Assessment of the Rocky Mountain National Park Breeding Bird Monitoring Program

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Abstract

Rocky Mountain National Park implemented 13 years of a habitat-based monitoring program to track population trends of breeding birds. Data were collected using multiple point transects and from 2000 to 2006, incorporated distance sampling methodology. An important part of an effective monitoring program is continual evaluation of the effectiveness of survey methods and making appropriate changes based on that information. The methodology of the Park's breeding bird monitoring program was evaluated in 2000; however, this is the first time that the data were analyzed for annual trends in estimated densities. Unfortunately, due to inconsistencies in the data before and after 2000, only the most recent 7 years of data (2000 to 2006) were analyzed. The Rocky Mountain Bird Observatory collected 10 years of data throughout the state of Colorado using similar distance-sampling methods to those employed by the Park and will continue these monitoring efforts into the future. In order to assess if RMBO data could be used for management planning in the Park, annual densities were estimated for each year from 2000 to 2006 for the Park and compared to breeding bird data collected for the state of Colorado by the Rocky Mountain Bird Observatory. Trends in annual density estimates were not evident in the RMNP data for all of the species because the confidence intervals overlapped across many of the years. There were also no clear differences between the RMNP and RMBO data for most species in most habitat types due to overlapping confidence intervals between the two datasets. Four species in high-elevation riparian habitat showed different densities in the park data than the statewide data, while seven species in ponderosa pine habitat had larger densities in the RMNP data than the statewide data. Although a distinct comparison between the two datasets was inconclusive, the results of this study provided information to make future monitoring recommendations for optimum time intervals, targeting indicator species, increasing sample sizes, and improving data quality.

Introduction

This paper provides a review of the breeding bird monitoring program that Rocky Mountain National Park (RMNP) has used over the past several years and future recommendations that may make these monitoring efforts more useful and cost effective. A critical component of monitoring programs is periodic review by experts (Fancy and Sauer 2000). Reliable data is crucial for demonstrating that environmental changes are real and not artifacts of poor sampling design or to justify management actions (Noon 1999, Fancy 2000). Analysis and review of the RMNP and statewide RMBO datasets could help to identify if the statewide RMBO data is adequate for management decisions within the Park. This analysis and review of both datasets will assist in providing recommendations on monitoring methods and to help prioritize monitoring efforts.

This study included an analysis of RMNP's monitoring program data and a comparison of RMNP data to RMBO's statewide data. It also provided the opportunity for making recommendations for adapting the RMNP program for the future, in light of expected budget constraints and the need for more effective/efficient approaches.

Background

Biological monitoring is the process of measuring environmental characteristics over an extended period of time. Monitoring is used in an attempt to detect long-term environmental change early, provide insights to the ecological consequences of these changes and to help land managers make better informed management decisions (Noon et al. 1999). The National Park Service (NPS) uses a variety of different monitoring techniques to track a vast array of resources that are managed under its stewardship. These monitoring efforts have more recently fallen under the guidance of the Inventory and Monitoring Program (IMP). The ambitious nature of NPS monitoring and its relatively limited budget make careful design of monitoring programs critical. Effort must be strategically directed toward areas that give the most return of useful information for time and money invested (Silsbee and Peterson 1991).

Censusing breeding bird populations is a common practice among land management agencies and is conducted at multiple spatial and temporal scales. Birds are easy to sample with many species being relatively conspicuous and/or highly vocal (Pereira and Cooper 2006). Population monitoring plays a very important role in avian conservation and the assessment of environmental impacts on biotic communities. It also allows for the capability of estimation and tracking of biodiversity and long term changes in population abundances and helps to identify and trigger research needs (McNally 1997). Monitoring of bird populations may also be required under legislative mandates for certain land management agencies and multiple agency-wide or interdisciplinary long-range management and monitoring plans (Manley 1993, Sauer 1993, Leukering et al. 2000).

Many monitoring programs focus on birds because they play critical roles in ecosystems as predators, prey, pollinators and seed dispersers and thus are key indicators of environmental change (Rich et al. 2004). There has been a growing concern over population declines and reductions in species ranges in recent decades. Colorado Partners in Flight (PIF) have identified several species that are of special management concern (CPIF 2000). Anthropogenic habitat loss, habitat fragmentation, habitat degradation, and climate change all play a significant role in threats to avian populations (Rich et al. 2004).

Breeding Bird Survey and RMBO Monitoring Program

To address the lack of quantitative data on the status of bird populations in North America, the Breeding Bird Survey (BBS) was brought about in 1966 and has typically been the primary source for population information on migratory bird species on a nationwide scale (Robbins et al. 1986, Sauer 1993). Although the BBS has been useful in tracking general population trends in many species, it is likely to be less appropriate for basing management decisions; in part because it is a large-scale monitoring effort and does not take into account habitat characteristics making it difficult to pinpoint the cause of the decline of a species (Leukering et al. 2000, Sauer and Cooper 2000).

The growing concern over the status of migratory bird populations and other landbirds over the last several years has initiated the development and improvement of programs for monitoring bird populations (Rosenstock et al. 2002). One example involves a

Colorado statewide program developed by the Rocky Mountain Bird Observatory (RMBO) titled Monitoring Colorado Birds (MCB) which was initiated in 1995 in conjunction with state and federal agencies. Monitoring Colorado's Birds includes a system of permanent transects throughout the state within various habitat types, using 30 point transects randomly located in each habitat classification based on the Colorado Gap Analysis Program [CO-GAP] vegetation data (Leukering et al. 2000, Schrupp et al. 2000). The specific goal of the MCB program is to detect population declines at an early stage for all species monitored under the program and to develop and test hypotheses regarding the reasons for population changes in the future (Leukering et al. 2000).

Colorado statewide monitoring managed and implemented by RMBO has taken place for ten years since the time the program was first implemented in 1997. By 1999, following a successful first year of data collection, MCB protocol had been developed and tested for the habitat-based breeding bird monitoring program throughout the state of Colorado (Beason et al. 2007). The MCB monitoring program utilizes point transects and distance sampling techniques which allows RMBO researchers to estimate densities or abundance of each species while accounting for differences and biases in detectability (Norvell et al. 2003, Somershoe et al. 2006). This makes it possible to provide statistically rigorous trend data and to compare species which tend to differ in their detectabilities. Habitat characteristics can also influence detectability, thus each species is monitored within each habitat type separately (Rosenstock et al. 2002).

Specific objectives have been identified to help the MCB reach its goals effectively. "The objectives are to integrate existing bird monitoring efforts in the region to make available better information on distribution and abundance of all breeding birds; to supply basic habitat association data for most bird species to help address habitat management issues; to provide long-term status and trend data for all regularly occurring breeding species in Colorado with a target of detecting a 3.0% population decline per year over a maximum time period of 30 years; to maintain a high quality database that is accessible to all of our collaborators as well as the public; and to generate decision support tools such as population estimate models that help guide conservation efforts and provide a better measures of our conservation success" (Beason et al. 2007;2).

The coefficient of variation (CV) is defined as the standard deviation (σ) divided by the estimator (μ) (Buckland et al. 2001):

$$CV = \frac{\sigma}{\mu}$$

A coefficient of variation (CV) less than 0.50 is required for each species by the MCB program to meet the desired statistical rigor. Trends in population sizes can be difficult to determine with certainty and population declines are harder to detect than population increases because variation increases with smaller sample sizes (Leukering et al. 2000).

Recently RMBO has changed from using point transects with points laid out in a line to point transects laid within a 4 point by 4 point systematic grid. This design will no longer be based on habitat stratification and the transect will be placed on the landscape without respect to habitat type. The data can then be post-stratified based on the habitat of interest (Jennifer Blakesley pers. comm., October 28, 2008)

RMNP Monitoring Program

The goal of the National Park Service (NPS) monitoring initiative is to improve inventory and monitoring activities and to provide scientifically credible information on the status and trends of NPS resources and ecological "vital signs." National Parks are directed by legislation to conduct long-term ecosystem monitoring and research to establish baseline information and detect trends in the condition of park resources and to provide informed decision-making when it comes to planning management actions. The NPS monitoring program is required to be developed in cooperation with interagency monitoring programs to ensure a cost effective approach (National Parks Omnibus Management Act of 1998). Unfortunately, future annual budgets for RMNP are uncertain and there is a concern that they will not be able to cover continued monitoring of the full number of breeding bird plots every year.

The Park initiated a general avian monitoring program in 1993 by randomly establishing point count transects within major cover types in RMNP (Kotliar 2000, Ellis and Connor 2005). As developed by Partners in Flight, area importance (AI), attempts to identify regions of high importance to a species, and is used to reflect the significance of those areas to a species' conservation by evaluating its abundance within a given region relative to its abundance elsewhere. AI has been scored for each species by Colorado Partners in Flight and is used by RMNP as an indicator of the level of monitoring that would take place for each species. AI scores greater than two indicate species which exist in high abundances compared to other states (CPIF 2000).

The goals and objectives for the general avian monitoring program for the Park were adopted from the Partners in Flight Colorado Landbird Monitoring Program (CPIF 2000, Ellis and Connor 2005):

> *Goal*: All breeding birds in Rocky Mountain National Park (RMNP) will be monitored or tracked to document distribution, population trends, and abundance in a statistically acceptable manner.
>
> *Objective*: All species with an area importance (AI) score greater than two will be monitored with count-based methods.
>
> *Objective*: Species with AI scores of two will be tracked through count-based methods or their presence or absence noted.
>
> *Objective*: Some species such as colonial nesters and nocturnally-active species will be monitored or tracked using special techniques such as colony counts and nocturnal transects.

In 1994, the Park initiated their breeding bird monitoring program. At that time, 41 habitat-based point transect monitoring plots were established throughout the Park. In 1997, RMNP provided funds to RMBO to include four of the existing point transects within the MCB monitoring network (Ellis and Connor 2005). The RMNP point transect monitoring plots established by the Park follow methods similar to those used by RMBO.

Each point transect began from a randomly located starting point which was located within one mile of a road or trailhead and has a series of points (count stations) leading in one direction from the starting point. The Park's point transects are typically 3,500 meters in length with each count station spaced a distance of 250 meters apart. Most of the point transect plots contain 15 count stations as defined by the MCB protocols (Leukering et al. 1998, Ellis and Connor 2005). Park staff monitored the point transects using distance sampling methods in a similar manner to the methods used by RMBO. One notable difference in sampling between the two organizations is that the RMNP grouped distances into fixed categories (e.g., 0-10 meters, 11-25 meters, etc.) and RMBO recorded the estimated distance as an exact value for each observation.

In 2000, recommendations for modifications to the sampling design were provided following a review of the monitoring program by Kotliar (2000). The report provided a general evaluation of the existing methods and protocols and summarized past survey efforts and the data collected. Although the data collected from 1994 through 1999 were summarized to determine the numbers of points and transects sampled and bird species observed, annual densities for each species in each habitat type were not estimated nor were trends compared with other datasets.

Data from 1994 through 1999 were collected using only two distance categories of less than 50 meters and greater than 50 meters. Although an index of bird abundance could be estimated using the data collected within the "less than 50 meters" category by using a fixed-radius point count method, there are relatively significant density related biases associated with this method which is still not adjusted for detection probability (Howell et al. 2004). As a result, trends could only be detected if they were drastically large making the management response reactive versus proactive which will not suffice when managing for species of special management concern (Thompson 2002). Due to the short duration of monitoring under this method, valid density estimates and trends are not feasible based on the data collected over the course of those years.

The findings from the Kotliar report in 2000 helped to develop recommendations on methods that the Park should employ to best continue monitoring breeding birds. Kotliar (2000) also recommended in this report that the data should be summarized on a regular basis and more involved trend analyses should be conducted every five years. As a result, the Park incorporated the recommended changes into the avian monitoring program. Changes in time spent at each point (from 5 minutes to 7.5 minutes) and how distances were recorded (from two to six distance categories) took place in 2000 along with some changes to the database structure (Ellis and Connor 2005).

The RMNP bird transect data are stored in a Microsoft Access database containing point transect data from 1994 to 2006. In 2000, the database was reformatted and standardized to facilitate data analysis following recommendations by Kotliar (2000). Kotliar also made recommendations to survey all of the count stations the same number of times every year and at the same time of the season and that trend analyses should take place every five years to allow for the monitoring program to continually be re-evaluated and adjusted when necessary.

General Distance Sampling Methods and Assumptions

Standard distance sampling protocols have been described by Buckland et al. (2001). Distance sampling allows the researcher to account for differences in detectability at variable distances, among different species, and in different habitat types. This is accomplished by estimating distances from the point or line to the object. Detection probabilities are estimated based on the data and the fact that objects further away are more difficult to detect. Point counts alone, such as those used in the BBS with no distances recorded, provide only distributional information or a relative abundance index and do not allow for estimation of density or abundance (Buckland et al. 2001).

Common methods used for breeding bird monitoring include both line and point transects. Point transects are often referred to as variable circular plots (VCP) which involves multiple points placed along a line or transect at a given interval (Fancy 1997, Buckland et al. 2001). Line transects are also commonly used to monitor breeding bird populations, where the observer travels along a line, recording the perpendicular distance of each detected object (Buckland et al. 2001). Line transects are usually more time efficient and typically detect more species and individuals than point transects (Wilson et al. 2000). This is because the observer collects data continuously while walking along the transect, whereas during point transects the observer only records birds detected at each point along the transect. However, point transects are typically the preferred approach in areas of dense vegetation and rugged or hazardous terrain.

Distances can be difficult to estimate in the field, especially when a bird is only heard vocalizing which is most commonly the case (Rosenstock et al. 2002). As a result, observers collecting the data often have the tendency to round their recorded distances up or down as opposed to recording the correct distance which results in the data being heaped at certain distances. In order to avoid rounding or heaping of the data that is often a result of human sampling error and uncertainty, distances are frequently recorded into discrete distance intervals (Royle et al. 2004). Distances collected in the field can also be grouped during the data analysis stage which may allow for more flexibility in working with the data than grouping distances in the field. These distances or distance intervals are modeled using various different detection functions. The best fitting model is used to generate density estimates.

Density is estimated in program DISTANCE (Thomas et al. 2006) by fitting a detection function to the detection probability histogram for the species being modeled (Buckland et al. 2001, Thomas et al. 2006). There are three basic functions that are used in modeling distance data: The uniform model which has no parameters; the half normal model which has one parameter to be estimated from the data; and the hazard-rate function that requires two key parameters to be estimated. To improve the fit of the model to the data, adjustment parameters may be added as one of three different series expansions; cosine, simple polynomial and hermite polynomial (Buckland et al. 2001). In general, as the number of parameters in a model increases, the bias decreases and the sampling variance increases (Buckland et al. 2001).

There are three assumptions that are critical to producing reliable abundance estimates from the data in distance sampling. All three assumptions can be relaxed under certain circumstances; however, they are important in reducing biases related to detection probability (Buckland et al. 2001).

1) All objects on the line or point are detected with certainty (probability of detection at zero distance equals 1).
2) Objects are detected at their initial location.
3) Measurements are exact

Stratification will improve precision and reduce bias of estimates when detection patterns vary substantially among subunits of the data (Pendleton 1995, Buckland et al. 2001, Rosenstock et al. 2002). Stratifying the data by habitat type and by species or other variables that may play a role in detectability will help reduce variability in detection probabilities and can help address the reason behind population declines. Covariates, such as vegetation, observer differences and weather can also be incorporated into estimating detection functions (Buckland et al. 2001). Other factors, such as weather, topography, background noise, observer experience, and observer age may also impact the detection probability of species, especially for auditory detections (Simons et al. 2007). These elements can be problematic and may require some additional sampling to determine how they influence detection probability; however, distance sampling methods provide empirical estimates of detection probability, which helps to account for these potentially confounding effects (Kissling et al. 2007).

In this paper, I analyzed and evaluated 7 of the 13 years of breeding bird data collected at Rocky Mountain National Park (RMNP) using point transect sampling techniques. This is the first time the data were analyzed to evaluate whether or not precise density estimates and trends could be produced and compared with another dataset. With this analysis, recommendations for future monitoring efforts have been provided and the ability to use data collected from outside sources to base management decisions was evaluated. The Rocky Mountain Bird Observatory (RMBO) collected 10 years of statewide data using similar methods to those employed by the Park and have produced density estimates on an annual basis using program DISTANCE. The analysis and comparison of both the RMNP data and local statewide data collected by RMBO will help to identify the level of Park monitoring that is necessary to successfully achieve the Park's inventory and monitoring objectives.

Objectives

RMNP staff collected 13 years of data which have never been analyzed to determine estimates of density and abundance of breeding bird species in the Park and the ability to detect significant trends in species populations early. With the potential inability to continue the current monitoring program at its current level and the need for monitoring programs to continually be reassessed, this project provided an opportunity to look at the data with a new level of detail to help identify changes that needed to be made. My primary objective of this study was to develop recommendations for the Park's avian monitoring program that will improve upon the existing monitoring program by making it more statistically sound and cost effective. A reliable monitoring program is crucial to the Park to make well-informed management decisions (Thompson 2002). I also carried this project out to explore the potential for the Park to use RMBO data as guidance in making management decisions.

In this study, I reviewed the history of RMNP's monitoring program and compared it to RMBO MCB monitoring program. I analyzed the data to provide annual density estimates for each species and to determine the significance of any potential trends. I then compared the data to RMBO data. Using information gathered from comparison of the two monitoring programs and their datasets and a review of the literature provided me with useful information concluding that the data for RMNP were deficient. This information helped guide my recommendations for improving the existing monitoring program.

Study Area

The study area was located within Rocky Mountain National Park (RMNP), which is situated in north central Colorado. The Park covers an area of approximately 107,500 hectares and is recognized as an Important Bird Area by the National Audubon Society.

The Continental Divide roughly bisects the Park, dividing it into two distinct watersheds, where the headwaters of several river basins (Big Thompson, North Fork of the Colorado, North Fork of the Saint Vrain, and Cache la Poudre) begin and form multiple alpine lakes and wetlands. Almost half the area in RMNP is above treeline. Elevation ranges from approximately 2,400 meters to 4,346 meters at the highest mountain peak (Long's Peak).

Habitat types in RMNP vary along an elevational gradient and generally include ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), lodgepole pine (*P. contorta*), Engelmann spruce/subalpine fir (*Picea engelmannii/Abies lasiocarpa*), and alpine tundra (Peet 1981). Aspen (*Populus tremuloides*) occurs throughout this elevation range, its densities are highest from approximately 2,800 meters to 3,000 meters (Kaye et al. 2003). High-elevation riparian corridors also exist throughout the Park, and are often dominated by willow species (*Salix* spp.).

Climate is variable throughout RMNP depending on elevation and topography, but is divided into two distinct climatic patterns by the Continental Divide. The eastern side of the Divide is drier, with annual precipitation averaging around 40.03 centimeters in Estes Park, while Grand Lake on the west side of the Divide receives an average of 48.8 cm annually. This precipitation comes in the form of rain or snowfall throughout the year. Average annual temperatures near Estes Park (105°30', 40°24'; at 2,360 meters elevation) range between a minimum of −5.9 and maximum of 13.6 degrees Celsius (°C). The west side of the Park is typically cooler, with the average minimum and maximum temperatures in the town of Grand Lake ranging from −6.7°C to 11.6 °C (Western Regional Climate Center 2008).

Methods

Methodological Assumptions

There are several assumptions that are common to most sampling methods. For this study the assumptions include: 1) the study is well-designed; 1) the methods are strictly adhered to; 3) birds are identified correctly; 4) points are randomly located with respect to bird distributions; and 5) detections are independent (Buckland 2001, Norvell et al. 2003). Additional assumptions were made based specifically on the RMNP monitoring data. Distance sampling relies on accounting for survey effort even when birds were not detected at a point. Some transects were missing one to two points in the middle of the transect. I verified if the points were sampled or not using the hardcopies of the datasheets for several transects; however, for the transects that did not have an explanation in the datasheet, I assumed that the point was monitored, but no birds were seen in order to account for survey effort. Where transects had ended, but were not completed, I assumed that the transect was not completed due to weather or time, so the remainder of the points were left out of the data analysis, not accounting for survey effort. Surveys of each point transect for the avian monitoring program were conducted by multiple observers each year which included resource managers, a variety of different field technicians, and volunteers. As a result, is I assumed that each observer was trained to use standardized procedures and that no significant observer bias was present.

