The Impact of Changes in Average Winter Temperatures and Habitat Modification on Populations of Terrestrial Birds Over-wintering in Inland Areas of Massachusetts

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Abstract

This study investigates the impact of the increasing average winter temperatures and habitat modification on winter populations of terrestrial birds in Massachusetts, based on Christmas Bird Count (CBC) data recorded annually by volunteers for the National Audubon Society. The large archival database of records for birds' species in their winter range was used to examine whether bird species are extending their winter ranges into more northerly regions. The ratio of southern to northern for bird populations in eight CBC across within four ecologically diverse regions of Massachusetts were shown to have increased significantly from the winter of 1980/1 to 2004/5, but there was a weak correlation when the ratios were compared to average winter temperatures. Examination of the changes in land-use in the CBC areas, over the same time period showed a correlation with the area of residential use, and the length of edge between forested and developed areas, which is increasing as a result of forest fragmentation. Separation of the bird species into habitat preferences of edge, woods, and grassland, showed a preferential distribution of birds in the edge habitat. Additionally, analysis of the feeding preferences of the bird species showed a predominance of seed-eating birds. Examination of individual species that use bird feeders as a supplementary winter food resource showed they are increasing in abundance and/or expanding their winter ranges. The increasing popularity of feeding wild birds may be improving the winter survival of some

species at the expense of species diversity. These results suggest that the increasing numbers of winter populations of southern species in Massachusetts are occurring in response to a complex interaction of factors that include climate change, habitat modification, and supplementary winter food resources.

Dedication

This is dedicated to my husband whose enthusiasm, support, and understanding has made its' completion possible. My heartfelt thanks is also given to my children whose pride in their mother has been an incredible motivator!

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My thanks to the hundreds of volunteers who face the cold weather and field conditions on Massachusetts in the winter to collect data for the Christmas Bird Count. Without their dedication studies like this would not be possible.

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Chapter I

Introduction

The expanding human population is making a significant impact on the Earth's environment (McCarty, 2001; Vitousek et al., 1997). Man's dependence on fossil fuels is one of the factors producing an escalation of the enhanced greenhouse effect that is driving global climate change (IPCC, 2001). In addition, anthropogenic demands for land are impacting natural ecosystems through land-use changes and habitat modification. Information on how the earth's flora and fauna are responding to these changes is needed to anticipate future changes and develop conservation strategies for reducing the destruction in the biosphere and preventing further degradation of biodiversity.

The Intergovernmental Panel on Climate Control (IPCC) has demonstrated that historic records document the rapid increase in temperatures in the Northern Hemisphere in the twentieth century (Figure 1). The surface temperature of the Earth rose by approximately one degree Fahrenheit in the last century, with accelerated warming occurring within the last two decades (National Institutes of Science – Figure 2). The ten warmest years of the 20th century all occurred after 1985, with 1998 being the warmest year on record (Figure 3). This warming trend continues in the twenty-first century, with record high temperatures reported in 2005 (Gore, 2006). In December 2006 the National Oceanic and Atmospheric Administration (N.O.A.A.) recorded the highest ever temperatures in December for the Northeast region of the United States, including

Massachusetts. January 2007 continued the warming trend with temperatures 4-6°F above normal in Massachusetts, (Figure 4) (<http://www.ncdc.noaa.gov/oa/climate/>).

In addition to climate change, urbanization and its' associated infrastructures, together with intensive agricultural practices are causing habitat destruction, fragmentation and drastic changes in land-use. Many animals are responding to local climate changes resulting from global anomalies produced by anthropogenic activity. The responses observed include poleward and elevational movement of distributional ranges, changes in animal abundance, changes in body size, and shifts in the timing of events, such as earlier breeding in spring (ref). Possible climate associated shifts in animal ranges and densities have been noted on many continents and within each major taxonomic group of animals (IPCC, 2001). Understanding how plants and animals are responding to these changes is important in the development of conservation strategies for protecting ecosystems and species diversity in the future.

Birds have been identified as a group of species that can play a key role in a global monitoring system (Donald, 2001). Birds are good indicators of the health of local, and regional environments, since their mobility of allows them to respond more quickly to environmental changes than more sedentary species. Changes in the distribution and behavioral characteristics of bird populations potentially offer an early indication of the impact of global warming and habitat modification.

For many years, non-governmental organizations (NGOs) such as the National Audubon Society have been using volunteers to collect field data, and have amassed a large and valuable database resource for research into avian ecology.

Using historical data collected during the annual Audubon Society Christmas Bird Count (CBC) from 1961 through 1972, Root (T.L. Root, 1988a, , 1988b) determined that

there was a correlation between the northern distributional limits of specific bird species across the United States coincidental with winter temperature anomalies and habitat modification. However, large-scale studies may not be representative of local environments.

Using CBC data (1903 - 2002), Valiela (Valiela et al., 2003) demonstrated that local climate changes and habitat modification specifically impacted the winter ranges of bird species in Cape Cod, Massachusetts. Northward shifts in winter bird distributions were correlated with local increases in minimum winter temperatures resulting from to global temperature anomalies, and that the impact of climate change was apparently greater than that of habitat modification. Unless small-scale studies are representative of a region, it is difficult to extrapolate meaningful results for conservation planning. The Cape Cod region is not representative of the whole of Massachusetts, therefore the present study was designed to investigate CBC areas that are representative of the inland region of the state. Examining the impact of climate change and habitat modification on the composition of terrestrial bird populations in inland regions of Massachusetts may provide insight into how species using that region are adapting to the impact of climate change and habitat modification during the winter months. Using historic data collected by the annual National Audubon Society's Christmas Bird Count (CBC) during the winters of 1980/1 to 2004/5 this study investigated changes in winter bird populations to determine whether they were linked to climate factors or changes in physical characteristics of the local environment.

Chapter II

Materials and Methods

The rate of increase in global warming has accelerated over the twenty-five year time period from 1980 to 2005, therefore average winter temperatures recorded during the winters of 1980/1 through to 2004/5 were used as the basis for investigation into the impact of climate changeon bird species over-wintering in inland areas of Massachusetts. To determine whether changes in average winter temperatures and/or habitat modification are associated with changes any observed changes in the population of bird species, the following criteria were examined.

Changes in the Winter Climate of Massachusetts from 1980/1 to 2004/5

Massachusetts has a humid continental climate that is characterized by warm summers and cold winters. Average winter temperatures showed an increasing trend in the last two decades of the twentieth century, and that trend has continued into the present century, with record temperatures recorded for Massachusetts in the winter of 2006/7 (Figure 4). The National Climate Data Center (NCDC) at the National Oceanic and Atmospheric Administration's (N.O.A.A.) National Weather Service, maintains historical climate monitoring data. Their records indicate that the average winter temperature from

December to February in Massachusetts from 1980 through 2005 were obtained from the NCDC. In addition, average winter temperatures for the northeast region, and the continental United States were examined to determine whether regional and national climate anomalies were reflected at a local level. The data obtained from the NCDC (Table 1) were transferred to a Microsoft Excel© spreadsheet, and trends over time were calculated (Figure 4). The average winter temperatures for Massachusetts were subsequently used to determine any correlation between changes in temperature and the ratio of southern to northern (S/N) bird species in order to assess whether the ranges of birds over-wintering in Massachusetts have extended northwards.

Selection of Study Areas

The landscape of Massachusetts defines the composition of the bird populations found across the state. Valiela (Valiela et al., 2003) examined coastal data, which suggests that their observations might not be representative of the composition of bird populations over-wintering in other regions of Massachusetts, or a response of those populations to environmental changes. To provide a broader perspective while still maintaining local detail, this study focuses on terrestrial bird species over-wintering in inland regions of Massachusetts.

Massachusetts is comprised of two distinct eco-regions, the Northeastern Highlands and the Northeastern Coastal plain (Figure 5) (Griffith et al., 1994). Ecological regions (eco-regions) are areas having general similarity in ecosystems, as well as similarity in the type, quality, and quantity of environmental resources. An eco-region

incorporates all major components of an ecosystem: air, water, land, and biota, including humans and are defined by soil type, elevation, and forest type. Collectively these factors determine the species of birds found within each region, and variations in their population densities.

The United States Environmental Protection Agency (EPA) in Massachusetts has defined six different types of "eco-regions" within the Northeastern highlands of western Massachusetts. The Taconic Mountains, Western New England Marble Valleys, Lower Berkshire Hills, Berkshire Highlands, Vermont Piedmont, and Berkshire Transition (Griffith et al., 1994). The remaining inland region of Massachusetts is comprised of the Northeastern coastal zone that includes the Connecticut River Valley and Southern New England Plains and Hills sub-regions.

The areas selected for this study are located at intervals across the state and are located in specific eco-regions/sub-regions (Figure 7). Central Berkshire (MACB), North Berkshire (MANB), and Westminster (MAWE) are located in the Northeastern highlands, and Northampton (MANO), Springfield (MASP), Worcester (MAWO), Concord (MACO), and Millis (MAMI) are in the Northeastern coastal zone. Other considerations regarding the selection of the study areas are described in the following section of this thesis (page 8).

Note: The above codes are those designated by the National Audubon society. The areas will be referred to as Central Berkshire (CB), North Berkshire (NB), and Westminster (WE), Northampton (NO), Springfield (SP), Worcester (WO), Concord (CO), and Millis (MI) in the remainder of this thesis.

The Christmas Bird Count

The primary objective of the Christmas Bird Count (CBC) is to monitor the status and distribution of bird populations in the winter months. The data gathered in the CBC is based on counts conducted on a single calendar day, between December 14th and January 5th each year. Groups of volunteers count the total numbers of birds seen (or heard) within a specified fifteen-mile (24km) diameter circle, on whatever day the count is conducted. A designated count compiler then enters the count data for each CBC circle into the National Audubon Society's on-line database at http://www.audubon.org/bird/cbc. The basic guidelines describing how counts are conducted are shown in Table 2. Copies of the Compiler's Manual and Data Entry Manual are available at http://www.audubon.org/bird/cbc.

The historical data reported on the CBC web site are in the public domain, and provide a readily available resource for investigation of bird behavior and distribution that can subsequently be used to support bird conservation strategies. This website makes it possible to the download raw data as shown in Table 3, or it can be used to generate graphs of species trends over time (e.g. Figure 27) or maps of bird distribution (e.g. Figure 28).

Selection of Christmas Bird Count Circles

There are thirty-three CBC circles in Massachusetts (Figure 6a). Parameters used to select CBC circles for analysis included the geographic location within an ecological

region, latitude, coastline component, and the historic consistency of the counts for each CBC (i.e. annually recorded counts).

Latitude of geographic center. CBC circles were selected that had a geographic center located between 42.0° N and 42.7°N latitude, i.e. the inland borders of Massachusetts, and 69°W and 73° W longitude (Figure 6b).

Lack of a coastline component. CBC circles containing coastline within the counting area were excluded from the analysis to eliminate the influence of coastal environmental effects and the presence of marine bird species.

Census consistency. Not all CBC circles in Massachusetts are monitored annually. To increase the validity of comparisons, the circles selected were ones that were monitored consistently between 1980/81 and 2004/5. Seven of the chosen CBC circles were monitored annually, and one was monitored for twenty-three years of the time period of the study (the Millis CBC circle (MI) did not report data for 1992 & 1993).

The CBC circles selected (Figure 7) are listed on page 7 of this thesis. The areas within the circles cover a range of vegetation types, and different types and extents of land use change. The categories of land-use and land-use changes over time were analyzed within each circle and are discussed on page 14 of this thesis.

Selection of Bird Species

More than one hundred species of birds have been recorded in Christmas Bird Counts conducted in Massachusetts since it began in 1900 (www.audubon.org/birds/cbc/) and includes bird species in all types of habitats. To reduce the complexity of this limited study, only terrestrial bird species (birds with no links to aquatic habitats for feeding or breeding) were considered.

Terrestrial Bird Species Excluded from the Analysis

A number of terrestrial bird species were also excluded from the study based on the following criteria.

Extremely rare species. Bock and Root (Bock, 1981) have shown that species that are extremely rare are inadequately represented in CBC data. Eighteen bird species rarely recorded in Massachusetts (but which have occasionally been recorded in the CBC) were not included in the analysis, and are listed in Table 4. In addition, eight species were recorded in such low numbers that they were designated too rare to count (trtc), and were also excluded from the analyses (Table 4).

Nocturnal species. The data for owls are often more representative of the enthusiasm of the observers rather than the true incidence of the birds (T.L. Root, 1993), therefore seven species of owls were not included in the analyses and are listed in Table 4.

Ninety-five terrestrial bird species were identified as appropriate for analysis in this study, and are listed in Table 5.

Christmas Bird Count Data

Records were obtained from the Christmas Bird Count historical results database at http://www.audubon.org/birds/cbc.

Christmas Bird Count Data Analysis

Historic records from the Christmas Bird Count were obtained from the database at http://www.audubon.org/birs/cbc for all species from count number 80 (1980/81) through count number 105 (2004/2205) for each of the selected count circles i.e. North Berkshire (MANB), Central Berkshire (MACB), Northampton (MANO), Springfield (MASP), Westminster (MAWE), Worcester (MAWO), Concord (MACO), and Millis (MAMI), and saved in a Microsoft Excel© Spreadsheet. Records for excluded species (see pages 9-10 of this thesis) were removed from the database, and the data for the remaining ninety-five species were used for all subsequent analyses. To compensate for the variation in counting effort from year to year and site to site, the numbers of birds per party hour (#pph) were used. The number of birds per party hour is calculated from the effort (total number of hours spent counting) and the number of individuals participating in the count for each CBC circle.

Copies of the raw data used in all analyses can be obtained from the historic results page at www.audubon.org/birds/cbc/

Winter Ranges of Species in the Census Areas

Each of the ninety-five selected species was assigned a winter range designation based on ranges specified in The Sibley Guide to Birds (Sibley, 2000) and (T.L. Root, 1988a). Species were defined as northern (N) if greater than fifty percent (50%) of their winter range was north of latitude (>) 42.30 and southern (S) if greater than fifty percent (50%) of their winter range was south of latitude (<) 42.30 (42.30 is the approximate mid-latitude of Massachusetts). Bird species that are routinely recorded throughout the year in Massachusetts were defined as year-round species (Y).

Average Densities of Birds

The average number of each species in each geographic range category was calculated by adding the number of birds per party hour (#pph) for each species over the twenty-five year period, and then dividing by the number of years counted.

The mathematical expression for calculating the average density is given as:

$$X = \Sigma_1 N^{25}/25$$

where X= average density of a species

and $\Sigma_1 N^{25}$ = the sum of the #pph from year 1 through year 25

The average densities of birds of northern, southern, and year round range preferences were calculated and the relative proportions of each category estimated.

Ratio of Southern (S) to Northern (N) Species (S/N)

If southern species of birds that are sensitive to cold extend their winter range northwards, there should be an increasing trend in the ratio of southern to northern birds. Comparing the ratio (using #pph data) of southern (S) to northern (N) birds (S/N) and measuring the trend in data over the selected time period (1980/1 to 2004/5), should reflect whether or not climate change is impacting the winter ranges of these birds.

For each of the selected CBC circles, the southern to northern (S/N) ratio was calculated for each year, and the significance of observed trends over the time period of the study was calculated from fitted linear regressions.

Correlation of Changes in Average Winter Temperatures and S/N Ratios

A primary focus of this study was to examine the correlation between recorded changes in the average winter temperatures in Massachusetts from 1980/1 to 2004/5, and changes in the winter bird populations recorded in the Christmas Bird Count over the same period. This correlation was examined by plotting the average winter temperatures against the S/N ratio and fitting a linear regression line to the association. The statistical significance, expressed as the Pearson Correlation coefficient (R^2) and probability (p values) of any observed correlations are reported.

Habitat Preferences of Birds Over-wintering in Massachusetts

The Christmas Bird Count circles examined in this study cover a range of vegetation and habitat types. To determine whether species in a particular habitat type or those having a particular feeding preference are affected differently by temperature changes or land-use modification, the bird species selected for study were assigned habitat preference (page 15) and feeding guild categories (page 16).

Habitat Preference

The ninety-five species of terrestrial birds selected for analysis were grouped into the following three categories, forest, edge, and grassland, according to their habitat preference as defined by Sibley (Sibley, 2000, , 2001). The category assigned to each species was based on the principal habitat used in winter, even though many species will utilize a variety of habitats.

The relative number of species within each category was recorded, and the average number of birds recorded in each habitat designation was calculated. The sum of the number of birds per party hour (#pph) for each species over the twenty-five year period was divided by the number of years counted (see page 12 of this thesis).

Habitat Modification

If the changes in the number of over-wintering species that prefer a specific habitat type reflect a positive correlation with the observed changes in that habitat, then habitat modification may be a determining factor affecting winter distribution. Changes in habitat were estimated from changes in the appropriate categories of land use using data from the Massachusetts Geographic Information System (Mass GIS) database.

Land-Use data

MassGIS land-use data was available for 1985 and 1999 within the time period studied. Data was also available for 1971 and was included in the initial analysis to determine whether there were trends in the changes in land-use over time. The data were combined into four major land-use types, forested areas, open land, residential and recreational areas, and industry and commercial land. To assess the impact of habitat fragmentation, the length of edge between forest and developed areas was calculated using the "Extract Raster Edge" tool from the Hawth's Analysis Tools (Beyer, 2004).

The percentage of change over time was determined for each of the land-use categories for all eight CBC circles combined, and also independently for each of the four defined eco-regions.

Land-use Changes and Southern to Northern Ratios

The 1971, 1985, & 1999 records of area for each CBC circle, together with the fitted data for each land-use category were used to estimate the trend in the observed changes in each of the previously described categories from 1971-1999. The equations for the estimated trend lines were used to calculate data points for the years 1985 through 1999 for each land-use category.

Using the ratio of southern to northern birds as an indicator of the change in winter ranges (see page 12 of this thesis) may determine whether there is a combined effect of temperature and habitat modification on the winter distribution of terrestrial bird populations. Data for the S/N ratio of species in each CBC circles were graphed against calculated areas of forest, open land, residential and recreational land, and length of forest edge. Linear regression lines were fitted and used to calculate the significance, of the relationship between the S/N ratio and land-use change, from the regression value of the correlation coefficient and probability (p value).

Feeding Guilds

Bird species recorded in the eight selected CBC circles were segregated into four mutually exclusive feeding guilds to investigate any association between winter ranges and habitat modification. These four guilds do not include all species, since some species do not fall into a specific feeding category, for example crows and jays.

The feeding guilds were defined as raptors and shrikes, bark gleaners (e.g. woodpeckers, nuthatches, and brown creepers), foliage gleaners (e.g. wrens, and kinglets), and seed eaters (e.g. sparrows and finches).

Species Composition of Feeding Guilds

The species composition of each guild was determined with reference to data from Root (T.L. Root, 1988a) and Leahy (Leahy, 2004). The number per party hour (#pph) within each guild was calculated for each count year, and the trends in numbers of birds recorded over time in each of the guilds was estimated. Data for bird species that showed significant trends in their winter population were examined further.

Feeder Birds

A number of the bird species that include Massachusetts in their winter range supplement their winter food supply by visiting feeders. Species that visit feeders were identified based on information from Sibley (Sibley, 2001), Root (T.L. Root, 1988a), and Poole (Poole et al., 2006), as well as from personal observations. The CBC data reported for these species in the selected circles were examined to determine if there was a significant change in their abundance during the study period. Data for bird species that showed significant trends in their populations were investigated further.

Statistical Analyses

Data sets compared in this study were fitted with linear regression lines whenever

appropriate and the equation of the trend line calculated. The significance of observed trends were estimated by the square of Pearson Regression coefficient (R^2) and the probability (p) where values of $p \leq 0.010$ are statistically significant (Pagano et al., 1993).

In interpreting a monitoring data set such as that from the Christmas Bird Count, it is reasonable to assume that there are one or more underlying trends for the population, but that the observed data will not fit this trend exactly due to inherent variability. The sources of variability include general weather conditions, sampling variability (how well the selected sample points represent the overall population), and the ability of the observer to record the correct identification or number of birds. The relationship between number of birds seen and the number of party hours is not linear, and is not the same for all species. Therefore any inferences drawn from analysis of the data has to consider the limitations of the data as a result of the survey design.

The results of the analyses detailed above are presented in Chapter III.

Chapter III

Results

The results reported pertain to analyses of bird species data from eight fifteen-mile diameter circles across Massachusetts that were surveyed in the National Audubon Society's annual Christmas Bird Count (CBC) over the twenty-five year period from 1980/1 to 2004/5). The analyses examine the geographic winter ranges of the ninety-five selected bird species, and the habitat preferences of each species. Comparisons were made between data collected in four different eco-regions of Massachusetts. In addition, an investigation into the potential role of bird feeders as a factor influencing the survival ability of over-wintering species was performed.

The results of these analyses are described in the following sections.

Climate Change

Average winter temperatures (December to February) were obtained from the National Climate Data Center (NCDC) for 1980 through 2005 (Table 1). Average winter temperatures for the United States were compared to those of the Northeast region and Massachusetts (Figure 4). These data show that there are similar increasing trends in average winter temperatures in all three areas. This extrapolates to a 0.83°F increase in

temperature per decade in Massachusetts, compared to a 0.64°F for the North East regions and 0.84°F for the continental United States. The temperature anomalies in all three regions are comparable. These data were used to compare the average winter temperatures in Massachusetts to changes in the populations of birds regularly over-wintering in Massachusetts (page 26).

Selection of Study Areas

Christmas Bird Counts are conducted annually within defined fifteen-mile diameter circles. There are thirty-three CBC circles in Massachusetts (Figure 5a), and a representative number of eight inland circles were selected for this study based on latitude, lack of coastline, and census consistency (Figure 7).

Christmas Bird Count Circles

Data collected in the CBC from 1980/81 through 2004/5 in eight circles in Massachusetts were analyzed. The circles analyzed were North Berkshire (NB), Central Berkshire (CB), Northampton (NO), Springfield (SP), Westminster (WE), Worcester (WO), Concord (CO) and Millis (MI).

The North (NB) and Central Berkshire (CB) circles, (Eco-region 1), are located in the Taconic Mountain/Western New England Marble Valley region of the Northeastern highlands, and the Westminster (WE) circle (Eco-region 3) is in the Worcester Plateau of

the same major eco-region. The Northampton (NO) and Springfield (SP) circles (Eco-region 2) are within the Connecticut River Valley region of the Northeastern coastal zone (NECZ) region. The final three circles of Worcester (NO), Concord (CO), and Millis (MI) (Eco-region 4) are all located in the southern New England coastal plains and hills of the NECZ (Figure 5). Figure 6a shows the location of the selected count circles within the eco-regions of Massachusetts, and the co-ordinates for the geographic centers of each circle are shown in Figure 6b. The CBC circles selected cover a range of climate and vegetation types, and embrace different types and extents of land use change.

Land-Use changes in Massachusetts

The areas of different types of land-use within the CBC circles selected were obtained from the Commonwealth of Massachusetts Office of Geographic and Environmental Information (MassGIS). Data was available for 1985 and 1999 in the selected time period, but data from 1971 was also included in the analyses to establish the trend of change over the study period (1980– 2004).

Changes in the area of major land-use categories

The land-use areas were combined into the four major categories of open areas, residential and recreational areas, and industry and commercial areas, prior to further analyses. Forest area data used was taken directly from MassGIS, and the length of forest

edge adjacent to developed land was calculated as described on page 16 of this thesis.

Changes in the area of open, residential/recreational land, and industrial/commercial land. The combined data for all eight circles of changes in the area of open area, residential/recreational (r/r) land, and industrial/commercial land use is shown in Figure 8. The percentage change for each count circle is shown in Table 4.

The data reflect a decreasing trend in the area of open land in all four eco-regions, with the greatest decline (-27.62%) in eco-region 4. This eco-region, which includes the cities of Worcester, Concord, and Millis, also has the greatest increase in residential/recreational land (62.50%). The individual circle with the greatest increase in development of the r/r category of land use is Westminster (WE) in eco-region 3. Westminster was also associated with the lowest change (-0.79%) and the smallest loss in the area of open land.

Changes in the area of forests. The area (square meters) and the percent changes in forest are shown in Table 8. The calculated decreases are shown in Figure 9. There was a small (0.61%) increase in the forested area in Central Berkshire (CB), but all other circles showed a marked decrease. The greatest loss of over 58,000,000 m^2 of forest was recorded in Eco-region 4.

Changes in the length of edge of forest to developed areas The length of edge between forest and developed lands within the CBC circles selected are shown in Figure 10 and Table 9. The largest increase was seen in Eco-region 4, which also includes the largest CBC circle increase (MI – Millis) of 415,347 kilometers.

Birds Species Data

The winter ranges of birds species recorded in the selected Christmas Bird Count circles in Massachusetts were classified as northern (N), southern (S), or year round species (Y).

Geographical ranges of Birds Over-wintering in Massachusetts

Of the ninety-five selected species, thirteen species (13.68%) were defined as having a northern (N) distribution, fifty-eight species (61.05%) a southern distribution, (S), and twenty-four species (25.26%) were defined as having a year -round (Y) distribution (Figure 11a). The list of the geographic range preference (N, S, or Y) of the ninety-five selected species is shown in Table 6.

Figure 11b shows the total proportion of southern, northern and year round species recorded in all eight circles. The average densities of birds in each geographic range category calculated for each CBC circle are listed in Table 5. Figure 11a shows the relative abundance of southern, northern and year round species based on these average densities. Within eco-regions the greatest abundance of birds was recorded in eco-region 2 (NO, average density = 87.30 pph; and SP, average density = 84.36 pph) i.e. the Connecticut River valley.

The number of northern birds recorded over the twenty-five year time period, for

all circles combined, is shown in Figure 12a. These data show that there was a significant decreasing trend ($p<0.0005$) in the numbers of northern birds. This compares with the significant increasing trend ($p<0.0005$) in the number of southern birds, shown in Figure 12b. The data for the numbers of birds that are resident in Massachusetts year round and recorded in the CBC, show that these changes in the numbers of southern and northern birds has had little impact on the numbers of year round birds (Figure 13).

Ratio of Southern to Northern species (S/N)

Comparing the ratio of southern to northern birds (S/N) to average winter temperatures for 1980/1 through 2004/5 may determine if the climate changes are influencing bird population ranges. Similarly, comparing the trend in the ratio of southern to northern birds (S/N) to the change in land-use data may determine the combined impact of habitat modification and temperature on the selected bird populations.

Changes in the Southern to Northern Ratio

The S/N ratio for the cumulative data (all circles combined) showed a significant increase (Figure 14a: $p<0.0005$). Similarly, the S/N ratio for each eco-region (1-4) demonstrated a significant positive increase at each of the sites over the time period of the study (Figures 15a – 18a).

Correlation between Average Winter Temperatures and the S/N Ratio

The S/N ratio of birds in each of the four eco-regions was plotted against the average winter temperatures for the years 1981 through 2005, and linear regression lines were fitted to the data. In each of the four eco-regions, there was an insignificant correlation between S/N ratios and average winter temperature (Figures 15b – 18b).

Additional statistical mixed-model analyses using S-Plus for Windows, version 7 was performed. Since the S/N data are not normally distributed, the data were log-transformed (i.e. log(S/N + 1; where the +1 is to compensate for zero data points). A simple regression on all the data (log(S/N+1) = b0 +b1*temp) gives values of 0.038 for the intercept b0 and 0.036 for the slope, with p-values of 0.93 for the intercept and 0.02 for the slope. This suggests that a model forced through the origin fits as well as one with an intercept, and that there is a significant effect of temperature on S/N. Note that not much of the variance is explained ($r^2 = 0.03$). Analysis of the data for each count circle showed that in all eight circles there was a similar response to increased temperature.

