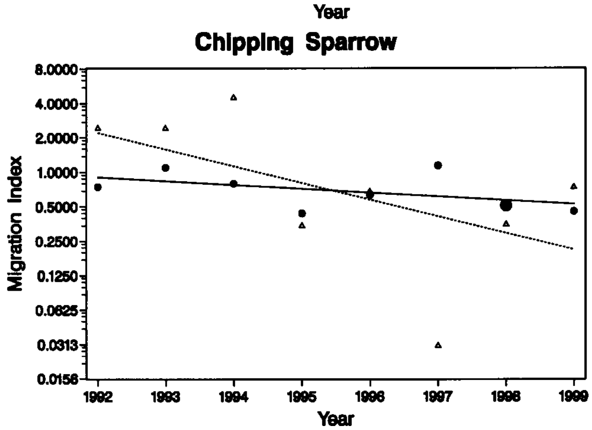
Appendix 5 - Graphs showing annual population indices for spring and fall, and estimated population trajectories for each species at Beaverhill Bird Observatory (1992-1999). The solid circles represent spring indices, while hollow triangles represent fall indices. The smaller symbols represent seasons 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 similar 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 based on linear regression for the period 1994-1999, for both seasons separately. Significance of the trends can be determined from the tables in Appendix 2.

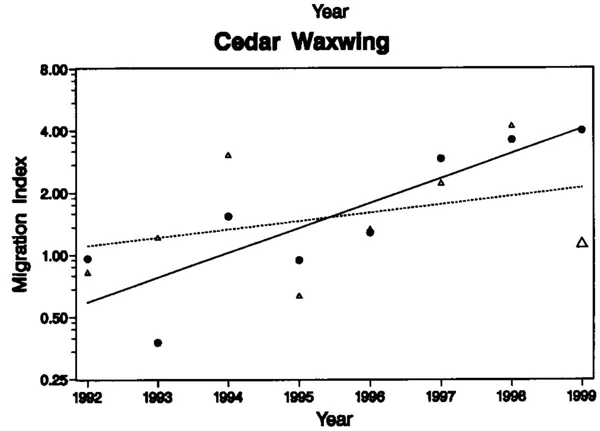

Alder Flycatcher
Migration Index
4.0
2.0
1.0
0.5
1992 1993 1994 1995 1996 1997 1998 1999
Year


Brown-headed Cowbird
Migration Index
32
16
8
4
1992 1993 1994 1995 1996 1997 1998 1999
Year

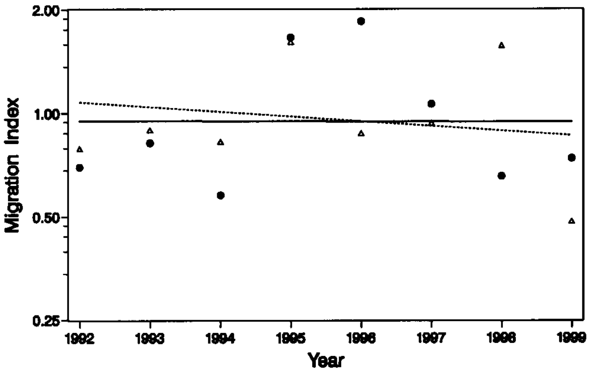

Pine Siskin
Migration Index
2.000
1.000
0.500
0.250
0.125
1992 1993 1994 1995 1996 1997 1998 1999
Year


White-throated Sparrow
Migration Index
8.0
4.0
2.0
1.0
0.5
1992 1993 1994 1995 1996 1997 1998 1999
Year

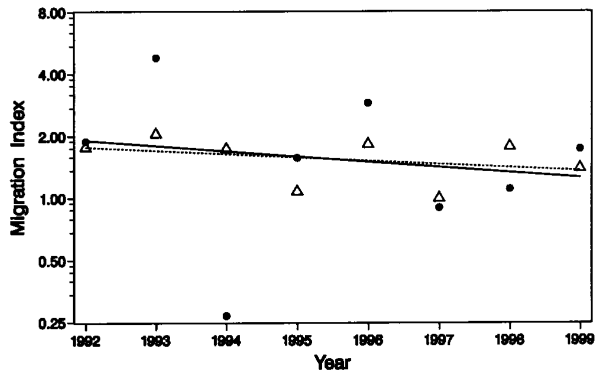

Chipping Sparrow
Migration Index
8.0000
4.0000
2.0000
1.0000
0.5000
0.2500
0.1250
0.0625
0.0313
0.0156
1992 1993 1994 1995 1996 1997 1998 1999
Year


Cedar Waxwing
Migration Index
8.00
4.00
2.00
1.00
0.50
0.25
1992 1993 1994 1995 1996 1997 1998 1999
Year