Field Methods

RMBO Field Protocols

I compiled the field protocols and annual methods for this section using the annual MCB reports and the general RMBO point transect protocol (Leukering et al. 1998, 2001, 2002, 2004; Leukering and Levad 2000, 2003; Beason et al. 2005a, 2005b, 2007; Hutton et al. 2006). RMBO established point transects throughout the state of Colorado composed of 15 point counts in 30 randomly selected stands in each of 5 to14 habitats every year since the 1998 field season. "These point transects were based on distance sampling theory, which estimates detection probability as a function of the distances between the observer and the birds detected" (Buckland et al. 1993 in Hutton et al. 2006). Transects were surveyed using protocol described by Leukering (1998) and later modified by Panjabi (2006). Each transect was only surveyed by one observer.

Once the randomly selected stand was located by the observer, the transect was laid out using a randomly selected bearing. If the observer ran out of appropriate habitat, they turned a random direction running perpendicular to the transect. Each point count station was located 250 meters apart with a total of 15 five minute point counts. The points along transects in high-elevation riparian habitat were actually spaced 200 meters apart because large contiguous stands of this habitat type were frequently difficult to find.

The sections between each point were surveyed using line transect sampling. For each point, the radial distance from observer to bird was recorded for any species identified, while along each section of line, only a short list of selected birds were recorded and the perpendicular distance from observer to bird was recorded. The species chosen for line transect sampling were species that are not as easily or frequently detected using point counts, such as grouse, woodpeckers, raptors, and other uncommon species. For these species, even when they were recorded at point counts, the perpendicular distance was recorded in order to use the data from the points in the line transect analysis.

All transects were surveyed in the morning within a half hour before sunrise to 1100 hours typically from mid-May to mid- to late-July. Date and time the transect began and ended were recorded. Weather at the time of each transect was also recorded including temperature, cloud cover, precipitation and wind speed. Other information that was recorded on the datasheets included the Universal Transverse Mercator (UTM) coordinates for each point and other pertinent information that may affect the data, such as vegetation characteristics (composition and structure). Birds flying overhead at the time of the point counts (flyovers) were recorded separately. For each bird detected, observers recorded the species, sex, how it was detected, and distance from the observer. Birds of the same species that were observed in a group of two or more birds were recorded as one observation to meet the assumption of independence of each observation. Distances were measured using laser rangefinders. When the bird was heard and not seen, the distance was measured from the observer to the object that the bird was thought to be calling from. If no birds were detected at any given point, it was recorded as having "no birds" (NOBI).

From 1999 through 2007, RMBO staff surveyed an average of 280 transects with an average of 25 transects in each habitat type. Ponderosa pine and spruce-fir were surveyed from 1998 through 2007 with the exception of 2003 when an attempt to initiate biennial survey efforts versus annual took place (Leukering et al. 2004). High-elevation riparian was monitored from 1999 through 2007 with the exception of 2003 when only line transects were used to monitor that habitat type (Leukering et al. 2004). Aspen was monitored from 1998 through 2005, while alpine tundra was monitored from 1999 through 2005. Lodgepole pine was only surveyed once in 2000 and had a smaller than average sample size with only 17 transects having been completed (J. Blakesley, personal communication, July 2, 2008). In spruce-fir in 2007, RMBO experimented with using 8-minute point counts versus 5-minute point counts.

RMNP Field Protocols

The Park avian monitoring program was initiated using individual point count stations within major cover types. In 1994, the program was modified to include multiple, habitat-based point transects. Point count stations that made up a transect began from a randomly located starting point. Each transect made up a series of approximately 15 points spaced 250 meters apart. All of the point count stations were located within a single cover type and as a result, the transects varied in length. Many of the transects had fewer points (as few as 6 points) and some had more points (as many as 23 points).

Point counts usually began 30 minutes after sunrise and typically were completed between 0900 and 1100 hours. Low elevation transects were surveyed first beginning in early June and moving higher in elevation as the season progressed. Transects were typically completed by mid-July. From 1993 to 1999, point counts lasted five minutes and were recorded into intervals of 0 to 3 minutes and 3 to 5 minutes. During this time period, distances were also recorded into two categories of less than 50 meters and greater than 50 meters. As recommended by Kotliar (2000) the data collected by RMNP from 2000 through 2006 were recorded in three different time intervals; where observers noted the individual birds seen into three different categories of time: 0 to 3 minutes, 3 to 5 minutes, and 3 to 7.5 minutes.

In 2000, following the monitoring program's first review by Kotliar (2000), methods were changed and implemented to make the data compatible with distance sampling methodology. Distances from the observer to the bird were recorded into 6 categories; 0 to 10 meters, 10 to 25 meters, 25 to 50 meters, 50 to 75 meters, 75 to 100 meters, and greater than 100 meters. Distances were estimated using laser rangefinders. Similar to RMBO, date and time the transect began and ended were recorded as well as the time at each point count station. Weather at the time of each transect was also recorded including cloud cover, precipitation and wind speed. Birds flying overhead at the time of the point counts (flyovers) were recorded separately. For each bird detected, observers recorded the species, sex, how it was detected, and the distance category it was seen within from observation point. Birds of the same species that were observed in a group of two or more birds were recorded as one observation to meet the assumption of independence of each observation.

From 2000 through 2006, RMNP staff surveyed an average of 34 point transects with an average of 6 transects in each habitat type. High-elevation riparian, ponderosa pine, and lodgepole pine were surveyed every year from 2000 through 2006. Aspen was surveyed from 2000 through 2006 with the exception of 2001. Alpine tundra was surveyed from 2001 through 2006, while spruce-fir was surveyed from 2000 through 2005.

Surveys

For the 13-year duration of the avian monitoring project across all habitat types, the Park personnel surveyed an average of 31 transects and 364 points annually. I calculated the average annual numbers of point transects and points surveyed by habitat type to show the degree of effort that took place within each habitat each year. Average annual point transects and points surveyed by habitat are shown in Table 1. The most intensively monitored habitat types were high-elevation riparian and ponderosa pine. Aspen was monitored the least of the habitat types which is due to the small number of transects in that habitat type.

Table 1. Average Annual Point Transects and Points Surveyed by Habitat Type.

Habitat	Point Transects	Points
Alpine Tundra	5	62
Aspen	2	27
High-elevation Riparian	8	76
Lodgepole Pine	4	53
Ponderosa Pine	7	88
Spruce-fir	5	58

In 2006, the number of transects and points surveyed was significantly less than in previous years (8 transects and 93 points). The largest number of transects surveyed in one year was in 2003 with 41 transects and a total of 547 points. All transects analyzed in this study were surveyed during the breeding season. Ninety-six percent (96%) of the transects monitored throughout the duration of the 13-year period were completed in the month of June with the remaining 4% most typically taking place during the end of May and the beginning of July. Point transects that were monitored outside of the breeding season were not included in this analysis.

Analytical Methods

Data Preparation

Each observation in the dataset provides information on the transect and point sampled, species, number of individuals observed in the group or cluster, how the species was detected, if it was a flyover, and other pertinent biological information. Data must be imported into DISTANCE as a text file with the data fields in a specific order understood by the program. This required export of the data from the Access database that it is stored into an Excel workbook where the data fields could be manipulated to take on the desired organization for analysis in DISTANCE.

I obtained the database and hard copies of the datasheets containing twelve years of avian point transect monitoring data from the Park. I then reviewed the database for completeness and checked for recording errors. Where possible, I corrected errors in the database using information written in the datasheets. If critical information such as the recorded distance of the observation were missing, I did not include the observation in the data analysis. I also did not include birds detected as flyovers in the data analysis. I obtained density estimates through 2007 from RMBO for high-elevation riparian, ponderosa pine, and spruce-fir and through 2005 for alpine tundra, aspen, and wetlands for comparison with RMNP data. RMBO only surveyed Lodgepole pine in 2000 in only 17 transects and was not used for comparison purposes with the RMNP data.

Habitats

Habitat can influence detection probabilities depending on the vegetation composition and density represented at a site (Rosenstock et al. 2002). As a result, it is very useful to stratify sampling efforts by habitat type to avoid issues or biases related to differences in habitat.

Because the RMNP transects were not categorized into the same habitat classifications assigned by RMBO to the MCB transects, I obtained spatial data representing the point transect locations and vegetation map from the Park in order to standardize the habitat classifications between the two datasets. I joined the CO-GAP dataset (Schrupp et al. 2000) with the RMNP vegetation map using ArcGIS (Version 9.2) Geographic Information Systems (GIS) software to classify each transect into a standard habitat type used by RMBO (Table 2). I also used the original hard copy datasheets to determine the dominant cover for each transect, providing it was recorded.

Table 2. Point transect locations and habitat types in RMNP as defined by RMBO (Transects that are not named have been discontinued from further monitoring).

Transect	***Name***	***Habitat***
700	Ute Trail	Alpine Tundra
1500	Gore Range Overlook	Alpine Tundra
2300		Alpine Tundra
2600	Mount Ida	Alpine Tundra
4500		Alpine Tundra
5700	Crater	Alpine Tundra
5800	Fall River	Alpine Tundra
5900	Lava Cliffs	Alpine Tundra
6000 (MCB)	Sundance	Alpine Tundra
400	Mill Creek	Aspen
2200	Moraine Park Museum	Aspen
4400		Aspen
4900	Upper Beaver Meadows	Aspen
800 (MCB)	Bierstadt Moraine	Aspen
100	Moraine Park	High-elevation Riparian
600	Lower Horseshoe	High-elevation Riparian
900	Hallowell Park	High-elevation Riparian
1200		High-elevation Riparian
1300	Upper Horseshoe	High-elevation Riparian
1800	Poudre Willow	High-elevation Riparian
2000	Moraine Park North	High-elevation Riparian
2100	Moraine Park South	High-elevation Riparian
2800		High-elevation Riparian
3000		High-elevation Riparian
3200		High-elevation Riparian
4700		High-elevation Riparian
1100	Bear Lake to Bierstadt	Lodgepole Pine
1700	Lawn Lake	Lodgepole Pine
2400		Lodgepole Pine
2500	Timber Creek	Lodgepole Pine
5300	Long's Peak	Lodgepole Pine
5400	Sandbeach	Lodgepole Pine
5500	Onahu Lodgepole	Lodgepole Pine
200	North Lateral Moraine	Ponderosa Pine
300	Fall River Ponderosa	Ponderosa Pine
500	North Beaver Ponderosa	Ponderosa Pine
1000	Museum Trail/Boneyard	Ponderosa Pine
1900		Ponderosa Pine
2900		Ponderosa Pine
4200	Cow Creek North	Ponderosa Pine
4300	Cow Creek South	Ponderosa Pine
4800		Ponderosa Pine
5000	Macgregor	Ponderosa Pine
5100	Deer Mountain	Ponderosa Pine
5200	South Beaver Ponderosa	Ponderosa Pine

Transect	***Name***	***Habitat***
1600	Bear Lake to Odessa	Spruce-fir
3500		Spruce-fir
3800		Spruce-fir
4600		Spruce-fir
5600	Onahu Spruce	Spruce-fir
6300	Forest Canyon	Spruce-fir
6400	Ypsilon	Spruce-fir
6500		Spruce-fir
2700 (MCB)	Poudre Spruce	Spruce-fir
4000 (MCB)	Upper Hidden Valley	Spruce-fir
3400	Kawunechee	Wetland
6100	Big Meadows	Wetland
6200	Long Meadow	Wetland

RMBO used the CO-GAP dataset to randomly locate the MCB plots within specific habitat classifications. The habitat classifications RMBO identified that corresponded with RMNP point transects, included alpine tundra (AT), aspen (AS), high-elevation riparian (HR), mixed conifer (MC), ponderosa pine (PP), lodgepole pine (LP), spruce-fir (SF), and wetlands (WE). Each of these habitat types have been specifically described by RMBO and are summarized as follows (Beason et al. 2005a; 6-8):

Alpine Tundra

Alpine tundra encompasses high elevation areas above treeline that are dominated by high-elevation grass and shrub species. In RMNP the most common shrub species include willow, Engelmann spruce, and subalpine fir. Occasionally these shrub species may take the form of wind-formed trees referred to as krummholz.

Aspen

This habitat consists of small or large stands of forested areas dominated by quaking aspen. Other tree species that may be present include ponderosa pine, Douglas-fir, lodgepole pine, Engelmann spruce, and subalpine fir. Several understory shrub species may occur within aspen stands which most commonly include gooseberry (*Ribes* spp.), common juniper (*Juniperus communis*), and snowberry (*Symphoricarpos oreophilus*). Many aspen stands in RMNP have understories that are composed completely of grass and herbaceous plants.

High-elevation Riparian

Mountain streams lined with willows and other shrubs account for the high-elevation riparian habitat. Trees may be present within this habitat; however, trees are not dominant. The tree species that can be found within this habitat type include Engelmann spruce, subalpine fir, and lodgepole pine. In RMNP, the most common shrub species in this habitat type are willows.

Mixed Conifer

This habitat consists of mid-elevation conifer-dominated forests that are made up of a diverse suite of tree species. Common tree species found in this habitat within RMNP include Douglas-fir, aspen, and ponderosa pine. Shrubs can also be found in this habitat, including gooseberry and willow.

This habitat type was not well represented in the transect data and was not used in the analysis due to small sample sizes. Many of the transects that were originally identified as mixed conifer were combined with lodgepole pine if there was a significant amount of lodgepole pine cover shown in the vegetation map and noted on data sheets.

Ponderosa Pine

This habitat is composed of arid conifer stands dominated by ponderosa pine. It may also contain a component of Douglas-fir. Understory plant species that are most commonly found within the Park include snowberry, common juniper, mountain mahogany (*Cercocarpus montanus*), gooseberry, antelope bitterbrush (*Purshia tridentata*), and rabbitbrush (*Chrysothamnus* spp.).

Lodgepole Pine

Lodgepole pine largely dominates this habitat type and occurs as an even-aged stand with minimal understory species. Some shrub species may occur in lodgepole pine communities; however, depending on the stand structure, the understory is typically sparse. Engelmann spruce or subalpine fir may be mixed with the canopy or important in the understory, but is not dominant.

Spruce-fir

This habitat is composed of high-elevation coniferous trees, such as Engelmann spruce, Douglas-fir, blue spruce (*Picea pungens*), and subalpine fir. In RMNP, understory shrub species in this habitat type may include gooseberry, common juniper, willow, kinnikinnick (*Arctostaphylos uvi-ursi*), and/or snowberry.

Wetlands

Wetlands in RMNP are most typically wet meadows dominated by sedges (*Carex* spp.), rushes (*Juncus* spp.) and other water tolerant grasses. The amount of standing water depends on the year (amount of snowpack) and time of the season because wetlands in the Park are most typically fed by snowmelt or springs.

This habitat type was not well represented in the Park data. Only one transect was monitored during two of the years and was not used in the analysis. The three transects in this dataset that are classified as wetlands were combined with the high-elevation riparian data due to similarities in species that were observed in each habitat type. Although detection probabilities may slightly differ between the high-elevation riparian and wetland habitat types, I was able to model each species more effectively when they were combined. In doing so, I assumed that detection functions did not differ significantly between the two habitat types.

Density Estimation

I used only the last seven years of data (2000 to 2006) in this analysis because the data collection of distances differed between the 1994 to 1999 and 2000 to 2006 data (from two categories of 0 to 50 m or greater than 50 m to multiple grouped categories). Use of the data with only two distance categories is not compatible with analysis in DISTANCE. Because the last category has no designated end-point, it would have to be truncated from the dataset, leaving only one distance category, thus, a detection function could not be modeled. Other methods to analyze the earlier year's data would not account for detection probability and would only be capable of estimating and index to general abundance and would not be comparable to the data collected using the 2000 through 2006 methods.

I used the statistical software package, DISTANCE (Buckland et al. 2001, Thomas et al. 2006) to estimate the densities (*D*) of several species of birds within each habitat each year. I assigned a numerical value to each of the categorical distances which was the center point of each bin for input into DISTANCE. A detection function was then fit to the categorized data. I estimated the detection functions using uniform, half-normal, and hazard-rate functions followed by a parameter adjustment of a cosine, simple polynomial, or hermite polynomial to improve the model fit. I selected the best detection functions based on the lowest value of Akaike's Information Criterion corrected for small sample size (AIC_c; Akaike 1973), significance of the chi-square (X^2) model fit statistics (at the $\alpha = 0.05$ significance level), and visual inspection of detection probability plots.

I imported the data into DISTANCE stratified by year and separately for each habitat type. I analyzed each species separately by habitat type because different species and different habitats may exhibit different detection functions. I grouped the distance bins if necessary to help improve model fit. The variety of break points used for grouping was limited due to the data already being previously grouped during the data collection process. I consistently truncated the data at 100 meters because the distance category greater than 100 meters had no specified end point; however, I occasionally truncated the data at 75 meters if the model fit was improved and if less than 10% of the birds were detected beyond that distance.

I pooled the data across years to maximize the number of detections for as many species as possible in order to meet the recommended minimum number of 60 to 80 detections to estimate the detection function accurately. Species with fewer than 60 detections total, before truncation, were eliminated from analysis. Very few species included in the analysis had a minimum of 60 detections annually; thus, the use of annual detection functions was not warranted for most species in estimating densities. No more than one to three species had greater than 60 detections each year. For species with enough detections each year, annual detection functions were modeled and compared with global detection functions. Annual detection functions were not used for estimating densities because so many of the years for each species were difficult to model based on detection probabilities.

When modeling each species in each habitat type, I chose global detection functions as opposed to annual detection functions for all species due to several years with poor detection distributions (Norvell et al. 2003). Global detection functions pool all of the data collected across several years to model a detection function, while annual detection functions model a separate detection function for each year's data. Each species' detection probability histogram with the best modeled detection function is presented in Appendix A and the resulting density estimates for each species are shown in Appendix B.

I estimated the annual densities using clusters as opposed to analyzing each species as its own independent observation. This procedure was intended to help meet a general sampling assumption that observations are independent of one another. Numbers of individuals that were counted within a cluster were recorded in one observation; therefore, the number of observations (n) estimated for each species within a habitat type may have been less than the number of individuals (N) observed for each species within each habitat type. I analyzed all species in each habitat using cluster analysis in DISTANCE. Because the data were broken down into three different time intervals (0 to 3 minutes, 3 to 5 minutes, and 5 to 7.5 minutes) and RMBO surveys point count stations for 5 minutes, I estimated densities for all of the data collected within 5 minutes and again for all of the data collected within 7.5 minutes to compare the effectiveness of the additional 2.5 minutes of surveying. RMBO data that were used in this study were analyzed by RMBO personnel annually from 1998 through 2007.

Trend Analysis and Comparison with RMBO Data

Data were insufficient to conduct a trend analysis with adequate statistical power. I visually inspected annual fluctuations and the mean annual change to verify if the data could be used to track species populations. I also compared them to RMBO data. To do this, I displayed the annual density estimates for each species with an adequate number of detections for RMNP on a graph with density estimates of the same species in the same habitat type generated by RMBO. Originally, I only intended to use RMBO point transects within a 30-mile radius of the Park for comparison to RMNP data. However, only a small number of transects for each habitat type were included within that radius. In order to capture a large enough sample size within all habitat types, I used RMBO data collected for the entire state of Colorado for comparisons.