Correlation between Changes in Land-use and the S/N Ratio

Based on the data from 1971,1985, & 1999, trend data was estimated for forest area, forest edge, open land, and residential/recreational land, in the four eco-regions.

Correlation between changes in the area of forest and the S/N ratio. The S/N ratio of

birds, in each of the four eco-regions, was plotted against the area of forest (m^2) for the years 1985 through 1999. In all eco-regions there was a weak negative correlation between the area of forest and the S/N ratio (Figure 19).

Correlation between changes in the length of forest edge and the S/N ratio. The S/N ratio of birds, in each of the four eco-regions, was plotted against the length of forest edge for the years 1985 through 1999. In all eco-regions, there was a positive correlation between the length of forest edge and the S/N ratio (Figure 20).

Correlation between changes in the area of open land and the S/N ratio. The S/N ratio of birds, in each of three eco-regions, was plotted against the area of open land for the years 1985 through 1999. In all eco-regions, except eco-region 3 where there was no trend there was a significant negative correlation between the area of open land and the S/N ratio (Figure 22).

Correlation between changes in the area of residential/recreational land and the S/N ratio. The S/N ratio of birds, in each of the four eco-regions, was plotted against the area of residential/recreational land for the years 1985 through 1999. In all eco-regions, there was a positive correlation between the area of residential/recreational land and the S/N ratio (Figure 21).

Habitat Preferences of Birds Over-wintering in Massachusetts

The ninety-five bird species were grouped into a forest, edge, or grassland category according to their habitat preference. A list of bird species in each of the three categories is shown in Table 10.

Habitat Preference

Twenty-seven species were defined as forest dwelling birds (W), fifty species were defined as forest-edge birds (E), and eighteen species were defined as grassland dwelling birds. The proportion of species in each category is shown in Figure 23b. The greatest number of species was found in the edge habitat (52.63%) with 24.42% of species preferring the woodland habitat and 18.95% preferring grassland.

Estimation of the average densities for each count circle (Figure 23a: Table 5) showed that in all circles the highest relative abundance of birds (#pph) was comprised of edge dwelling species (86.04%-95.00%). The highest abundance of woodland species was recorded in eco-region 1 (NB, average density =5.98;CB, average density =9.0) and eco-region 3 (WE, avg. dens. =9.04). These CBC circles are all located in the wooded, higher elevations of the northeast highlands. Grassland birds were generally recorded in low numbers across Massachusetts, but were recorded in somewhat higher numbers in eco-region 2 (NO and SP) in the lower elevations of the Connecticut River valley.

Winter Range Preference of Birds in Each Habitat Category

Separation of each habitat preference category into their winter geographic ranges (Figure 24) showed that of the thirteen species of birds that have a northern winter range distribution 46.15% preferred the forest (W) habitat. Species with a southern winter range that preferred the edge (E) habitat (48.28%), and bird species found in Massachusetts year round showed a similar preference for the edge habitat (75.00%).

Analysis of the #pph data (Figure 25) showed that in all four eco-regions there was a significant increase in the numbers of southern edge dwelling birds, with little or no trend seen in the numbers of northern edge birds. Note: only Eco-region 2 shows a statistically significant decline in the number of northern edge birds.

This is in contrast to the numbers of woodland species birds (Figure 26), where there was little or no change in the numbers of southern birds but a significant decline in northern woodland birds. The numbers of grassland species recorded were so small that they were not considered for analysis.

Further investigation of the numbers of northern woodland birds showed that records for five of the six species (Figure 27a), showed peaks in some years with few or no birds in other years, which is characteristic of the irruptive species such as “winter finches”. However, one species, the Evening Grosbeak (*Coccothraustes vespertinus*), showed the characteristic peaks and troughs pattern of a typical “winter finch” (Figure 27b), but there was a significant decline in population numbers throughout the study period. This decline was associated with a widespread constriction of its' range in the Northeast region of the North America, as shown in distribution maps (Figure 28) for the Evening Grosbeak obtained from the NAS website (www.audubon.org/birds/cbc).

Feeding Guilds and Feeder Birds

Species were segregated into mutually exclusive feeding guilds to determine if feeding ecology is affecting their winter distributions. Bird species were assigned to four feeding guilds, raptors and shrikes, bark gleaners, foliage gleaners, and seedeaters. Omnivorous species such as crows, that opportunistically feed on a number of food sources, or insectivorous /grub-eating species such as the American Robin (*Turdus migratorius*). These species were not included in the categorization since individuals may over-winter at Northern latitudes when they alter their diet to include berries with a high wax content to serve as high-energy food source.

The component species of each guild and relative proportions of the guild categories are shown in Figure 29.

Raptors and Shrikes

Species recorded in this guild, were few in number (Figure 30) with the exception of the Red-tailed Hawk (*Buteo jamaicensis*). The numbers of this species recorded in Massachusetts showed a significantly increasing trend ($p<0.0005$) over the study period (Figure 31a). Distribution maps (Figure 31b) also showed expansion of the range of this species.

Bark Gleaners

This group includes the woodpeckers, and the Red-bellied Woodpecker (*Melanerpes carolinus*), is a member of this group that has shown an increase in numbers over the study period (Figure 32), with the greatest increases taking place in Eco-regions 2 and 4. The increase was not linear over the time period studied, but an exponential equation of $y=0.0067xe^{0.1943x}$ fits the combined data curve and is statistically significant ($p<0.0005$).

Foliage gleaners

This group contains birds that are inconsistently recorded, and usually in low numbers during the study period. An exception is the Carolina Wren (*Thryothorus ludovicianus*), that has shown significantly increasing numbers ($p<0.0005$) and range expansion (Figure 33).

Seed Eaters

This group contained the largest number of species, including the American Goldfinch (*Carduelis tristis*), that showed a significant increase ($p<0.0005$) in numbers, and range expansion (Figure 34) was documented during the study period.

Winter finches

This group was discussed in the previous section of this thesis (page 31) with the exception of the Rose-breasted Grosbeak (*Pheucticus ludovicianus*), a species that has a southern winter range, and is only occasionally recorded in the CBC.

Range expansion of Feeder Birds

Figure 35 shows the twenty-four bird species that regularly use bird feeders as a supplementary food source in the winter months. The majority (54.17%) of feeder visitors are year round residents, but nine southern species (37.5%), and only two northern species (8.33%) included in this group.

Edge dwelling birds that visit feeders.

The numbers of southern edge feeder birds showed significantly ($p<0.005$) increasing trends in three eco-regions (Figure 35), but no significant trend ($p>0.10$) in eco-region 2, in contrast to data for northern edge birds that visit feeders where eco-region 2 showed a significant decline ($p>0.005$).

Woodland dwelling birds that visit feeders.

The northern woods species are comprised of six "winter finches". Details of the

trends in their numbers are shown in Figure 24. The southern species of woodland birds were recorded in very small numbers and are consequently not shown.

Chapter IV

Discussion

Global atmospheric changes are affecting the distributions and survival of natural populations(Hughes, 2000; IPCC, 2001; McCarty, 2001; Parmesan et al., 2003; T. L. Root et al., 2002; Valiela et al., 2003; Walther et al., 2002). The stress of global warming must now be included with the other numerous environmental factors that wildlife must contend with, including habitat degradation and fragmentation, pollution, and competition with invasive species. In the United States, particular attention has been made to the sharp decline in the numbers of breeding birds (National Audubon Society, 2004) and the loss of over-wintering habitats for neo-tropical migrant species (Anders et al., 2006; Sillett et al., 2000). However, the survivability of birds that over-winter in the United States can have a marked effect on the numbers of birds that subsequently breed here. Alterations in local habitats together with the impact of changes in the winter climate are potentially contributing to the observed changes in bird populations within the United States.

Using historic data from the National Audubon Society's Christmas Bird Count, this study examined the impact of climate change and habitat modification on specific bird populations that winter in Massachusetts.

Reliability of the Christmas Bird Count Data

The Christmas Bird Count (CBC) was started in 1900 by a group of conservationists led by Frank Chapman, an ornithologist at the American Museum of Natural History. A decline of wild bird populations prompted the group to promote the counting of birds in a “Christmas Day Census”, rather than hunting birds as a holiday tradition. The CBC is now an annual event, which is described by the current CBC Director (Geoff LeBaron) as being “the best, if not only, tool available for assessing the long-term trends in the early winter bird populations of North America".

The National Audubon Society’s CBC web site includes historic records for the Christmas Bird Count, data summaries, and graphs (www.audubon.org/bird/cbc). This database is a vast source of field data, but the CBC was not designed as a scientific method for monitoring bird populations. There are a number of factors that influence the actual number of birds counted in a CBC circle, and different methods used by different count-circle coordinators. The numbers of birds counted varies within and among circles, depending on the amount of counting effort, the weather, the time of day, the identification skills of the volunteers, the mode of travel (driving compared to walking etc.), the type of habitat, and the distribution of effort among different habitats (Stewart, 1954). The reliability of the CBC data due to these variables has been discussed in numerous review articles (Arbib, 1981; Bock et al., 1981; Raynor, 1975; Sauer et al., 2002; J. S. Sauer et al., 2004).

In addition to the issues mentioned above, the number of CBC circles increased dramatically since the inception of the count, as has the numbers of observers participating in the counts (G. S. Butcher et al., 1990; Yunick, 1988) further adding to the

variability of the data collected. Additionally, the different methods of counting affects the number of birds detected by count participants, and many participants now contribute from stationary counts from watching bird feeders. The number of birds counted while watching a feeder is very different from those recorded in the field. Dunn (E.H. Dunn, 1995) showed that the increase in feeder watching introduced substantial bias into CBC trend estimates for certain species that frequent feeders.

Despite these variables, the Christmas Bird Count provides a valuable source of field data of wintering bird species in North America. The data from the CBC correlates well with data from the North American Breeding Bird Survey (BBS) that also reflects changes in bird abundance (G.S. Butcher et al., 1990; E.H. Dunn et al., 1997). Similarly, strong correlations have been noted in data collected by "citizen science" programs such as Project Feeder Watch (PFW). The Cornell Lab of Ornithology designed PFW specifically to monitor the numbers of birds resident in winter that frequent feeders (King et al., 2003; Lepage et al., 2002).

The National Audubon Society (NAS) convened a panel of experts to address the question of CBC data reliability. The panel reviewed the survey design, data collection techniques, management and production of the Christmas Bird Count historic database. The published findings in 2004 (E. H. Dunn et al., 2004) recommended that the NAS use effort-adjusted data in summaries and graphs presented on the CBC website. The number of birds per party hour (Raynor, 1975), is the most commonly used effort-adjustment factor (J. R. Sauer et al., 2004), and the NAS subsequently made both raw and effort-adjusted counts available for downloading.

Effort adjusted counts using the number of birds per party hour were used in the analyses in this study. The data were also normalized by using internal comparisons

comparing the ratio of the numbers of birds with a southern winter distribution (S) to those with a northern winter distribution (N). Results showed a predominance of southern species recorded, but the most abundant species were comprised predominantly of year round species (Figure 9). This is consistent with the fact that the majority (75%) of species that nest in North America exhibit some form of migration in winter (Sibley, 2001) and that only species that can physiologically tolerate cold temperatures (T.L. Root, 1988b) can successfully winter in the colder climates of the northeast region of the United States.

Examination of the numbers of southern and northern birds in all the CBC circles examined (Figure 12a) showed that there was a significant ($p<0.0005$) increase in the numbers of southern birds over the twenty-five year period of the study, compared to a significant decline ($p<0.0005$) in the numbers of northern birds. It should be noted that these changes had little impact on the numbers of year round birds recorded over the same time period (Figure 12b). Therefore the increasing numbers of southern species did not negatively impact the overall numbers of the winter population of year round species.

The question thus becomes: Are the numbers of southern species increasing because changes in the winter climate are allowing less cold-tolerant birds to survive New England winters? The ratio of southern to northern birds (S/N) shows a significant increase ($p<0.0005$) that could be indicative of northward extension of the winter ranges of the southern species of birds.

Climate Change

"Global warming" is often used synonymously with "climate change". The United Nations Framework Convention on Climate Change (UNFCCC) defined climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (United Nations Framework Convention on Climate Change, 1992). Global temperatures are increasing and disrupting the earth's climate system causing shifts in regional temperatures (IPCC, 2001; National Research Council, 2001) that are subsequently impacting areas locally.

Examination of the average winter temperatures in the United States (Figure 4: Table 3) shows that national, regional, and local average winter temperatures showed an increasing trend over the twenty-five year period from 1980 to 2005. In Massachusetts, there has been a 0.83°F increase per decade (National Climate Data Center, 2007). The impact of this increasing trend on winter populations was investigated using the southern to northern ratio.

The initial linear regressions fitted to the S/N ratio versus average winter temperatures for Massachusetts, showed no significant correlation ($p>0.10$) for the combined data (all CBC circles in all eco-regions) recorded (Figure 13). However, additional analyses (page 24) that took into account the non-normal distribution of the species data produced a model that showed a significant effect of temperature on S/N, but the variance was not explained ($r^2 = 0.03$). Despite the fact that all regions showed a positive trend in the S/N ratio (Figures 14a – 17a), there was also no correlation between the two factors in any of the four individual eco-regions (Figures 14b – 17b), but again

additional more complex statistical analysis of the data for each count circle showed that in all eight circles there was a similar response to increased temperature. This demonstrates the complexity of interpretation of the Christmas Bird Count data and emphasizes the need for sophisticated statistical analysis (J. S. Sauer et al., 2004).

Habitat Modification

Brown (Brown et al., 1995) showed that winter distributions of bird species are determined by the interaction of several environmental factors. Habitat modification directly influences bird distributions as species respond to changes in habitat distributions (Goss-Custard et al., 1994). Natural habitats that were once continuous landscapes are now increasingly fragmented mosaics of natural and man-made areas (Harris, 1984). There has been a distinct change in the landscape of Massachusetts, with the expansion of urban sprawl (urban sprawl is defined as a mosaic pattern of sub-urban, industrial, urban and other human delineated land cover) changing habitats available for wildlife. Figure 8 shows increasing areas of land for residential and recreational use. This is at the expense of areas in open land (Figure 6) and forest (Figure 7). In association with the decrease in forest area there was an increase in the length of edge between forest and developed areas (Figure 9). This increase in edge also indicates the extent of fragmentation of the forest habitat.

The recorded changes in land-use were different for the four eco-regions examined in this study (Tables 6 – 8) The North Berkshire (NB) and Central Berkshire (CB) CBC circles investigated (Eco-region 1) are located in the northern highlands of

western Massachusetts where mesic forests (mesic forests are those which have a moderate or well-balanced supply of moisture) with a mixture of hardwoods and conifers, and oak-hickory transition forests (depending on the elevation) provide a biologically diverse ecosystem with an abundance of bird species (Griffith et al., 1994). The region contains suburban and semi-urban communities along with croplands and pastures. The Westminster count circle (WE) is in a sub-region that contains hilly areas of the central uplands where forests are largely northern and transition hardwoods, and there is relatively little semi-urban development. These three circles are located in forested areas with relatively higher elevation. This reflects the average densities and the highest abundance of woodland birds, and relatively fewer numbers of edge birds compared to those circles that have higher conversions of land to residential use.

The Northampton (NO) and Springfield (SP) count circles are in the Connecticut Valley sub-region (Ecoregion 2), that is relatively level, with only small hills (100-500 feet). Oak-hickory forests and transition hardwoods of maple, beech, and birch are found on the ridges. The lower valley areas contain both urban and agricultural areas. The river valley has a milder climate which, when combined with the lower elevation and more southerly forest type produces a sub-region clearly distinct from the others in western Massachusetts. This sub-region also supports the greatest overall abundance of winter birds of all four eco-regions (Table 5). The average density data showed that this region also supported more grassland birds in the winter months than any other area studied. These observations are consistent with the diversity of habitats and the relatively milder temperatures of the Connecticut River valley. The Connecticut River valley is also a migration corridor (Sibley, 2001). This may influence the numbers of southern birds that pass through the region in the fall which, under optimal conditions encounter favorable

temperatures and a plentiful food supply, may obviate their need for further southward migration.

The remaining three count circles of Worcester (WO), Concord (CO), and Millis (MI) comprise Eco-region 4. These count circles are in eastern Massachusetts where the northeastern coastal forest is composed of temperate broadleaf and mixed forest ecosystems (Kuchler & Zonneveld, 1988). Suburban sprawl has resulted in the loss of much of the natural habitat in this eco-region, producing habitat fragmentation and degraded patches of the original habitat. Eco-region 4 showed the greatest modification in habitats of all aspects of land-use investigated in this study. However, the data did not show that these effects had any detrimental impact on the numbers of southern, northern or year round birds present in that area.

The eight CBC count circles were segregated into four (4) clearly distinct regions (Eco-regions 1-4). If habitat and land-use play a major role in defining the winter distributions of the bird species across Massachusetts, then there should be clear distinctions between the eco-regions. Linear regressions fitted to the southern to northern (S/N) ratio versus changes in land-use for each eco-region demonstrated a negative correlation ($p<0.025$) with the decrease in forest (Figure 18) and open land (Figure 21). Conversely there was a positive correlation ($p<0.025$) between the S/N ratio of birds and the increase in the length of forest edge that borders forest areas (Figure 17), as well as with the increase in residential and recreational land (Figure 18). This suggests that the increase in residential and recreational land area and the extension of the forest to developed land edge is having an impact on the S/N. Caution must be used in the interpretation of these correlations, since there were only data from only two time points within the study period (1985 and 1999). These data were used together with data from

1971 to generate a trend line on which the interpolated data for these comparisons were based. In addition, the land-use data was not extrapolated beyond 1999, so the most recent CBC records of winter birds were not included.

To determine whether the observed increase in numbers of southern species and decrease in northern species was disproportionate across habitat preferences of the recorded species, the CBC data were separated into habitat categories (edge, woods, and grassland). Figure 22 shows that the greatest numbers of species (52.63%) prefer the edge habitat, and that the greatest abundance (86.04% - 95.00%) of birds recorded also prefer edge habitats. This may be explained by the fact that bird species that inhabit ecotones (edge habitats) often contain bird species that typify the abutting habitats as well as those that prefer the edge habitat itself. The highest abundance in birds that prefer the edge habitat was recorded in Eco-region 2 (NO and SP). However, the greatest increase in length of edge (Table 9) was found in Eco-region 4 (969.186 km), as was the greatest decrease (Table 8) in forest area (58.04 km^2). This data is suggestive that the increase in edge birds is not directly associated with the changes in land-use within the count circles or eco-regions.

Separation of the bird species in given habitats into their winter range preferences (Figure 23) showed that the majority (75%) of year round species prefer edge habitats, as well as the majority of southern species (48.28%). This compares with the northern species group where the majority of bird species prefer woodland habitats. The numbers of all grassland birds routinely recorded in the CBC were so small that they were not included in additional analyses. The number of southern edge birds (Figure 24) in each of the eco-region areas has increased significantly over the study period, with the most significant ($p<0.0005$) increases recorded in eco-regions 1 and 4. Again these increases

cannot directly be attributed to the expansion of edge habitat or other recorded changes in land-use (Tables 7,8, and 9).

This compares dramatically to the species of birds that prefer woodland habitats (Figure 25). In all eco-regions, there was a significant decline in the number of northern birds that favor a woodland habitat, over the time period studied. The numbers of southern woodland birds showed population fluctuations over the same time period, that were consistent with those found in natural populations. Examination of the component species of northern woodland birds showed that the group is comprised primarily of "winter finches". Winter finches are "irruptive" species, meaning that they periodically move south during winter in search of food. However, if food resources are adequate in central and northern Canada, these species are rarely recorded in Massachusetts CBCs (Poole et al., 2006). The data (Figure 26a) show the cyclical nature of the records for this group of species and count data from 1992/3 (count #93) onwards shows "irruptions" approximately every other year. To determine whether the incidence of these irruptions has increased would require further investigation of these populations. The Common Redpoll (*Carduelis flammea*)and Pine Siskin (*Carduelis pinus*) are clearly found in increased numbers during irruptive years but the data is suggestive that their overall numbers are declining. This is supportive of the observations of McWilliams and Brauning (McWilliams et al., 2000) that showed a significant decline in winter irruptions in the eastern United States since the mid-1980s when birds were recorded less frequently and in far fewer numbers than before this period. However, the numbers of Evening Grosbeak (*Coccothraustes vespertinus*)(Figure 26b) showed a significant decline in numbers across the study period and have rarely been recorded numbers in Massachusetts since the winter of 1998/9 (count #99). The distribution map for this species (Figure 27)

also shows a northward shift in its' overall winter range. Whether the observed changes in this population are related to environmental factors such as climate change or habitat modification are outside the scope of this study.

The Edge Effect and Bird Feeders

An edge effect is produced by the close proximity of contrasting environments or ecosystems. This term is often used to describe the boundary between natural habitats, especially forests, and disturbed or developed land. When an edge is created in a natural ecosystem, and the area outside the boundary is a disturbed or unnatural area, there is a significant impact on the natural ecosystem both at the edge and for some distance into the ecosystem. When land adjacent to a forest is cut, it creates an open land/forest boundary, where sunlight and wind can penetrate to a greater extent, drying out the interior of the forest close to the edge and encouraging growth of opportunistic species at the edge. Edge effects are especially pronounced in small habitat fragments and may extend throughout the patch (Fletcher, 2005; Saunders et al., 1991).

Harrison and Bruna (Harrison et al., 1999) suggested that edge effects drive the observed impact of habitat fragmentation. Therefore understanding the effects of habitat fragmentation and edge effects, requires an understanding of the multiple factors that impact the edge response including the type of edge (Fletcher, 2005). To investigate the relationship between the changes in numbers of birds with defined winter ranges and habitat modification, the bird species recorded in the CBC circles were segregated into four mutually exclusive feeding guilds (Figure 30). Data for bird species that showed

significant trends in their winter population were examined further.

Species in the raptors and shrikes guild were recorded in small numbers with the exception of the Red-tailed Hawk (*Buteo jamaicensis*). The range of this species has expanded throughout the North East region of the United States in response to forest clearing (Preston et al., 1993) and its range varies inversely with the amount of unbroken woodland (Austing, 1964). The data from the CBC in Massachusetts (Figure 26a) potentially reflect the response of this species to the habitat modification recorded for the study area. The distribution pattern (Figure 31) for the Red-tailed Hawk also shows increases in the numbers reported in the CBC, but does not reflect a northward progression of the winter range of the species. This may indicate that fewer birds are moving south in winter months.

In the bark gleaners guild, (Figure 30), numbers of the Red-bellied Woodpecker (*Melanerpes carolinus*) have increased in the four eco-regions of Massachusetts studied, and the distribution maps show a northward progression of the woodpeckers' winter range (Figure 27a). This is generally not considered to be a migratory species (Bock et al., 1975), but northern populations have been shown to move south in harsh winter conditions (Winkler et al., 1995). The flexible feeding habits of this species including the use of bird feeder to supplement its winter diet may have played a role in it's northward expansion.

With the exception of the Carolina Wren (*Thryothorus ludovicianus*), the foliage gleaner guild contains birds that were recorded inconsistently and in low numbers throughout the study period,. This species has shown increasing numbers and range expansion (Figure 32). Forest fragmentation and the increased formation of thickets have benefited this species (Brewer et al., 1991). Data for the selected CBC circles also

supports the conclusion that the increasing numbers of bird feeders have greatly benefited this species' ability to survive winters in the northern portion of its range. A combination of improved habitat and increased winter food supplies has contributed to this species to northward winter range expansion (Figure 32b).

The seedeater guild contains the largest numbers of species, including the American Goldfinch (*Carduelis tristis*). This seedeater showed an increase in numbers as well as an overall expansion of its range (Figure 33) based on the Massachusetts CBC records. This is an example where the results of the Breeding Bird Survey are not consistent with the Christmas Bird Count data. The American Goldfinch (*Carduelis tristis*) is designated as a common bird (Middleton, 1993) but the Breeding Bird Survey of North America (Sauer et al., 2005) show a decline in the population at a mean rate of 4% per year. Root (T.L. Root, 1988a) proposed that the winter distribution of the American Goldfinch (*Carduelis tristis*) is governed by temperature constraints, with birds moving to a more southern location when winter temperatures decline. Birds that winter in Massachusetts may not be the same population that breeds here in the summer. Therefore, the CBC and BBS records may not be contradictory, if fewer birds are leaving their summer breeding grounds in Massachusetts and are being joined by those birds from more northerly locations in the winter months (Figure 29b). This increase may also correlate with the increasing numbers of bird feeders that supplement the winter food supply of the American Goldfinch (*Carduelis tristis*).

The previous examples indicate that the availability of supplemental winter food supplies in the form of bird feeders may be influencing the winter survival success of birds in the study area. The bark gleaners and seed eating guilds are most often associated with bird feeders, and Figure 34 shows the twenty-four bird species that regularly use

bird feeders as a food source in the winter months. The majority (54.17%) of species are year round birds, with nine southern species (37.5%), and only two northern species (8.33%). Figure 35 shows that in three of the eco-regions studied (E-1,E-3, and E-4) the numbers of southern edge species that visit feeders showed significantly ($p<0.005$) increasing trends compared to the northern edge species, which show weakly declining numbers.

Data for feeder birds in eco-region 2 (NO and SP) in the Connecticut River valley showed insignificant ($p>0.10$) increase in the numbers of southern feeder birds compared to a significant decline ($p<0.005$) in the numbers of northern feeder birds. These results suggest that climate and habitat modification are not affecting bird populations in this region in the same manner as the other eco-regions studied. The Connecticut River valley may not be representative of the majority of environments that birds encounter in Massachusetts. This illustrates the importance of local knowledge in the design of monitoring studies for conservation planning. This kind of local knowledge will help to ensure that areas studied are truly indicative of a given region.

In summary, the results presented here support the argument (Blair, 1996) that some bird species are capable of exploiting resources associated with forest edge and human built environments for winter survival, and that the bark gleaners and seed eating guilds are most often associated with bird feeders. This favorable influence of forest fragmentation on human-tolerant species is offset by the potential negative impact on forest interior specialists.

The growing popularity of feeding wild birds together with the expanding residential land area may be impacting the species composition of birds that winter in many regions of Massachusetts. Where residential areas form an edge with fragmented

forests, bird feeders offer a readily available source of the high-energy food necessary for survival in cold temperatures. This is in addition to the increased food resources provided by edge invasive species such as the Oriental Bittersweet (*Celastrus orbiculatis*) shown to provide nutritional benefits to American Robins (*Turdus migratorius)* (Alden, 2004) and allow a bird population that was rarely seen in Massachusetts in winter, to now be a common sight during most winter months.

Changing environmental conditions that favor winter survival may obviate the need for high-risk migration, however, the expansion and intensification of land-use also create unfavorable conditions for many migratory species. Migrants returning to their breeding grounds encounter higher rates of edge related impacts such as nest predation and brood parasitism (Askins, 1995; Robinson et al., 1995) as well as increased competition for available breeding sites.