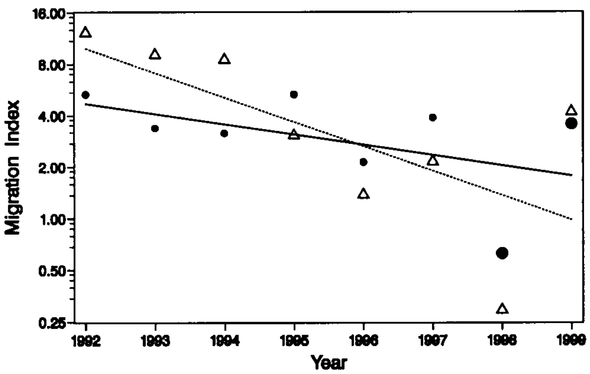
Orange – crowned Warbler



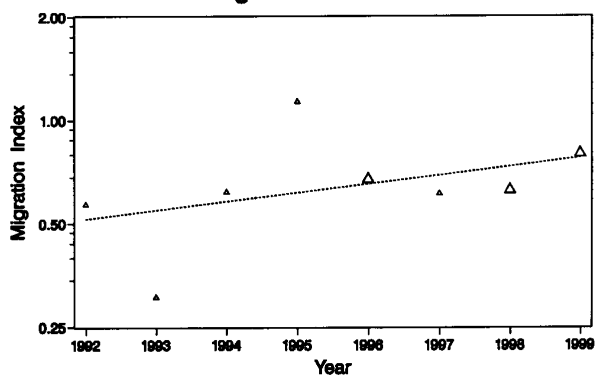
Tennessee Warbler



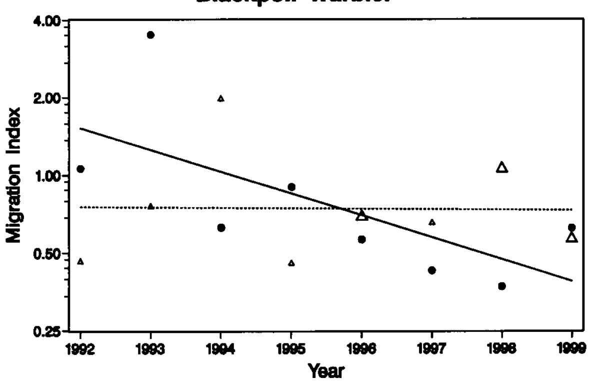
Myrtle Warbler



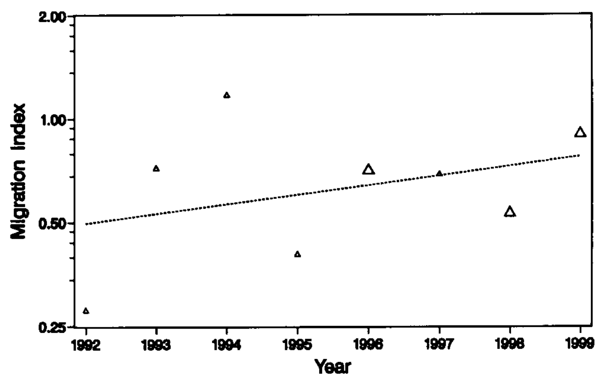
Magnolia Warbler



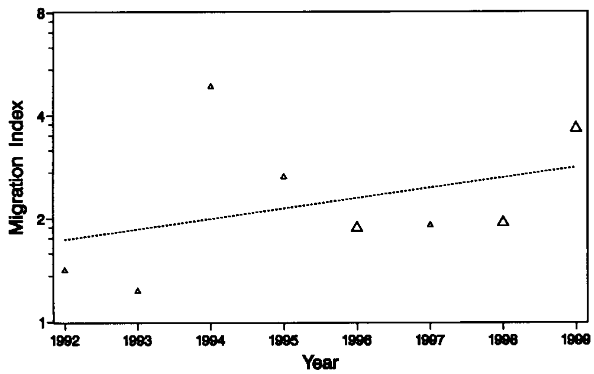
Blackpoll Warbler



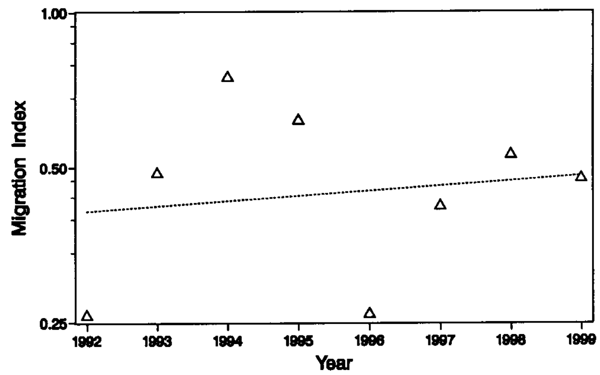
Wilson's Warbler



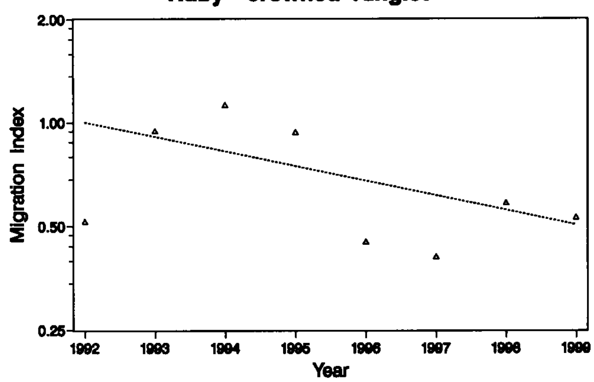
American Redstart



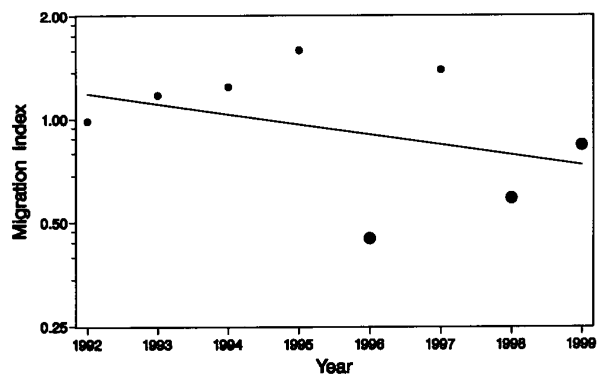
Red–breasted Nuthatch



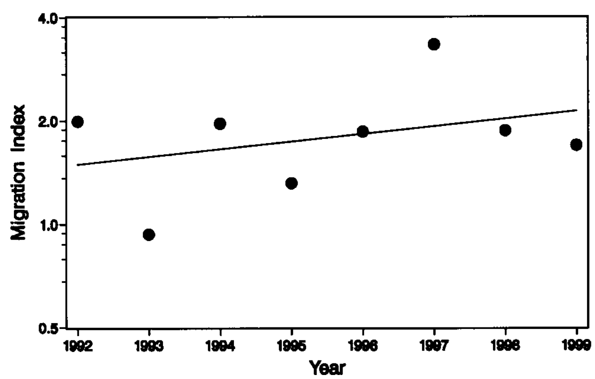
Ruby–crowned Kinglet



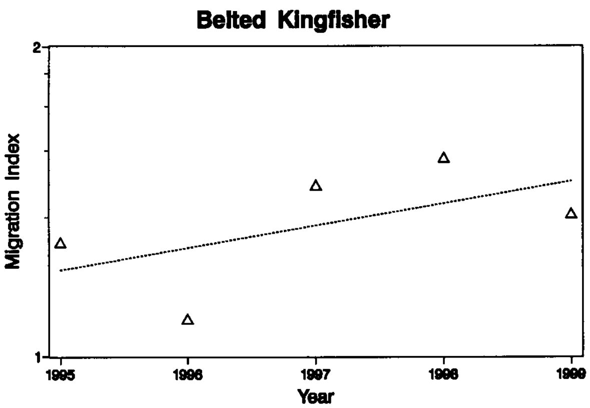
Swainson's Thrush