I made comparisons between the two datasets with the understanding that the actual trends were not significantly detectable because the 90% confidence intervals were wide for the RMNP data and overlapped in many instances. Confidence intervals were found to overlap for most species for each year in all habitat types. As a result, I could not detect significant trends and fluctuations in density estimates in each habitat and for each species for both the RMBO and the RMNP datasets. Although inconclusive on its own, a visual comparison of the two datasets and a better understanding of the deficiencies in the data helped to provide some insight and guidance to generate hypotheses and direct future monitoring efforts.

Results

From 1994 to 2006, RMNP staff observed a total of 33,237 birds of 154 different species for all transects and habitats. Of the species observed for all of the transects for all years, 24 are identified by Partners in Flight as priority species under the Colorado Landbird Conservation Plan (CPIF 2000) and 13 of them are identified as species of special management concern by RMNP. The average number of birds and bird species observed annually are shown in Table 3.

Table 3. Average Annual Numbers of Birds and Bird Species Observed by Habitat Type in RMNP.

Habitat	Average Annual Number of Birds	Average Annual Number of Species
Alpine Tundra	329	22
Aspen	206	38
High-elevation Riparian	698	53
Lodgepole Pine	278	32
Ponderosa Pine	757	55
Spruce-fir	339	31

Density Estimates

Surveying each point for 7.5 minutes versus 5 minutes resulted in an average of 20% more birds detected per habitat, including 4% more species across all habitat types. The percentage of increase in birds and species detected by habitat are shown in Table 4. Estimating densities for the data collected within 7.5 minutes was not more accurate or easier to model than the data collected within 5 minutes. The density estimates were only slightly greater with the longer time period and generally followed similar annual peaks and declines in density estimates with no greater precision. For comparison purposes with RMBO data, I did not include data collected in the 5 to 7.5 minute timeframe to estimate the final densities.

Table 4. Percentage increase of birds and bird species detected in the 5 to 7.5 minute time interval by habitat type in RMNP.

Habitat	Percentage Increase in Birds Detected	Percentage Increase in Species Detected
Alpine Tundra	18.2%	6.5%
Aspen	16.4%	0.0%
High-elevation Riparian	36.3%	7.8%
Lodgepole Pine	14.9%	1.5%
Ponderosa Pine	18.2%	7.7%
Spruce-fir	16.4%	0.0%

For the last 7 years of RMNP data that I analyzed, Park staff surveyed an average of 34 point transects and 439 points each year. Park personnel observed an average of 3,650 birds and 90 bird species annually. The number of point transects and points sampled each year for each habitat was not consistent over the years (Table 5).

Table 5. Number of transects surveyed by year and habitat type from 2000 to 2006 in RMNP. Note that transect revisits were inconsistent over time.

Habitat Type	Number of Samples	2000	2001	2002	2003	2004	2005	2006	Total
Alpine Tundra	Transects	5	7	7	7	6	5	0	37
	Points	71	100	102	100	89	74	0	536
Aspen	Transects	4	2	3	3	3	3	1	19
	Points	30	24	35	35	35	35	10	204
High-elevation Riparian	Transects	10	8	9	10	9	10	4	60
	Points	99	90	102	108	106	109	38	652
Lodgepole Pine	Transects	4	6	6	6	6	6	1	35
	Points	54	90	92	90	89	92	15	522
Ponderosa Pine	Transects	7	8	9	8	10	7	2	51
	Points	71	116	130	118	137	107	30	709
Spruce-fir	Transects	5	5	5	7	6	5	0	33
	Points	59	61	72	97	87	73	0	449

During the 7-year monitoring period from 2000 through 2006, Park staff detected 140 species across all of the point transects and habitat types. Of those species, 42 had enough detections (minimum of 60 detections pooled across 7 years) to estimate densities for at least one habitat type. Of the total species detected during the monitoring period, the same number of Partner's in Flight priority species and RMNP species of special management concern were detected as in the data collected for the entire duration of the monitoring project (20 priority species and 13 RMNP species of special management concern). Eight of these priority species had enough detections pooled across all of the seven years to estimate densities. Most of the habitats analyzed in this study contained priority species of special management concern; aspen had two priority species, alpine tundra had one priority species, high-elevation riparian had four priority species, lodgepole pine had one priority species, ponderosa pine had five priority species, and spruce-fir had no priority species.

The number of species observed was generally highest in the high-elevation riparian and ponderosa pine habitat types and was not noticeably different between the remaining four habitats (Table 3). In the RMNP data, bird abundance appeared to be a function of the habitat type, depending on the habitat requirements of each specific species, which was well demonstrated in the RMNP data. For example, yellow-rumped warbler (*Dendroica coronata*) had the highest estimated densities in lodgepole pine and spruce-fir forests. Other generalist species, such as broad-tailed hummingbird (*Selasphorus platycercus*), mountain chickadee (*Poecile gambeli*), ruby-crowned kinglet (*Regulus calendula*), American robin (*Turdus migratorius*), dark-eyed junco (*Junco hyemalis*), and pine siskin (*Carduelis pinus*) are common in RMNP and were well represented in at least four or more habitat types; however, their abundance varied among habitats. Specialist and uncommon species in the Park were only represented in one or two habitat types.

Coefficients of variation ranged from 10.54% for ruby-crowned kinglet in lodgepole pine in 2006 to 136.04 in 2006 for Wilson's warbler (*Wilsonia pusilla*) in high-elevation riparian. Confidence intervals (90%) were extremely wide in years for in which the number of transects was less than three. For example, aspen had a sample size of two in 2001 and three in most other years. The 90% confidence intervals were generally larger in aspen than in the other habitat types as a result of the small sample sizes each year. Only two transects were sampled in ponderosa pine in 2006 which accounted for extremely large 90% confidence intervals for that year in the density estimates for all of the species in that habitat type. In 2001, there was only one transect sampled in aspen habitat which resulted in an inability for DISTANCE to calculate variance due to only one sample collected. Only one transect was sampled in 2006 in lodgepole pine which exhibited the same issues related to variance.

Comparison of RMNP density estimates to RMBO density estimates

I compared RMNP density estimates of several different species in five different habitat types to density estimates from statewide data collected by RMBO. RMBO had only surveyed the lodgepole pine habitat type in 2000 and only surveyed 17 transects (as opposed to their usual 25 to 30 transects). As a result, RMBO estimates of bird species densities in lodgepole pine were not used for comparison to RMNP estimates.

In each of the 5 habitats, there were several species that could be compared between the two datasets; alpine tundra had 8, aspen had 10, high-elevation riparian had 16, ponderosa pine had 23, and spruce-fir had 10. None of the species exhibited a statistically significant or notable trend for both datasets. Many species in the RMNP dataset had overlapping 90% confidence intervals each year, and although RMBO data had much narrower 90% confidence intervals than the RMNP data, trends seemed to appear relatively stable with some overlap in confidence intervals.

In alpine tundra, horned lark (*Eremophila alpestris*) only had significant differences in density estimates between the two datasets for 2003 and 2004 where the RMNP estimates were higher. All of the confidence intervals overlapped across all of the years for RMNP, thus, no significant trend was evident. Ruby-crowned kinglet and Lincoln's sparrow (*Melospiza lincolnii*) did not have significant trends detectable, but had significantly higher densities in 2004 and 2005 in the RMNP data than RMBO data (Figures 1 and 2)

Figure 1. Ruby-crowned kinglet in alpine tundra habitat appears to have an upward trend in RMNP; however, overlapping 90% confidence intervals across the years indicate that trends are not significant. Densities in RMNP appear to be significantly higher than statewide densities. (density = birds/km^2).

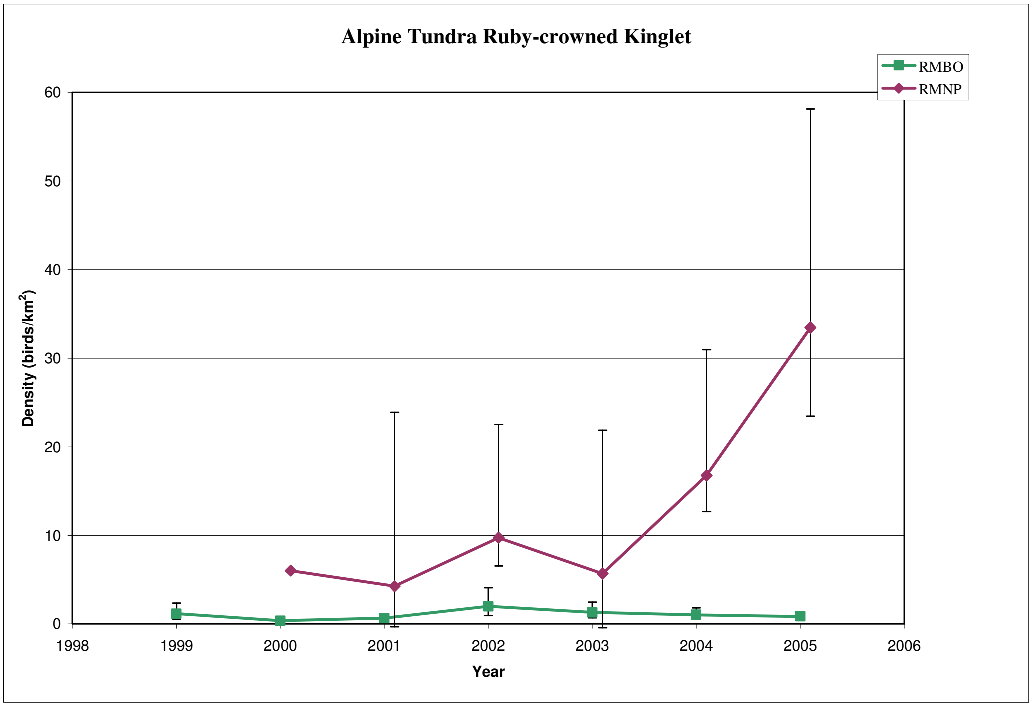
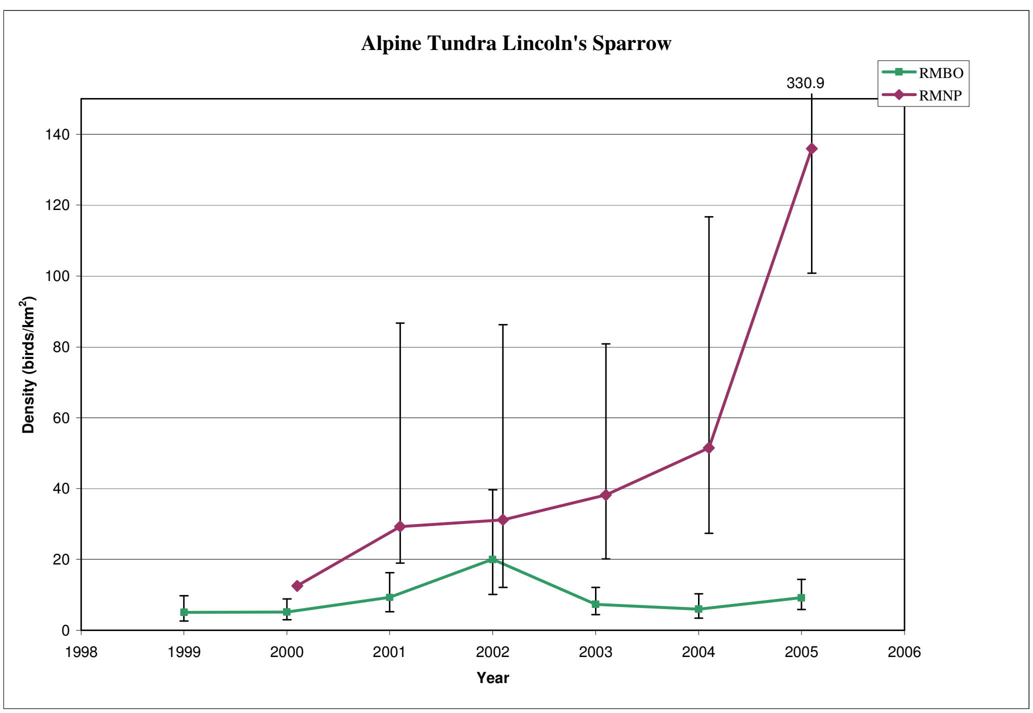


Figure 2. Lincoln's sparrow in alpine tundra habitat appears to have an upward trend in RMNP; however, overlapping 90% confidence intervals across the years indicate that trends are not significant. The 2005 RMNP density estimate is greater than the RMNP densities from 2000 through 2003, making a potential trend seem evident. Densities in RMNP appear to be significantly higher than statewide densities for most of the data years. (density = birds/km^2).



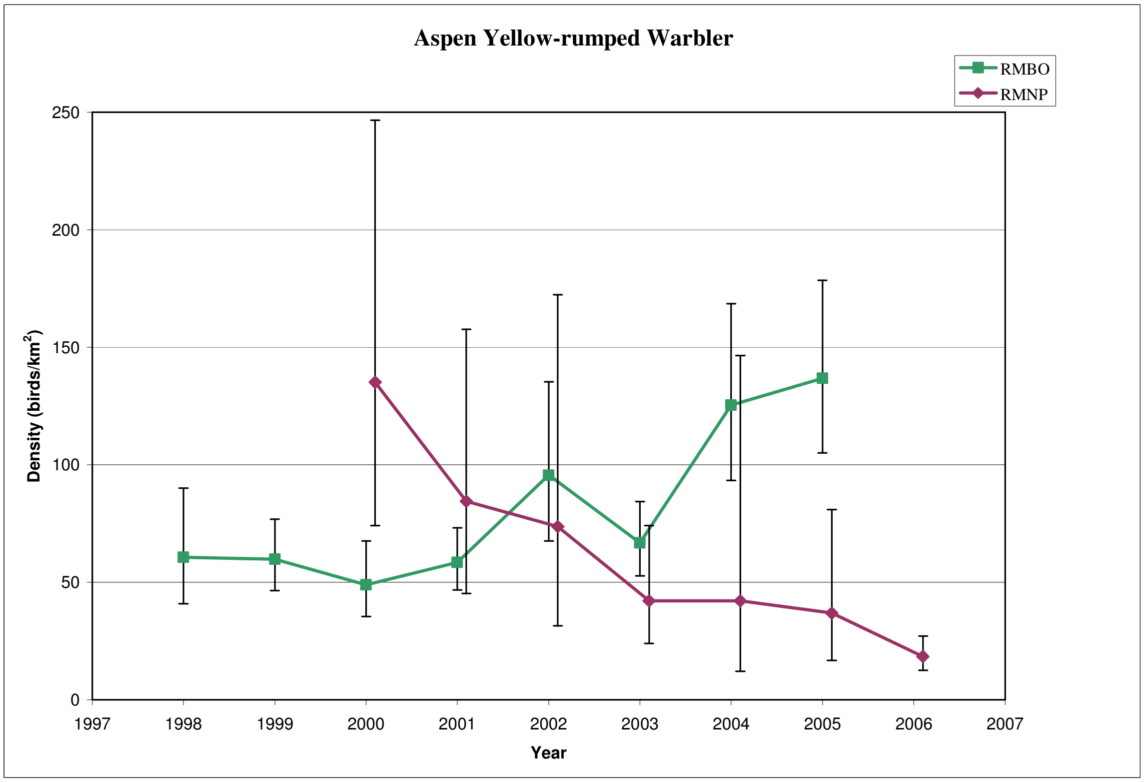
American robin, American pipit (*Anthus rubescens*), Wilson's warbler, white-crowned sparrow (*Zonotrichia leucophrys*), and dark-eyed junco all were not significantly different from RMBO data. All of these species appeared to show different trends, but the confidence limits overlapped across all years and between both datasets, making any differences or trends insignificant. Wilson's warbler was a really good example of overlapping confidence intervals (Figure 3).

Figure 3. Wilson's warbler alpine tundra habitat appears to have an upward trend in RMNP and a stable trend in RMBO; however, overlapping 90% confidence intervals across the years and between the two datasets indicate that trends and differences in density are not significant (density = birds/km^2).

Confidence intervals for many species in aspen habitat were very wide due to the small number of transects surveyed each year and modeling difficulties. Density estimates for RMNP in 2006 for this habitat type were highly suspect because only one transect was sampled that year and as a result, variance could not be estimated. Consequently, density estimates for many of the species appear to have very small or no confidence limits for that year. Trends appeared to be declining for about half the species in RMNP in this habitat; however, all of the species had overlapping confidence intervals between data years and datasets, and thus had no significant trends and differences between the two datasets. The species compared for this habitat type include broad-tailed hummingbird, western wood-pewee (*Contopus sordidulus*), warbling vireo (*Vireo gilvus*), house wren (*Troglodytes aedon*), American robin, mountain chickadee, ruby-crowned kinglet, yellow-rumped warbler, green-tailed towhee (*Pipilo chlorurus*), and dark-eyed junco.

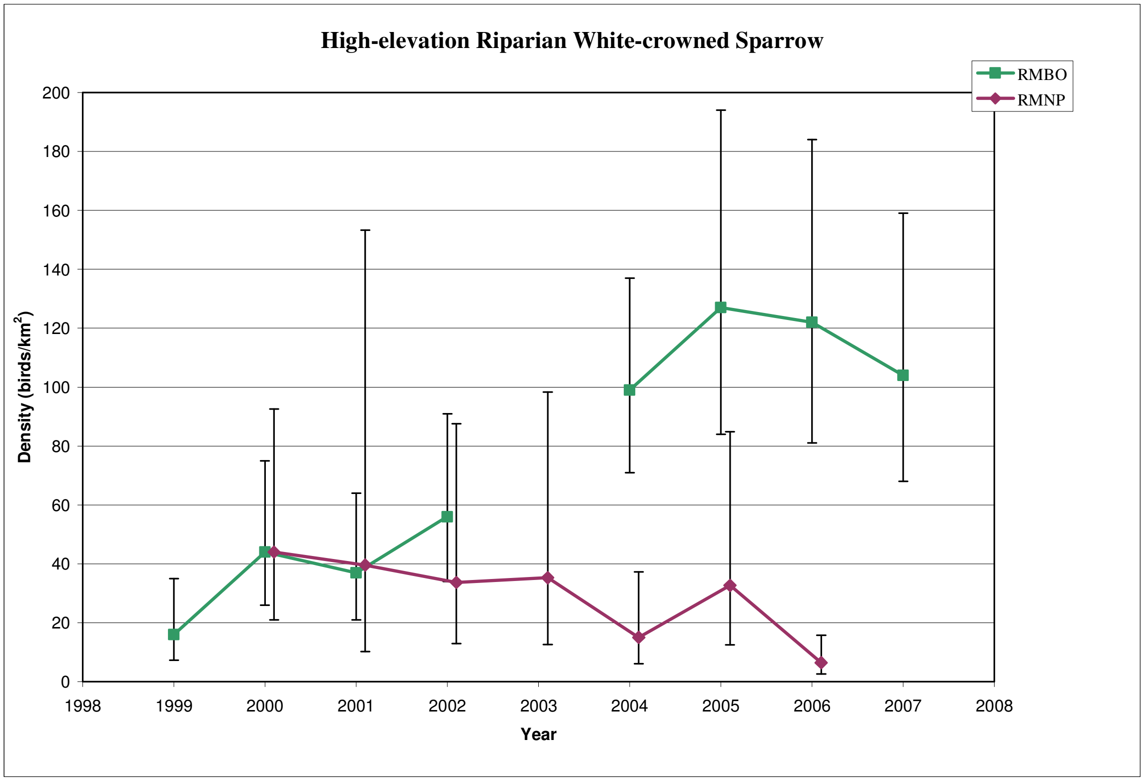
Yellow-rumped warbler in aspen habitat had the most potential for some difference between RMNP and RMBO density estimates, but has overlapping confidence intervals for most of the data years from 2001 through 2004. There is no significant trend evident in the RMNP data (Figure 4).

Figure 4. Yellow-rumped warbler in aspen habitat appears to have different trends; however, overlapping 90% confidence intervals indicate that trends and differences are not significant (density = birds/km^2).