In conclusion, the impact of land use along with climate other aspects of the environment are interrelated and their independent associations with bird distributions are difficult to quantify (Allen et al., 2000; Saunders et al., 1991). The results presented here clearly indicate that the observed changes in winter bird distributions cannot besolely attributed to changes in the winter climate. Habitat modification is causing changes not only in food and shelter availability for birds, but other human generated factors such as providing bird feeders as an alternative food source are impacting the winter survivability of birds. Whilst there are a number of factors that influence the interpretation of findings based on the Christmas Bird Count data, it is clearly a valuable resource for monitoring bird populations as long as appropriate data interpretation and statistical analyses are undertaken. Combining the findings of this study with additional information provided by other bird monitoring programs such as Project Feeder Watch and the Breeding Bird

Survey would provide a more reliable interpretation of the impact of climate change and habitat modification on bird populations. The findings of this study also demonstrate that responses to changes in environmental factors are not uniform across avian species. More detailed studies that take into account different factors, such as physiology and feeding behaviors of taxonomic groups of bird species, are necessary to give a more accurate picture. Conservation initiatives must be based on as complete knowledge of the natural history of species as possible in order to be effective, and the results emphasize the importance of analyzing interrelationships among anthropogenic and non-anthropogenic variables as part of ecological studies.

Appendix I

List of Figures

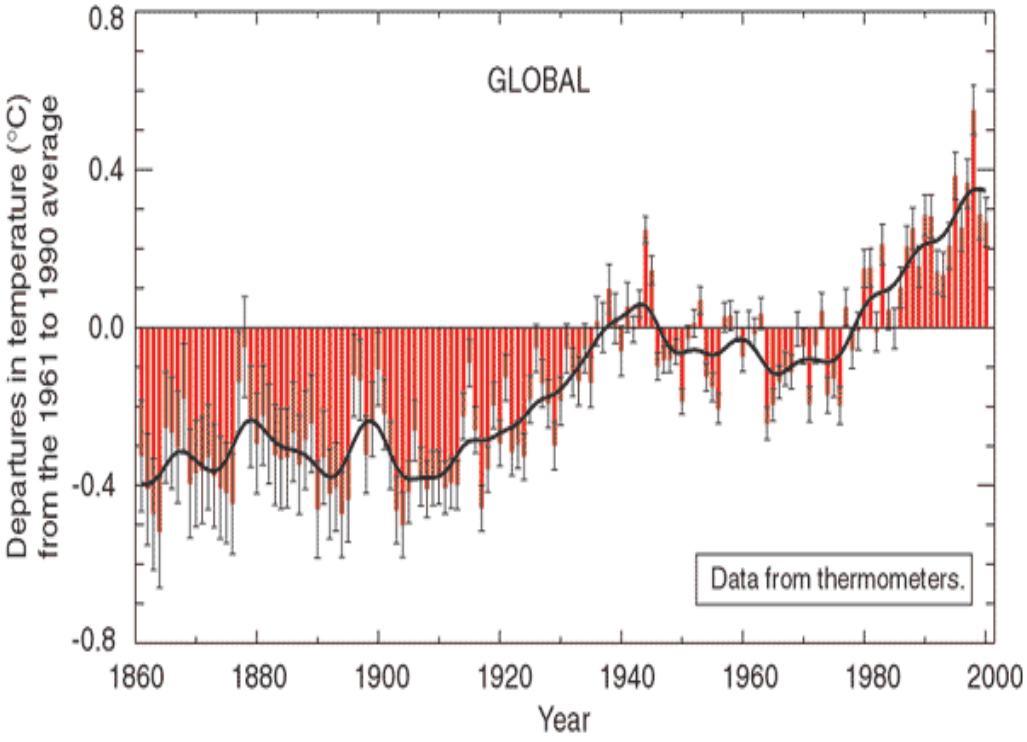


Figure 1. Global Temperatures from 1861 to 2000

Combined annual land-surface air and sea surface temperature anomalies (°C) 1861 to 2000, relative to 1961 to 1990. Two standard errors are shown as bars on the annual number.

Source: IPCC 2001 Third Assessment Report Working Group I The Scientific Basis

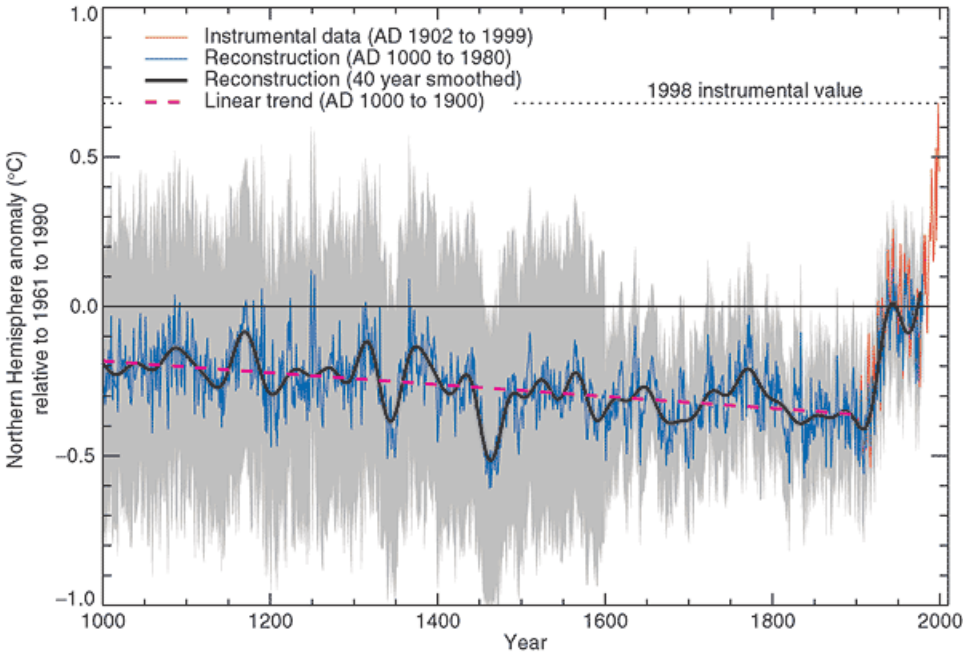
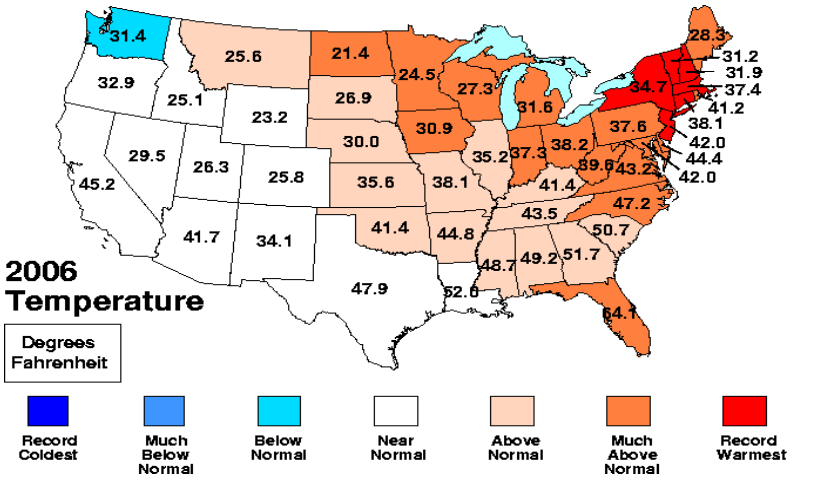


Figure 2. Northern Hemisphere Temperatures for the Last Millenium.

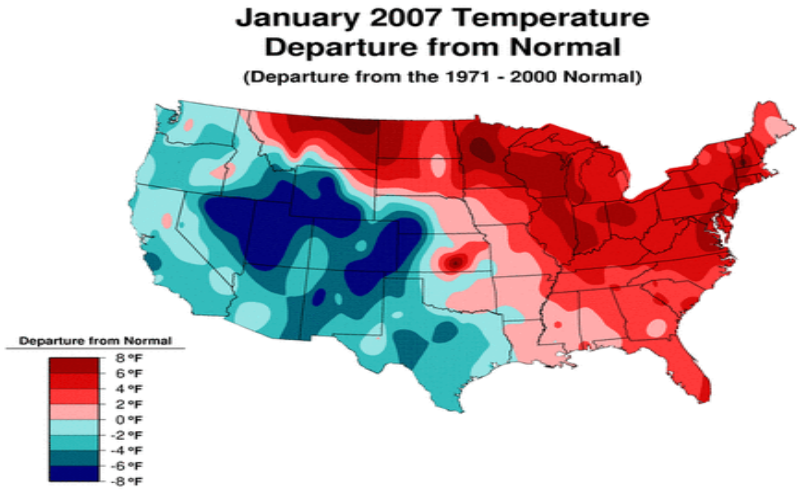
Northern Hemisphere (NH) temperatures for the past millennium. Reconstructed (blue) and instrumental data (red) from AD 1000 to 1999. Smoother version of NH series (black), linear trend from AD 1000 to 1850 (purple-dashed) and two standard error limits (gray shaded) are shown.

Source: IPCC 2001 Third Assessment Report Working Group I The Scientific Basis.



Label	Meaning
Record Coldest	Coldes period on record (a 113 year period of record 1895-2007)
Much Below Normal	One of the 11 coolest such periods on record
Below Normal	One of the 38 coolest such periods on record
Near Normal	An average temperature that was not one of the 38 warmest or 38 coolest on record
Above Normal	One of the 38 warmest such periods on record
Much Above Normal	One of the 11 warmest such periods on record
Record Warmest	Warmest period on record (a 113 year period of record, 1895-2007)

3 a). December 2006 NOAA recorded the highest December temperatures for the North East region including Massachusetts.



3 b). January 2007 NOAA recorded temperatures 4-6°F higher than normal for Massachusetts .

Figure 3. Current Anomalies of Average Winter Temperatures in the United States.

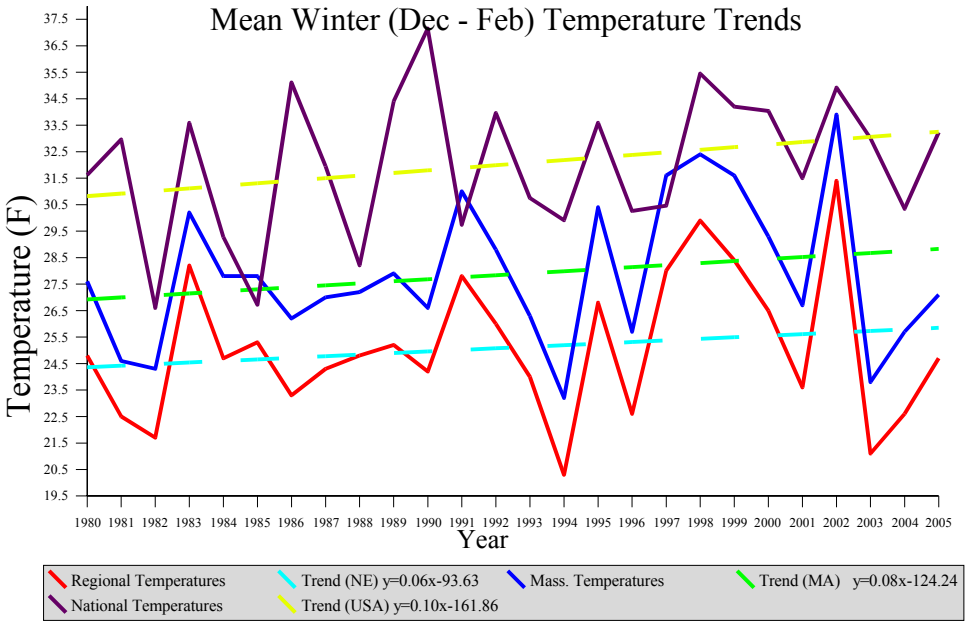


Figure 4. Average Winter Temperatures: National, Regional, and State (Massachusetts) from 1981 - 2005.

Dashed lines indicate the trends and the legend includes the equations for trend lines. These data show that although all three show similar trends, the temperatures in Massachusetts are lower than the National average but higher than the North East region states combined. Details of the differences fo the tree areas are given below:

a) National (USA): Winter (Dec-Feb) 1981 – 2005.
Trend = 0.84 °F / Decade compared to the Winter (Dec-Feb) 1901 - 2000 Average = 34.07 °F

b) Regional (North East): Winter (Dec-Feb) 1981 – 2005. Trend = 0.64 °F / Decade compared to the Winter (Dec-Feb) 1901 - 2000 Average = 25.22 °F

c) Massachusetts: Winter (Dec-Feb) 1981 – 2005.
Trend = 0.83 °F / Decade compared to the Winter (Dec-Feb) 1901 - 2005 Average = 27.89 °F

Source: http://www.ncdc.noaa.gov/oa/climate/research/

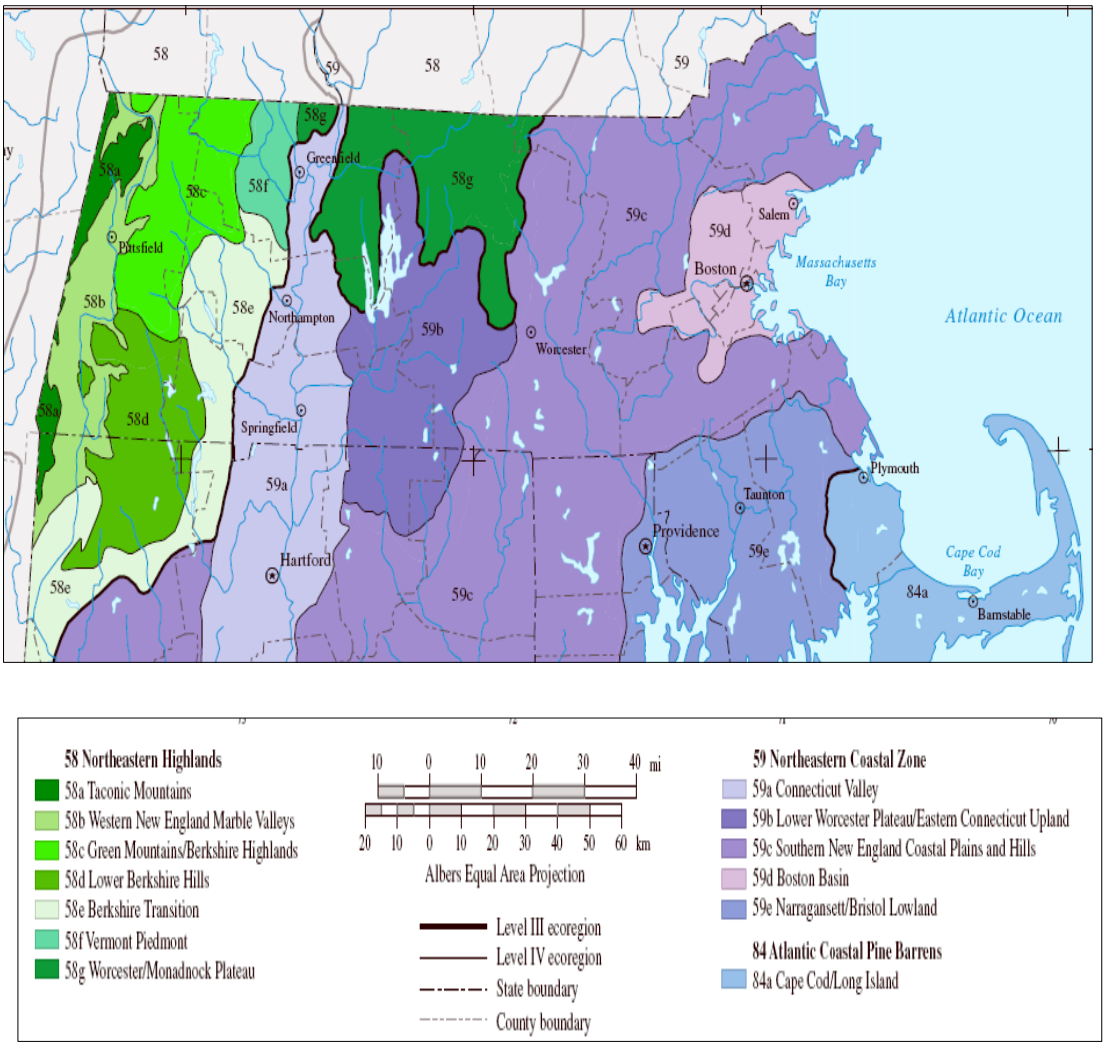
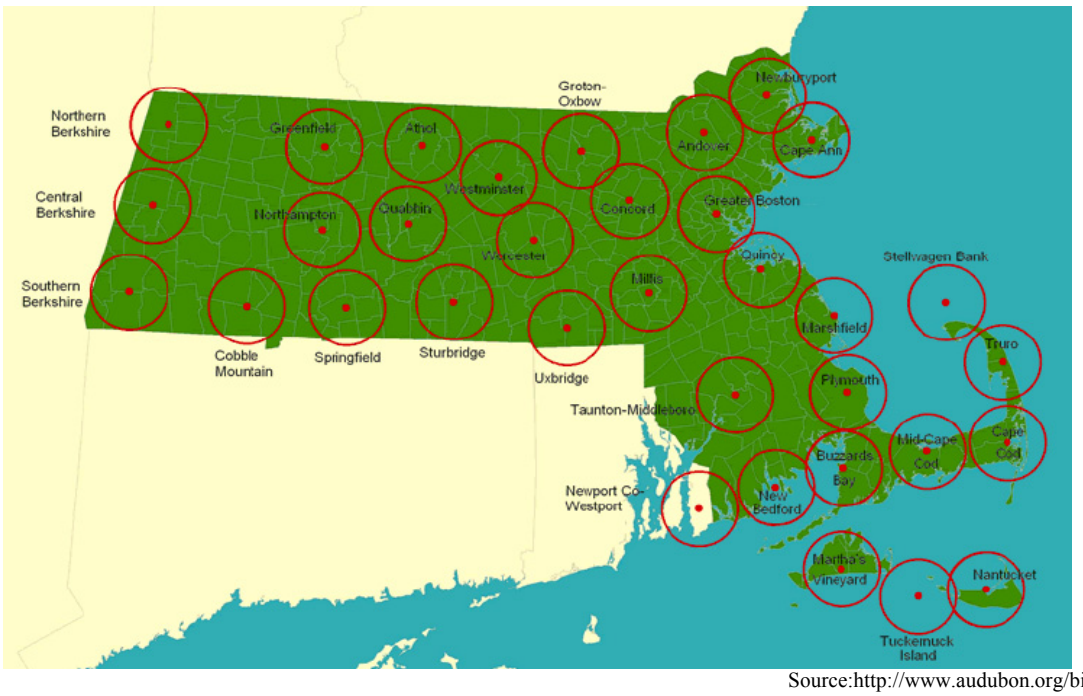


Figure 5. Sub-ecoregions of the Northeastern Highlands and Northeastern Coastal Zone Ecoregions of Massachusetts.

The principal ecoregion components of the Christmas Bird Count circles selected for analysis in this study are;

North Berkshire (NB) – Taconic Mountains & West New England Marble Valleys
Central Berkshire (CB) - West New England Marble Valleys & Berkshire Highlands
Northampton (NO) – Berkshire transition & Connecticut River Valley
Springfield (SP) - Connecticut River Valley & Lower Worcester Plateau
Westminster (WE) – Worcester Monadnock Plateau & Lower Worcester Plateau
Worcester (WO) – Southern New England Coastal Plains & Hills
Concord (CO) - Southern New England Coastal Plains & Hills
Millis (MI) - Southern New England Coastal Plains & Hills

See Figure 6 for circle locations within these ecoregions



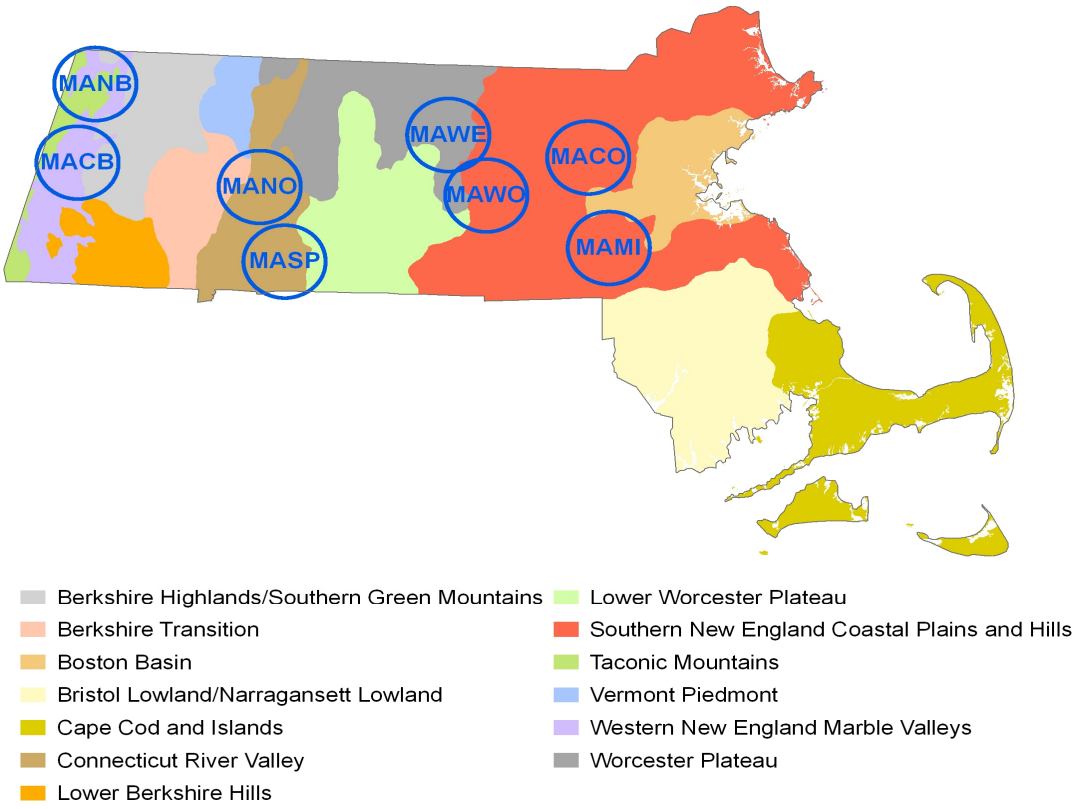
Source:http://www.audubon.org/bird/cbc

6 a). Location of Christmas Bird Count circles reporting data for Massachusetts.

	Latitude	Longitude
Central Berkshire	42.40867906	-73.25337101
Concord	42.43725000	-71.43006486
Millis	42.16745519	-71.35710840
Northampton	42.34427789	-72.60175528
North Berkshire	42.64377521	-73.19605095
Springfield	42.12236710	-72.50979213
Westminster	42.50336353	-71.93044374
Worcester	42.32378227	-71.79366266

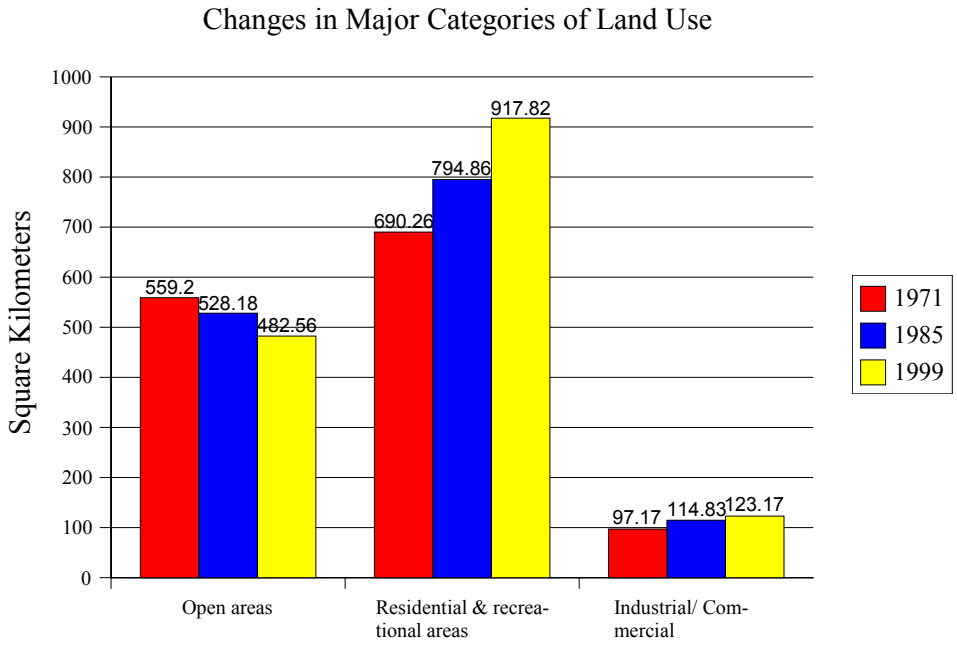
6 b). The geographic location of the Christmas Bird Count circles selected for analysis

Figure 6. Locations of Christmas Bird Count Circles in Massachusetts.



MANB – North Berkshire
MACB – Central Berkshire
MANO – Northampton
MASP – Springfield
MAWE – Westminster
MAWO – Worcester
MACO – Concord
MAMI - Millis

Figure 7. Location of the Eight Selected Christmas Bird Count Circles within Eco-regions of Massachusetts.



Open Areas include;-

CroplandPasture Open meadows
Cranberry BogsGrasslandsNon-forested wetlands

Residential and Recreational includes: -

High, medium, and low density housing
Participation recreation e.g. golf courses, soccer fields
Spectator recreation e.g. professional sports facilities
Residential infrastructures scuh as roads

Industrial & Commercial includes:-

Light industry, general industry, and commercail business areas
Waste disposal areas
Mining
Institutional e.g. healthcare

Figure 8. Changes in Major Categories on Land Use for the Combined Eight CBC Circles.

The figure shows the total area of the three major categories of land use, (open land, residential and recreational land, & industrial and commercial land) within all of the eight CBC circles analyzed for the years 1971, 1985, & 1999.

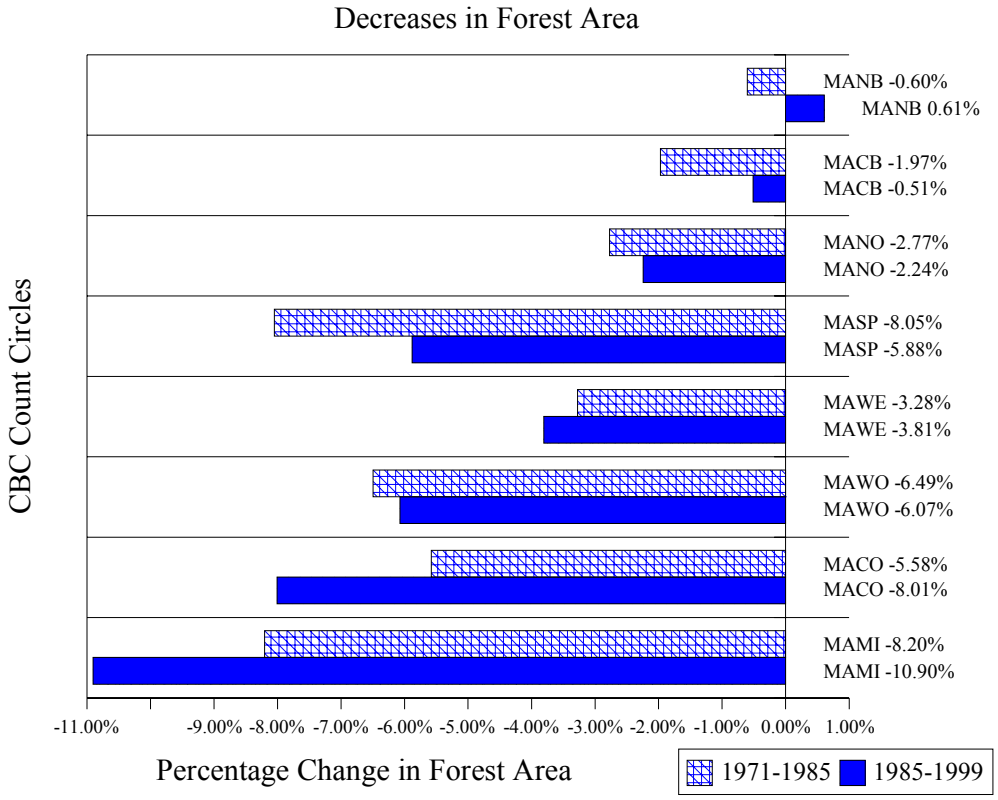


Figure 9. Changes in the Forested Area of Each CBC Circle.