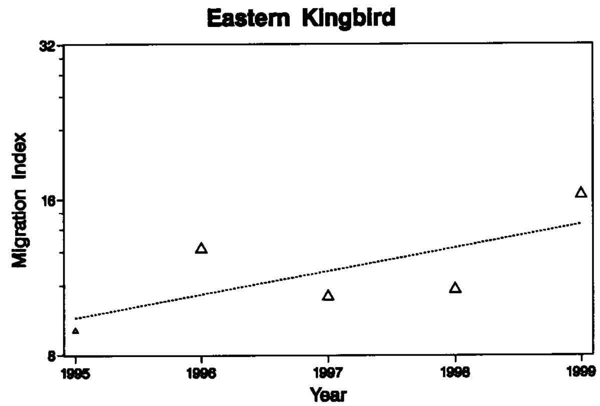


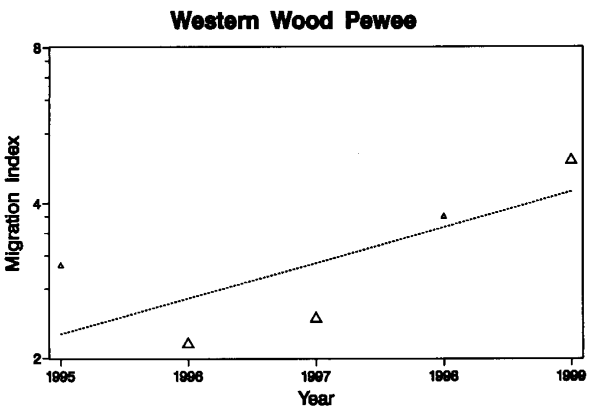
American Robin

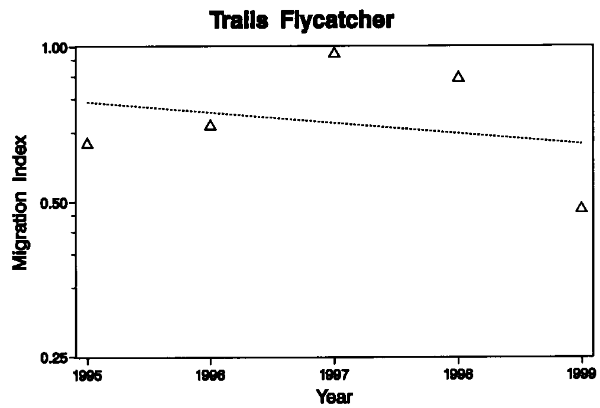


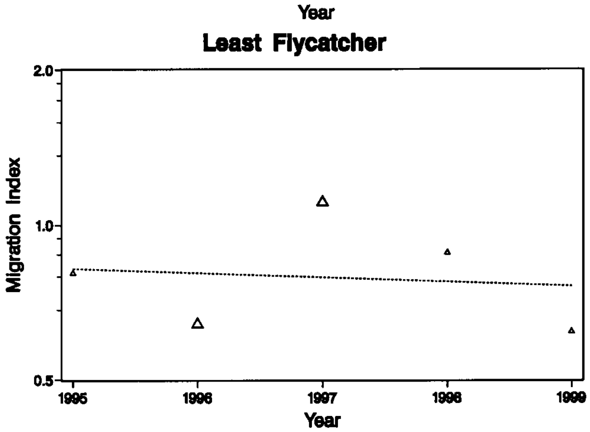
Appendix 6 - Graphs showing annual fall population indices, and estimated population trajectories for each species at Inglewood Bird Sanctuary (1995-1999). The smaller symbols represent seasons with reduced coverage (less than 30 station-days). Seasons in which there were fewer than 10 station-days during the migration window for a species were excluded from the analyses. Significance of the trends can be determined from the tables in Appendix 3.