There were no significant trends for any of the species represented in high-elevation riparian habitat in RMNP. All confidence intervals were overlapping to a large degree across all of the data years within the RMNP data. Warbling vireo, violet-green swallow (*Tachycineta bicolor*), ruby-crowned kinglet, American robin, yellow-rumped warbler, Wilson's warbler, Lincoln's sparrow, dark-eyed junco, and pine siskin (*Carduelis pinus*) all had overlapping confidence intervals between RMNP and RMBO data showing no significant differences in density estimates. Savannah sparrow (*Passerculus sandwichensis*) had the same density estimates for both datasets with the exception of 2006 where RMNP had significantly larger densities than RMBO. Broad-tailed hummingbird had some overlap of confidence intervals between RMNP and RMBO, but did not overlap as much as the other species aforementioned and the RMNP density estimates appeared to be slightly greater than RMBO density estimates. Other species in this habitat type, including spotted sandpiper (*Actitis macularius*), dusky flycatcher (*Empidonax oberholseri*), song sparrow (*Melospiza melodia*), red-winged blackbird, and brown-headed cowbird (*Molothrus ater*) had overlapping confidence intervals in the first few and last few years, but many of them showed an increase in density from 2002 to 2005 where confidence intervals did not overlap between the two datasets. White-crowned sparrow in high-elevation riparian was one example of a species that may have differing densities between the two datasets. The confidence intervals overlap and originate at similar density estimates for both the Park and statewide data, but depart after 2003 where the confidence intervals no longer overlap. Again, a trend is not detectable in the RMNP data due to the overlapping confidence intervals, while a slight trend may be detectable for RMBO data (Figure 5).

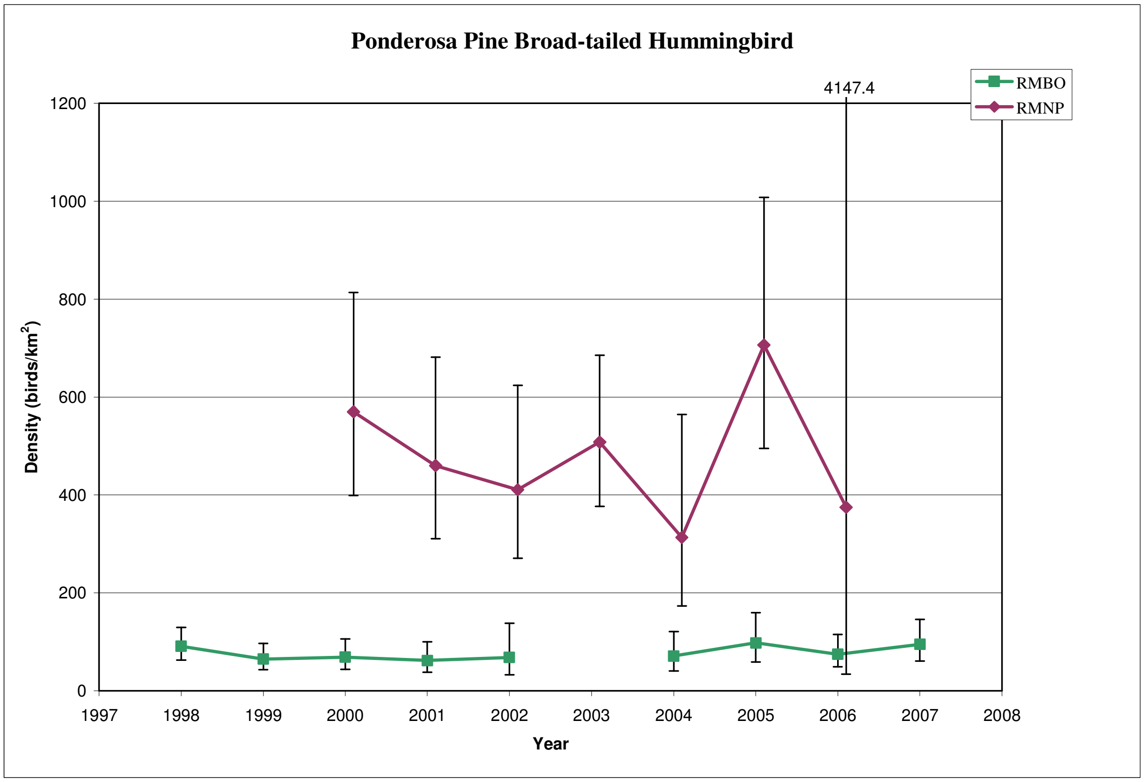
Figure 5. White-crowned sparrow in high-elevation riparian habitat shows slightly different trends in the RMNP than the statewide data (density = birds/km^2).



Although lodgepole pine was not compared with RMBO data, density estimates for each species in this habitat type were graphed. No trends were evident for any species in this habitat type. The graphs for lodgepole pine are included in Appendix C.

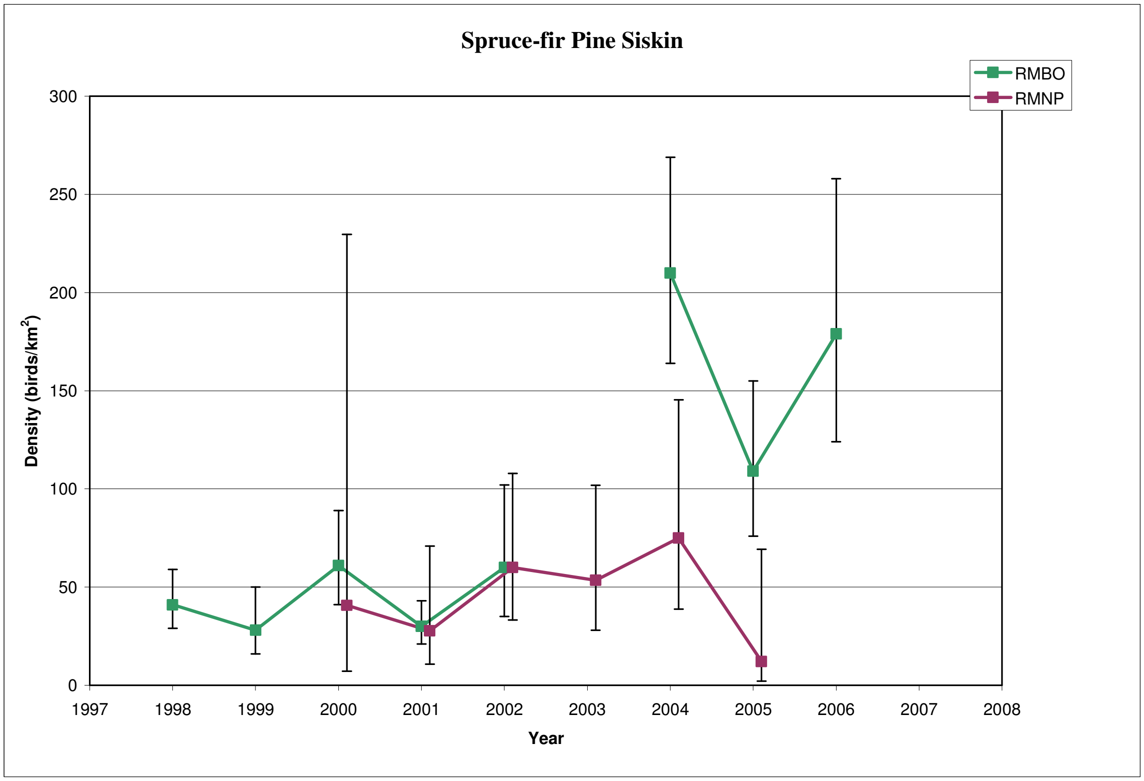
Similar to all of the species in all of the habitats, there were no significant trends for any of the species recorded in ponderosa pine in RMNP and all of the confidence intervals were overlapping to a large degree across all of the data years within the RMNP data. The sample size in 2006 was extremely small, thus confidence limits were frequently wide during that year for each species. Dusky flycatcher, warbling vireo, violet-green swallow, mountain chickadee, red-breasted nuthatch (*Sitta canadensis*), white-breasted nuthatch (*Sitta carolinensis*), American robin, yellow-rumped warbler, western tanager (*Piranga ludoviciana*), chipping sparrow (*Spizella passerina*),green-tailed towhee, dark-eyed junco, and pine siskin had overlapping confidence intervals between RMNP and RMBO data showing no significant differences in density estimates. Pygmy nuthatch (*Sitta pygmaea*) was not significantly different between RMNP and RMBO over most years; however, there were a lot of annual fluctuations where this species was slightly more abundant in 2000 and 2005. Mountain bluebird (*Sialia currucoides*) had some overlap in confidence intervals between the two datasets, but densities were slightly higher in RMNP. Broad-tailed hummingbird, western wood-pewee, cordilleran flycatcher (*Empidonax occidentalis*), Steller's jay (*Cyanocitta stelleri*), house wren, ruby-crowned kinglet, and Townsend's solitaire (*Myadestes townsendi*) all appeared to have significantly higher estimates the Park than statewide. Hammond's flycatcher (*Empidonax hammondii*), had some overlap in confidence intervals between the two datasets, but densities were mostly higher in RMNP. Figure 6 illustrates significantly higher density estimates in RMNP than in RMBO.

Figure 6. Broad-tailed hummingbird in ponderosa pine habitat shows significantly higher density estimates in RMNP than the statewide data (density = birds/km^2).



Similar to all other habitats, RMNP data did not show any significant trends due to overlapping confidence intervals. Most of the species in this habitat type, including mountain chickadee, red-breasted nuthatch, golden-crowned kinglet (*Regulus satrapa*), American robin, yellow-rumped warbler, dark-eyed junco, and pine grosbeak (*Pinicola enucleator*) did not have significantly different density estimates between the two datasets. Hermit thrush (*Catharus guttatus*) was not significantly different between the two datasets with the exception of a spike in abundance in RMNP in 2004. Ruby-crowned kinglet had significantly larger density estimates in the Park than statewide data. Pine siskin had overlapping confidence intervals between the two datasets from 2000 to 2002, but RMBO estimates were significantly higher from 2004 to 2006.

Figure 7. Pine Siskin in spruce-fir habitat shows significantly higher density estimates in RMBO from 2004 to 2006 than RMNP (density = birds/km^2).



Appendix C includes graphs of all of the comparisons between the RMNP and RMBO density estimates of each species by habitat type.

Discussion

Thirteen years of breeding bird data were collected by RMNP which provided an excellent opportunity to take a closer look at the data and see what types of useful information it could provide and what limitations it may have. Only seven of those years used distance sampling methodology, thus only a subset of the most common bird species could be adequately analyzed using DISTANCE software. Data collected prior to 2000 could be used to estimate an index to general abundance, and is not capable to detect trends that result from ecological changes. Although the first six years were not included in the analysis due to changes in data collection methods, the most recent seven years (2000 to 2006) provided enough data to estimate densities for approximately one-third of the species detected using a global detection function. Of the species that had enough detections to estimate density, eight were priority species of conservation concern (Table 7).

Table 7. Priority species that had sufficient occurrences on point transects to estimate densities in DISTANCE with their preferred habitat and rationale for priority status (CPIF 2000).

Common Name	Scientific Name	Preferred Habitat	Reason for Priority Status	Species that use similar habitat or may respond in a similar way to threats
Broad-tailed Hummingbird	*Selasphorus platycercus*	Open ponderosa pine, mixed conifer, aspen, and riparian woodlands.	A very high proportion of this species' total population occurs within the Rocky Mountain Region indicating that this area has high responsibility for the conservation of this species.	House Wren, Lincoln's Sparrow, White-crowned Sparrow, and Dark-eyed Junco.
Hammond's Flycatcher	*Empidonax hammondii*	Mature closed-canopy spruce-fir, mixed-conifer, and aspen forests with limited ground vegetation.	This species shares habitat components with other bird species of mature spruce-fir forests, and thus serve as a suitable "umbrella" species for management actions.	Golden-crowned Kinglet and Hermit Thrush.
Cordilleran Flycatcher*	*Empidonax occidentalis*	Shady coniferous and deciduous forests, usually near streams or moist ravines.	A high proportion (estimated at 11.3%) of these flycatchers' total population occurs within this physiographic area, indicating that this area has high responsibility for the conservation of this species.	Broad-tailed Hummingbird, Ruby-crowned Kinglet, Golden-crowned Kinglet. In deciduous riparian forests, associates include Western Wood-Pewee and Warbling Vireo
American Pipit	*Anthus rubescens*	Alpine meadows dominated by grass and sedge vegetation, or fell fields with lush vegetation or cushion plants.	This species occupies a unique habitat and is representative of other species in this habitat type.	Horned Lark
Violet-green Swallow	*Tachycineta thalassina*	Edges of aspen-dominated woodlands or within open stands, on cliffs, and in cavities in riparian embankments. They also breed in lesser numbers in open ponderosa pine and spruce-fir stands.	This species has a moderately high conservation need throughout its range, along with high representation in the physiographic area and an uncertain population trend.	Mountain Chickadees, Pygmy and White-breasted Nuthatches, House Wrens, Mountain Bluebirds, and Western Bluebirds.

Common Name	**Scientific Name**	**Preferred Habitat**	**Reason for Priority Status**	**Species that use similar habitat or may respond in a similar way to threats**
Macgillivray's Warbler	*Oporornis tolmiei*	Foothills and mountain shrubland and willow carrs.	This species is representative of many other species in the montane riparian habitat type because they occupy habitat typically used by other species.	Broad-tailed Hummingbird, Virginia's Warbler, and Green-tailed Towhee. In willow carr ecosystems, associated species include Broad-tailed Hummingbird, Dusky Flycatcher, Wilson's Warbler, and Lincoln's Sparrow.
Wilson's Warbler	*Wilsonia pusilla*	Willow and alder thickets of stream banks, lake shores, and wet meadows.	This species has a moderately high conservation need throughout their range, and they have high representation in the Rocky Mountain Region.	Broad-tailed Hummingbird, MacGillivray's Warbler, Lincoln's Sparrow, and White-crowned Sparrow.
Green-tailed Towhee*	*Pipilo chlorurus*	Dry shrubby hillsides (Gambel oak [*Quercus gambelii]*, mountain mahogany [*Cercocarpus montanus*], serviceberry [*Amelanchier* spp.], sagebrush [*Artemisia* spp.], snowberry [*Symphoricarpos* spp.], chokecherry [*Prunus virginiana*], and antelope bitterbrush [*Purshi*	Colorado contains between 20% and 40% of the entire breeding population of Green-tailed Towhees (Kingery 1998); therefore, Colorado has high responsibility for the conservation of this species. Colorado Breeding Bird Atlas abundance calculations rank this	Dusky Flycatcher, House Wren, and Virginia's Warbler.

*RMNP Species of Special Management Concern

Some species were slightly more difficult to model than others which could either be due to small sample sizes or a failure to meet distance sampling assumptions. It appeared that the most commonly violated assumption was that all objects at the point are detected. The data collected for several of the species also potentially violated the distance sampling assumption that objects are detected before moving from their initial location. Some species had higher detection probabilities further away from the observation point and lower detection probabilities closer to the observation point. For most species this issue was resolved by grouping the first two distance intervals and then modeling the new detection curve off of the new detection probability histogram. Using grouped distance categories did not help to satisfy the assumption that distances are exact. Although measuring exact distances rather than assigning observations into broad distance categories may be subject to some recorder error, it allows more lenience when analyzing the data.

Detection functions not only differed by species within the same habitat type, but also slightly differed between the same species in different habitat types. A few species had the same detection functions across most habitat types. Species such as the broad-tailed hummingbird, tree swallow (*Tachycineta thalassina*), and violet-green swallow all had similar detection probabilities that dropped off rapidly after the first or second distance intervals. This may be due to the fact that these species may be more difficult to detect at greater distances regardless of habitat type. Ruby-crowned kinglet across habitat types had a large number of detections across all of the distance bins beyond the first bin which had the largest detection probability. This is not common among all species and may be due to bird behaviors, such as frequent wing flicking, constant movement, and loud and continuous calling, making the bird easier to detect further away.

Some habitats with denser vegetation, such as high-elevation riparian, lodgepole pine, and spruce-fir, relatively consistently had a large number of detections at the observation point and rapidly dropped off in subsequent distances. Although some distinguishing detection functions were evident, most species and habitats were quite variable in their detection functions which made it difficult to establish specific detection functions that were characteristic of a specific habitat type and a specific species.

Many of the confidence intervals did not indicate any sign of trends or differences between the RMNP and RMBO data. Overall, 90% confidence intervals for the density estimates of all of the species in each habitat type were relatively wide and overlapping and the annual coefficients of variation (CV) for each species in each habitat type were quite variable (Appendix A). This is likely due to the small and inconsistent sample sizes collected each year in each habitat type. Variability in habitat characteristics along several transects may have also produced some biases or altered species detection probabilities. Another factor that may influence precision is that estimated densities have the tendency to be more variable between models when the analysis is based on grouped data, such as the data collected by RMNP (Buckland et al. 2001).

Limitations exist for detecting trends and comparing the RMNP and RMBO datasets as a result of large confidence intervals and small sample sizes of the RMNP data. A visual review of the existing density estimates provided insight into ways that monitoring techniques could be improved for RMNP in the future and to help develop *a priori* hypotheses. Identification of deficiencies in the data will help to choose future monitoring methods that would provide more statistically valid information. The RMBO MCB program was developed with specific objectives and *a priori* statistical goals, making it a relatively sound dataset to base comparisons with RMNP data. RMNP data does not meet RMBO's rigorous statistical goals of 80% power to detect a 3.0% decline in 30 years, solely based on the Park's small sample sizes as compared to the sample sizes of approximately 20 to 30 transects for each habitat type per year for the RMBO monitoring program (Leukering et al. 2001, Beason et al. 2005a, 2005b, Hutton et al. 2006, Beason et al. 2007).

For the most part, patterns between the same species within the different habitat types and between different species within the same habitat type were difficult to identify due to the inability to detect trends for any of the Park species. There are some patterns that appeared to be evident, including the number of species that had significantly greater densities in ponderosa pine in the Park than statewide.

The ease of comparison depended on confidence intervals and the degree of annual peaks and depressions. For example, in high-elevation riparian, RMNP density estimates for Lincoln's sparrow appeared to track well with RMBO density estimates and not only appeared to have similar trends, but appeared to have similar peaks and depressions. This was also demonstrated in density estimates for yellow-rumped warbler in spruce-fir habitat.

On the other hand, there were a few examples of species that appeared to have different trends between the two datasets. One is the white-crowned sparrow (*Zonotrichia albicollis*) in high-elevation riparian habitat. The density estimates for white-crowned sparrow from the RMBO data showed an apparent upward trend which departed from the RMNP density estimates beginning in 2004 where the confidence intervals did not overlap in the most recent years (Figure 5). Trends for yellow-rumped warbler in aspen habitat were a good example where the datasets appeared to show opposite trends that were not significant due to overlapping confidence intervals (Figure 4).

It could easily be expected that RMNP data would reveal different trends than the RMBO data. Point transects monitored by RMBO take place throughout the state of Colorado on lands under a variety of different land management practices than those carried out by the National Park Service. Climate patterns are also variable across the State, especially between the northern and southern portions of the state which may play a role in breeding bird abundances as a result of food availability (Dettinger et al. 1998, Sillett et al. 2000, Anders and Post 2006). Besides climatic differences, there are also localized demographic and behavioral patterns that may influence bird populations in specific areas that are different from the rest of the region being studied (Adahl et al. 2006). The RMBO statewide data may be useful to track and follow population trends for breeding bird species on a broad scale, but is not adequate for RMNP to use as a basis to direct management decisions. However, if the Park participates in the RMBO monitoring program, they can use that data to identify and plan research efforts that have the statistical power to detect trends.