The figure shows the percentage change in the area of forest in each CBC circle from 1971 – 1985 and from 1985 – 1999. The North Berkshire circle (NB) shows a slight (0.61%) increase from 1985 – 1999, but all other areas show a decrease in area for both time periods.

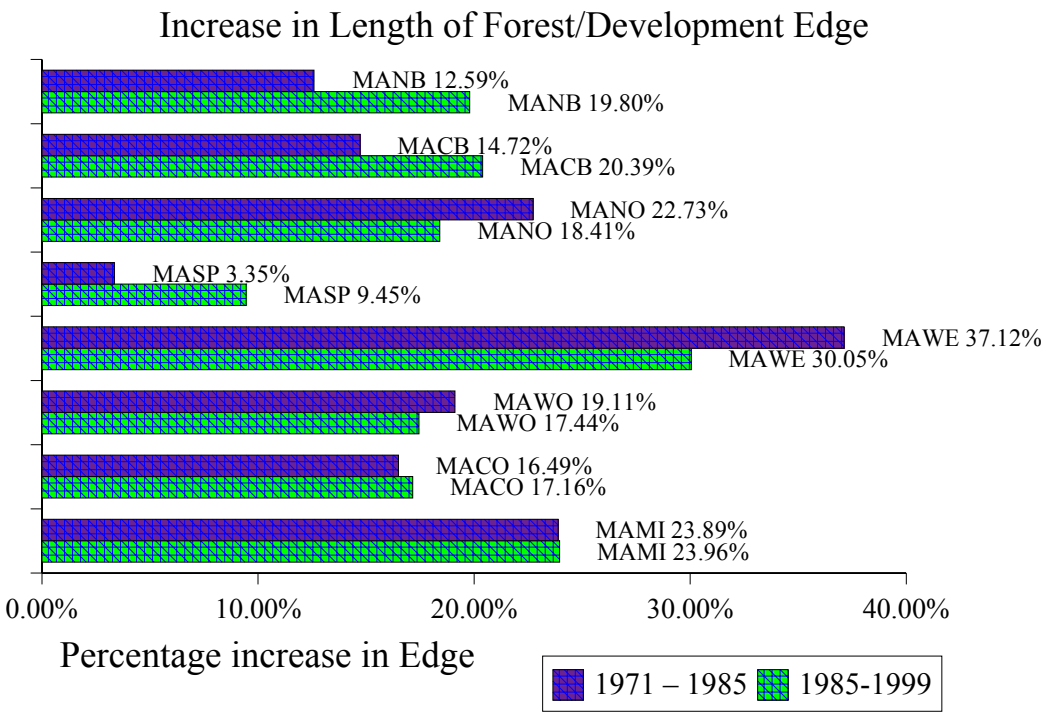
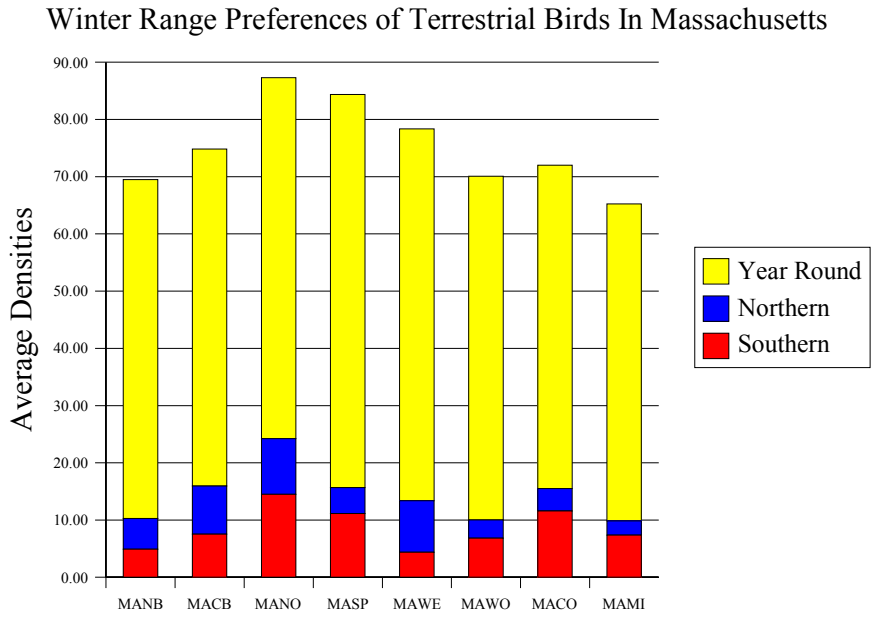


Figure 10. Changes in the Length of the Edge Between Forest and Developed Areas in Each of the Selected CBC Circles.

The figure shows the percentage change in the length of the edge between forest and developed areas in each CBC circle from 1971 – 1985 and from 1985 – 1999. All circles show an increase in edge for both time periods. The greatest increases (37.12% and 30.05%) were seen in the Westminster (WE) circle.

	MANB		MACB		MANO		MASP	
	Av. Density	% Comp.	Av. Density	% Comp.	Av. Density	% Comp.	Av. Density	% Comp.
Southern	4.89	7.04%	7.54	10.07%	14.50	16.60%	11.13	13.20%
Northern	5.39	7.75%	8.40	11.22%	9.72	11.13%	4.53	5.37%
Year Round	59.21	85.21%	58.88	78.70%	63.09	72.27%	68.7	81.44%
Total	69.49		74.82		87.30		84.36	
	MAWE		MAWO		MACO		MAMI	
	Av. Density	% Comp.	Av. Density	% Comp.	Av. Density	% Comp.	Av. Density	% Comp.
Southern	4.38	5.59%	6.83	9.75%	11.57	16.06%	7.36	11.28%
Northern	8.99	11.48%	3.18	4.54%	3.93	5.46%	2.50	3.84%
Year Round	64.98	82.93%	60.07	85.72%	56.52	78.48%	55.39	84.88%
Total	78.35		70.08		72.02		65.26	

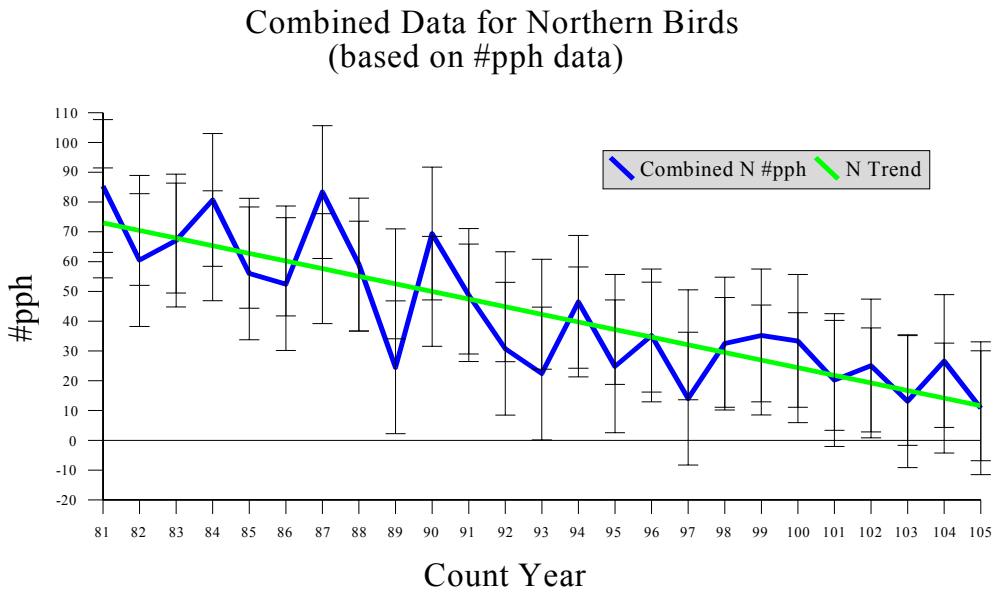
11 a). Relative abundance of birds in the geographic range preferences categories.



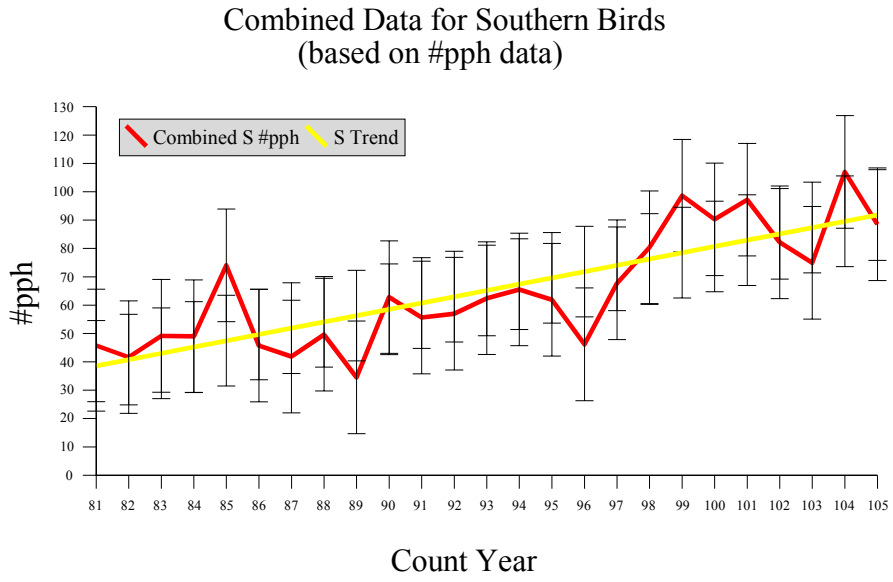
11 b). Species composition of the geographic range preferences of birds recorded in the Christmas Bird Count for the eight circles.

Figure 11. Winter Range Preference of Birds in Massachusetts; Relative Abundance & Species Composition Based on Average Densities.

The largest number of species recorded in the Christmas Bird Count have a Southern range preference, but the greatest abundance is of birds with a year round distribution.



12 a). Trend in the number of birds with northern winter range preferences. The figure shows the declining numbers of birds that have a Northern winter range preference ($y=280.24-2.56x$; $R^2=0.68$).



12 b). Trend in the number of birds with Southern winter range preferences. The figure shows the increasing numbers of birds that prefer a Southern winter range ($y=2.22x-141.03$;$R^2=0.65$).

Figure 12. Trend in the Number of Northern and Southern Birds in the Christmas Bird Counts for the Eight CBC Circles in Massachusetts.

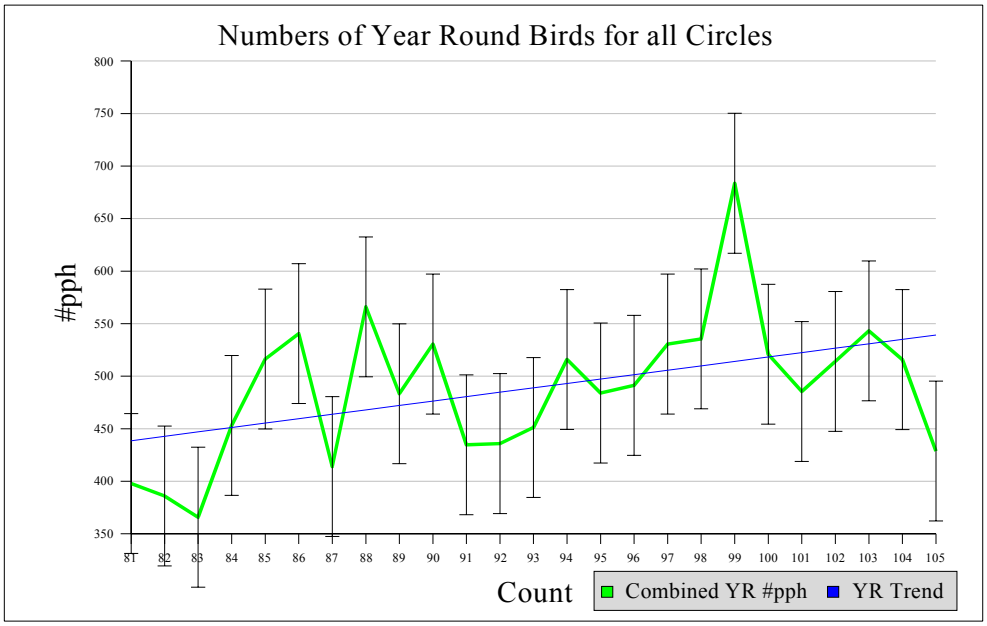
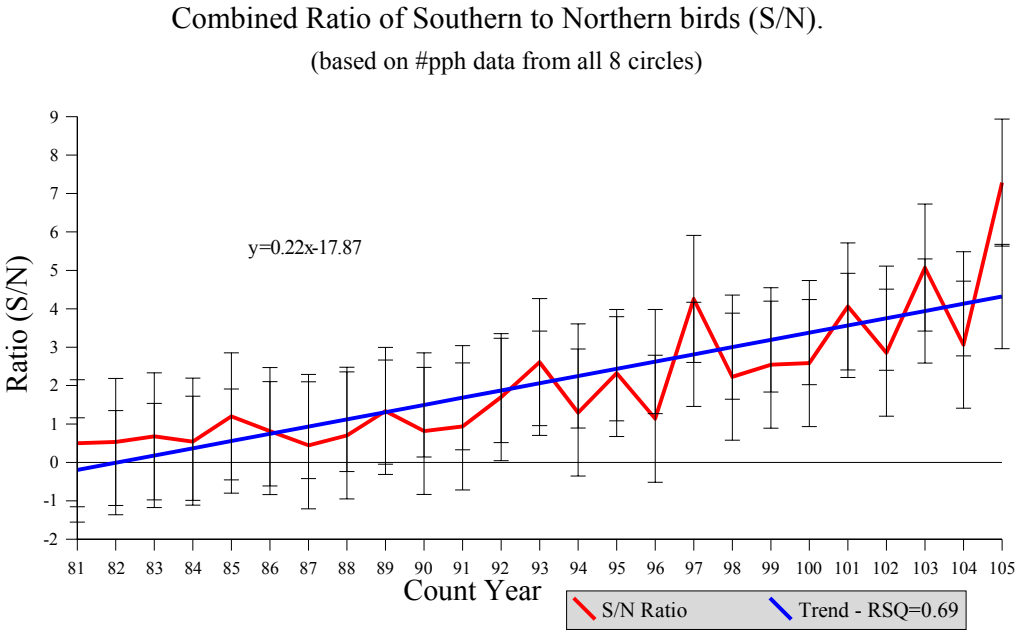
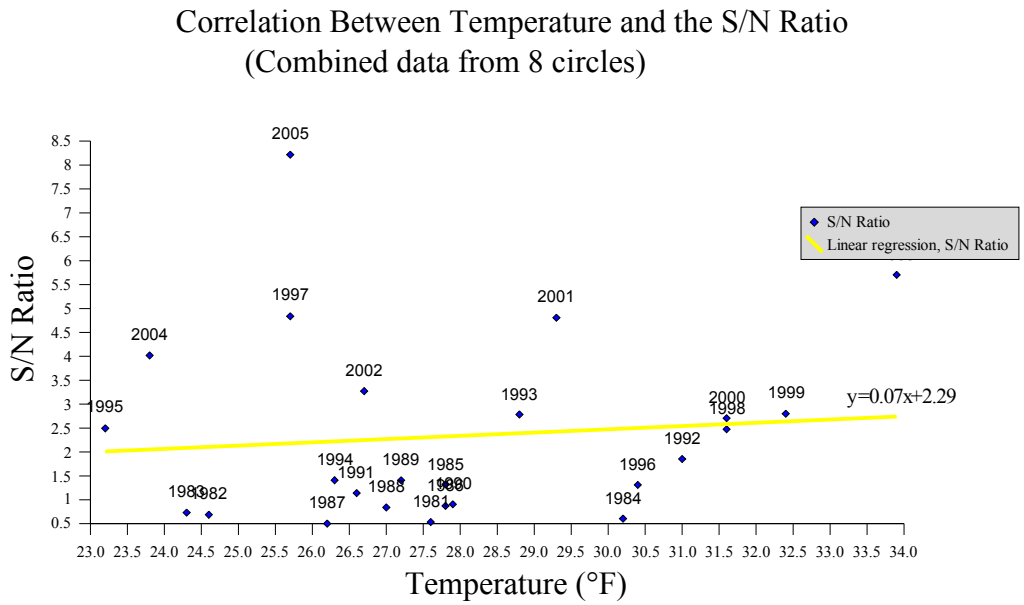


Figure 13. Trend in the Number of Birds Resident Year Round in Massachusetts Recorded in the Christmas Bird Counts for the Eight CBC Circles.

The figure shows that despite increasing numbers of birds with a southern range preference, the numbers of resident birds are not declining, but also show an increasing trend.

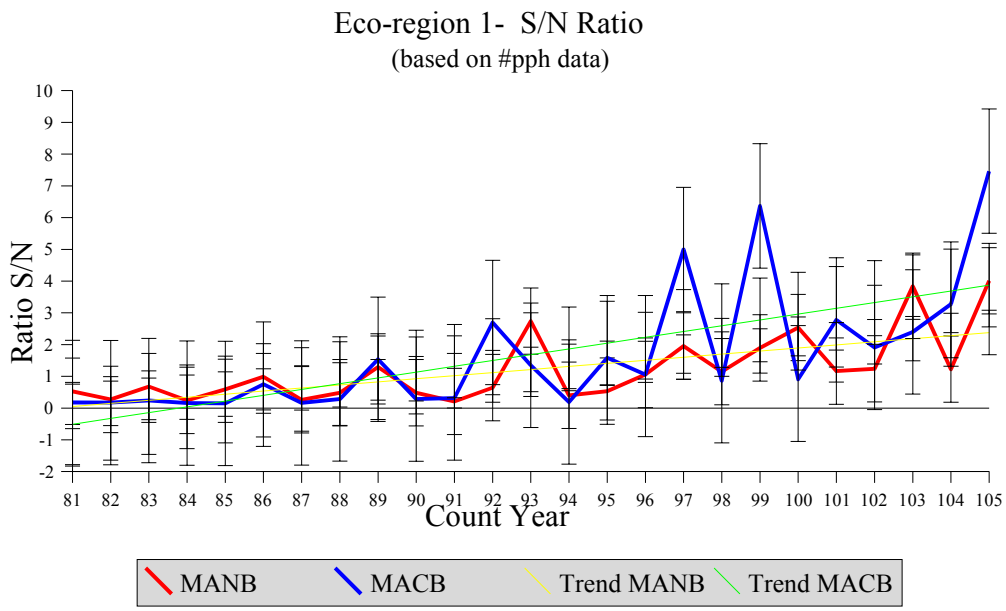


14 a). Ratio of Southern to Northern Birds (based on #pph) based on the total birds recorded for all eight CBC circles.

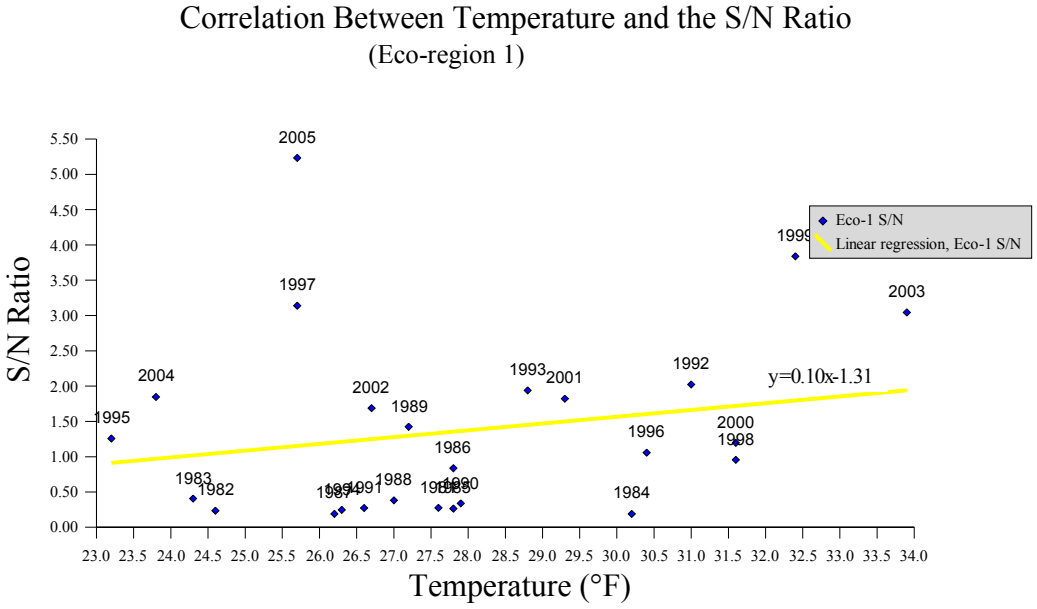


14 b) Relationship between the ratio of Southern to Northern Birds and average winter temperatures for 1980/1 – 2004/5 in Massachusetts (R^2=0.00)

Figure 14. Correlation Between the Southern and Northern (S/N) Ratio and Average Winter Temperatures in Massachusetts.

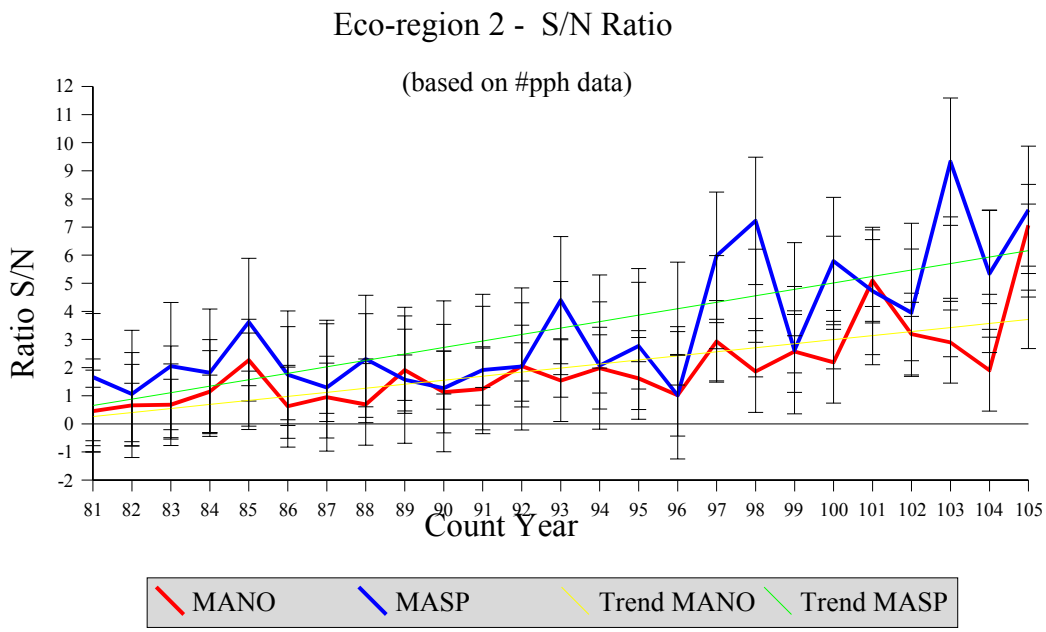


15 a) Ratio of Southern to Northern Birds (based on #pph) of the total birds for North Berkshire (NB) and Central Berkshire (CB) CBC count circles.

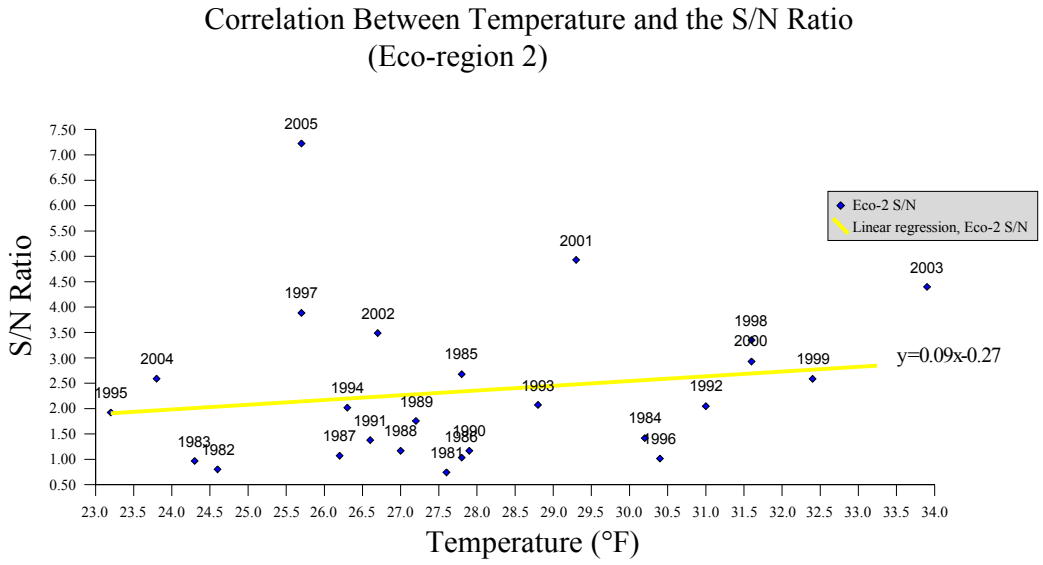


15 b). Relationship between the ratio of Southern to Northern Birds and average winter temperatures for 1980 – 2005 in eco-region 1 of Massachusetts (R^2=0.04).

Figure 15. Increasing Trends of the S/N ratio from Eco-region 1 and the Impact of Changes in Average Winter Temperatures on the Ratio.