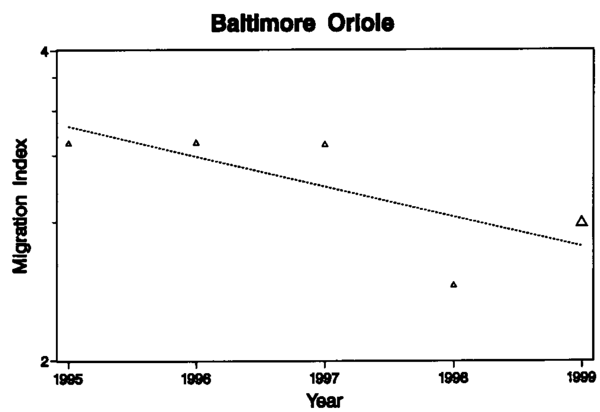

Belted Kingfisher
Migration Index
2
1
1995
1996
1997
1998
1999
Year

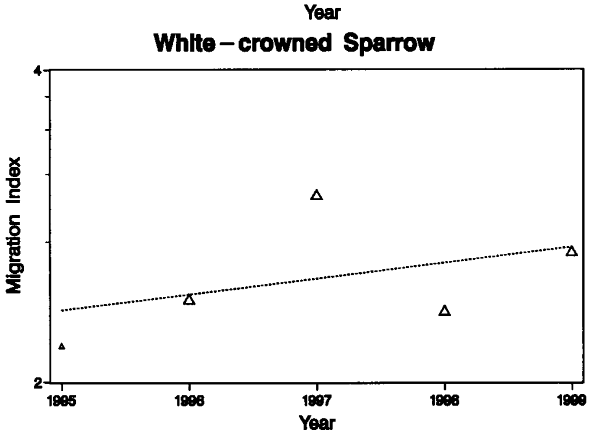

Eastern Kingbird
Migration Index
32
16
8
1995
1996
1997
1998
1999
Year

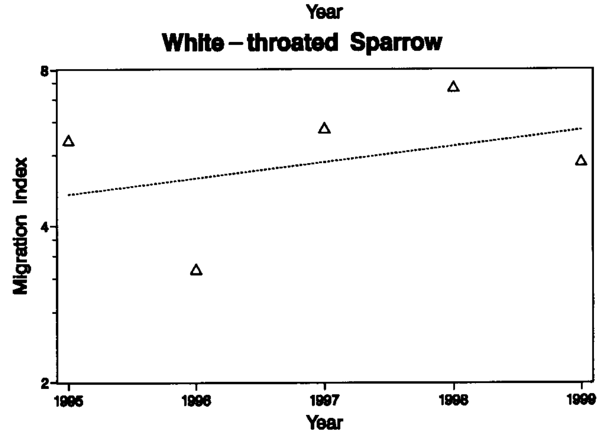

Western Wood Pewee
Migration Index
8
4
2
1995
1996
1997
1998
1999
Year

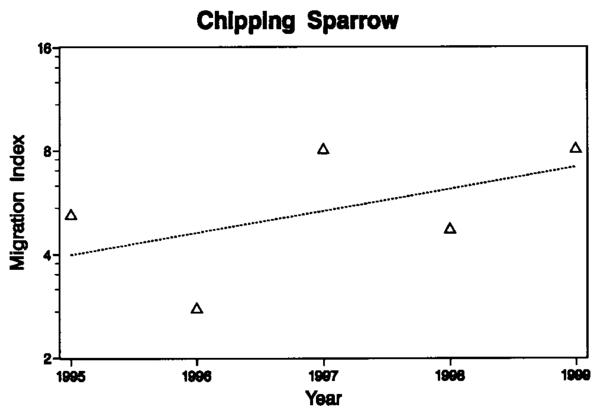

Trails Flycatcher
Migration Index
1.00
0.50
0.25
1995
1996
1997
1998
1999
Year

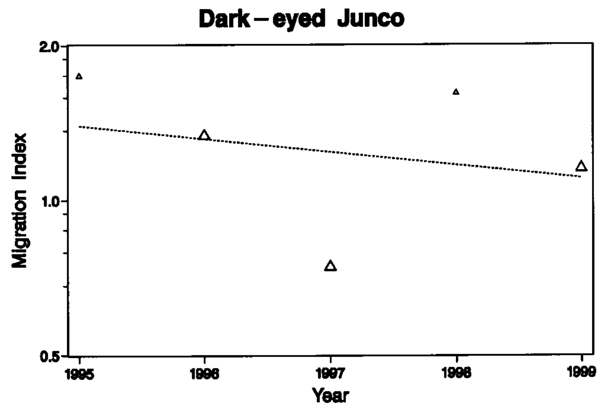

Least Flycatcher
Migration Index
2.0
1.0
0.5
1995
1996
1997
1998
1999