Recommendations

Monitoring programs to track breeding bird populations are carried out by multiple agencies. Far too often, these programs are cut short due to funding issues. The point of ecological monitoring is to detect long-term environmental change and to help guide management efforts. This project provided the opportunity analyze the long-term breeding bird data collected by RMNP and to reassess the effectiveness of monitoring efforts during that time. It is important that monitoring programs are continually evaluated to determine if the program is meeting its objectives, and if not, they can be adapted to better meet those objectives (Fancy 2000, Nichols and Williams 2006). The RMNP breeding bird monitoring program was critiqued by Kotliar (2000) by reviewing the methods that were being used at the time; however, an analysis of annual densities to determine its validity for tracking bird species trends was not carried out. This paper is the first time a complete assessment and analysis of trend data have been carried out to determine if the methods being used are effective for identifying changes in bird densities over time.

Monitoring practices are often used to track a wide array of species across multiple habitats and are sometimes referred to as surveillance monitoring. The RMNP and RMBO monitoring programs can be classified as surveillance monitoring. This type of monitoring can be useful depending on the area to be monitored, how the program was set up, and the goals and objectives of the monitoring project. However, in some cases, surveillance monitoring can be inefficient. Using only the detection of a population decline as a trigger for management actions, without taking any other environmental factors into consideration is not a very effective method for basing management decisions (Nichols and Williams 2006). This is true especially if the monitoring design cannot indicate causality or identify what management actions should take place as a result.

There are often concerns regarding the accuracy of the results and cost effectiveness of large scale monitoring in an attempt to capture every component of the ecosystem. These monitoring efforts are also sometimes cut short due to funding constraints. However, there are several arguments for continuing monitoring programs. These arguments include the uncertainty over the condition of species and ecosystems over time, the costs that may be associated with not monitoring, and the degree of reversibility of change following a decline in species or system state. There has been discussion of discontinuing the breeding bird monitoring program at RMNP due to the lack of funding; however, it could potentially be replaced by a more cost effective alternative that can be less expensively carried out and still meet monitoring objectives.

From this review of the RMNP point transect data, several recommendations can be made for future monitoring efforts. There are several tactics that can be employed that are cost effective and may garner more support for funding in the future. The data gathered by the current RMNP breeding bird monitoring program is useful and can serve as a baseline for developing and continuing monitoring efforts in the future. With that in mind, guidelines that could help in designing future monitoring plans are offered here.

Elements that are essential in a framework for informed decision-making include clear objectives, an idea for the potential management actions that could take place, measures of statistical confidence in the models and data, and finally a monitoring program providing estimates of the system state (Nichols and Williams 2006). These elements can be carried out by developing focused objectives prior to designing a monitoring program; identifying target species or systems to be monitored; choosing the best methods to use that will account for any biases and assumptions that may be present; developing a clear and descriptive protocol and training that will not only guide managers, but other staff that may carry out monitoring activities; routinely assessing the effectiveness of the monitoring program and making adjustments as necessary; and collaborating with other organizations (Silsbee and Peterson 1993).

Develop more focused objectives prior to setting up the monitoring design

It is important to focus monitoring efforts on crucial information needs in the conservation process. To gain support for monitoring programs, they must be concrete, and have relevant purposes, with apparent contributions (Noon et al. 1999). Targeted (or focused) monitoring is the preferred approach to a monitoring and design and implementation based on *a priori* hypotheses (Nichols and Williams 2006). RMNP has general objectives adopted from the Partner's in Flight Colorado Landbird Monitoring Program (CPIF 2000) which are also useful to consider when planning the monitoring program; however, RMNP may want to consider developing objectives that are unique to the Park's management needs. The Park's objectives are better focused on management concerns that are specific to RMNP and the habitats that are most at risk or have the potential to be impacted or altered by human influences. The appropriate monitoring objectives should be related to the Park's management goals. Identifying the stressors related to those management goals should also help to define the monitoring objectives (Noon et al. 1999).

Identification of target species and ecosystems

Instead of attempting to monitor every species that could be impacted by changes in the ecosystem, monitoring efforts should be focused on a few abundant species that are good indicators of environmental change. Changes detected in the population trends of chosen environmental indicator species can then trigger more detailed research into the cause of the decline and to explore whether or not other species are being impacted as well. The choice of what to monitor may also depend on the monitoring objectives identified. Distance sampling is one of several applicable sampling methods to estimate abundance and track trends in breeding bird populations; however, if the monitoring objective is to determine survival and breeding success after specific management actions, a more targeted approach (e.g., constant effort mist netting) would be more appropriate (Fancy and Sauer 2000). One example would be a study that was conducted on green-tailed towhee response to prescribed fire that combined distance sampling techniques with vegetation sampling and nest searches to determine reproductive success (Jehle et al. 2006).

Distance sampling works best for species that are easily identified, abundant, and territorial with clear songs and calls (Norvell et al. 2003), and thus it is not very effective for monitoring species that are rare or elusive. Monitoring efforts designed for distance sampling should be centered on species that have commonly been observed and detected in the past. If these poorly detected species are considered important for monitoring, another method should be chosen that is more effective, such as targeted research that will focus on either that particular species of interest, or a suite of species that fall within the same ecological guild of that species.

Species of special interest, priority species, or habitats of management concern are frequently good indicators of environmental change and should be the central focus for designing the monitoring plan. The choice of ecological indicator species on which to target monitoring efforts can be challenging. The species that are chosen should capture the complexities of the ecosystem, yet remain simple enough to be easily and routinely monitored (Noon et al. 1999, Dale and Beyeler 2001). There are several criteria that should be used in selecting ecological indicators. The species or ecosystem should be easily measured, sensitive to stresses on the system, respond to stress in a predictable manner, be an early indicator before irreversible impacts take place, predict changes that can be averted by management, be integrative and inclusive of other ecosystem components, have a known response to disturbances, and have low variability in responses to disturbance (Dale and Beyeler 2001). It may be useful to develop a conceptual model linking the relevant ecosystem components in order to help define the species and ecosystems of interest.

Table 7 lists several priority species that have been commonly detected on multiple transects in RMNP that had a substantial presence in habitats of special management concern for the Park. Some of the species have even been detected in high numbers in multiple habitats. One example of a species that may be appropriate for focusing monitoring efforts would be the Wilson's warbler in high-elevation riparian habitat. This habitat type is also of high management concern in the Park. Wilson's warblers are relatively common, but require shrubby riparian habitat for breeding which makes them a great indicator of the condition of this habitat type (Finch 1989). As a result, it may be best to monitor a larger number of transects in high-elevation riparian habitat in order to increase the sample size of Wilson's warbler to help make the data more robust in determining trends for this species. Other species are identified in the table that may use the habitat type in a similar way or may respond in a similar way to threats are included in Table 7 as secondary species that could be good indicators of environmental change. White-crowned sparrow would also be a good example of species that should deserve higher monitoring priority because it uses similar habitat to Wilson's warbler and may respond to threats in a similar way. The high-elevation riparian graph showing density estimates of white-crowned sparrow appeared to decrease to a significant level below the statewide data which would warrant a more thorough investigation.

The Park might consider focusing a greater monitoring effort in aspen, high-elevation riparian and ponderosa pine habitats. All of these habitats had a significant number of different species that are of special management concern and are at the greatest threat of anthropogenic change. These habitats are heavily influenced by population growth and development, elk numbers, vegetation and wildlife management, and fire management programs carried out by park management. A larger number of randomly located point transects in each one of these habitat types would help to significantly increase sample size and decrease variance.

Refine methodology
Survey methods that account for detection probability should be used if the objective is to compare bird abundance among species, habitats, or sites, or in determining population trends (Fancy and Sauer 2000). Distance sampling is an effective method for monitoring several bird species and accounts for some common biases that occur with point counts (Buckland et al. 2000, Rosenstock et al. 2002). However, it is important to be aware of the fact that issues with detection probability may arise when the majority of the detections are auditory. As a result, other methods, such as double-observer sampling (two observers conduct a single count), removal model (recording new individuals observed in different timeframes of the point count), or a combination of sampling techniques may be useful depending on the Park's objectives and the environmental factors that may cause variability in the data (Nichols et al. 2000, Farnsworth et al. 2002, Kissling and Garton 2006).

For auditory detections, there are two probabilities that may influence detection of birds during a point count: the probability the bird sings during the count, and the probability the bird is detected given that it sings (Farnsworth et al. 2002, Simons et al. 2007). Distance sampling and double-observer sampling accounts for the second probability, but not for the first. Although there may be some uncertainty in detection probability, in general, it is best to account for it during point counts. After analyzing and reviewing the Park data, methods were found to be relatively sound, but could be modified to reduce variability in the data. However, refinements can be recommended for improving the precision in the data collected.

<u>Improving precision and power to detect trends</u>
In general, to obtain estimates with reasonable precision, a minimum of 60 to 100 observations per species are required and the total number of transects sampled in each habitat type should be larger than 1 or 2 per year. However, this is the minimum observation and sample size that can be analyzed using distance sampling. A larger sample size is required to obtain the precision necessary to estimate annual densities and detect population trends.

Small datasets are problematic because they often lack the statistical power to identify the likelihood of a significant effect. This becomes a considerable issue when studying declining species or species of concern due to the risk of not detecting the decline in a timely manner (McGarvey 2007). The lack of statistical power is likely to produce a hypothesis test resulting in a type II error, where there is a failure to detect a significant effect when it does in fact, exist (error of not rejecting the null hypothesis (H_0) when it is not true). Many research efforts strive to avoid type I errors where a significant effect is concluded when there is no significant effect (error rejecting the H_0 when it is true); however, when conservation objectives are the subject of research, a type II error is more severe. In regards to ecological systems and species populations, there are significant issues in a hypothesis test resulting in a type II error (McGarvey 2007). A type II error runs the risk of an irreversible decline or loss in species and/or ecosystem state without the knowledge that the decline is occurring.

There are three factors that influence statistical power in a research program: the degree of significance and certainty that is required to reject the null hypothesis, the number of samples generated for the study, and the size of the effect that is being detected (McGarvey 2007). The size of the sample required can be calculated by conducting a power analysis *a posteriori* on existing data to identify the sample size required *a priori* for future monitoring. The existing data collected by RMNP and/or RMBO could be used to accomplish this task. Using the RMBO data to calculate the sample size required for a given power to detect trends would help the Park to tie in to the RMBO monitoring program more closely.

Power to detect trends in species populations may be further confounded by environmental factors that create more variability in the data being collected (Kissling et al. 2007), especially for auditory detections which have a larger degree of environmental variables that could impact detection probability (Simons et al. 2007). Other sources of variation may be due to variation in encounter rates and different observers. Identifying sources of variation not only could improve monitoring efforts, but could also provide information about the underlying ecological processes driving changes in the distribution and abundance of the species in question (Kissling et al. 2007). The Park may consider consulting with a wildlife statistician to most accurately identify and estimate sources of variability in the data and to apply that information to determine the sample sizes needed to obtain high statistical power.

Finally, while conducting a trend analysis which meets the desired statistical power, determining the significance of the trend should be conducted using a sound *a posteriori* analysis for comparison, such as an analysis of variance (ANOVA). The same technique could be used for both within years while comparing the dataset to another dataset and among years within the same dataset. This additional statistical analysis could be conducted on species in habitats that appear as if there could potentially be a trend and to verify the significance of a trend.

<u>Increase sample size</u>
Depending on limitations related to program funding and staffing, the Park may want to consider increasing the number of transects surveyed each year. Also, point transects require a larger sample size than line transects to increase precision. Depending on the objectives chosen and area to be sampled, it may be more practical to use line transects; however, given the terrain and vegetation characteristics of the Park, it may be most appropriate to continue the use of point transects.

There are several ways to increase the sample size every year. Transects can be sampled more than one time per season. Studies have found that multiple revisits to points in the same season did not produce statistically different estimates of bird abundance than only one survey in a season (Brooks et al. 2001). It has been found that repeated observations of the same individual on multiple visits or during the same visit do not violate the assumption of independence as long as individuals are not detected more than one time from the same line or point in a given survey (Rosenstock et al. 2002).

It would also be more effective to develop a larger number of plots in habitats of management concern to the Park, such as aspen, high-elevation riparian, and ponderosa pine, and reduce the number of, or eliminate transects in other habitats that have fewer management concerns. This would help to increase the sample size in areas of management focus to provide more accurate estimates. The number of transects and/or sample size to be surveyed each year and in each habitat will depend on the hypothesis being tested, the objectives of the monitoring program, and the results of the power analysis.

Besides increasing the sample size, it is a good idea to randomly monitor approximately the same number of point transects each year in each habitat type to ensure that adequate sample sizes are collected. It would also be useful to make sure that habitat details and weather variables are included in the data sheets, along with comments on why transects or points may not have been completed so that covariates and survey effort can be accounted for.

<u>Refine distance intervals</u>

As opposed to continuous distance estimates, RMNP has been using distance intervals (grouped data). There are some issues that may exist with grouping data in the field. There is much less flexibility while analyzing the data collected in grouped (categorical) distances and it is more difficult to group and truncate the data to improve the fit of the model. If distances are collected as exact distances and then grouped during data analysis, there would be wide latitude to compensate for rounding errors. Grouping data can allow for accurate density estimates; however, recording exact distances allows a more in-depth inspection of assumption violations and will give more flexibility within the data analysis stage (Norvell et al. 2003).

The Park should collect data using exact distances. This is made relatively accurate using laser rangefinders. In the event were the bird is heard and not seen, the observer could measure the distance to the object the bird is believed to be calling from. Exact distances may pose challenges in dense vegetation, but is preferable for most situations. Distance intervals may help to reduce issues related to heaping or rounding that frequently take place while an observer is collecting data. Choosing the correct intervals to use can be a daunting task. Ideally, interval width should increase with increasing distance from the line or point and the total number of intervals should be between four and eight. Using too many intervals makes classification of objects into the correct distance interval more time-consuming and error-prone, whereas using too few intervals results in loss of precision when estimating detection probability (Buckland et al. 2000). Also, the final interval should have no upper bound to avoid incorrect heaping of detections actually located farther away (Buckland et al. 2000, Rosenstock et al. 2002). As a result, the final distance category would always be truncated from the data analysis. This is particularly an issue if the final interval included in the modeling after truncation has a large detection probability (i.e., >0.10 detection probablility).

Many of the species analyzed for this study had a detection probability of less than 0.1 in the final distance interval which represented a relatively consistent issue in modeling detection functions for each of the species. Distance categories made it difficult to truncate the final distance category as recommended by Buckland et al. (2001) as it became more difficult to fit a curve to a smaller number of distance categories.

Provide a descriptive protocol and training to new observers

Monitoring protocols are 1) a key component of quality assurance for monitoring programs to ensure that data meet defined standards of quality with a known level of confidence, 2) necessary for the program to be credible so that data stand up to external review, 3) necessary to detect changes over time and with changes in personnel, and 4) necessary to allow comparisons of data among places and agencies (Oakley et al. 2003). Besides a descriptive narrative, a monitoring protocol can include other supplemental materials and standard operating procedures (SOPs). The most important goal of the protocol is to ensure consistency and data quality over the course of several years and among different observers. Training observers to properly carry out and adhere to the monitoring protocol is also an effective way to ensure consistency and accuracy.

For example, there are several methods that can be employed to ensure consistency and avoid violating the three assumptions of distance sampling. Movement of birds in response to the observer is a common issue with distance sampling. One way to alleviate this problem is to provide a waiting period to allow birds to settle down (approximately 1 to 2 minutes) immediately after an observer has arrived at a point (Rosenstock et al. 2002). This could be implemented by including a method in the protocols where the observer records the weather and vegetation data sheets prior to the initiation of the survey. It is also a good idea to keep count duration as short as possible (e.g., 5 minutes per point) to avoid double-counting birds and to help reduce the potential influence of evasive movements (Scott and Ramsey 1981). Because there was not much difference between the 5 and 7.5 minute data analyzed for RMNP, the Park should keep the point count duration down to 5 minutes to save on time and effort.

Carry out adaptive management practices on the monitoring program

Adaptive management is designed to specifically deal with uncertainty that is inherent in monitoring or management programs (Nichols and Williams 2006). It is important that as new data and information become available, the decision process is then revisited to determine if a different decision would benefit the program to a greater degree (Noon et al. 1999). Adaptation of a monitoring program can take place following a pilot study, or it can take place after data has been collected for several years. In either case, it is important to continue to evaluate the effectiveness of the monitoring being conducted and whether or not more effective methods could be employed as the program continues to adapt.

Collaborate with other monitoring programs

Future monitoring and research efforts in RMNP should be developed in compliance with the National Park Service's Rocky Mountain Network (ROMN) Inventory and Monitoring Program. Guidelines for developing a sampling design based on the planned objectives are outlined by the ROMN Vital Signs Monitoring Plan for ROMN (Britten et al. 2007). It is also valuable to continue collaboration with RMBO to ensure that statewide information on population trends can also continue to be tracked by the Park and that new methods being employed by the RMBO could be adopted by the Park.

If a species is beginning to decline at a statewide level, it may help determine where additional/future monitoring efforts should be focused. The statewide data would be useful to leverage RMNP monitoring programs and to standardize the data across park borders and could help to identify changes in populations occurring outside of the Park. The statewide data collected by RMBO would also provide useful information to help identify monitoring objectives for the Park. Collaborating with other monitoring programs and programs of a much larger scale will increase the degree of comparability between RMNP data and other data.

Besides collaborating with the RMBO and other parks within the ROMN, the Park should also pay attention to broad-scale trends occurring outside of the park boundaries. Neotropical migratory birds may be impacted by activities and processes occurring from northern North America, to the tropics in Central and South America and may not reflect management or conservation issues within the Park. It would be important to identify the reason behind declining trends because it may have no relevance to Park management practices.

Conclusion

With all of these guidelines in mind and funding permitting, a focused and efficient breeding bird monitoring program can continue in RMNP. If the Park participates in the RMBO monitoring program, they can use that data to identify and plan research efforts that have the statistical power to detect trends. RMBO data will be useful for planning monitoring programs, but will not be sufficient for guiding specific NPS management decisions. It is also true that Rocky Mountain National Park is managed for natural conditions as opposed to multiple use land which is managed for a variety of different human uses and thus would have very different objectives than programs addressing responses to intensive forest management practices (Silsbee and Peterson 1992). The continuation of avian monitoring in the Park, using point transect methods is crucial and can help anticipate population changes of indicator species in key management areas and at an early stage, help to trigger more in-depth research that may need to take place and management actions that may need to be carried out or changed.