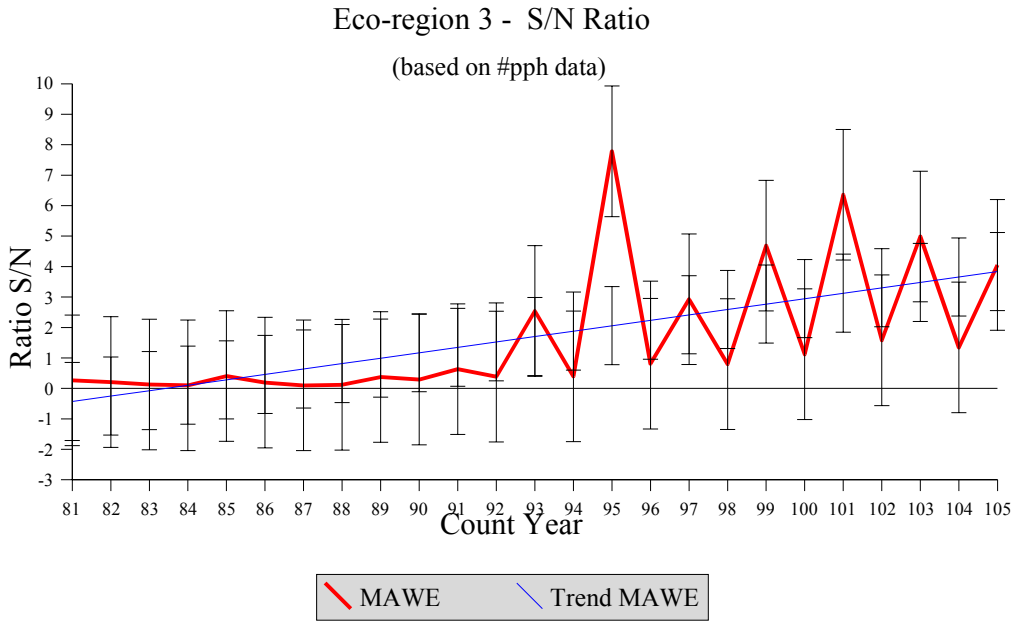


16 a). Ratio of Southern to Northern Birds (based on #pph) of the total birds for Northampton (NO) and Springfield (SP).

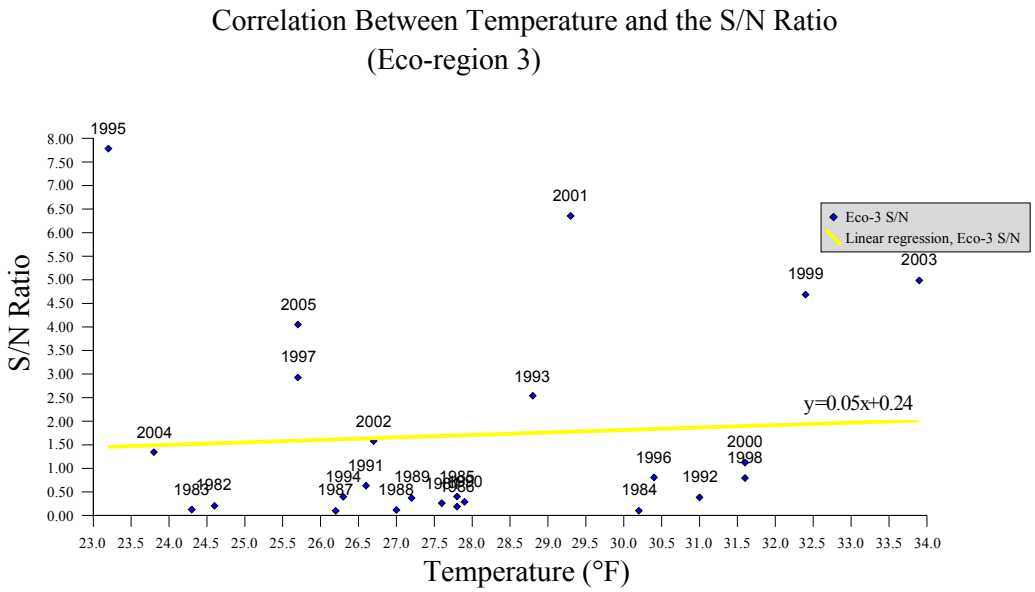


16 b). Relationship between the ratio of Southern to Northern Birds in Eco-region 2, and average winter temperatures for 1980 – 2005 in Massachusetts (R^2=0.03).

Figure 16. Increasing Trends of the S/N ratio from Eco-region 2 and the Impact of Changes in Average Winter Temperatures on the Ratio.

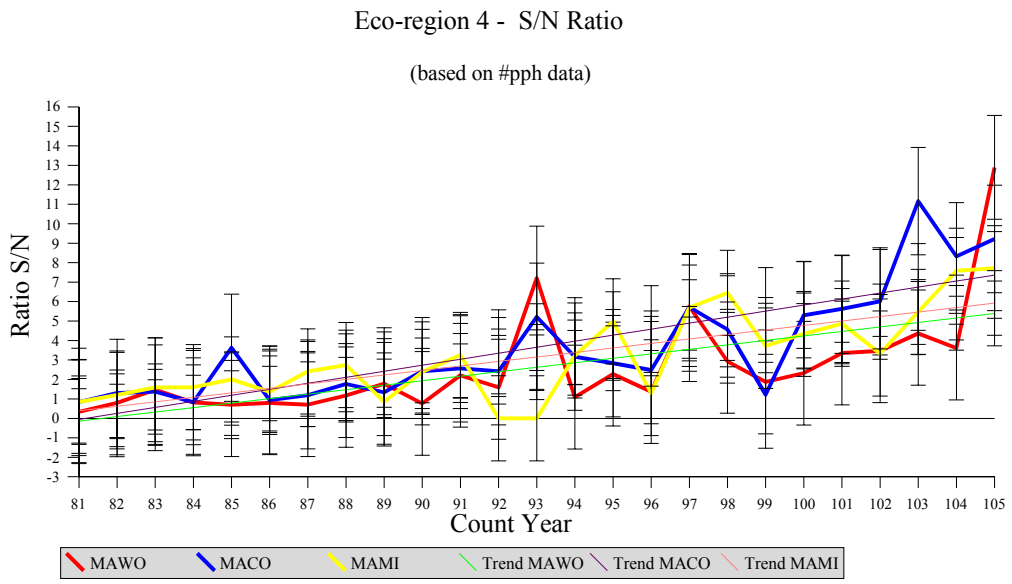


17 a). Ratio of Southern to Northern Birds (based on #pph) of the total birds for the Westminster (WE) CBC count circle.

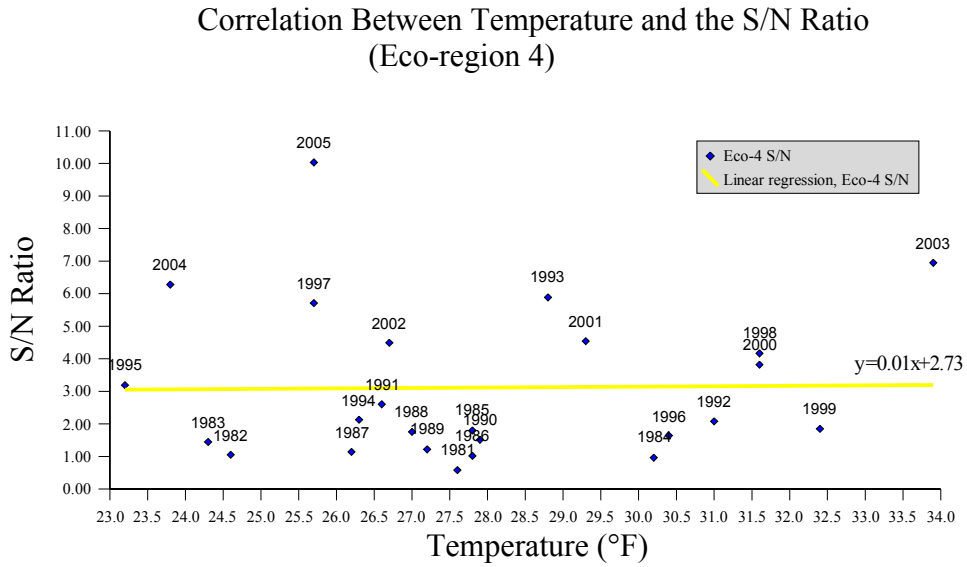


17 b). Relationship between the ratio of Southern to Northern Birds in Eco-region 3, and average winter temperatures for 1980 – 2005 in Massachusetts (R^2=0.0).

Figure 17. Increasing Trends of the S/N ratio from Eco-region 3 and the Impact of Changes in Average Winter Temperatures on the Ratio.



18 a). Ratio of Southern to Northern Birds (based on #pph) of the total birds for Worcester (WO), Concord (CO), & Millis (MI).



18 b). Relationship between the ratio of Southern to Northern Birds in Eco-region 4, and average winter temperatures for 1980 – 2005 in Massachusetts (R^2=0.0).

Figure 18. Increasing Trends of the S/N ratio from Eco-region 4 and the Impact of Changes in Average Winter Temperatures on the Ratio.

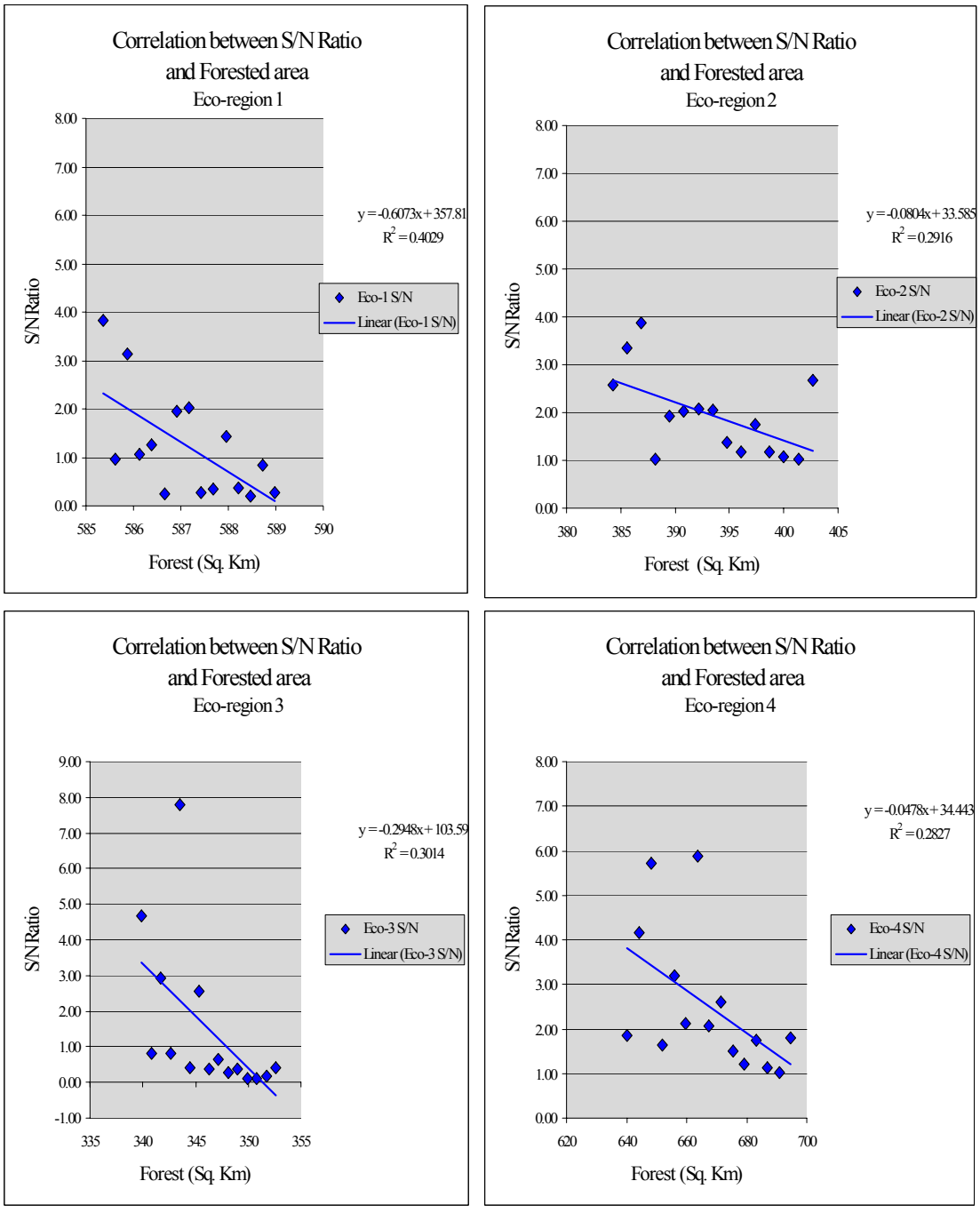


Figure 19. Correlation Between the S/N Ratio and Area of Forest in the Four Eco-regions.

All regions show a weakly negative correlation between the change in forest area and the S/N ratio. Eco-region 3 shows the highest correlation (y=103.59-0.29x).

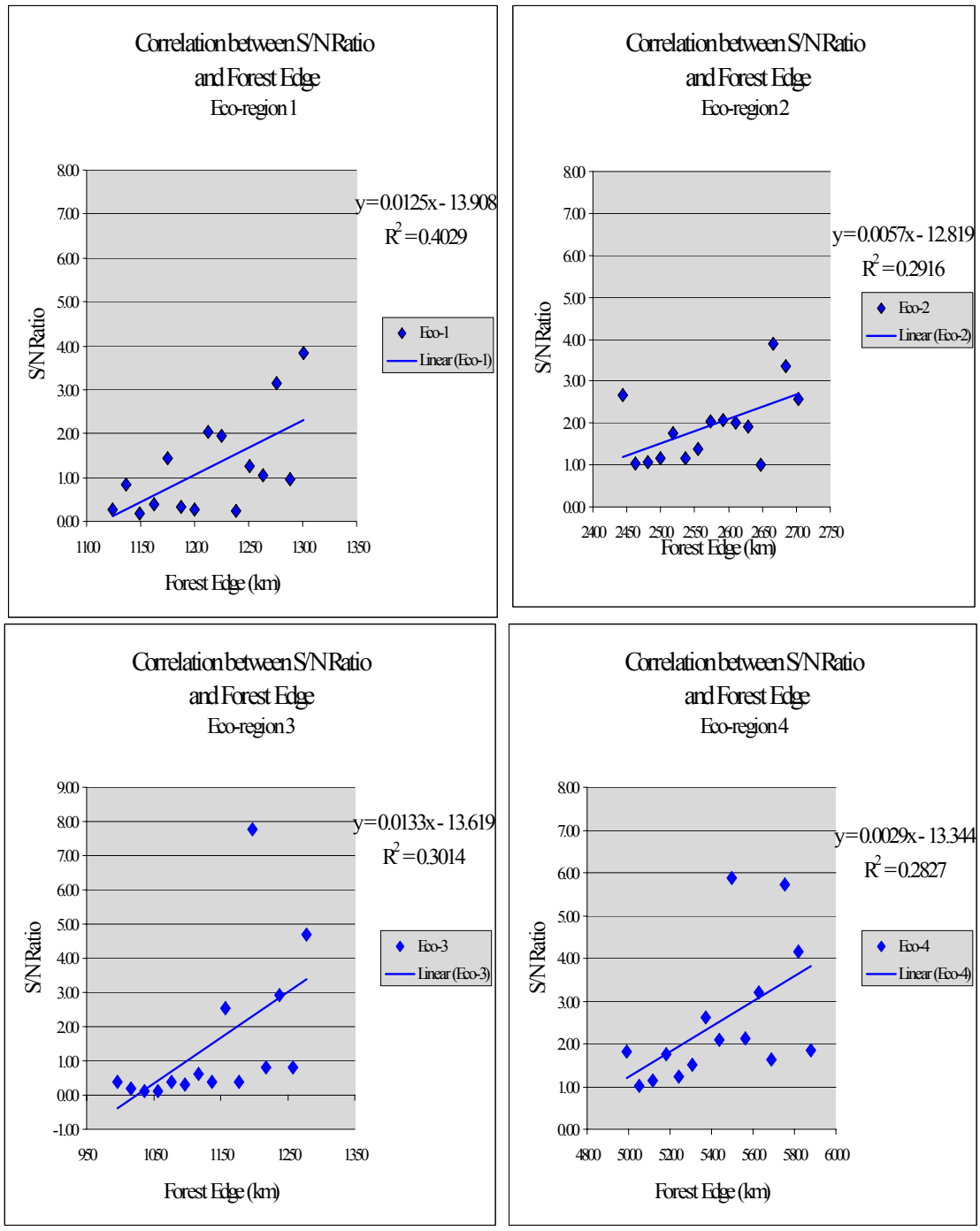


Figure 20. Correlation Between the S/N Ratio and Length of Forest to Developed Area Edge in the Four Eco-regions.

All regions show a weakly positive correlation between the change in forest edge and the S/N ratio.

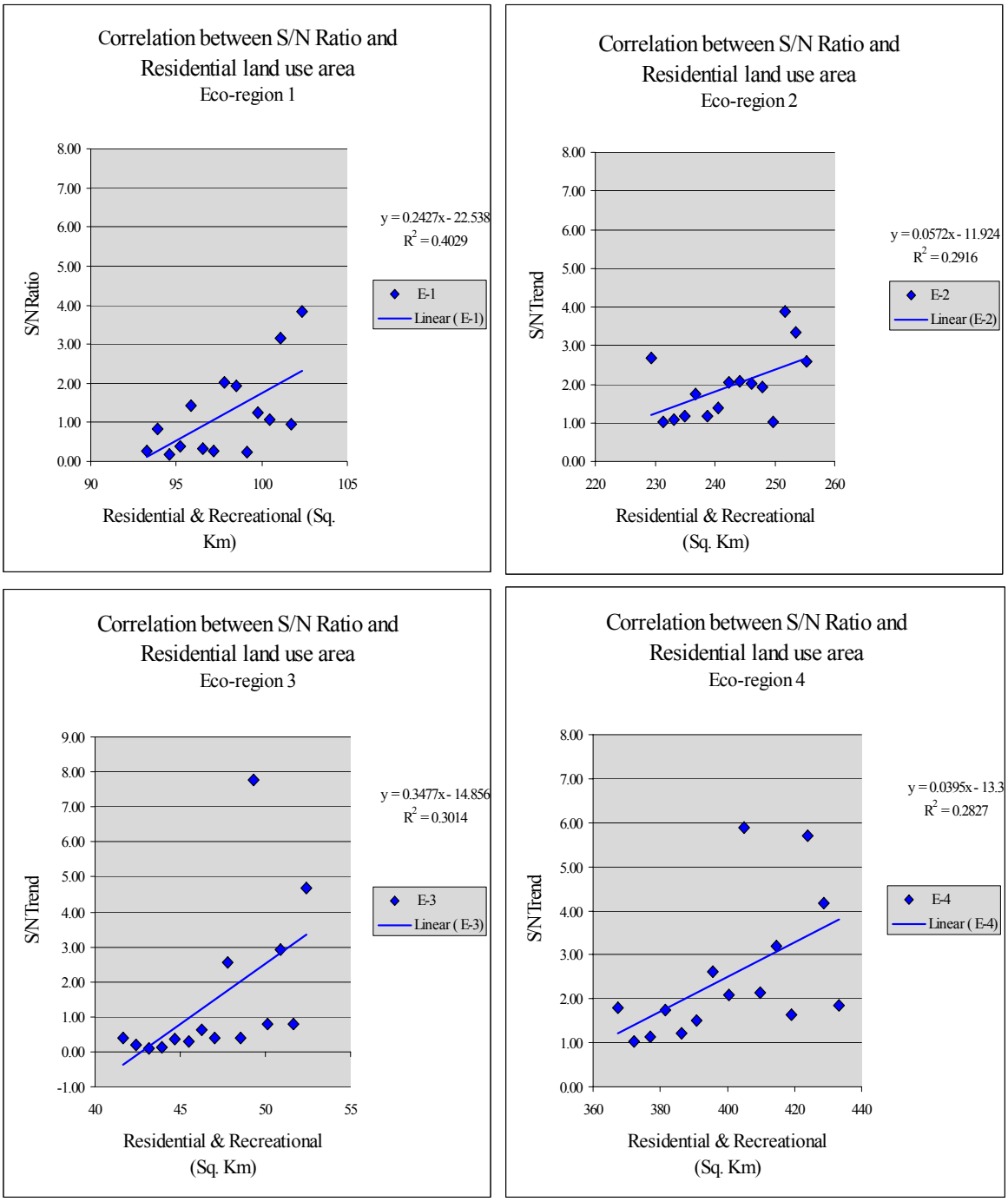


Figure 21. Correlation Between the S/N Ratio and Area of Residential/Recreational Land in the Four Eco-regions.

All eco-regions show a weak positive correlation between the change in the area of residential and recreational land and the S/N ratio.

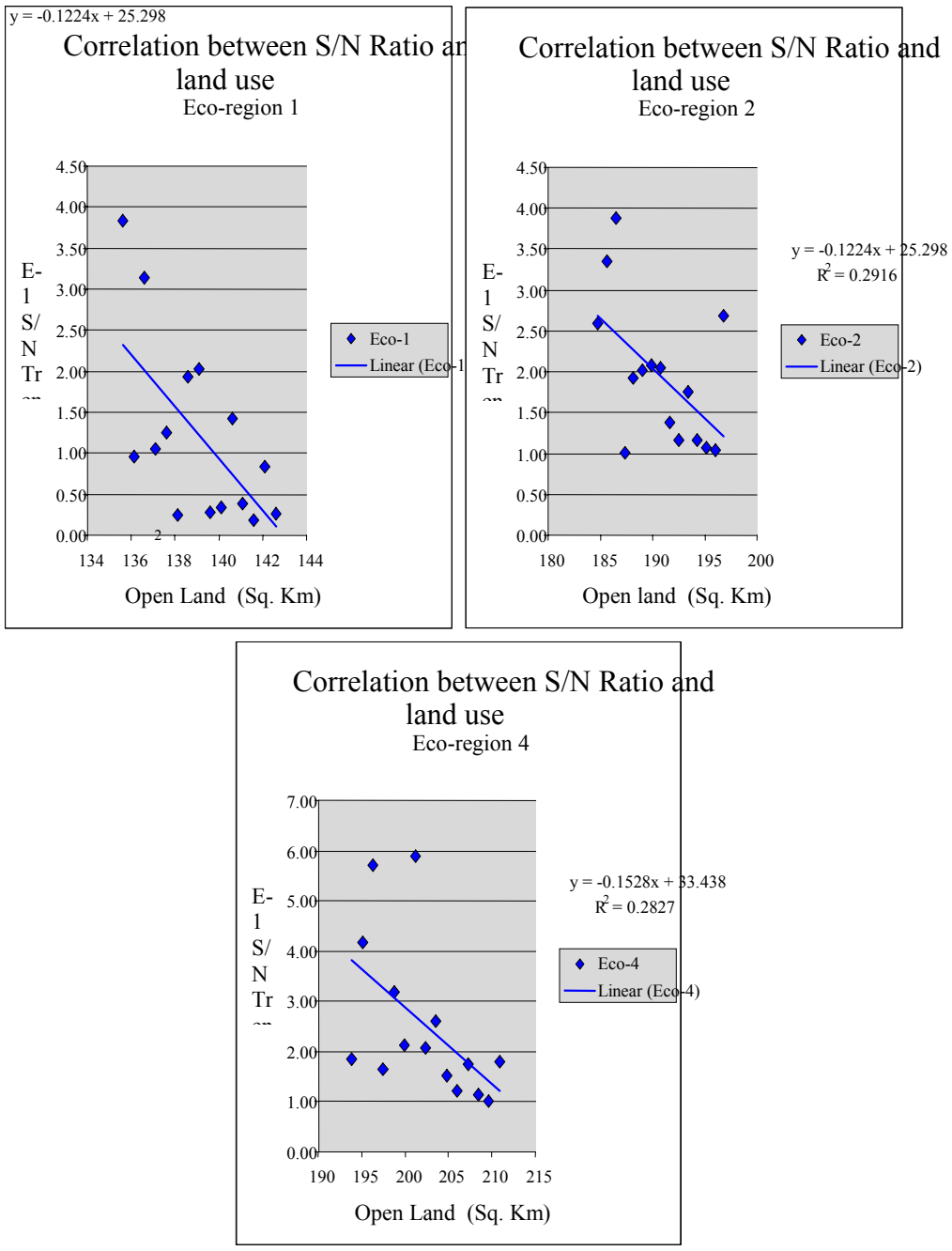
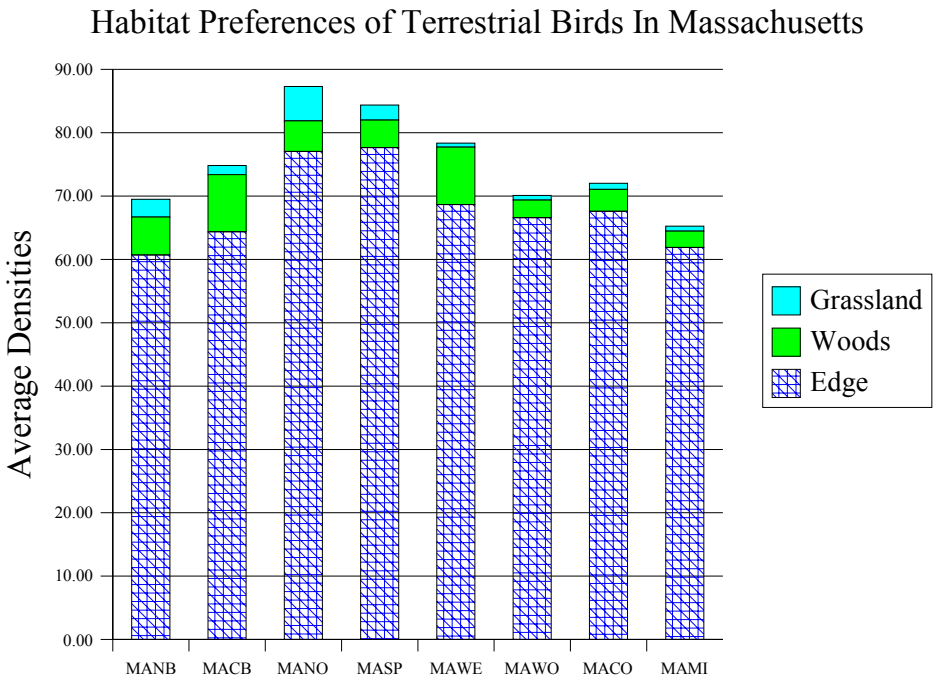


Figure 22. Correlation Between the S/N Ratio and Area of Open Land in the Four Eco-regions.

Three eco-regions show a weakly negative correlation between the change in the area of open land and the S/N ratio. Eco-region 3 showed no trend in the change of the area of open land in the three years recorded (1971,1985, & 1999) and was excluded from the analysis.

	MANB		MACB		MANO		MASP	
	Av. Density	% Comp.	Av. Density	% Comp.	Av. Density	% Comp.	Av. Density	% Comp.
Edge	60.71	87.37%	64.37	86.04%	77.04	88.25%	77.65	92.05%
Woods	5.98	8.60%	9.00	12.03%	4.82	5.52%	4.34	5.14%
Grassland	2.79	4.02%	1.44	1.93%	5.44	6.23%	2.37	2.81%
Total	69.49		74.82		87.3		84.36	
	MAWE		MAWO		MACO		MAMI	
	Av. Density	% Comp.	Av. Density	% Comp.	Av. Density	% Comp.	Av. Density	% Comp.
Edge	68.68	98.83%	66.58	88.99%	67.60	77.43%	61.89	73.37%
Woods	9.04	13.01%	2.79	3.73%	3.46	3.96%	2.57	3.05%
Grassland	0.63	0.91%	0.71	0.95%	0.96	1.10%	0.80	0.94%
Total	78.35		70.08		72.02		65.26	

23 a). Relative abundance of birds in the geographic range preferences categories.



23 b). Species composition of the habitat preferences of birds recorded in the CBC.

Figure 23. Winter Habitat Preference of Birds in Massachusetts; Relative Abundance & Species Composition Based on Average Densities.