Year

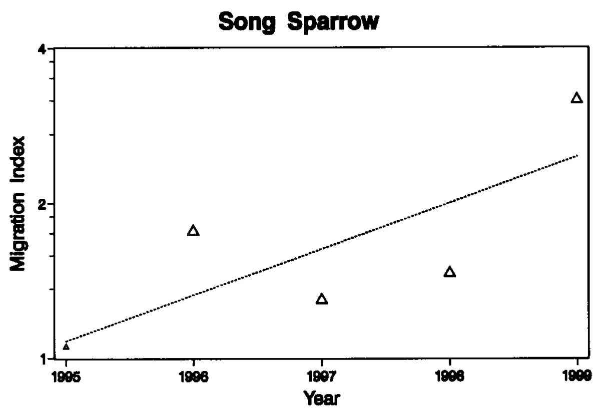

Baltimore Oriole
Migration Index
4
2
1995
1996
1997
1998
1999
Year

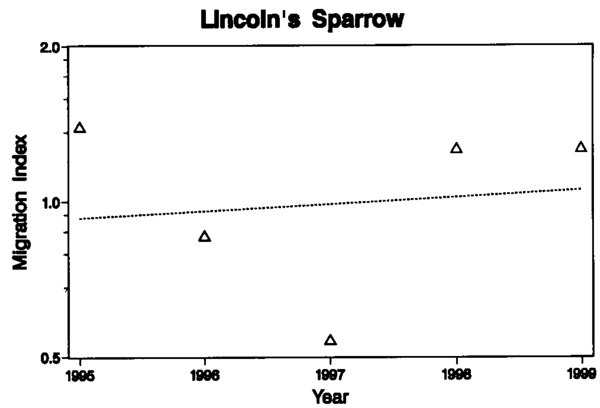

White-crowned Sparrow
Migration Index
4
2
1995
1996
1997
1998
1999
Year

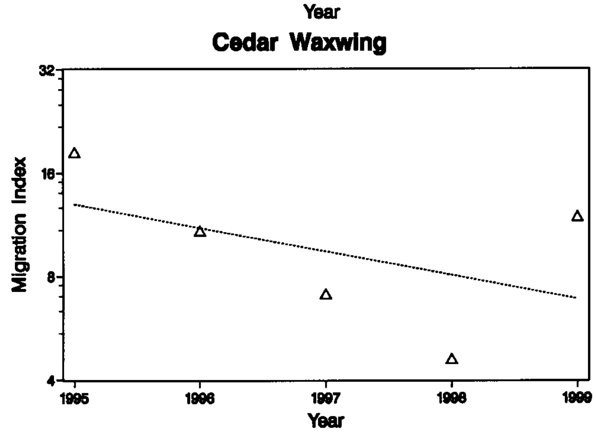

White-throated Sparrow
Migration Index
8
4
2
1995
1996
1997
1998
1999
Year

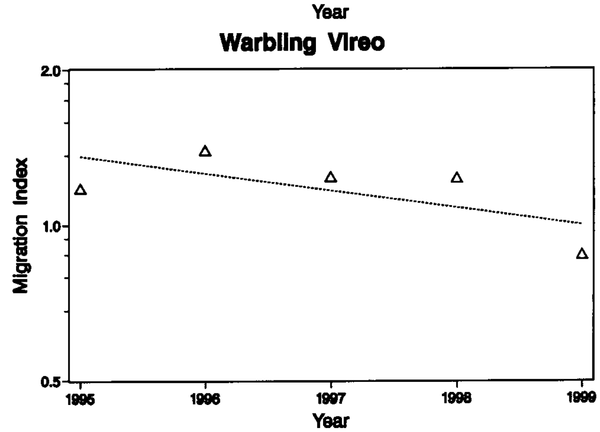

Chipping Sparrow
Migration Index
16
8
4
2
1995
1996
1997
1998
1999
Year

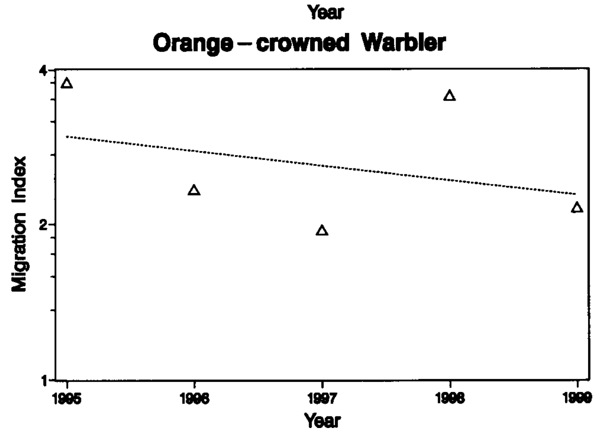

Dark-eyed Junco
Migration Index
2.0
1.0
0.5
1995
1996
1997
1998