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Appendix A – Species Density Estimates by Habitat Type and Year

Alpine Tundra Species Density Estimates

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Horned Lark	2000	48.1	52.3	17.1	135.2	29
	2001	47.4	47.7	19.8	113.2	41
	2002	63.7	46.2	27.3	148.5	57
	2003	63.9	49.9	25.8	158.5	60
	2004	105.2	35.1	53.9	205.4	66
	2005	67.0	53.3	23.6	189.9	35
Ruby-crowned Kinglet	2000	6.0	85.6	1.4	25.6	6
	2001	4.3	87.1	1.1	17.0	6
	2002	9.7	60.0	3.7	25.9	14
	2003	5.7	77.7	1.6	19.9	8
	2004	16.8	55.1	6.8	41.4	19
	2005	33.5	67.7	10.6	105.6	34
American Robin	2000	17.9	47.5	7.3	43.8	9
	2001	33.9	43.4	15.9	72.3	21
	2002	41.6	38.6	21.9	79.1	24
	2003	22.6	46.4	10.0	51.1	15
	2004	54.0	35.2	28.9	101.0	33
	2005	85.4	56.3	29.6	246.4	44
American Pipit	2000	106.4	19.9	73.0	155.2	72
	2001	88.0	36.9	44.6	173.7	86
	2002	92.8	29.2	54.3	158.8	86
	2003	104.3	25.7	64.9	167.4	107
	2004	150.4	33.0	80.9	279.8	91
	2005	170.6	47.2	67.2	432.8	82
Wilson's Warbler	2000	2.1	97.0	0.4	11.7	1
	2001	10.4	98.9	2.1	51.3	7
	2002	17.4	54.6	6.6	45.7	9
	2003	25.1	52.4	9.8	64.3	15
	2004	21.6	48.6	8.8	53.3	12
	2005	72.0	79.5	16.4	314.9	30

Alpine Tundra Species Density Estimates (Continued)

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Lincoln Sparrow	2000	12.6	98.5	2.3	70.0	7
	2001	29.3	61.0	10.2	84.3	23
	2002	31.2	49.4	13.2	73.8	22
	2003	38.2	57.2	14.1	103.4	30
	2004	51.5	65.0	16.3	162.6	31
	2005	136.0	48.0	55.9	330.9	54
White-crowned Sparrow	2000	88.8	42.8	38.2	206.8	45
	2001	105.6	47.6	44.5	250.3	76
	2002	125.0	40.6	59.6	262.2	86
	2003	134.4	49.3	55.0	328.1	93
	2004	204.9	36.3	103.8	404.5	98
	2005	323.3	40.4	145.7	717.6	120
Dark-eyed Junco	2000	13.8	70.5	3.9	48.9	5
	2001	7.9	77.4	2.2	28.4	4
	2002	7.7	57.5	2.9	20.4	4
	2003	7.9	100.6	1.6	38.5	4
	2004	46.4	78.5	12.2	175.9	20
	2005	38.9	56.4	14.3	105.9	15

[a]D = density estimate in birds/km^2
[b]%CV = coefficient of variation of D
[c]LCL and UCL = lower and upper 95% confidence limits on D
[d]n = number of observations used to estimate D

Aspen Species Density Estimates

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Broad-tailed Hummingbird	2000	85.9	40.1	38.0	194.1	8
	2001	161.0	24.0	98.7	262.7	11
	2002	119.6	17.6	88.8	161.1	13
	2003	147.2	19.1	106.8	203.0	15
	2004	128.8	45.4	45.4	365.9	12
	2005	202.4	31.3	105.0	390.4	20
	2006	64.4	15.4	49.9	83.2	2
Western Wood-pewee	2000	23.0	56.4	8.5	61.9	5
	2001	40.2	52.9	12.2	132.6	7
	2002	31.5	71.4	7.4	134.7	8
	2003	23.6	78.0	4.7	118.9	6
	2004	35.4	41.9	17.5	71.9	9
	2005	43.3	60.2	13.5	138.9	11
	2006	--	--	--	--	0
Warbling Vireo	2000	52.7	20.3	33.9	82.0	18
	2001	76.9	41.0	7.6	780.8	21
	2002	105.4	47.0	29.4	377.8	42
	2003	77.8	41.0	25.4	238.3	31
	2004	80.3	52.4	19.5	330.5	32
	2005	97.9	46.8	27.8	344.5	36
	2006	43.9	6.0	39.8	48.5	5
House Wren	2000	222.5	40.8	95.2	520.2	25
	2001	278.1	53.3	20.7	3,738.9	24
	2002	247.2	35.5	102.6	595.8	35
	2003	233.1	27.5	124.0	438.0	32
	2004	360.2	40.9	130.9	991.4	43
	2005	310.8	27.5	178.5	541.1	33
	2006	321.4	11.5	265.8	388.6	13
American Robin	2000	60.9	35.5	30.9	119.7	9
	2001	50.7	91.3	1.1	2,432.1	5
	2002	86.9	46.5	31.2	242.4	13
	2003	110.1	31.2	61.4	197.7	15
	2004	208.7	44.3	78.5	554.9	31
	2005	69.1	48.7	23.8	200.9	12
	2006	221.4	21.3	155.9	314.4	11

Aspen Species Density Estimates (Continued)

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Mountain Chickadee	2000	114.4	62.0	34.7	377.7	18
	2001	67.8	28.4	41.4	110.8	9
	2002	46.5	28.7	28.7	75.3	9
	2003	67.1	53.6	21.6	208.3	12
	2004	56.8	35.7	30.1	107.3	10
	2005	41.3	76.1	7.9	215.6	6
	2006	36.1	24.5	24.1	54.1	2
Ruby-crowned Kinglet	2000	46.7	33.9	23.2	94.1	24
	2001	24.3	13.6	19.4	30.5	10
	2002	36.7	21.3	23.8	56.5	22
	2003	37.5	36.3	15.6	90.3	23
	2004	48.3	16.8	35.7	65.5	29
	2005	42.9	40.7	16.6	111.4	22
	2006	5.8	12.6	4.7	7.2	1
Yellow-rumped Warbler	2000	135.1	34.4	74.0	246.7	21
	2001	84.5	31.5	45.2	157.7	11
	2002	73.7	42.0	31.5	172.4	14
	2003	42.1	31.7	23.9	74.1	8
	2004	42.1	56.2	12.1	146.5	8
	2005	36.9	39.8	16.8	81.0	7
	2006	18.4	23.4	12.5	27.1	1
Green-tailed Towhee	2000	45.4	53.5	18.0	114.8	8.0
	2001	56.8	63.4	9.3	347.6	9.0
	2002	47.6	72.2	10.6	212.8	11.0
	2003	21.6	65.0	6.4	73.5	4.0
	2004	30.3	52.8	11.2	81.9	7.0
	2005	26.0	63.1	8.0	84.5	4.0
	2006	60.6	32.4	35.6	103.0	4.0
Dark-eyed Junco	2000	162.9	36.6	86.8	305.8	19
	2001	61.1	81.7	2.3	1,656.0	6
	2002	76.8	45.9	30.7	191.9	11
	2003	76.8	33.8	42.5	138.7	11
	2004	55.9	54.0	17.9	174.7	8
	2005	48.9	45.2	21.1	113.0	6
	2006	48.9	25.9	31.9	74.8	2

[a]D = density estimate in birds/km^2
[b]%CV = coefficient of variation of D
[c]LCL and UCL = lower and upper 95% confidence limits on D
[d]n = number of observations used to estimate D

High-elevation Riparian Species Density Estimates

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Mallard	2000	84.2	76.7	25.2	281.1	12
	2001	14.0	86.0	3.5	56.7	1
	2002	105.3	73.1	32.9	336.4	6
	2003	19.8	90.4	5.0	79.0	4
	2004	91.6	43.0	44.0	190.8	14
	2005	133.3	42.1	65.4	271.8	13
	2006	--	--	--	--	0
Spotted Sandpiper	2000	29.1	33.7	16.7	50.8	23
	2001	17.8	68.1	5.7	55.5	11
	2002	24.3	55.2	9.8	60.2	13
	2003	32.4	39.0	17.0	61.9	19
	2004	37.1	37.2	19.9	69.1	24
	2005	25.4	45.8	11.9	54.4	16
	2006	3.8	135.1	0.4	40.2	1
Broad-tailed Hummingbird	2000	371.5	29.1	225.4	612.3	51
	2001	336.5	55.0	128.4	881.5	36
	2002	404.1	27.5	249.4	654.7	47
	2003	490.7	28.0	301.1	799.6	63
	2004	481.4	31.8	274.9	842.9	60
	2005	547.9	25.5	352.7	851.1	60
	2006	553.4	38.9	242.2	1264.4	24
Dusky Flycatcher	2000	10.5	107.7	2.2	50.6	5
	2001	19.6	67.0	6.3	61.5	7
	2002	71.7	42.7	34.0	151.2	29
	2003	114.4	39.3	58.0	225.7	47
	2004	99.9	39.9	49.8	200.7	41
	2005	90.2	44.1	42.2	192.8	38
	2006	26.5	70.5	6.2	114.3	4
Warbling Vireo	2000	12.2	113.5	2.4	62.3	7
	2001	30.3	82.9	7.8	117.5	13
	2002	55.5	68.1	17.9	172.3	27
	2003	42.7	70.7	13.5	135.3	21
	2004	62.2	61.9	22.0	176.2	31
	2005	42.3	66.4	14.2	126.2	21
	2006	--	--	--	--	0

High-elevation Riparian Species Density Estimates (Continued)

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
American Crow	2000	37.4	193.2	4.6	302.5	10
	2001	47.3	195.2	5.8	387.1	9
	2002	2.2	203.7	0.3	18.8	1
	2003	6.2	193.8	0.8	50.6	3
	2004	14.9	197.0	1.8	122.9	7
	2005	28.8	197.5	3.5	238.0	7
	2006	53.1	198.9	6.3	445.9	6
Tree Swallow	2000	157.1	82.6	47.1	524.4	10
	2001	--	--	--	--	0
	2002	290.4	90.7	78.5	1074.4	10
	2003	324.1	82.6	96.8	1085.0	17
	2004	190.3	77.8	60.3	601.0	19
	2005	308.8	74.5	102.1	933.8	18
	2006	141.7	93.0	34.3	585.6	4
Violet-green Swallow	2000	61.7	45.7	29.1	130.7	6
	2001	--	--	--	--	0
	2002	99.8	68.3	33.3	299.4	6
	2003	128.5	60.9	47.3	349.4	7
	2004	44.9	80.5	12.4	162.8	5
	2005	169.8	40.7	86.0	335.1	10
	2006	97.4	71.6	25.7	368.8	3
Ruby-crowned Kinglet	2000	20.6	51.3	8.9	47.7	30
	2001	24.7	43.2	11.9	51.3	27
	2002	29.9	40.1	15.3	58.4	35
	2003	18.3	56.6	7.2	46.6	24
	2004	19.5	35.0	10.9	34.8	24
	2005	29.5	47.9	13.3	65.3	33
	2006	2.2	75.1	0.5	9.4	1
American Robin	2000	65.0	31.0	38.2	110.3	34
	2001	64.4	27.9	39.2	105.7	29
	2002	99.9	24.1	66.1	151.1	43
	2003	66.6	29.0	40.3	110.3	35
	2004	124.5	34.6	67.9	228.2	58
	2005	111.9	22.2	76.7	163.1	52
	2006	36.8	37.5	17.8	76.3	6

High-elevation Riparian Species Density Estimates (Continued)

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Yellow-rumped Warbler	2000	13.2	65.2	4.6	37.6	14
	2001	26.4	51.3	11.1	62.8	21
	2002	13.3	67.2	4.4	40.1	12
	2003	32.5	54.8	13.2	80.3	31
	2004	11.8	58.0	4.5	30.8	11
	2005	27.0	38.0	14.4	50.7	26
	2006	--	--	--	--	0
Wilson's Warbler	2000	75.0	45.3	35.9	156.7	27
	2001	107.0	51.1	45.7	250.5	24
	2002	153.4	49.4	68.0	345.9	35
	2003	159.7	42.7	79.4	321.4	42
	2004	155.2	40.9	79.3	303.6	41
	2005	180.3	42.5	90.0	361.2	44
	2006	52.8	136.0	5.1	545.0	5
Vesper Sparrow	2000	7.2	91.3	1.8	29.0	15
	2001	9.0	112.0	1.7	49.0	14
	2002	1.7	66.7	0.6	5.2	2
	2003	--	--	--	--	0
	2004	7.1	101.8	1.5	33.7	13
	2005	5.8	114.0	1.1	30.8	11
	2006	9.1	87.6	1.6	50.8	6
Savannah Sparrow	2000	41.2	49.3	17.9	94.7	35
	2001	59.8	60.2	21.0	170.3	34
	2002	37.5	68.5	11.9	117.8	22
	2003	69.5	52.8	28.2	171.6	50
	2004	49.5	53.9	19.5	125.3	32
	2005	71.5	59.1	26.4	193.8	48
	2006	249.8	45.6	92.0	678.2	66
Song Sparrow	2000	17.2	32.3	9.9	30.0	9
	2001	68.9	54.9	26.4	179.6	25
	2002	96.8	44.4	44.6	210.1	43
	2003	97.8	41.0	48.1	199.0	44
	2004	93.2	36.1	49.5	175.5	41
	2005	128.5	39.4	65.3	253.0	47
	2006	54.4	67.3	13.4	221.6	9

High-elevation Riparian Species Density Estimates (Continued)

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Lincoln's Sparrow	2000	216.2	19.8	153.0	305.4	125
	2001	185.3	21.6	124.9	274.9	79
	2002	304.8	23.6	199.2	466.3	146
	2003	278.3	18.6	200.3	386.8	143
	2004	398.2	21.3	271.6	583.7	195
	2005	304.1	20.4	211.9	436.5	142
	2006	276.3	45.7	101.2	754.8	48
White-crowned Sparrow	2000	44.0	44.7	20.9	92.5	41
	2001	39.6	83.3	10.2	153.2	28
	2002	33.7	56.8	13.0	87.6	27
	2003	35.3	62.1	12.7	98.3	30
	2004	15.1	53.6	6.1	37.3	13
	2005	32.7	57.5	12.6	84.9	24
	2006	6.5	45.1	2.7	15.7	2
Dark-eyed Junco	2000	8.9	70.2	2.9	27.6	14
	2001	11.1	51.0	4.6	26.8	13
	2002	6.0	75.4	1.8	20.6	8
	2003	7.8	63.9	2.7	22.4	11
	2004	17.3	59.8	6.4	47.4	19
	2005	21.8	63.4	7.7	62.0	22
	2006	10.1	73.4	2.3	44.5	5
Red-winged Blackbird	2000	31.3	64.7	11.0	88.9	22
	2001	3.6	65.6	1.2	11.0	2
	2002	48.0	45.4	22.5	102.5	26
	2003	33.3	63.4	11.7	94.3	20
	2004	35.4	55.0	14.0	89.6	23
	2005	38.9	57.3	15.0	100.8	23
	2006	--	--	--	--	0
Brown-headed Cowbird	2000	18.8	49.5	8.3	42.5	8
	2001	16.9	79.5	4.8	59.8	6
	2002	34.4	48.0	15.2	77.8	14
	2003	30.2	46.6	13.8	65.8	11
	2004	40.2	34.3	22.6	71.5	15
	2005	48.3	38.8	25.4	91.8	15
	2006	26.4	41.8	11.6	59.9	4

High-elevation Riparian Species Density Estimates (Continued)

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Pine Siskin	2000	38.5	52.9	16.3	91.0	13
	2001	21.2	58.7	7.9	57.0	7
	2002	50.7	53.4	20.9	122.8	14
	2003	27.7	64.6	9.8	78.4	7
	2004	28.2	56.8	11.0	72.3	9
	2005	54.9	44.3	26.4	114.1	16
	2006	42.9	77.3	10.1	183.3	4

[a]D = density estimate in birds/km^2
[b]%CV = coefficient of variation of D
[c]LCL and UCL = lower and upper 95% confidence limits on D
[d]n = number of observations used to estimate D

Lodgepole Pine Species Density Estimates

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Broad-tailed Hummingbird	2000	32.7	101.1	5.6	192.0	4
	2001	19.6	84.0	5.1	76.2	4
	2002	43.2	47.1	20.3	92.1	9
	2003	19.6	89.9	4.6	83.0	4
	2004	59.6	61.8	21.9	162.1	11
	2005	57.6	47.9	26.7	124.5	12
	2006	--	--	--	--	0
Warbling Vireo	2000	12.5	57.7	3.8	40.8	8
	2001	10.3	52.5	4.0	26.8	11
	2002	10.1	46.9	4.4	23.4	10
	2003	9.4	58.1	3.3	26.8	10
	2004	10.5	65.1	3.3	33.5	11
	2005	9.2	70.2	2.6	31.9	10
	2006	--	--	--	--	0
Mountain Chickadee	2000	85.2	20.9	60.0	121.0	19
	2001	58.1	24.8	37.6	89.8	25
	2002	75.0	21.8	51.7	108.8	29
	2003	55.8	20.4	39.6	78.5	21
	2004	89.3	22.7	60.6	131.5	31
	2005	65.9	30.5	38.4	113.3	26
	2006	139.4	14.6	109.6	177.3	10
Ruby-crowned Kinglet	2000	80.1	25.6	47.5	135.3	30
	2001	101.0	26.8	61.4	166.2	62
	2002	138.0	16.7	103.2	184.5	85
	2003	139.5	12.3	113.7	171.0	86
	2004	167.0	21.0	114.1	244.4	102
	2005	109.8	21.2	74.6	161.4	70
	2006	153.9	10.5	129.4	183.0	16
American Robin	2000	57.1	66.5	14.7	221.8	14
	2001	36.7	37.2	18.9	71.4	14
	2002	26.4	29.4	15.7	44.3	11
	2003	34.3	40.9	16.3	72.0	14
	2004	74.3	47.0	31.7	174.1	28
	2005	69.5	28.1	42.5	113.5	28
	2006	29.4	16.7	22.3	38.7	2

Lodgepole Pine Species Density Estimates (Continued)

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Yellow-rumped Warbler	2000	87.8	24.6	55.1	140.0	33
	2001	68.7	27.9	41.5	113.7	43
	2002	87.5	29.4	51.3	149.1	54
	2003	105.4	19.9	74.9	148.2	65
	2004	114.6	19.0	83.0	158.4	70
	2005	75.0	24.7	48.4	116.2	48
	2006	201.2	13.8	160.4	252.3	21
Dark-eyed Junco	2000	101.2	42.1	45.3	226.1	26
	2001	42.7	37.2	22.3	81.8	19
	2002	58.4	24.8	38.8	88.1	27
	2003	85.4	24.7	56.9	128.3	37
	2004	152.9	30.7	90.6	257.9	66
	2005	114.4	38.4	58.4	223.9	48
	2006	229.3	22.1	159.9	328.8	15
Pine Siskin	2000	8.7	57.8	2.6	29.1	2
	2001	10.5	52.1	4.0	27.2	4
	2002	41.0	34.6	21.9	76.6	15
	2003	26.2	36.4	13.7	50.2	9
	2004	45.0	55.7	16.3	124.5	17
	2005	43.6	46.8	18.7	101.7	14
	2006	78.6	14.6	61.7	100.1	5
Red Crossbill	2000	5.1	104.9	0.7	36.2	1
	2001	6.1	67.0	1.9	19.8	2
	2002	24.0	39.3	12.1	47.5	8
	2003	21.4	91.7	4.9	93.4	3
	2004	105.3	49.3	44.6	249.0	23
	2005	33.0	58.4	12.5	87.0	8
	2006	36.8	22.0	25.5	53.0	2

[a]D = density estimate in birds/km^2
[b]%CV = coefficient of variation of D
[c]LCL and UCL = lower and upper 95% confidence limits on D
[d]n = number of observations used to estimate D

Ponderosa Pine Species Density Estimates

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Broad-tailed Hummingbird	2000	570.1	20.3	399.4	813.8	54
	2001	460.0	22.4	310.6	681.1	72
	2002	411.0	24.2	270.8	623.8	78
	2003	508.2	17.5	376.6	685.7	79
	2004	313.3	33.9	173.8	564.8	56
	2005	706.5	20.5	495.1	1,008.2	95
	2006	374.8	48.0	33.9	4,147.4	15
Western Wood-pewee	2000	74.7	19.5	53.8	103.8	36
	2001	54.2	29.2	32.5	90.1	45
	2002	25.2	32.2	14.5	43.9	28
	2003	60.3	26.6	38.2	95.3	46
	2004	55.0	22.4	37.7	80.2	51
	2005	66.4	24.3	43.6	101.0	48
	2006	55.8	21.8	33.4	93.3	12
Hammond's Flycatcher	2000	15.5	30.4	9.1	26.4	8
	2001	7.1	47.8	3.1	16.3	6
	2002	11.5	58.9	4.3	30.8	13
	2003	16.3	54.4	6.4	41.6	13
	2004	25.7	33.7	14.5	45.6	23
	2005	20.2	36.3	10.6	38.5	17
	2006	4.6	101.2	0.0	619.6	1
Dusky Flycatcher	2000	--	--	--	--	0
	2001	3.2	117.8	0.5	18.5	1
	2002	19.1	52.8	7.8	46.5	8
	2003	25.0	56.8	9.4	66.7	8
	2004	51.2	39.2	26.2	99.9	18
	2005	93.8	51.4	38.0	231.6	26
	2006	--	--	--	--	0
Cordilleran Flycatcher	2000	25.6	50.7	11.4	57.3	6
	2001	52.2	60.1	20.2	135.2	20
	2002	23.5	68.6	8.1	68.3	12
	2003	43.7	60.1	16.9	113.0	17
	2004	8.8	71.6	2.9	26.9	4
	2005	14.9	69.6	4.9	45.1	6
	2006	70.7	43.7	35.0	142.7	7