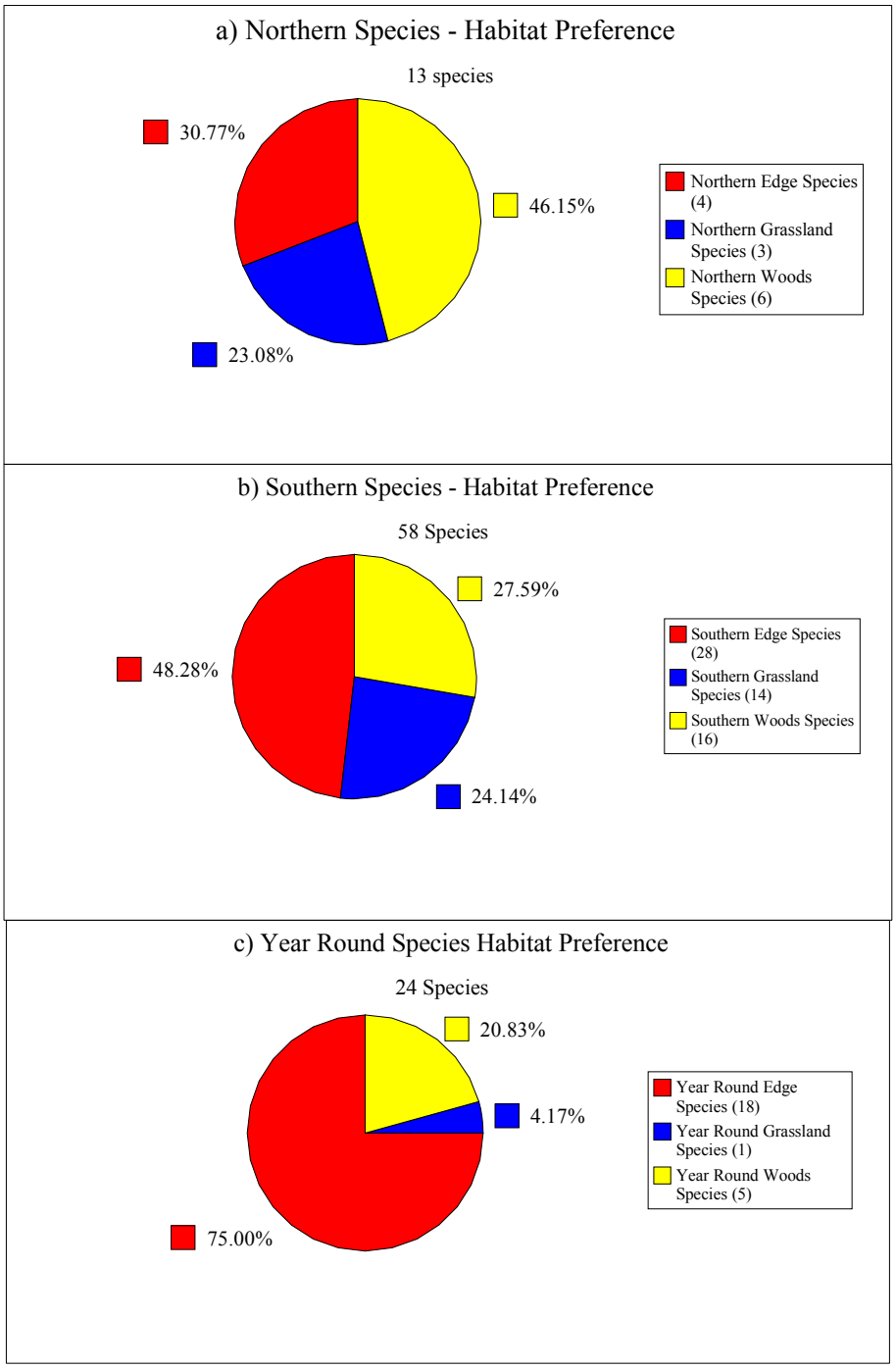


Figure 24. Winter Habitat Preference of Species.

a) Southern species, b) Northern species, & c) Year round species

The greatest numbers of southern species prefer the edge habitat, and the greatest number of Year round species also prefer the edge habitat. In the Woodland habitat the largest number of species have a predominantly Northern winter range.

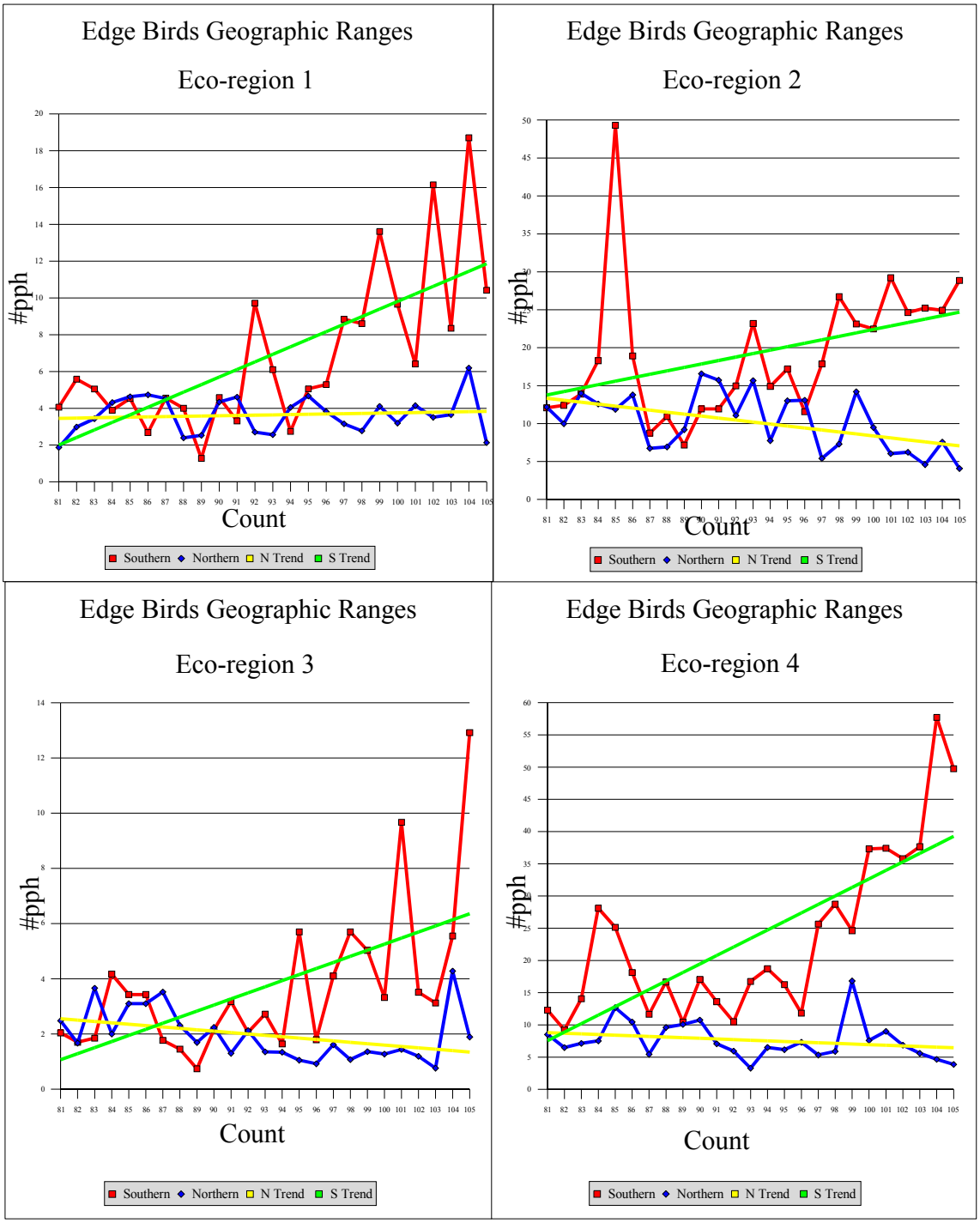


Figure 25. Trends in the Number of Edge Birds in the Four Eco-regions Studied.

In all eco-regions, there was an increase in the number of southern edge birds over the time period studied. The numbers of northern edge birds showed population fluctuations over the same time period, consistent with those found in natural populations.

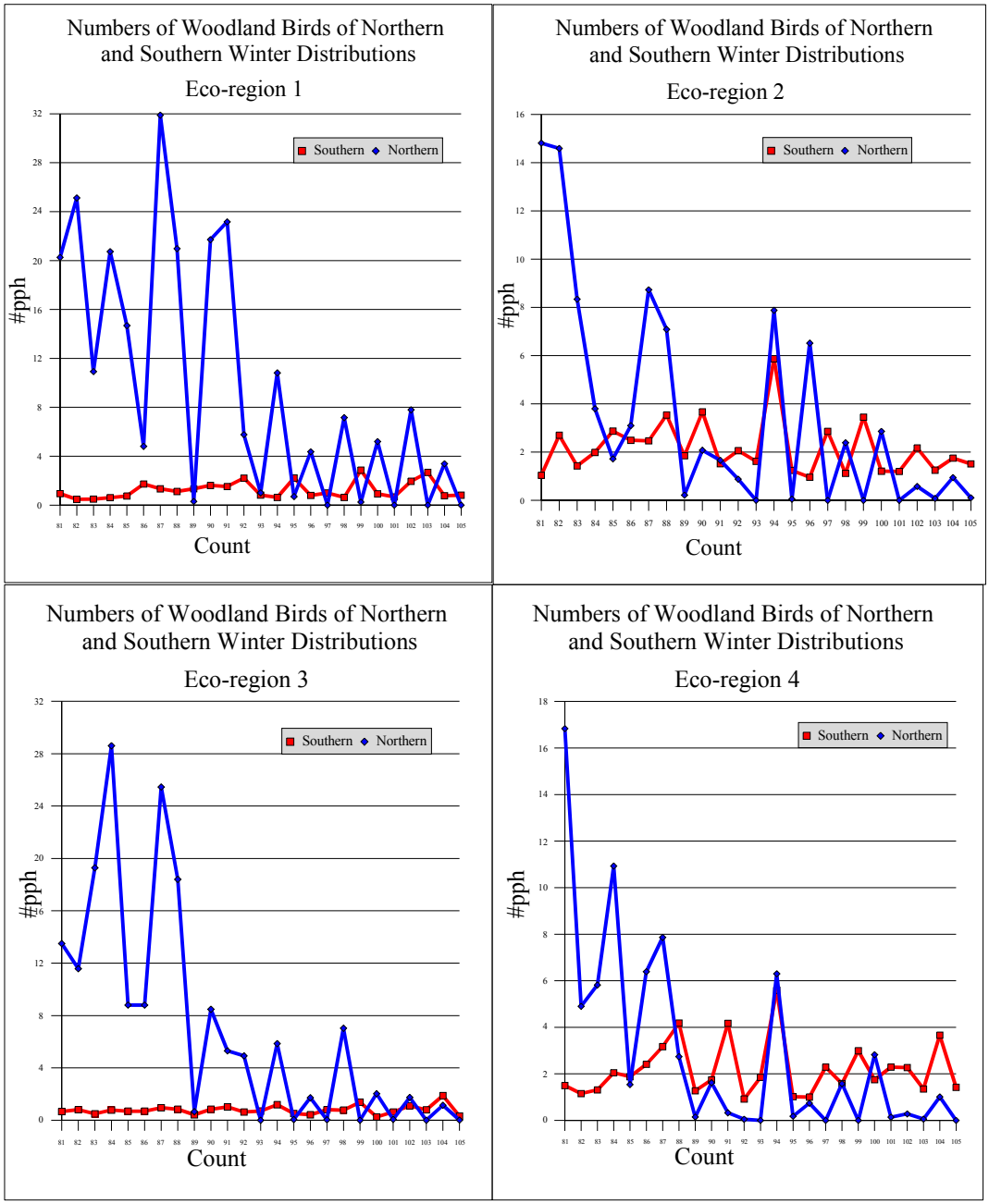
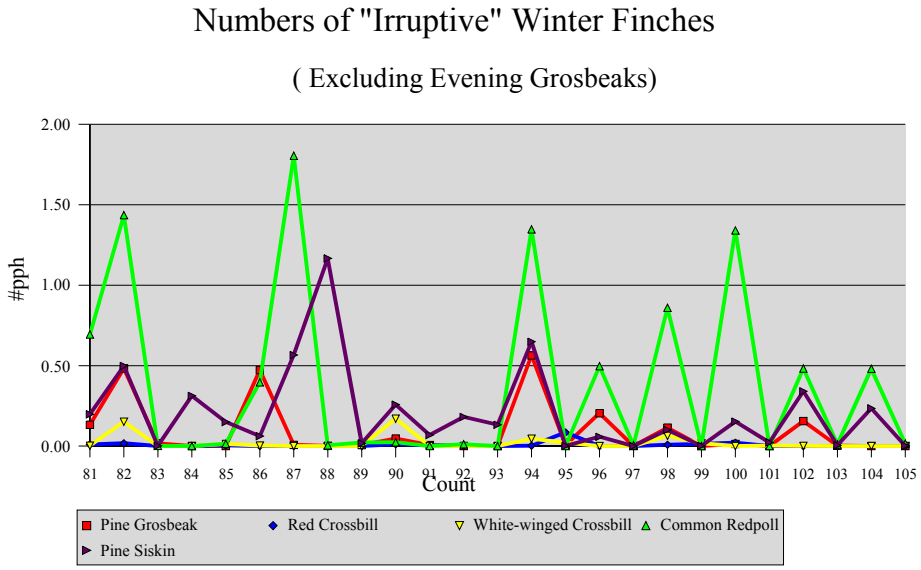
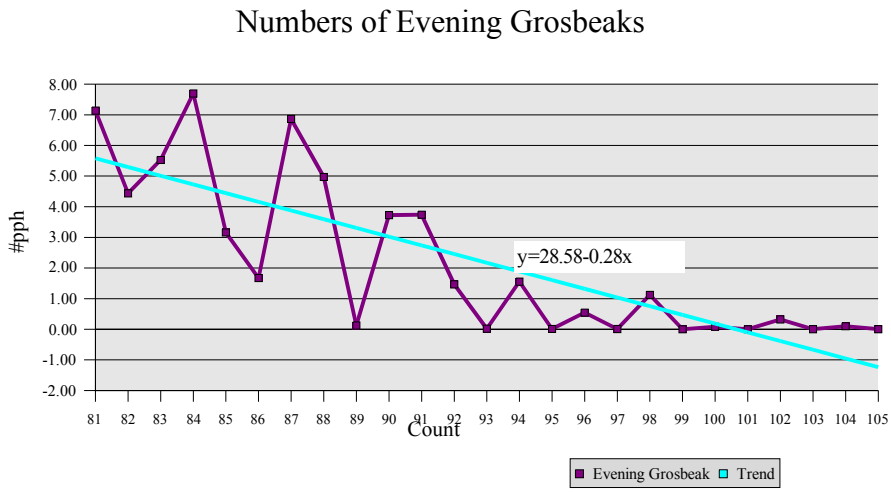


Figure 26. Trends in the Number (#pph) of Woodland Birds in the Four Eco-regions Studied.

In all eco-regions, there was a dramatic decline in the number of northern birds that favor a woodland habitat, over the time period studied. The numbers of southern woodland birds showed population fluctuations over the same time period, consistent with those found in natural populations.



27 a). Numbers of winter finches recorded in all eight CBC circles analyzed.

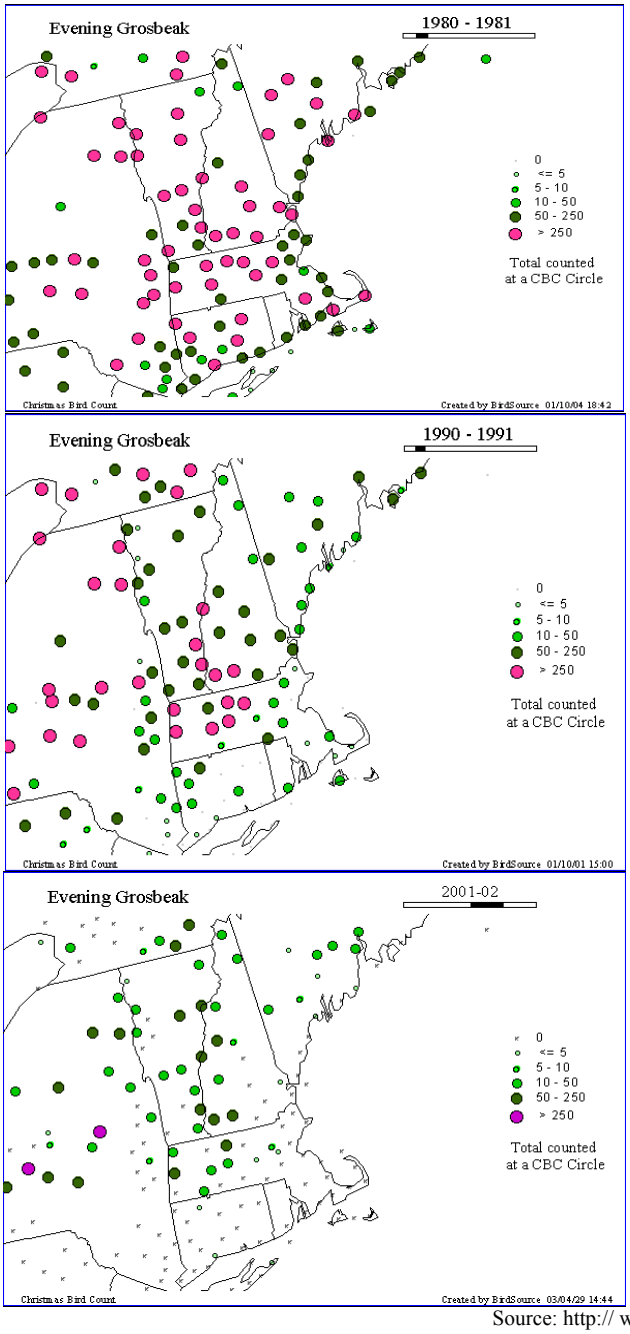


27 b). Downward trend in the numbers of Evening Grosbeaks in all eight circles.

Figure 27. Trends in the Total Number (#pph) of Winter Finches in the Four Eco-regions studied.

a) the winter finch group excluding Evening Grosbeaks, & b) the trend in numbers of Evening Grosbeaks.

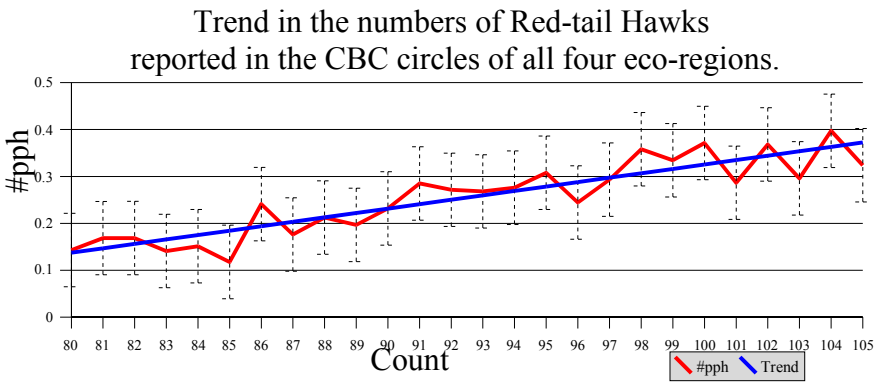
The numbers of winter finches from 1980-2005 show irruptive patterns i.e. a year of high abundance followed by year(s) of no sightings, without showing a declining trend in number over the same time period. This is compared to the number of evening grosbeaks, which shows a significant decline to zero numbers from 2000 to 2005. (see Figure 28).



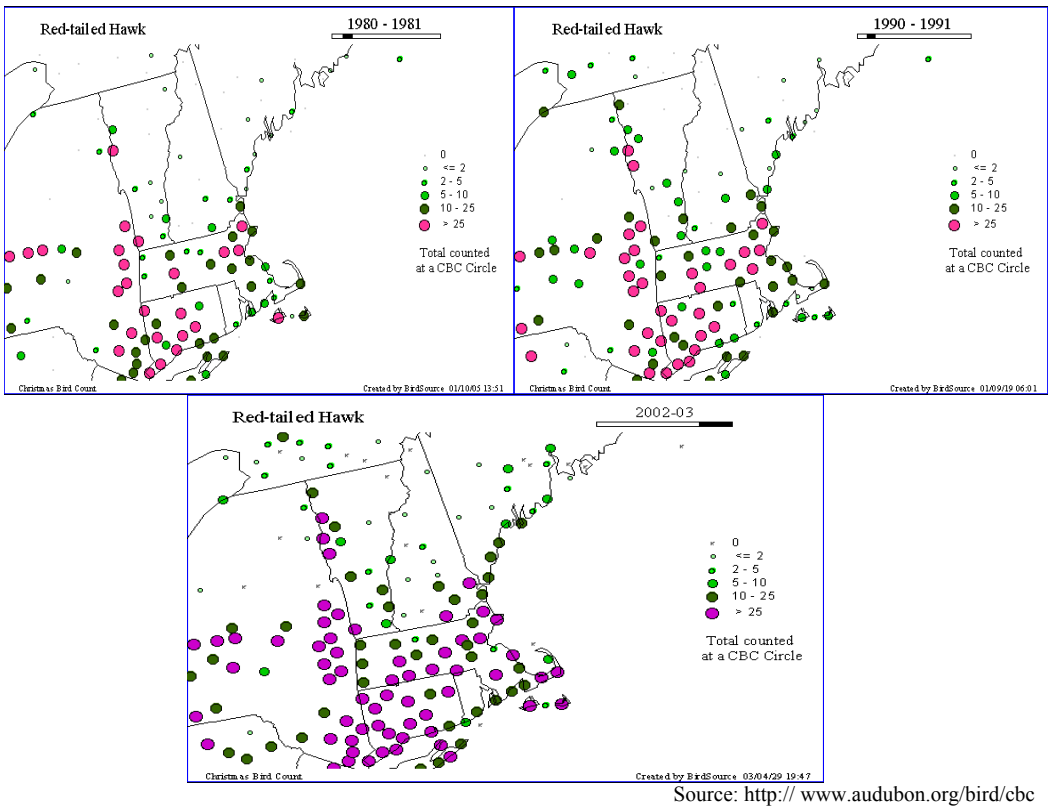
Source: http:// www.audubon.org/bird/cbc

Figure 28. Distribution Pattern of the Numbers of Evening Grosbeaks Recorded in the Christmas Bird Count.

The numbers of evening grosbeaks recorded in 1980-1981 (count #81) show most CBC circles in Massachusetts reporting numbers of 50-250 birds, and ten of the circles reporting numbers greater than 250 birds. The 1990-1991 (count #90) records show much fewer birds recorded in the MA circles. In the 2001-2 count (#102) only nine of the circles in MA reported birds and three of those reported <10 birds. (Note; from Fig. XXIV counts 81, 90, &102 occurred in irruptive years .)



29 a). Increasing trend in the numbers of Red-tailed Hawks wintering in Massachusetts.

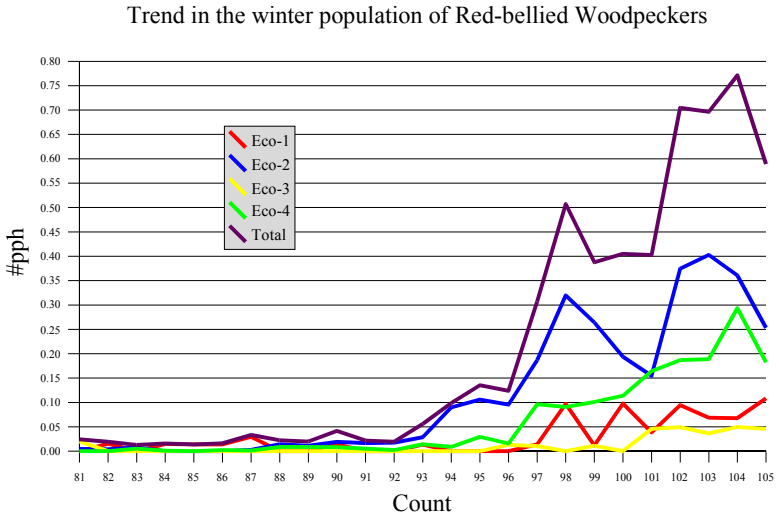


Source: http:// www.audubon.org/bird/cbc

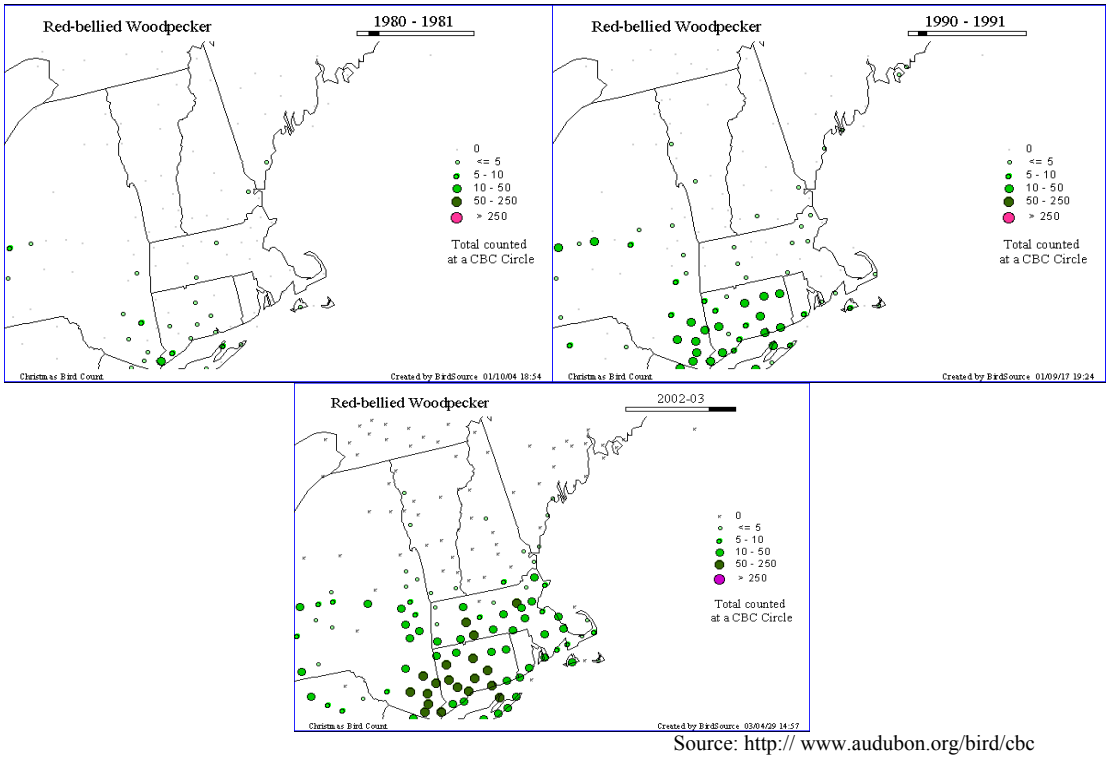
29 b). Distribution patterns of the numbers of Red-tailed Hawks recorded in the Christmas Bird Counts

Figure 29. The Trend (a) and Distribution Pattern (b) of Red-tailed Hawks Recorded in the Christmas Bird Count.