1999
Year

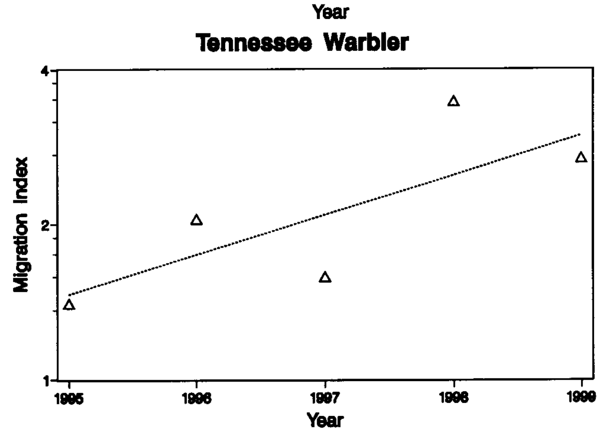

Song Sparrow
Migration Index
4
2
1
1995
1996
1997
1998
1999
Year


Lincoln's Sparrow
Migration Index
2.0
1.0
0.5
1995
1996
1997
1998
1999
Year

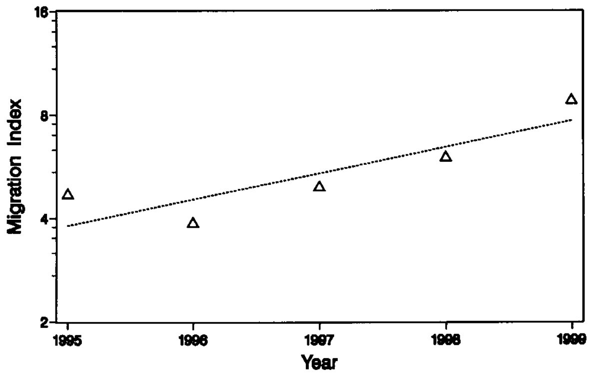

Cedar Waxwing
Migration Index
32
16
8
4
1995
1996
1997
1998
1999
Year


Warbling Vireo
Migration Index
2.0
1.0
0.5
1995
1996
1997
1998
1999
Year

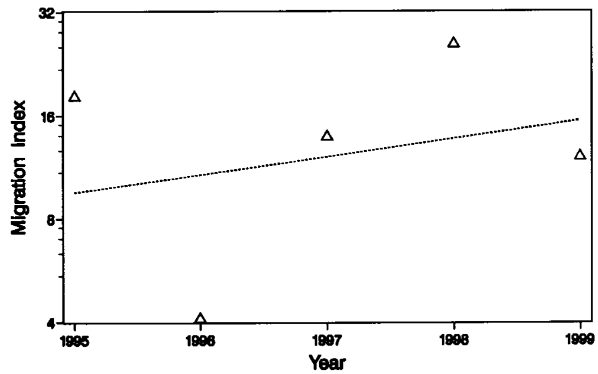

Orange-crowned Warbler
Migration Index
4
2
1
1995
1996
1997
1998
1999
Year


Tennessee Warbler
Migration Index
4
2
1
1995
1996
1997
1998
1999