Ponderosa Pine Species Density Estimates (Continued)

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Warbling Vireo	2000	14.3	50.0	6.2	33.2	11
	2001	13.5	54.8	5.4	33.7	17
	2002	16.7	56.1	6.7	41.7	27
	2003	9.4	58.3	3.6	24.8	12
	2004	18.2	53.3	7.6	43.5	26
	2005	18.2	46.2	8.4	39.3	21
	2006	--	--	--	--	0
Steller's Jay	2000	27.2	30.6	16.1	45.8	12
	2001	23.6	31.8	13.8	40.3	16
	2002	10.4	46.5	4.8	22.6	9
	2003	32.7	32.1	19.3	55.6	19
	2004	30.7	31.5	18.2	51.8	24
	2005	48.8	35.4	26.6	89.5	31
	2006	32.2	101.9	0.3	3,627.4	6
Black-billed Magpie	2000	32.6	140.6	5.7	187.9	10
	2001	6.6	128.6	1.3	34.5	5
	2002	6.5	147.2	1.1	38.6	9
	2003	17.0	130.1	3.2	89.4	11
	2004	21.4	130.8	4.0	113.1	10
	2005	31.6	125.1	6.3	159.5	16
	2006	15.4	156.1	1.7	136.0	1
Tree Swallow	2000	99.1	29.7	59.7	164.8	14
	2001	57.7	42.9	27.5	120.9	13
	2002	21.3	46.7	9.7	46.6	10
	2003	98.4	39.0	49.9	194.0	21
	2004	74.5	40.9	37.3	148.8	16
	2005	98.1	41.3	47.1	204.5	19
	2006	31.6	105.0	0.5	1,926.2	3
Violet-green Swallow	2000	78.0	75.5	21.9	277.3	12
	2001	66.8	58.5	24.5	182.0	18
	2002	41.1	42.8	20.1	84.2	13
	2003	103.4	37.8	53.9	198.4	28
	2004	125.3	38.1	65.4	240.0	30
	2005	49.9	39.8	24.8	100.6	18
	2006	101.5	23.9	65.0	158.6	7

Ponderosa Pine Species Density Estimates (Continued)

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Mountain Chickadee	2000	44.8	25.2	29.1	68.7	21
	2001	63.5	43.5	29.8	135.3	48
	2002	26.1	38.6	13.6	50.2	23
	2003	38.0	27.8	23.6	60.9	28
	2004	38.0	25.0	25.0	57.6	33
	2005	34.3	32.0	19.8	59.6	23
	2006	96.3	81.7	1.8	5,034.5	20
Red-breasted Nuthatch	2000	4.1	50.7	1.7	10.2	3
	2001	10.1	41.6	4.9	20.9	12
	2002	5.7	39.2	2.9	11.1	9
	2003	9.1	61.5	3.2	26.1	11
	2004	15.0	61.1	5.4	41.3	18
	2005	6.4	34.8	3.5	11.7	7
	2006	6.5	101.3	0.0	859.8	2
White-breasted Nuthatch	2000	48.0	34.0	26.9	85.8	20
	2001	30.9	51.4	12.8	74.3	21
	2002	17.6	32.7	10.2	30.4	16
	2003	11.6	45.0	5.4	24.7	7
	2004	17.4	35.2	9.7	31.3	13
	2005	27.0	34.8	14.9	48.8	20
	2006	22.7	54.1	2.9	179.7	4
Pygmy Nuthatch	2000	95.0	33.1	53.9	167.4	19
	2001	40.2	38.5	20.9	77.4	13
	2002	9.4	55.8	3.8	23.5	7
	2003	17.6	89.1	4.2	73.1	7
	2004	53.0	50.0	22.9	122.6	17
	2005	93.5	36.9	49.7	176.2	27
	2006	95.1	47.9	18.7	484.4	7
House Wren	2000	68.2	38.2	34.1	136.5	32
	2001	58.7	36.8	30.8	112.0	41
	2002	50.7	24.6	33.2	77.6	52
	2003	70.5	22.4	47.8	104.1	52
	2004	98.3	23.3	65.8	146.7	84
	2005	100.4	29.2	59.3	170.1	77
	2006	141.2	28.7	49.7	401.4	27

Ponderosa Pine Species Density Estimates (Continued)

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Ruby-crowned Kinglet	2000	22.9	33.5	12.7	41.6	12
	2001	22.2	32.8	12.5	39.4	19
	2002	29.8	35.6	16.2	54.8	34
	2003	43.7	39.9	21.7	88.0	37
	2004	83.2	33.0	47.4	146.2	76
	2005	72.3	57.0	26.5	197.3	58
	2006	4.5	101.2	0.0	615.4	1
Mountain Bluebird	2000	38.9	52.6	15.8	96.0	10
	2001	29.8	53.3	11.9	74.6	14
	2002	13.4	56.5	5.2	34.5	9
	2003	35.1	32.8	20.3	60.6	14
	2004	52.1	36.9	27.8	97.5	28
	2005	69.8	29.8	41.8	116.6	28
	2006	61.4	74.3	2.3	1,634.8	7
Townsend's Solitaire	2000	18.0	49.9	7.6	42.5	7
	2001	27.5	35.7	14.9	50.8	20
	2002	22.6	31.7	13.3	38.5	21
	2003	29.7	36.1	16.0	55.3	22
	2004	38.4	30.3	23.1	63.9	33
	2005	28.7	27.4	18.1	45.8	22
	2006	42.5	102.4	0.4	4,169.9	7
American Robin	2000	106.4	23.6	70.3	160.9	45
	2001	46.9	31.5	26.8	82.0	36
	2002	47.8	32.3	27.3	83.6	46
	2003	62.7	22.8	42.3	93.0	44
	2004	87.1	18.0	64.4	117.9	76
	2005	113.9	23.3	75.9	171.0	72
	2006	40.3	27.8	14.9	109.1	8
Yellow-rumped Warbler	2000	74.1	24.5	48.0	114.3	33
	2001	39.8	33.9	21.9	72.5	28
	2002	33.9	35.2	18.5	62.4	33
	2003	75.6	28.9	45.8	125.0	52
	2004	75.6	19.9	54.1	105.6	61
	2005	98.0	28.2	59.3	162.0	68
	2006	42.5	51.6	3.4	527.1	8

Ponderosa Pine Species Density Estimates (Continued)

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Western Tanager	2000	31.3	32.8	17.6	55.7	11
	2001	17.7	32.6	9.9	31.5	12
	2002	26.5	36.6	14.0	49.9	24
	2003	34.7	23.8	23.0	52.4	23
	2004	27.4	25.6	17.8	42.4	19
	2005	9.8	23.4	6.5	14.8	7
	2006	56.9	81.0	0.9	3,529.4	10
Green-tailed Towhee	2000	64.2	55.8	23.8	172.8	59
	2001	32.7	30.1	19.3	55.5	50
	2002	17.1	34.9	9.4	31.3	35
	2003	25.7	29.4	15.4	43.1	40
	2004	33.8	26.8	21.4	53.5	54
	2005	30.5	40.1	14.9	62.6	43
	2006	50.6	51.8	4.3	598.7	20
Chipping Sparrow	2000	35.8	41.4	17.3	74.2	15
	2001	54.7	27.7	34.1	87.8	37
	2002	43.0	25.3	28.2	65.7	39
	2003	30.9	42.1	14.9	64.1	20
	2004	34.9	34.4	19.4	62.6	28
	2005	29.9	48.7	12.7	70.7	21
	2006	37.0	21.8	24.2	56.8	7
Dark-eyed Junco	2000	83.2	53.8	34.6	200.0	22
	2001	41.7	44.0	20.6	84.4	17
	2002	48.5	49.3	22.0	106.7	24
	2003	41.0	47.1	19.2	87.2	16
	2004	60.8	46.2	29.0	127.1	29
	2005	160.7	45.1	77.6	332.6	62
	2006	116.3	91.4	4.7	2,862.8	13
Pine Siskin	2000	28.1	50.3	12.2	64.7	5
	2001	158.1	40.7	81.8	305.7	30
	2002	25.7	43.0	12.8	51.5	9
	2003	64.2	37.7	34.9	118.1	17
	2004	34.9	55.5	14.4	84.9	10
	2005	71.9	38.8	38.1	135.5	22
	2006	53.2	58.4	10.1	280.9	4

[a]D = density estimate in birds/km^2
[b]%CV = coefficient of variation of D
[c]LCL and UCL = lower and upper 95% confidence limits on D
[d]n = number of observations used to estimate D

Spruce-fir Species Density Estimates

Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Mountain Chickadee	2000	40.1	35.4	20.7	77.6	21
	2001	35.3	48.7	14.0	89.1	19
	2002	43.6	36.4	23.3	81.8	22
	2003	161.5	33.9	93.3	279.6	80
	2004	97.6	24.1	65.1	146.5	49
	2005	49.6	37.4	24.8	99.4	24
Red-breasted Nuthatch	2000	6.7	100.0	1.2	38.1	4
	2001	9.8	51.9	3.7	25.9	6
	2002	20.9	39.3	10.6	41.4	15
	2003	28.0	32.1	16.1	48.9	23
	2004	22.4	41.7	10.7	47.2	15
	2005	16.7	74.3	4.3	64.8	9
Golden-crowned Kinglet	2000	16.6	66.8	4.7	58.9	3
	2001	10.8	101.0	1.8	63.3	2
	2002	24.6	56.6	9.3	64.9	4
	2003	117.5	41.7	55.7	247.7	27
	2004	153.7	48.1	63.6	371.3	29
	2005	--	--	--	--	0
Ruby-crowned Kinglet	2000	83.2	43.9	35.2	197.0	47
	2001	98.2	38.9	45.8	210.8	57
	2002	105.8	38.1	52.9	211.6	78
	2003	98.2	17.8	72.3	133.6	75
	2004	125.3	31.6	69.6	225.3	83
	2005	182.4	22.0	122.0	272.8	86
Hermit Thrush	2000	12.9	49.2	5.1	32.6	14
	2001	7.2	46.2	3.0	17.1	8
	2002	19.8	42.2	9.4	41.4	29
	2003	19.6	40.9	9.5	40.1	29
	2004	62.0	23.5	41.9	91.9	80
	2005	36.0	32.0	20.4	63.6	34
American Robin	2000	58.0	54.9	20.9	161.1	17
	2001	43.0	42.1	19.4	95.4	16
	2002	20.4	48.4	8.6	48.0	10
	2003	82.6	37.6	42.6	160.2	36
	2004	55.6	49.0	22.9	135.2	22
	2005	74.5	42.8	33.4	166.4	24

Spruce-fir Species Density Estimates (Continued)

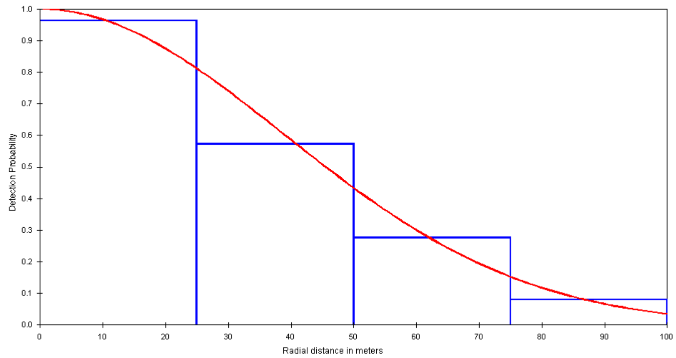
Species	Year	D[a]	%CV[b]	LCL[c]	UCL[c]	n[d]
Yellow-rumped Warbler	2000	62.4	29.1	35.0	111.1	36
	2001	68.9	38.0	32.2	147.5	42
	2002	47.2	36.5	24.1	92.6	37
	2003	109.5	18.6	78.3	153.1	87
	2004	106.1	23.3	68.4	164.5	75
	2005	99.5	33.1	51.4	192.3	55
Dark-eyed Junco	2000	65.7	41.6	29.4	147.0	32
	2001	42.0	36.6	20.8	84.8	21
	2002	45.4	30.0	26.6	77.5	29
	2003	113.9	17.0	85.8	151.2	72
	2004	160.2	18.4	117.3	218.8	91
	2005	102.7	23.1	67.9	155.3	47
Pine Grosbeak	2000	12.8	80.8	3.4	47.5	5
	2001	5.0	109.7	0.9	28.3	2
	2002	11.3	80.4	3.3	39.2	5
	2003	28.0	53.5	12.0	65.1	14
	2004	25.7	56.5	10.5	62.7	10
	2005	20.4	56.2	8.4	49.6	6
Pine Siskin	2000	40.7	102.1	7.2	229.7	9
	2001	27.7	54.5	10.8	70.9	5
	2002	60.0	35.7	33.3	108.0	16
	2003	53.4	38.8	28.0	101.7	16
	2004	75.0	39.5	38.8	145.3	19
	2005	12.2	107.0	2.1	69.3	2

[a]D = density estimate in birds/km^2
[b]%CV = coefficient of variation of D
[c]LCL and UCL = lower and upper 95% confidence limits on D
[d]n = number of observations used to estimate D

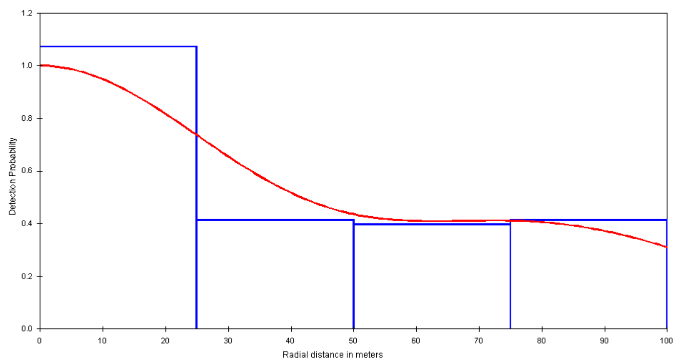
Appendix B – Species Detection Functions by Habitat Type

Alpine Tundra

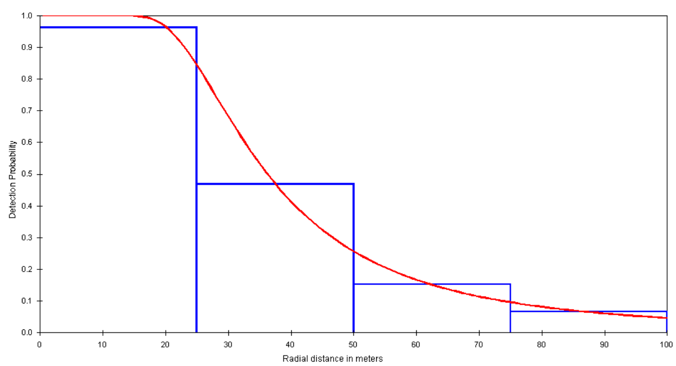
Horned Lark – Half Normal Cosine



Ruby-crowned Kinglet – Half Normal Cosine

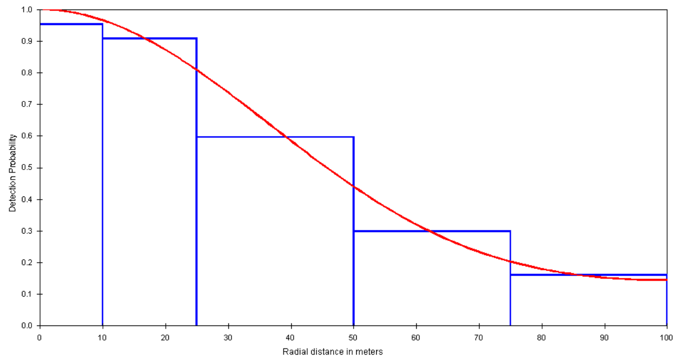


American Robin – Hazard Cosine

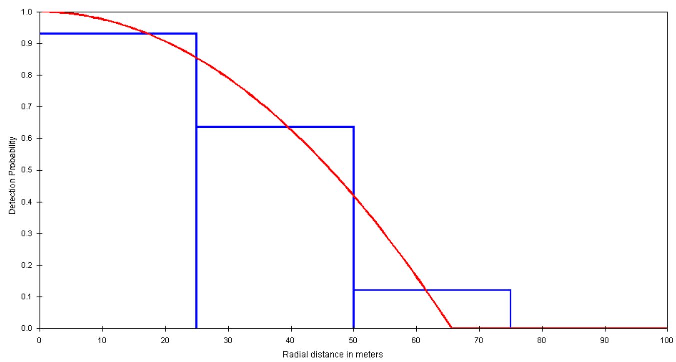


Alpine Tundra (Continued)

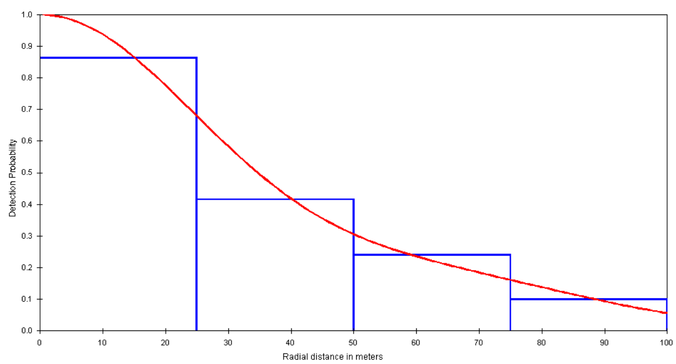
American Pipit – Uniform Cosine



Wilson's Warbler – Uniform Simple

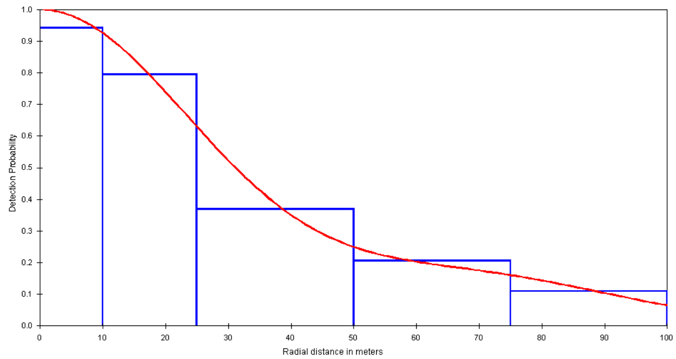


Lincoln's Sparrow – Half Normal Cosine

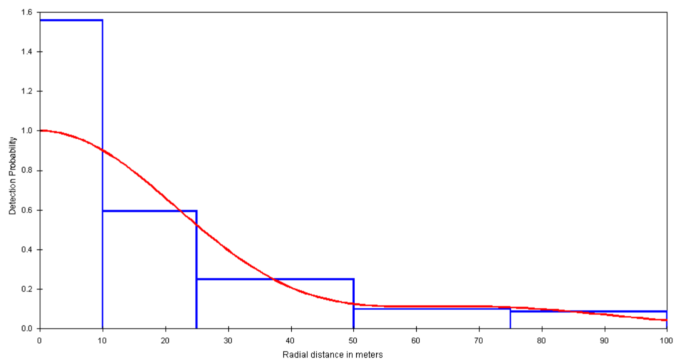


Alpine Tundra (Continued)