The numbers of Red-tailed Hawks recorded in 1980-1981 (count #81) shows 5 CBC circles in Massachusetts reporting numbers of >25 birds, with six of the circles reporting less than 2 birds. The 1990-1991 (count #90) records shows most MA circles recording higher numbers of birds. In the 2002-3 count (#103) fifteen of the circles in MA reported >25 birds. (Note:Count #103 is the most recent data available for distribution mapsfrom NAS).



30 a). Trend in the numbers of Red-bellied Woodpeckers in the four eco-regions and the total for all eight circles.

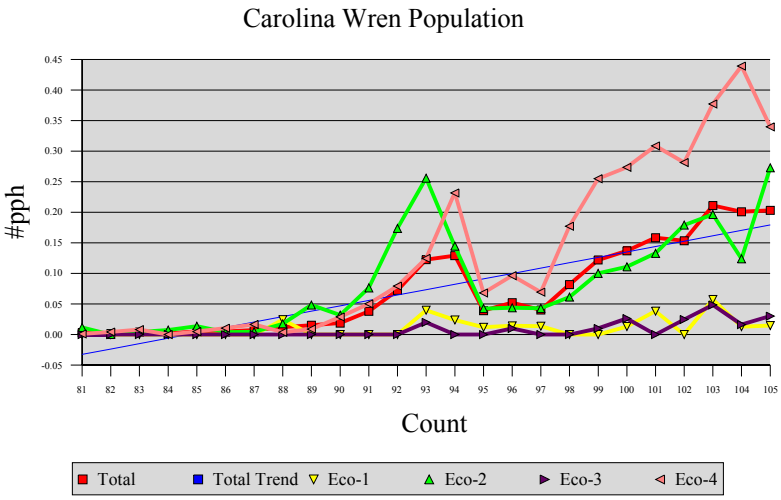


Source: http:// www.audubon.org/bird/cbc

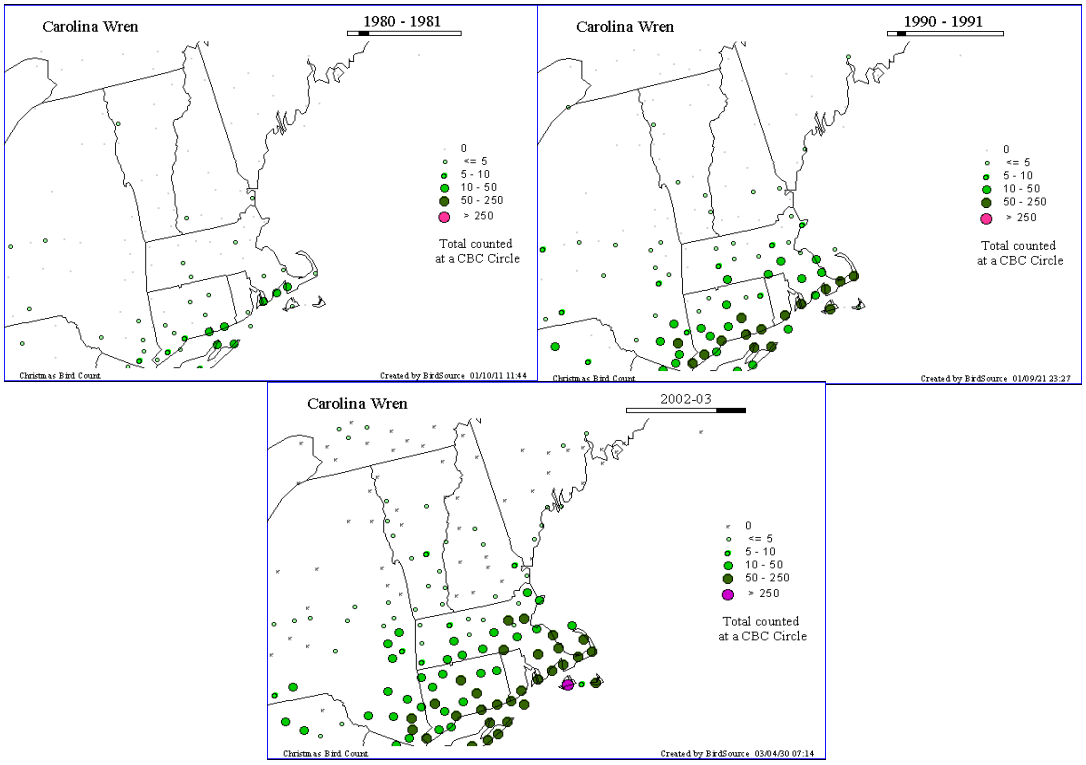
30 b). Changes in the winter range of the Red-bellied Woodpecker.

Figure 30. Changes in the Numbers and Range of the Red-bellied Woodpecker in Winter.

The numbers of Red-bellied Woodpeckers have increased in the four eco-regions of Massachusetts studied, and the distribution maps show a Northward progression of the woodpeckers winter range.



31 a). Trend in the numbers of the Carolina Wren in the four eco-regions and the total for all eight circles.

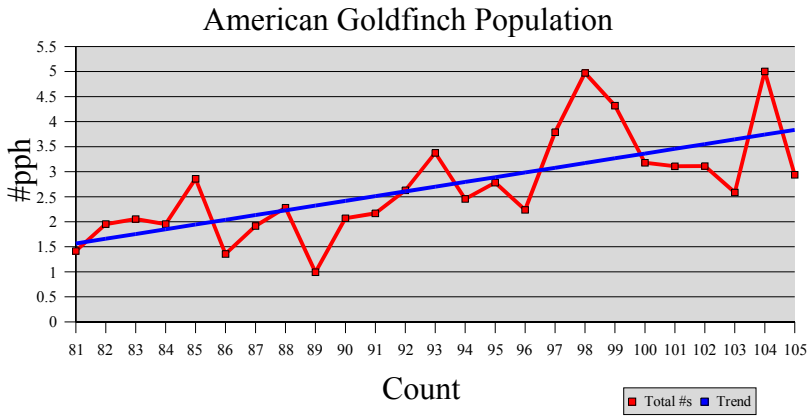


Source: http:// www.audubon.org/bird/cbc

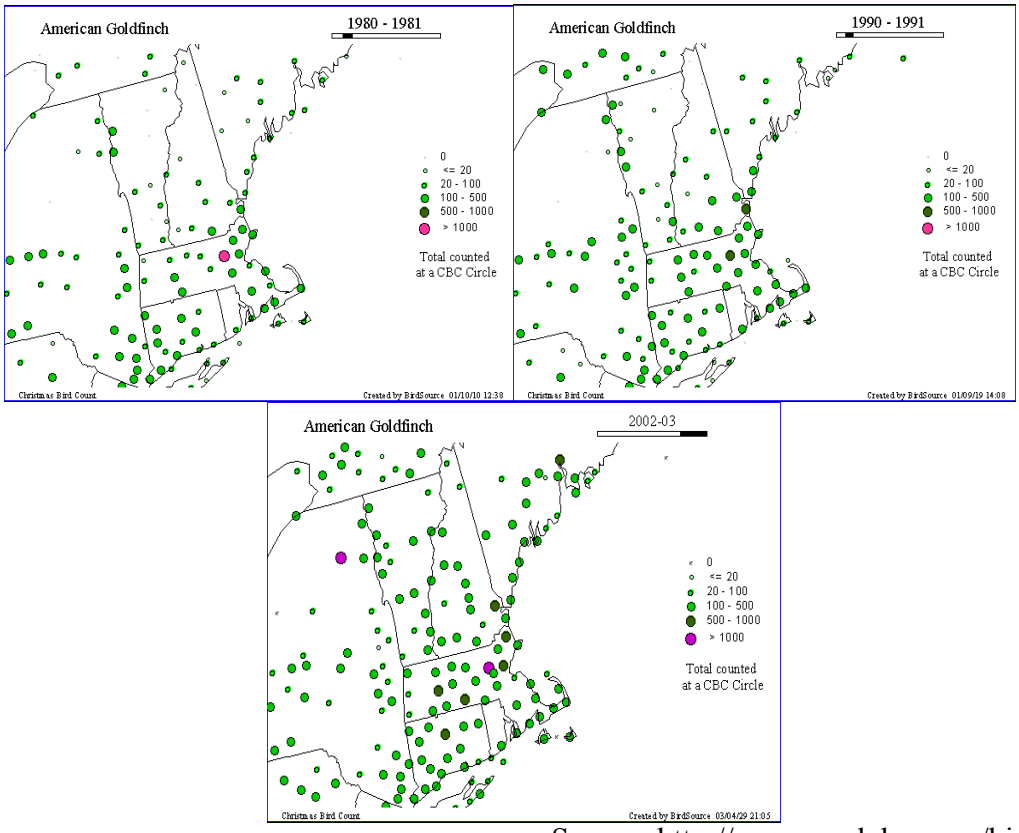
31 b). Changes in the winter range of the Carolina Wren

Figure 31. Changes in the Numbers and Range of the Carolina Wren.

The numbers of Carolina Wrens have increased in the four eco-regions of Massachusetts studied, and the distribution maps show a Northward progression of the birds' winter range.



32 a). Trend in the numbers of the American Goldfinch (total for all eight circles).

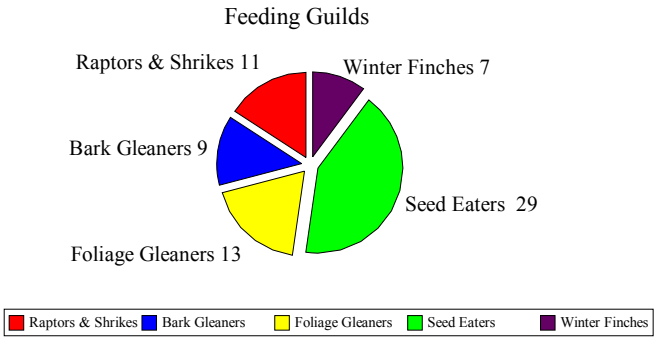


Source: http:// www.audubon.org/bird/cbc

32 b). Changes in the winter range of the American Goldfinch

Figure 32. Changes in the Numbers and Range of the American Goldfinch.

The numbers of American Goldfinch have increased in the four eco-regions of Massachusetts studied, and the distribution maps show a Northward progression of the birds' winter range.



Raptors & Shrikes (11 Species)

Rough-legged Hawk
Red-tailed Hawk
Merlin
Sharp-shinned Hawk
American Kestrel
Red-shouldered Hawk
Northern Harrier
Northern Goshawk
Northern Shrike
Cooper's Hawk
Peregrine Falcon

Foliage Gleaners (13 Species)

Common Yellowthroat
Carolina Wren
House Wren
Ovenbird
Nashville Warbler
Pine Warbler
Orange-crowned Warbler
Winter Wren
Marsh Wren
Yellow-rumped (Myrtle) Warbler
Golden-crowned Kinglet
Ruby-crowned Kinglet
White-eyed Vireo

Bark Gleaners (9 Species)

Brown Creeper
Yellow-bellied Sapsucker
Red-breasted Nuthatch
White-breasted Nuthatch
Northern (Yellow-shafted) Flicker
Pileated Woodpecker
Red-bellied Woodpecker
Downy Woodpecker
Hairy Woodpecker

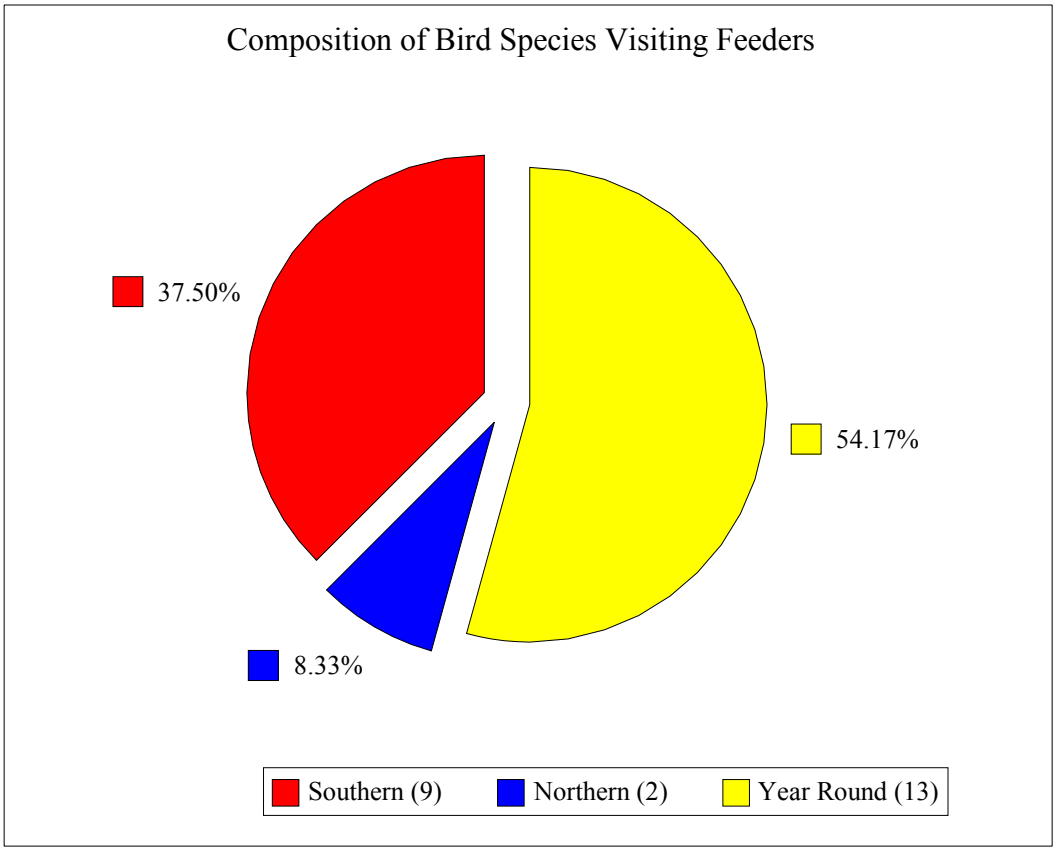
Seed Eaters (28 Species)

Fox Sparrow
American Tree Sparrow
Lapland Longspur
Snow Bunting
White-throated Sparrow
Chipping Sparrow
American Goldfinch
White-crowned Sparrow
Oregon Junco
Purple Finch
Northern Bobwhite
Swamp Sparrow
Song Sparrow
Vesper Sparrow
Savannah Sparrow
Lincoln's Sparrow
Field Sparrow
Brown-headed Cowbird
Eastern Meadowlark
Rock Dove
Mourning Dove
Dark-eyed Junco
Northern Cardinal
House Finch
Ring-necked Pheasant
Wild Turkey
Ruffed Grouse

Winter Finches (7 Species)

White-winger Crossbill
Pine Grosbeak
Pine Siskin
Rose-breasted Grosbeak
Common Redpoll
Red Crossbill
Evening Grosbeak

Figure 33. Feeding Guild Component Species.



Northern Species	Southern Species	Year Round Species
American Tree Sparrow (	Chipping Sparrow (E)	Dark-eyed Junco (E)
Fox Sparrow (E)	American Goldfinch (E)	House Finch (E)
	Purple Finch (E)	Mourning Dove (E)
	White-throated Sparrow (E)	Northern Cardinal (E)
	White-crowned Sparrow (E)	Tufted Titmouse (E)
	Song Sparrow (E)	Black-capped Chickadee (E)
	Red-breasted Nuthatch (W)	House Sparrow (E)
	Yellow-bellied Sapsucker (W)	Carolina Wren (E)
	Brown Creeper (W)	Northern (Yellow-shafted) Flicker (E)
		White-breasted Nuthatch (E)
		Red-bellied Woodpecker (W)
		Downy Woodpecker (W)
		Hairy Woodpecker (W)

Figure 34. Species Recorded in the CBC that Use Bird Feeders as a Supplementary Food Source in Winter.

(b) designates bark gleaners, (c) designates foliage gleaners, and (d) designates seed eaters.

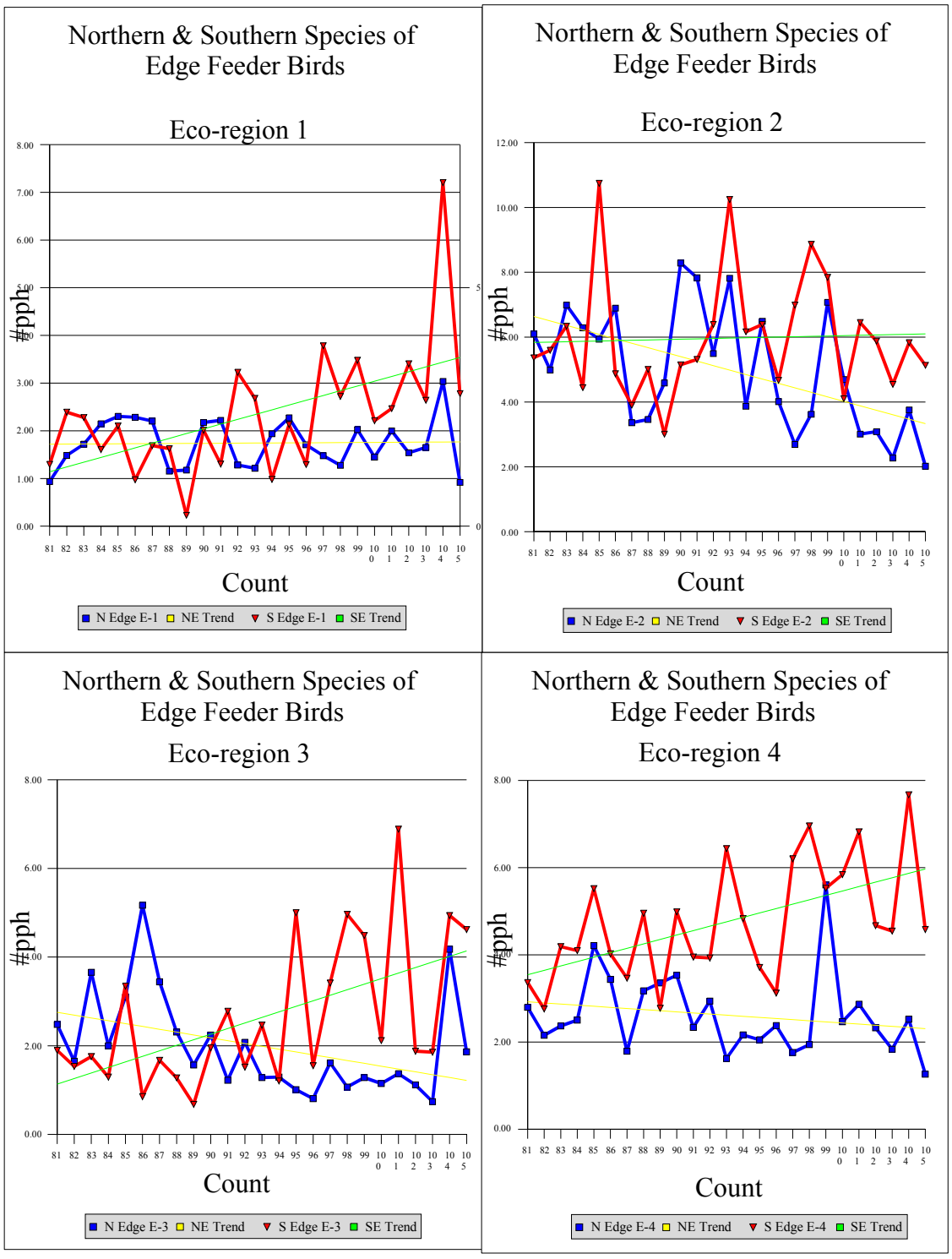


Figure 35. Trends in the Numbers of Edge Dwelling Birds that Use Bird Feeders as a Winter Food Source.

Appendix II

List of Tables

National Average Winter Temperatures			North East Average Winter Temperatures			Massachusetts State Average Winter Temperatures		
Year	National Temp (F)	Trend (USA) y=0.08x-124.24	Year	Regional Temp (F)	Trend (NE) y=0.06x-93.63	Year	State (MA) Temp (F)	Trend (MA) y=0.08x-124.24
1980	31.6	30.8	1980	24.8	24.4	1980	27.6	26.9
1981	33.0	30.9	1981	22.5	24.4	1981	24.6	27.0
1982	26.6	31.0	1982	21.7	24.5	1982	24.3	27.1
1983	33.6	31.1	1983	28.2	24.5	1983	30.2	27.1
1984	29.3	31.2	1984	24.7	24.6	1984	27.8	27.2
1985	26.7	31.3	1985	25.3	24.7	1985	27.8	27.3
1986	35.1	31.4	1986	23.3	24.7	1986	26.2	27.4
1987	32.0	31.5	1987	24.3	24.8	1987	27.0	27.5
1988	28.2	31.6	1988	24.8	24.8	1988	27.2	27.5
1989	34.4	31.7	1989	25.2	24.9	1989	27.9	27.6
1990	37.2	31.8	1990	24.2	25.0	1990	26.6	27.7
1991	29.7	31.9	1991	27.8	25.0	1991	31.0	27.8
1992	34.0	32.0	1992	26.0	25.1	1992	28.8	27.8
1993	30.8	32.1	1993	24.0	25.1	1993	26.3	27.9
1994	29.9	32.2	1994	20.3	25.2	1994	23.2	28.0
1995	33.6	32.3	1995	26.8	25.3	1995	30.4	28.1
1996	30.3	32.4	1996	22.6	25.3	1996	25.7	28.1
1997	30.5	32.5	1997	28.0	25.4	1997	31.6	28.2
1998	35.5	32.6	1998	29.9	25.4	1998	32.4	28.3
1999	34.2	32.7	1999	28.4	25.5	1999	31.6	28.4
2000	34.0	32.8	2000	26.5	25.6	2000	29.3	28.4
2001	31.5	32.9	2001	23.6	25.6	2001	26.7	28.5
2002	34.9	33.0	2002	31.4	25.7	2002	33.9	28.6
2003	33.0	33.1	2003	21.1	25.7	2003	23.8	28.7
2004	30.3	33.2	2004	22.6	25.8	2004	25.7	28.8
2005	33.2	33.3	2005	24.7	25.8	2005	27.1	28.8

Table 1. National, Regional, and Massachusetts Average Winter Temperatures 1980 to 2005 (Figure 4).

National, Regional, and Massachusetts average winter temperatures from 1980 through 2005, show similar positive trends. As expected, the average winter temperatures for Massachusetts are higher than the Regional averages, and lower than the National averages. However, the fluctuations in the temperatures for Massachusetts follow the same pattern as those of the North East region, with linear regression lines for both sets of data showing similar slopes.

MA regression line: y=0.08x-124.24
NE regression line: y=0.06x-93.63

The Basics

• *Circle:*
A count must be entirely within a 15-mile (24 kilometer) diameter circle.

• *Center Point:*
The same center point should be used each year.

• *Circle Overlap:*
Circles may not overlap or abut neighboring counts.

• *Count Period*:
Your count needs to be conducted within the official count period, 14 December thru 5 January, inclusive dates.

• *Count Day:*
Your count must be conducted within one 24-hour calendar day.

• Birds outside the circle seen by an observer standing in the circle should not be included in your census data.
• Count Hours & Observers:
Minimums of full daylight hours (at least 8 with exception of short daylight areas or pelagic counts) in field with 10 observers are preferred for best annual coverage.

• ID by Voice:
Birds may be identified by voice, but specimens or tracks are cw (count week) birds (unless you can document the fact that the specimen/track wasn't present in the area earlier than the count day).

• Linear pelagic CBC's are allowed, if the boat follows the same transect or covers the same area each season.

• Audubon requests that each CBC circle maintain one point of contact for mailing of count materials, receipt of update emails on the CBC and data entry of the count data. This "primary" circle contact needs to provide name, address, e-mail and phone numbers to the Audubon Science office upon creation of the circle. An email address is required for this "primary" contact. This one "primary" compiler may also designate other "secondary" compilers to receive emails, but only one main contact per circle can be maintained for other reasons.

Extracted from the Christmas Bird Count Compiler's Manual at *http://www.audubon.org/bird/cbc*

Table 2. Basic Guidelines for Conducting a Christmas Bird Count.

species.ID	species.commonName	year	number	#pph	hours
moudov	Mourning Dove	81	164	4.46	36.8
moudov	Mourning Dove	82	72	1.71	42
moudov	Mourning Dove	83	101	1.84	55
moudov	Mourning Dove	84	117	2.79	42
moudov	Mourning Dove	85	148	4.11	36
moudov	Mourning Dove	86	126	3.71	34
moudov	Mourning Dove	87	94	2.85	33
moudov	Mourning Dove	88	188	4.59	41
moudov	Mourning Dove	89	173	4.12	42
moudov	Mourning Dove	90	174	4.32	40.3
moudov	Mourning Dove	91	247	6.86	36
moudov	Mourning Dove	92	225	5.92	38
moudov	Mourning Dove	93	291	7.66	38
moudov	Mourning Dove	94	210	5.38	39
moudov	Mourning Dove	95	119	2.9	41
moudov	Mourning Dove	96	263	7.11	37
moudov	Mourning Dove	97	148	4.05	36.5
moudov	Mourning Dove	98	182	4.55	40
moudov	Mourning Dove	99	272	6.33	43
moudov	Mourning Dove	100	193	5.08	38
moudov	Mourning Dove	101	83	4.37	19
moudov	Mourning Dove	102	124	3.26	38
moudov	Mourning Dove	103	123	2.8	44
moudov	Mourning Dove	104	62	1.59	39
moudov	Mourning Dove	105	111	1.42	78

Table 3. Example of the Raw Data from the National Audubon Society's Website at www.audubon.org/birds/cbc.

The table illustrates the raw data obtained from the NAS website for the numbers of Mourning Doves recorded for the Central Berkshire (CB) count circle from count 80 (1980/81) to count 105 (2004/5)

	Common Name	Species Name
a	Bohemian Waxing	*Bombycilla garrulus*
a	Boreal Chickadee	*Poecile hudsonica*
a	Brewer's Blackbird	*Euphagus cyanocephalus*
a	Bullock's Oriole	*Icterus bullockii*
a	Clay-Colored Sparrow	*Spizella pallida*
a	Dark-eyed (Pink-sided) Junco	*Junco hymenalis*
a	Dickcissel	*Spiza americana*
a	Fish Crow	*Corvus ossifragus*
a	Gyrfalcon	*Falco rusticolus*
a	Le Conte's Sparrow	*Ammodramus leconteii*
a	Northern (Red-shafted) Flicker	*Colaptes auratus*
a	Red-headed Woodpecker	*Melanerpes erythrocephalus*
a	Says Phoebe	*Sayornis saya*
a	Sedge Wren	*Cistothorus platensis*
a	Summer Tanager	*Piranga rubra*
a	Varied Thrush	*Ixoreus naevis*
a	Western Kingbird	*Tyrannus verticalis*
b	Black-throated Blue Warbler	*Dendroica caerulescens*
b	Blue-gray Gnatcatcher	*Polioptila caerulea*
b	Blue-headed Vireo/ Solitary Vireo	V*ireo solitarius*
b	Grasshopper Sparrow	*Ammodramus savannarum*
b	Loggerhead Shrike	*Lanius ludovicianus*
b	Palm Warbler	*Dendroica palmarum*
b	Yellow-breasted Chat	*Icteria virens*
b	Yellow-throated Warbler	*Dendroica dominica*
c	Long-eared Owl	*Asio otus*
c	Short-eared Owl	*Asio flammeus*
c	Snowy Owl	*Nyctea scandiaca*
c	Barred Owl	*Strix varia*
c	Eastern Screech-Owl	*Otus asio*
c	Northern Saw-whet Owl	*Aegolius acadicus*
c	Great Horned Owl	*Bubo virginianus*

*Note: Taxonomy and/or nomenclature of certain birds has changed over the time period studied, and these two common names were used for the same species.