Year

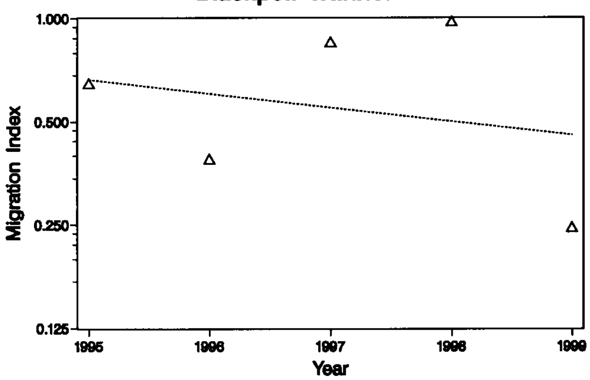
Yellow Warbler



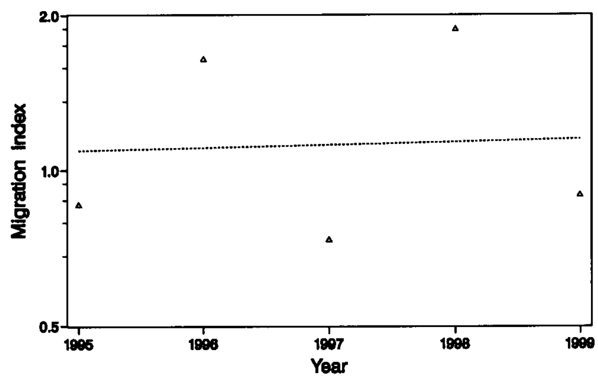
Myrtle Warbler



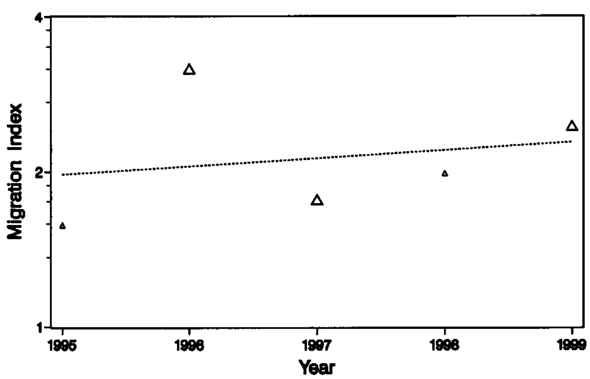
Blackpoll Warbler



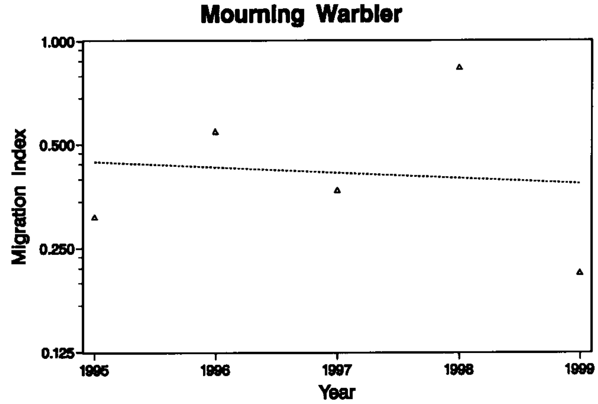
Ovenbird



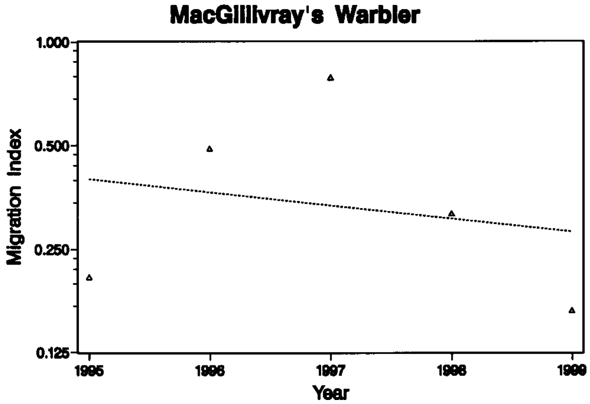
Northern Waterthrush



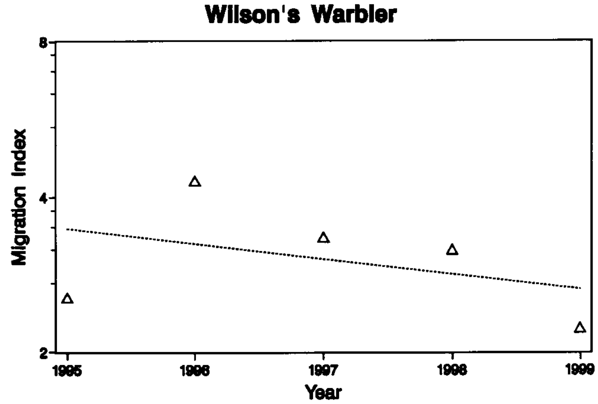
Mourning Warbler

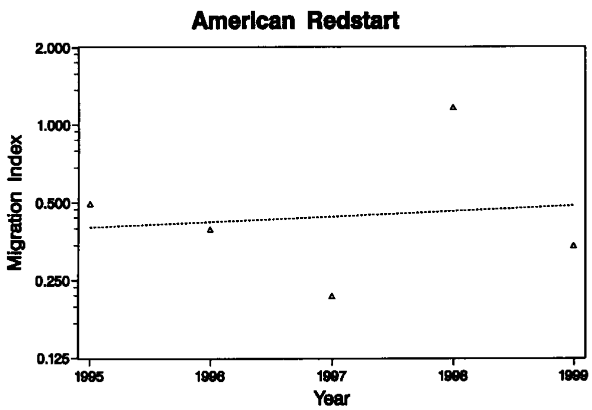


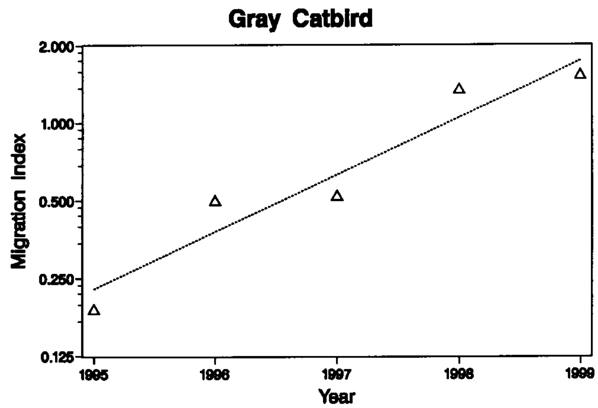
MacGillivray's Warbler

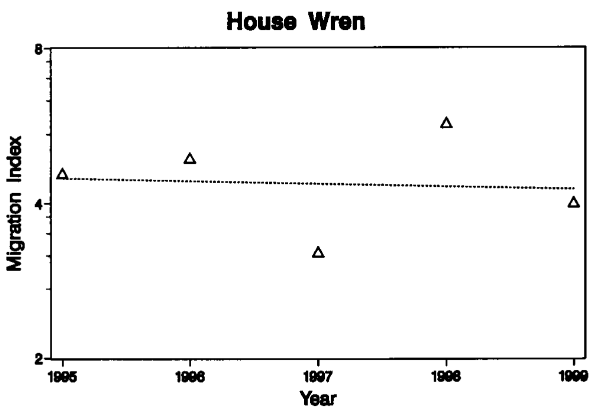


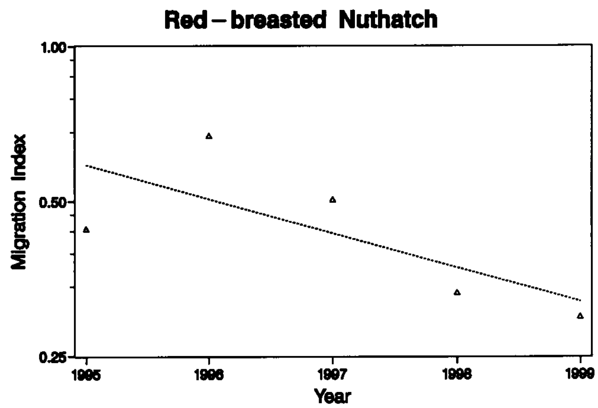
Wilson's Warbler

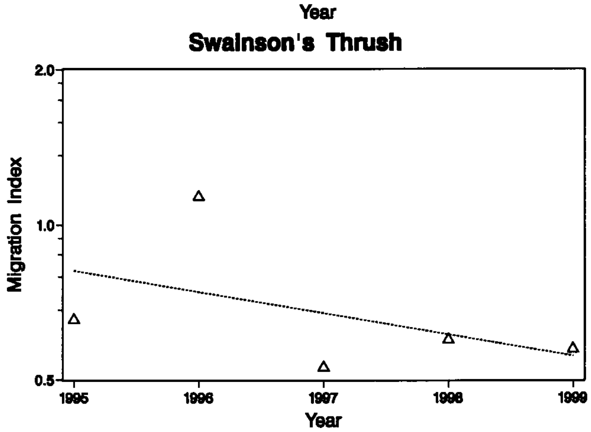


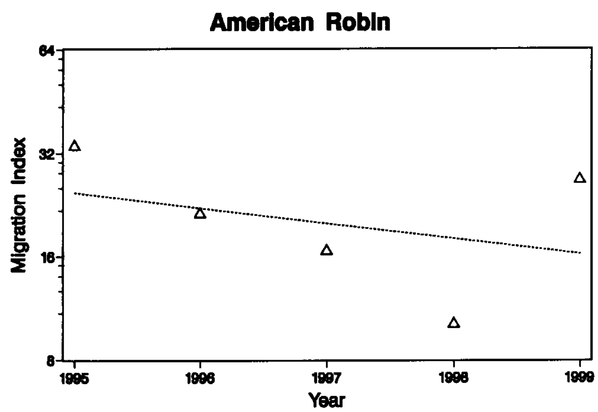

American Redstart
Migration Index
2.000
1.000
0.500
0.250
0.125
1995
1996
1997
1998
1999
Year


Gray Catbird
Migration Index
2.000
1.000
0.500
0.250
0.125
1995
1996
1997
1998
1999
Year


House Wren
Migration Index
8
4
2
1995
1996
1997
1998
1999
Year


Red-breasted Nuthatch
Migration Index
1.00
0.50
0.25
1995
1996
1997
1998
1999
Year


Swainson's Thrush
Migration Index
2.0
1.0
0.5
1995
1996
1997
1998
1999
Year


American Robin
Migration Index
64
32
16
8
1995
1996
1997
1998
1999
Year