Table 4. Species of Birds Excluded from the Analysis.

Rare species (a), species recorded too rarely to count (b), and nocturnal species such as owls (c), were excluded from analysis.

American Crow	*Corvus brachyrhyncus*	Northern (Yellow-shafted) Flicker	*Colaptes auratus*
American Goldfinch	*Carduelis tristis*	Northern Bobwhite	*Colinus virginianus*
American Kestrel	*Falco sparverius*	Northern Cardinal	*Cardinalis cardinalis*
American Pipit	*Anthus rubescens*	Northern Goshawk	*Accipiter gentilis*
American Robin	*Turdus migratorius*	Northern Harrier	*Circus cyaneus*
American Tree Sparrow	*Spizella arborea*	Northern Mockingbird	*Mimus polyglottos*
American Woodcock	*Scolopax minor*	Northern Oriole	*Icterus galbula*
Black-capped Chickadee	*Poecile atricapilla*	Northern Shrike	*Lanius excubitor*
Blue Jay	*Cyanocitta cristata*	Ovenbird	*Seiurus aurocapillus*
Blue-gray Gnatcatcher	*Polioptila caerulea*	Palm Warbler	*Dendroica palmarum*
Brown Creeper	*Certhia americana*	Peregrine Falcon	*Falco peregrinus*
Brown Thrasher	*Toxostoma rufum*	Pileated Woodpecker	*Dryocopus pileatus*
Brown-headed Cowbird	*Molothrus ater*	Pine Grosbeak	*Pinicola enucleator*
Carolina Wren	*Thryothorus ludovicianus*	Pine Siskin	*Carduelis pinus*
Cedar Waxwing	*Bombycilla cedrorum*	Pine Warbler	*Dendroica pinus*
Chipping Sparrow	*Spizella passerina*	Purple Finch	*Carpodacus purpureus*
Common Grackle	*Quiscalus quiscula*	Red Crossbill	*Loxia curvirostra*
Common Raven	*Corvus corax*	Red-bellied Woodpecker	*Melanerpes carolinus*
Common Redpoll	*Carduelis flammea*	Red-breasted Nuthatch	*Sitta canadensis*
Common Snipe	*Gallinago gallinago*	Red-shouldered Hawk	*Buteo lineatus*
Common Yellowthroat	*Geothlypis trichas*	Red-tailed Hawk	*Buteo jamaicensis*
Cooper's Hawk	*Accipiter cooperii*	Red-winged Blackbird	*Agelaius phoeniceus*
Dark-eyed (Oregon) Junco	*Junco hymenalis oreganus*	Ring-necked Pheasant	*Phasianus colchicus*
Dark-eyed (Slate-colored) Junco	*Junco hymenalis hymenalis*	Rock Dove/Rock Pigeon	*Columba livia*
Downy Woodpecker	*Picoides pubescens*	Rose-breasted Grosbeak	*Pheucticus ludovicianus*
Eastern Bluebird	*Sialia sialis*	Rough-legged Hawk	*Buteo lagopus*
Eastern Meadowlark	*Sturnella magna*	Ruby-crowned Kinglet	*Regulus calendula*
Eastern Phoebe	*Sayornis phoebe*	Ruffed Grouse	*Bonasa umbelus*
Eastern Rufous-sided Towhee	*Pipilo erythrophthalmus*	Rusty Blackbird	*Euphagus carolinus*
European Starling	*Sturnus vulgaris*	Savannah Sparrow	*Passerculus sandwichensis*
Evening Grosbeak	*Coccothraustes vespertinus*	Sharp-shinned Hawk	*Accipiter striatus*
Field Sparrow	*Spizella pusilla*	Snow Bunting	*Plectrophenax nivalis*
Fox Sparrow	*Passerella iliaca*	Song Sparrow	*Melospiza melodia*
Golden-crowned Kinglet	*Regulus satrapa*	Swainson's Thrush	*Catharus ustulatus*
Gray Catbird	*Dumetella carolinensis*	Swamp Sparrow	*Melospiza georgiana*
Hairy Woodpecker	*Picoides villosus*	Tufted Titmouse	*Baeolophus bicolor*
Hermit Thrush	*Ctharus guttatus*	Turkey Vulture	*Cathartes aura*
Horned Lark	*Eremophila alpestris*	Vesper Sparrow	*Pooecetes gramineus*
House Finch	*Carpodacus mexicanus*	White-breasted Nuthatch	*Sitta carolinensis*
House Sparrow	*Passer domesticus*	White-crowned Sparrow	*Zonotrichia leucophrys*
House Wren	*Troglodytes aedon*	White-eyed Vireo	*Vireo griseus*
Killdeer	*Charadrius vociferus*	White-throated Sparrow	*Zonotrichia albicollis*
Lapland Longspur	*Calcarius lapponicus*	White-winged Crossbill	*Loxia leucoptera*
Lincoln's Sparrow	*Melospiza lincolnii*	Wild Turkey	*Meleagris gallopavo*
Loggerhead Shrike	*Lanius ludovicianus*	Winter Wren	*Troglodytes troglodytes*
Marsh Wren	*Coistothorus palustris*	Yellow-bellied Sapsucker	*Sphyrapicus varius*
Merlin	*Falco columbarius*	Yellow-rumped Warbler	*Dendroica coronata*
Mourning Dove	*Zenaida macroura*		

Note: Species listed in alphabetical order not taxonomic order

Table 5. Ninety-five Species of Terrestrial Birds Analyzed.

	MANB	MACB	MANO	MASP	MAWE	MAWO	MACO	MAMI
Total	69.49	74.82	87.30	84.36	78.35	70.08	72.02	65.26
Southern (S)	4.89	7.54	14.50	11.13	4.38	6.83	11.57	7.36
Northern (N)	5.39	8.40	9.72	4.53	8.99	3.18	3.93	2.50
Year Round (Y)	59.21	58.88	63.09	68.7	64.98	60.07	56.52	55.39
Edge (E)	60.71	64.37	77.04	77.65	68.68	66.58	67.60	61.89
Woods (W)	5.98	9.00	4.82	4.34	9.04	2.79	3.46	2.57
Grassland (G)	2.79	1.44	5.44	2.37	0.63	0.71	0.96	0.80
S Edge	2.93	5.08	8.60	7.72	3.27	5.53	9.93	6.07
N Edge	1.45	2.12	7.01	3.19	2.12	2.46	3.21	2.09
Y Edge	56.34	57.17	61.43	66.74	63.28	58.59	54.46	53.74
S Woods	0.96	1.59	0.87	1.3	0.81	0.78	0.78	0.73
N Woods	3.55	6.14	2.40	1.15	6.76	0.69	0.64	0.41
Y Woods	1.47	1.27	1.55	1.89	1.46	1.32	2.03	1.44
S Grassland	1.00	0.87	5.02	2.11	0.29	0.52	0.85	0.57
N Grassland	0.39	0.13	0.31	0.19	0.11	0.03	0.08	0.01
Y Grassland	1.40	0.44	0.11	0.07	0.23	0.16	0.03	0.21

Table 6. The Average Densities (#pph) of Ninety-five Selected Bird Species in the Geographic and Habitat Categories.

The table shows the average densities (#pph) of species in the various categories of habitat and winter range preference categories for each of the eight CBC circles considered.

The greatest overall abundance of birds is found in Eco-region 2 (NO & SP).

Eco-region 2 also has the highest densities of southern birds together with the Concord circle (CO), of Eco-region 3.

The edge habitat is favored predominantly in all circles.

Woodland species are found in greater numbers in Eco-regions 1 (NB & CB) and 3 (WE) that are located in the higher elevation and wooded regions of the Northeast Highland region.

Although uncommon in most areas, grassland birds are recorded most frequently in the NO and SP circles of Eco-region 2 in the Connecticut River Valley.

American Tree Sparrow	*Spizella arborea*	Common Redpoll	*Carduelis flammea*
Common Raven	*Corvus corax*	Evening Grosbeak	*Coccothraustes vespertinus*
Fox Sparrow	*Passerella iliaca*	Pine Grosbeak	*Pinicola enucleator*
Northern Shrike	*Lanius excubitor*	Pine Siskin	*Carduelis pinus*
Lapland Longspur	*Calcarius lapponicus*	Red Crossbill	*Loxia curvirostra*
Rough-legged Hawk	*Buteo lagopus*	White-winged Crossbill	*Loxia leucoptera*
Snow Bunting	*Plectrophenax nivalis*		

a. Thirteen bird species with a northern (N) winter range preference.

American Goldfinch	*Carduelis tristis*	Northern Goshawk	*Accipiter gentilis*
American Kestrel	*Falco sparverius*	Northern Harrier	*Circus cyaneus*
American Pipit	*Anthus rubescens*	Northern Oriole	*Icterus galbula*
American Robin	*Turdus migratorius*	Northern Shrike	*Lanius excubitor*
American Woodcock	*Scolopax minor*	Orange-crowned Warbler	*Vermivora celata*
Black Vulture	*Coragyps atratus*	Ovenbird	*Seiurus aurocapillus*
Brown Creeper	*Certhia americana*	Peregrine Falcon	*Falco peregrinus*
Brown Thrasher	*Toxostoma rufum*	Pine Warbler	*Dendroica pinus*
Brown-headed Cowbird	*Molothrus ater*	Purple Finch	*Carpodacus purpureus*
Chipping Sparrow	*Spizella passerina*	Red-breasted Nuthatch	*Sitta canadensis*
Common Snipe	*Gallinago gallinago*	Red-shouldered Hawk	*Buteo lineatus*
Common Yellowthroat	*Geothlypis trichas*	Red-tailed Hawk	*Buteo jamaicensis*
Cooper's Hawk	*Accipiter cooperii*	Red-winged Blackbird	*Agelaius phoeniceus*
Dark-eyed (Oregon) Junco	*Junco hymenalis*	Rose-breasted Grosbeak	*Pheucticus ludovicianus*
Eastern Bluebird	*Sialia sialis*	Ruby-crowned Kinglet	*Regulus calendula*
Eastern Meadowlark	*Sturnella magna*	Rusty Blackbird	*Euphagus carolinus*
Eastern Phoebe	*Sayornis phoebe*	Savannah Sparrow	*Passerculus sandwichensis*
Eastern Rufous-sided Towhee	*Pipilo erythrophthalmus*	Sharp-shinned Hawk	*Accipiter striatus*
Field Sparrow	*Spizella pusilla*	Song Sparrow	*Melospiza melodia*
Golden-crowned Kinglet	*Regulus satrapa*	Swainson's Thrush	*Catharus ustulatus*
Gray Catbird	*Dumetella carolinensis*	Swamp Sparrow	*Melospiza georgiana*
Hermit Thrush	*Ctharus guttatus*	Turkey Vulture	*Cathartes aura*
Horned Lark	*Eremophila alpestris*	Vesper Sparrow	*Pooecetes gramineus*
House Wren	*Troglodytes aedon*	White-crowned Sparrow	*Zonotrichia leucophrys*
Killdeer	*Charadrius vociferus*	White-eyed Vireo	*Vireo griseus*
Lincoln's Sparrow	*Melospiza lincolnii*	White-throated Sparrow	*Zonotrichia albicollis*
Marsh Wren	*Coistothorus palustris*	Winter Wren	*Troglodytes troglodytes*
Merlin	*Falco columbarius*	Yellow-bellied Sapsucker	*Sphyrapicus varius*
Northern Bobwhite	*Colinus virginianus*	Yellow-rumped Warbler	*Dendroica coronata*

b. Fifty-eight bird species with a southern (S) winter range preference.

American Crow	*Corvus brachyrhyncus*	Northern Mockingbird	*Mimus polyglottos*
Black-capped Chickadee	*Poecile atricapilla*	Northern (Yellow-shafted) Flick	*Colaptes auratus*
Blue Jay	*Cyanocitta cristata*	Ring-necked Pheasant	*Phasianus colchicus*
Carolina Wren	*Thryothorus ludovicianus*	Rock Dove/Rock Pigeon	*Columba livia*
Cedar Waxwing	*Bombycilla cedrorum*	Tufted Titmouse	*Baeolophus bicolor*
Common Grackle	*Quiscalus quiscula*	White-breasted Nuthatch	*Sitta carolinensis*
Dark-eyed (Slate-colored) Junco	*Junco hymenalis*	Wild Turkey	*Meleagris gallopavo*
European Starling	*Sturnus vulgaris*	Downy Woodpecker	*Picoides pubescens*
House Finch	*Carpodacus mexicanus*	Hairy Woodpecker	*Picoides villosus*
House Sparrow	*Passer domesticus*	Pileated Woodpecker	*Dryocopus pileatus*
Mourning Dove	*Zenaida macroura*	Red-bellied Woodpecker	*Melanerpes carolinus*

c. Twenty-four bird species with a year round (Y) winter range preference

Table 7. Geographic Winter Range Preferences of the Ninety-five Selected Bird Species.

American Crow	*Corvus brachyrhyncus*	House Finch	*Carpodacus mexicanus*
American Goldfinch	*Carduelis tristis*	House Sparrow	*Passer domesticus*
American Kestrel	*Falco sparverius*	House Wren	*Troglodytes aedon*
American Robin	*Turdus migratorius*	Merlin	*Falco columbarius*
American Tree Sparrow	*Spizella arborea*	Mourning Dove	*Zenaida macroura*
American Woodcock	*Scolopax minor*	Northern (Yellow-shafted) Flicker	*Colaptes auratus*
Black Vulture	*Coragyps atratus*	Northern Bobwhite	*Colinus virginianus*
Black-capped Chickadee	*Poecile atricapilla*	Northern Cardinal	*Cardinalis cardinalis*
Blue Jay	*Cyanocitta cristata*	Northern Harrier	*Circus cyaneus*
Brown Creeper	*Certhia americana*	Northern Mockingbird	*Mimus polyglottos*
Brown Thrasher	*Toxostoma rufum*	Northern Oriole	*Icterus galbula*
Carolina Wren	*Thryothorus ludovicianus*	Northern Shrike	*Lanius excubitor*
Cedar Waxwing	*Bombycilla cedrorum*	Purple Finch	*Carpodacus purpureus*
Chipping Sparrow	*Spizella passerina*	Red-shouldered Hawk	*Buteo lineatus*
Common Grackle	*Quiscalus quiscula*	Red-tailed Hawk	*Buteo jamaicensis*
Common Raven	*Corvus corax*	Rock Dove/Rock Pigeon	*Columba livia*
Cooper's Hawk	*Accipiter cooperii*	Rusty Blackbird	*Euphagus carolinus*
Dark-eyed (Oregon) Junco	*Junco hymenalis*	Sharp-shinned Hawk	*Accipiter striatus*
Dark-eyed (Slate-colored) Junco	*Junco hymenalis*	Song Sparrow	*Melospiza melodia*
Eastern Bluebird	*Sialia sialis*	Swainson's Thrush	*Catharus ustulatus*
Eastern Phoebe	*Sayornis phoebe*	Tufted Titmouse	*Baeolophus bicolor*
Eastern Rufous-sided Towhee	*Pipilo erythrophthalmus*	Turkey Vulture	*Cathartes aura*
European Starling	*Sturnus vulgaris*	White-crowned Sparrow	*Zonotrichia leucophrys*
Fox Sparrow	*Passerella iliaca*	White-throated Sparrow	*Zonotrichia albicollis*
Gray Catbird	*Dumetella carolinensis*	Yellow-rumped Warbler	*Dendroica coronata*

a. Fifty bird species with an edge habitat preference.

Brown Creeper	*Certhia americana*	Pine Warbler	*Dendroica pinus*
Common Redpoll	*Carduelis flammea*	Red Crossbill	*Loxia curvirostra*
Cooper's Hawk	*Accipiter cooperii*	Red-bellied Woodpecker	*Melanerpes carolinus*
Downy Woodpecker	*Picoides pubescens*	Red-breasted Nuthatch	*Sitta canadensis*
Evening Grosbeak	*Coccothraustes vespertinus*	Red-shouldered Hawk	*Buteo lineatus*
Golden-crowned Kinglet	*Regulus satrapa*	Rose-breasted Grosbeak	*Pheucticus ludovicianus*
Hairy Woodpecker	*Picoides villosus*	Ruby-crowned Kinglet	*Regulus calendula*
Hermit Thrush	*Catharus guttatus*	Ruffed Grouse	*Bonasa umbelus*
Northern Goshawk	*Accipiter gentilis*	Swainson's Thrush	*Catharus ustulatus*
Northern Harrier	*Circus cyaneus*	White-eyed Vireo	*Vireo griseus*
Ovenbird	*Seiurus aurocapillus*	White-winged Crossbill	*Loxia leucoptera*
Pileated Woodpecker	*Dryocopus pileatus*	Winter Wren	*Troglodytes troglodytes*
Pine Grosbeak	*Pinicola enucleator*	Yellow-bellied Sapsucker	*Sphyrapicus varius*
Pine Siskin	*Carduelis pinus*		

b. Twenty-seven bird species with a forest (woodland) habitat preference.

American Pipit	*Anthus rubescens*	Marsh Wren	*Coistothorus palustris*
Brown-headed Cowbird	*Molothrus ater*	Peregrine Falcon	*Falco peregrinus*
Common Snipe	*Gallinago gallinago*	Red-winged Blackbird	*Agelaius phoeniceus*
Eastern Meadowlark	*Sturnella magna*	Rough-legged Hawk	*Buteo lagopus*
Field Sparrow	*Spizella pusilla*	Savannah Sparrow	*Passerculus sandwichensis*
Horned Lark	*Eremophila alpestris*	Snow Bunting	*Plectrophenax nivalis*
Killdeer	*Charadrius vociferus*	Swamp Sparrow	*Melospiza georgiana*
Lapland Longspur	*Calcarius lapponicus*	Vesper Sparrow	*Pooecetes gramineus*
Lincoln's Sparrow	*Melospiza lincolnii*	Wild Turkey	*Meleagris gallopavo*

c. Eighteen bird species with a grassland habitat preference.

Table 8. Habitat Preference of the Ninety-five Selected Bird Species.

Changes in Major Categories of Land Use						
	Open Areas		Residential/ Recreational		Industrial/ Commercial	
	1971-1985	1985-1999	1971-1985	1985-1999	1971-1985	1985-1999
NB	-1.47%	-7.20%	8.17%	10.79%	6.60%	-4.23%
CB	-2.80%	-7.65%	11.09%	10.27%	16.89%	5.71%
Eco-1 change	-4.27%	-14.85%	19.25%	21.06%	23.49%	1.48%
NO	-3.94%	-6.54%	16.79%	18.57%	28.11%	12.75%
SP	-5.18%	-10.02%	10.27%	8.88%	13.96%	7.73%
Eco-2 change	-9.12%	-16.56%	27.07%	27.45%	42.07%	20.48%
WE	0.51%	-0.79%	32.14%	28.05%	31.73%	27.54%
Eco-3 change	0.51%	-0.79%	32.14%	28.05%	31.73%	27.54%
WO	-4.10%	-7.42%	15.53%	15.21%	18.35%	4.95%
CO	-7.15%	-9.87%	15.20%	20.29%	21.14%	-0.38%
MI	-6.51%	-10.33%	25.31%	27.00%	18.03%	9.83%
Eco-4 change	-17.76%	-27.62%	56.04%	62.50%	57.52%	14.41%

Table 9. Changes in Major Categories of Land Use (Figure 8).

The table shows the percentage changes in the area of the three major categories of land use (open land, residential and recreational land, & industrial and commercial land) within the each of the CBC circles analyzed for the years 1971, 1985, & 1999. Changes for the four eco-regions are also shown in the highlighted areas. Maximum change in open land is shown in green, in res/rec. land in red, in ind /comm land in blue.

Changes in Forest Area (Square meters)				
	1971-1985		1985-1999	
	% change	Acreage (Sq. m)	% change	Acreage (Sq. m)
NB	-0.60%	-1,805,400	0.61%	1,809,000
CB	-1.97%	-5,799,600	-0.51%	-1,474,200
Eco-1 change	-2.57%	-7,605,000	0.10%	334,800
NO	-2.77%	-6,517,800	-2.24%	-5,126,400
SP	-8.05%	-15,056,100	-5.88%	-10,116,900
Eco-2 change	-10.82%	-21,573,900	-8.13%	-15,243,300
WE	-3.28%	-11,961,000	-3.81%	-13,440,600
Eco-3 change	-3.28%	-11,961,000	-3.81%	-13,440,600
WO	-6.49%	-16,512,300	-6.07%	-14,436,000
CO	-5.58%	-13,218,300	-8.01%	-17,915,400
MI	-8.20%	-21,057,300	-10.90%	-25,692,300
Eco-4 change	-20.27%	-50,787,900	-24.98%	-58,043,700

Table 10. Changes in the Area of Forest (Figure 9).

Percentage changes in the area of forest within the each of the CBC circles analyzed, for the years 1971, 1985, & 1999. Changes for the four eco-regions are also shown in the highlighted areas. Minimum change in forest is shown in green, maximum total for an eco-region is shown in red, and the three maximum changes for individual circle area is shown in blue.

Changes in length of Forest to Development Edge (km)				
	1971 – 1985		1985-1999	
MANB	12.59%	48,330	19.80%	85,560
MACB	14.72%	85,080	20.39%	135,180
Eco-1 change	27.32%	133,410	40.19%	220,740
MANO	22.73%	866,130	18.41%	159,480
MASP	3.35%	50,100	9.45%	146,190
Eco-2 change	26.08%	916,230	27.86%	305,670
MAWE	37.12%	266,970	30.05%	296,370
Eco-3 change	37.12%	266,970	30.05%	296,370
MAWO	19.11%	230,550	17.44%	250,590
MACO	16.49%	250,221	17.16%	303,249
MAMI	23.89%	334,263	23.96%	415,347
Eco-4 change	59.49%	815,034	58.56%	969,186

Table 11. Changes in the Length of the Edge between Forest and Developed Areas (Figure 10).

Changes in the length of edge between forest and developed area within each of the CBC count circles from 1971-1999. Total changes for the four eco-regions are also shown in the highlighted areas. The largest increase in edge for an eco-region is shown in red, the largest CBC circle increase is shown in blue.

American Crow	*Corvus brachyrhyncus*	House Finch	*Carpodacus mexicanus*
American Goldfinch	*Carduelis tristis*	House Sparrow	*Passer domesticus*
American Kestrel	*Falco sparverius*	House Wren	*Troglodytes aedon*
American Robin	*Turdus migratorius*	Merlin	*Falco columbarius*
American Tree Sparrow	*Spizella arborea*	Mourning Dove	*Zenaida macroura*
American Woodcock	*Scolopax minor*	Northern (Yellow-shafted) Flicker	*Colaptes auratus*
Black Vulture	*Coragyps atratus*	Northern Bobwhite	*Colinus virginianus*
Black-capped Chickadee	*Poecile atricapilla*	Northern Cardinal	*Cardinalis cardinalis*
Blue Jay	*Cyanocitta cristata*	Northern Harrier	*Circus cyaneus*
Brown Creeper	*Certhia americana*	Northern Mockingbird	*Mimus polyglottos*
Brown Thrasher	*Toxostoma rufum*	Northern Oriole	*Icterus galbula*
Carolina Wren	*Thryothorus ludovicianus*	Northern Shrike	*Lanius excubitor*
Cedar Waxwing	*Bombycilla cedrorum*	Purple Finch	*Carpodacus purpureus*
Chipping Sparrow	*Spizella passerina*	Red-shouldered Hawk	*Buteo lineatus*
Common Grackle	*Quiscalus quiscula*	Red-tailed Hawk	*Buteo jamaicensis*
Common Raven	*Corvus corax*	Rock Dove/Rock Pigeon	*Columba livia*
Cooper's Hawk	*Accipiter cooperii*	Rusty Blackbird	*Euphagus carolinus*
Dark-eyed (Oregon) Junco	*Junco hymenalis*	Sharp-shinned Hawk	*Accipiter striatus*
Dark-eyed (Slate-colored) Junco	*Junco hymenalis*	Song Sparrow	*Melospiza melodia*
Eastern Bluebird	*Sialia sialis*	Swainson's Thrush	*Catharus ustulatus*
Eastern Phoebe	*Sayornis phoebe*	Tufted Titmouse	*Baeolophus bicolor*
Eastern Rufous-sided Towhee	*Pipilo erythrophthalmus*	Turkey Vulture	*Cathartes aura*
European Starling	*Sturnus vulgaris*	White-crowned Sparrow	*Zonotrichia leucophrys*
Fox Sparrow	*Passerella iliaca*	White-throated Sparrow	*Zonotrichia albicollis*
Gray Catbird	*Dumetella carolinensis*	Yellow-rumped Warbler	*Dendroica coronata*

a. Fifty bird species with an edge habitat preference.

Brown Creeper	*Certhia americana*	Pine Warbler	*Dendroica pinus*
Common Redpoll	*Carduelis flammea*	Red Crossbill	*Loxia curvirostra*
Cooper's Hawk	*Accipiter cooperii*	Red-bellied Woodpecker	*Melanerpes carolinus*
Downy Woodpecker	*Picoides pubescens*	Red-breasted Nuthatch	*Sitta canadensis*
Evening Grosbeak	*Coccothraustes vespertinus*	Red-shouldered Hawk	*Buteo lineatus*
Golden-crowned Kinglet	*Regulus satrapa*	Rose-breasted Grosbeak	*Pheucticus ludovicianus*
Hairy Woodpecker	*Picoides villosus*	Ruby-crowned Kinglet	*Regulus calendula*
Hermit Thrush	*Charus guttatus*	Ruffed Grouse	*Bonasa umbelus*
Northern Goshawk	*Accipiter gentilis*	Swainson's Thrush	*Catharus ustulatus*
Northern Harrier	*Circus cyaneus*	White-eyed Vireo	*Vireo griseus*
Ovenbird	*Seiurus aurocapillus*	White-winged Crossbill	*Loxia leucoptera*
Pileated Woodpecker	*Dryocopus pileatus*	Winter Wren	*Troglodytes troglodytes*
Pine Grosbeak	*Pinicola enucleator*	Yellow-bellied Sapsucker	*Sphyrapicus varius*
Pine Siskin	*Carduelis pinus*		

b. Twenty-seven bird species with a forest (woodland) habitat preference.

American Pipit	*Anthus rubescens*	Marsh Wren	*Coistothorus palustris*
Brown-headed Cowbird	*Molothrus ater*	Peregrine Falcon	*Falco peregrinus*
Common Snipe	*Gallinago gallinago*	Red-winged Blackbird	*Agelaius phoeniceus*
Eastern Meadowlark	*Sturnella magna*	Rough-legged Hawk	*Buteo lagopus*
Field Sparrow	*Spizella pusilla*	Savannah Sparrow	*Passerculus sandwichensis*
Horned Lark	*Eremophila alpestris*	Snow Bunting	*Plectrophenax nivalis*
Killdeer	*Charadrius vociferus*	Swamp Sparrow	*Melospiza georgiana*
Lapland Longspur	*Calcarius lapponicus*	Vesper Sparrow	*Pooecetes gramineus*
Lincoln's Sparrow	*Melospiza lincolnii*	Wild Turkey	*Meleagris gallopavo*

c. Eighteen bird species with a grassland habitat preference.

Table 12. Habitat Preference of the Ninety-five Selected Bird Species.

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