White-crowned Sparrow – Half Normal Cosine

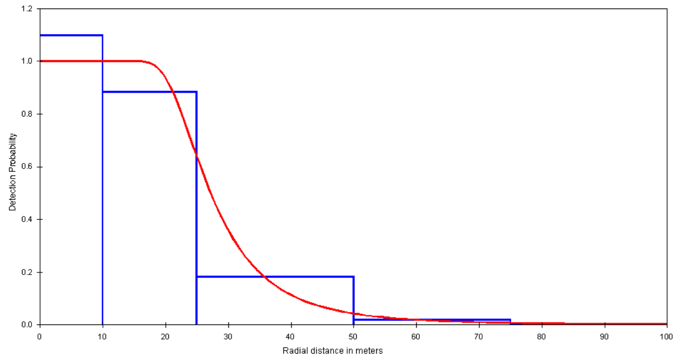


Dark-eyed Junco – Half Normal Cosine

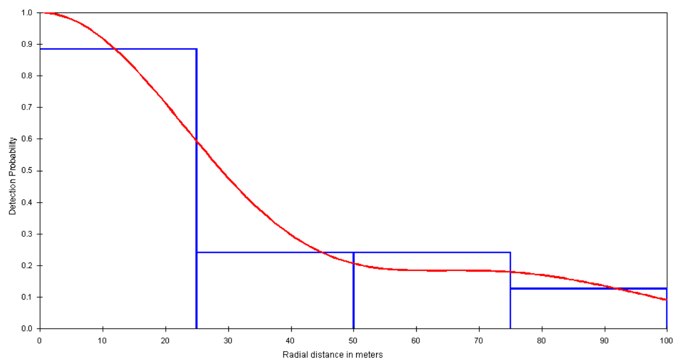


Aspen

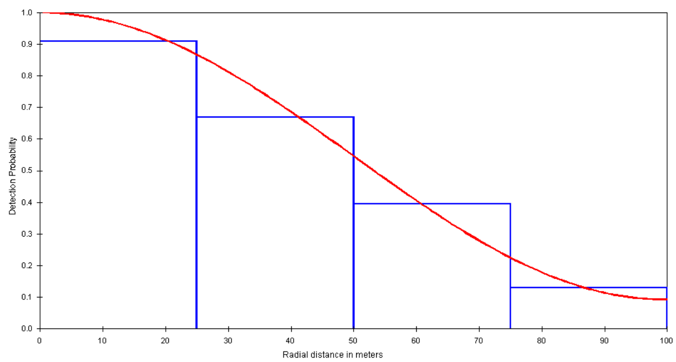
Broad-tailed Hummingbird – Hazard Cosine



Western Wood-pewee – Half Normal Cosine

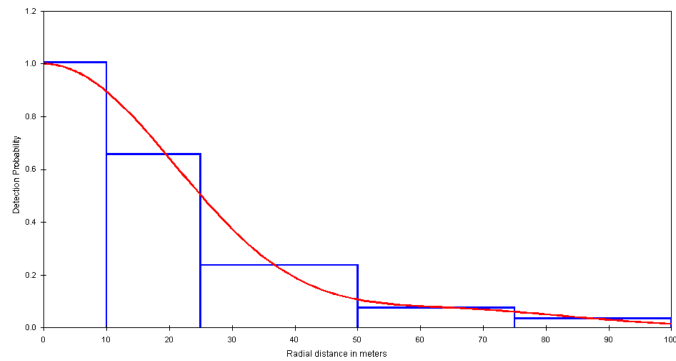


Warbling Vireo – Uniform Cosine

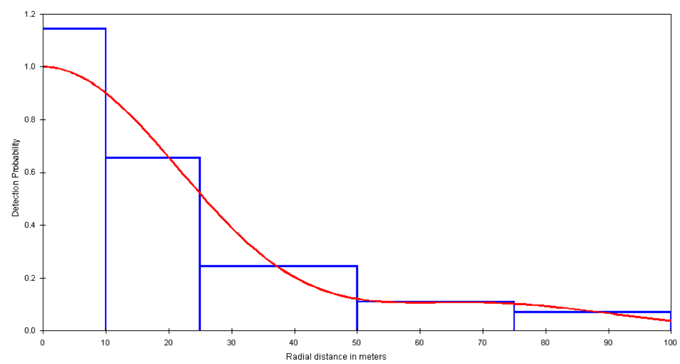


Aspen (Continued)

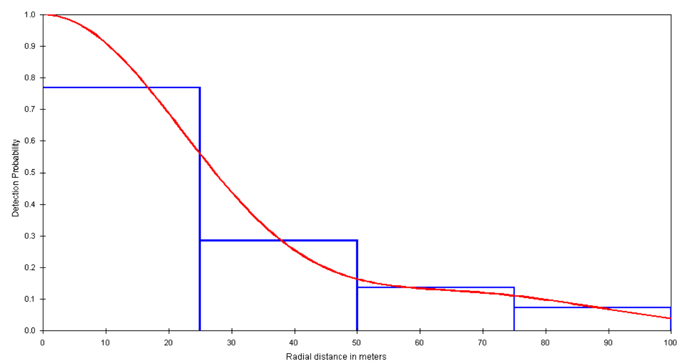
House Wren – Half Normal Cosine



American Robin – Half Normal Cosine

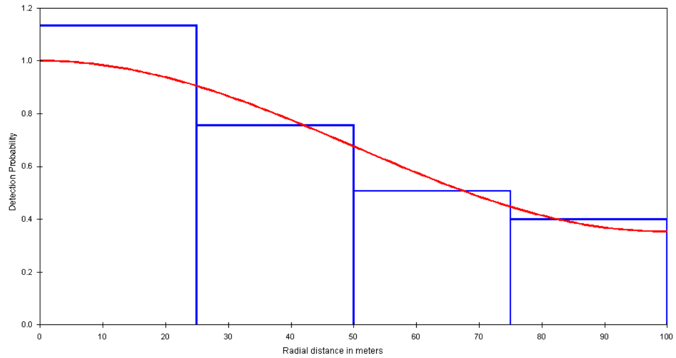


Mountain Chickadee – Half Normal Cosine

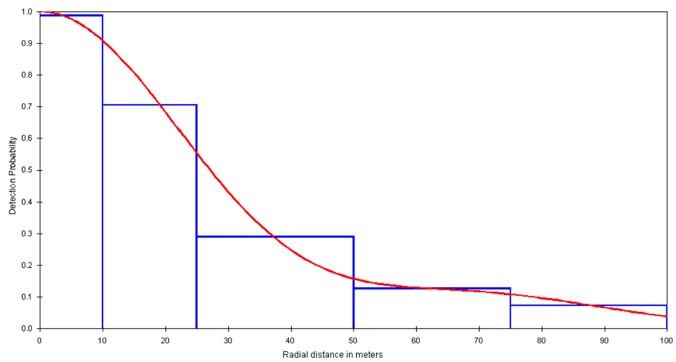


Aspen (Continued)

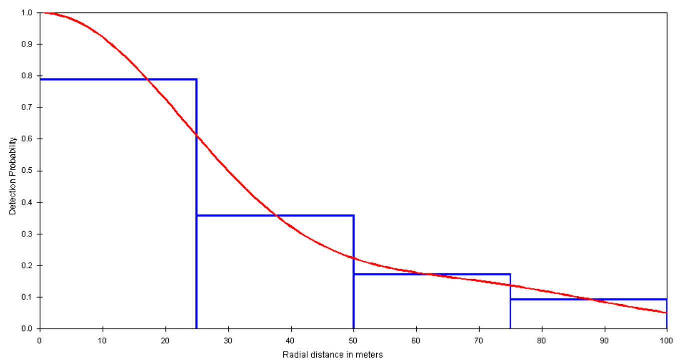
Ruby-crowned Kinglet – Uniform Cosine



Yellow-rumped Warbler – Half Normal Cosine

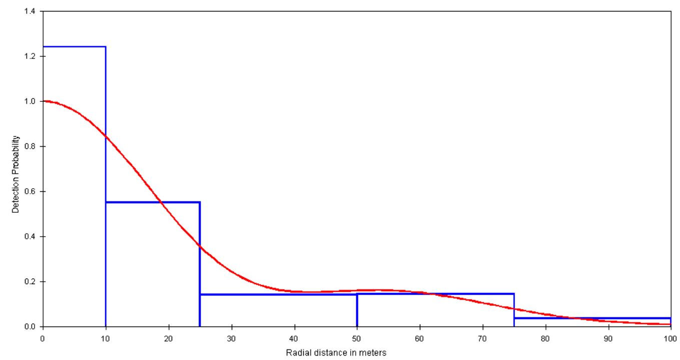


Green-tailed Towhee – Half Normal Cosine



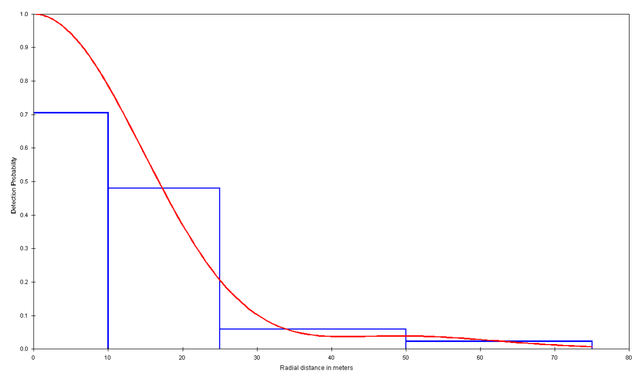
Aspen (Continued)

Dark-eyed Junco – Half Normal Cosine

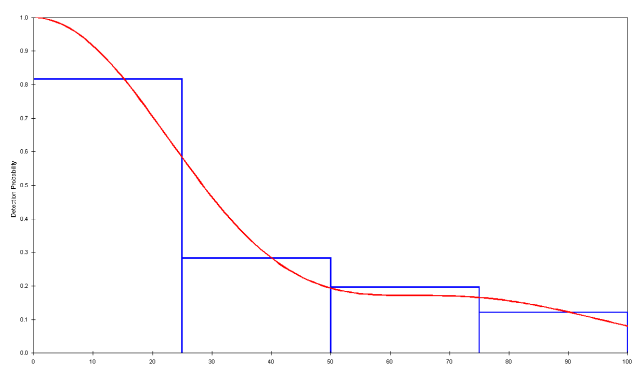


High-elevation Riparian

Mallard – Half Normal Cosine

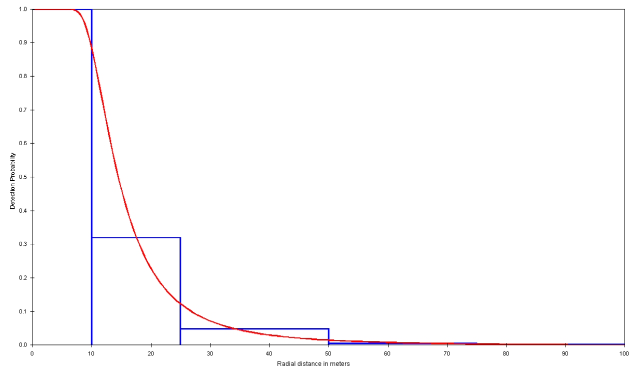


Spotted Sandpiper – Half Normal Cosine

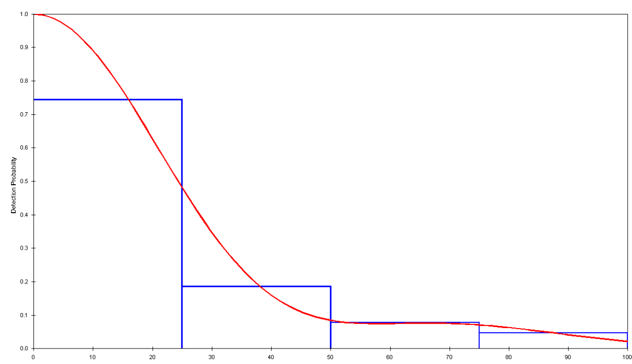


High-elevation Riparian (Continued)

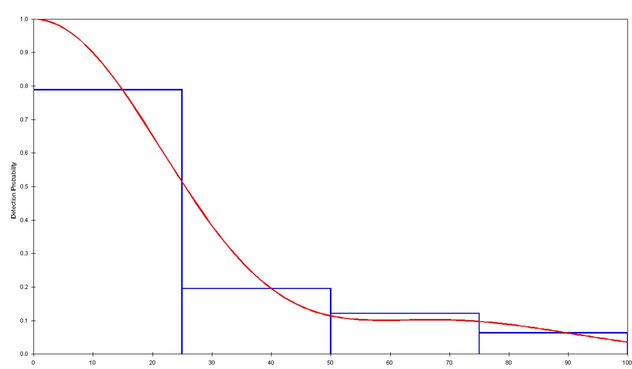
Broad-tailed Hummingbird – Hazard Simple



Dusky Flycatcher – Half Normal Cosine

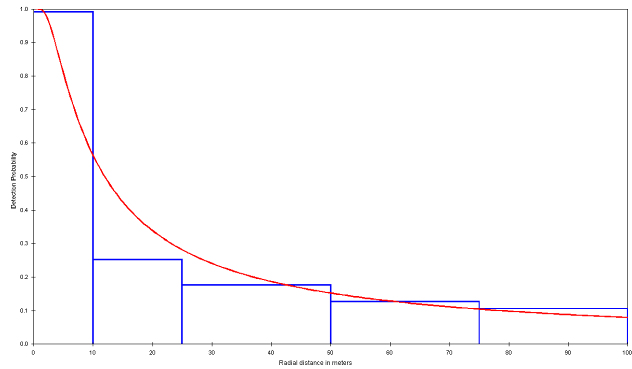


Warbling Vireo – Half Normal Cosine

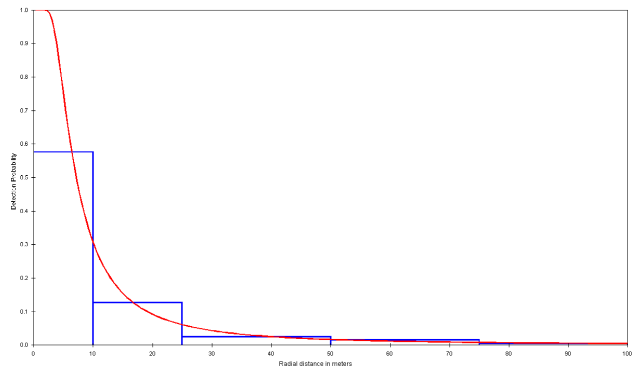


High-elevation Riparian (Continued)

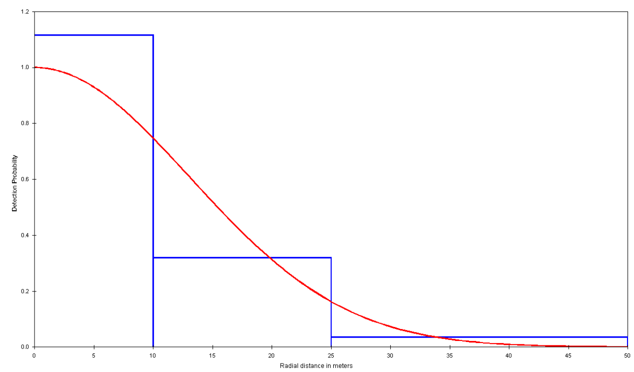
American Crow – Hazard Cosine



Tree Swallow – Hazard Cosine

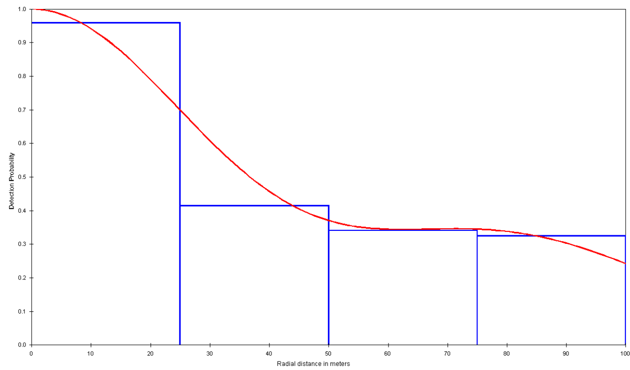


Violet-green Swallow – Half Normal Cosine

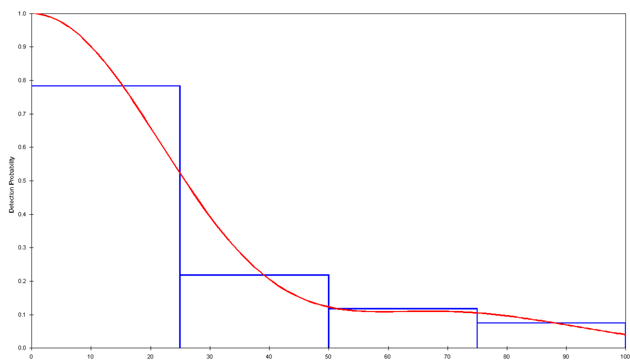


High-elevation Riparian (Continued)

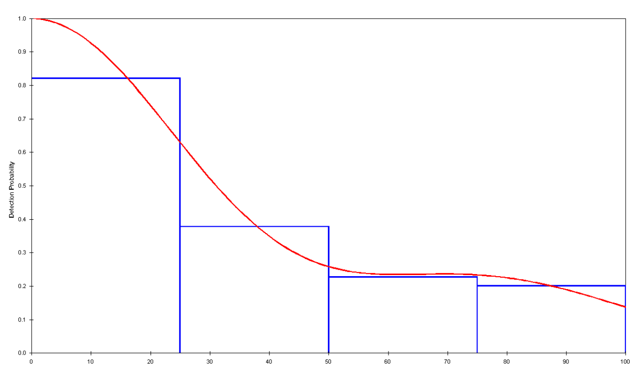
Ruby-crowned Kinglet – Half Normal Cosine



American Robin – Half Normal Cosine

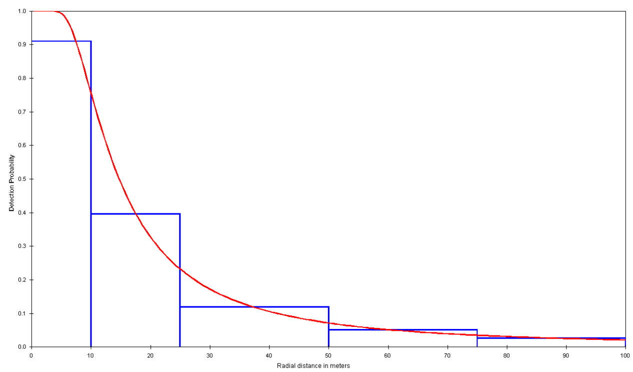


Yellow-rumped Warbler – Half Normal Cosine

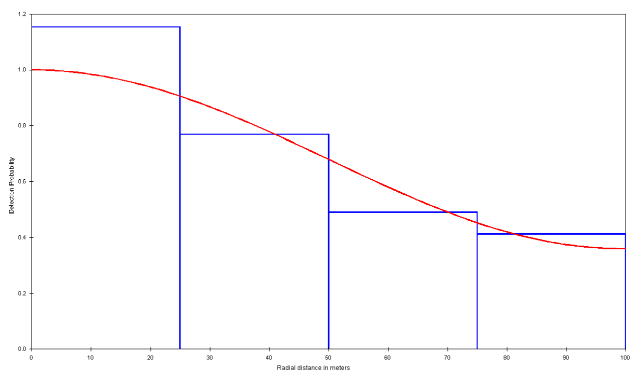


High-elevation Riparian (Continued)

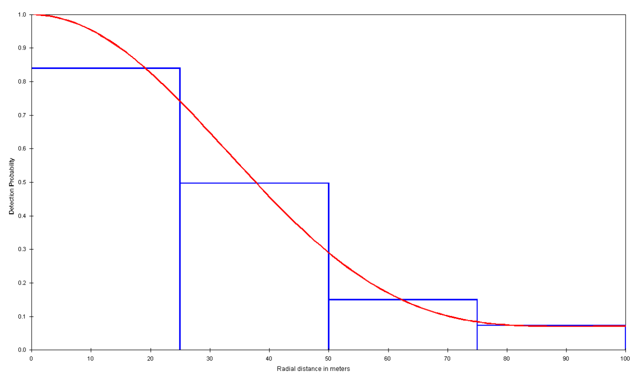
Wilson's Warbler – Hazard Cosine



Vesper Sparrow – Uniform Cosine

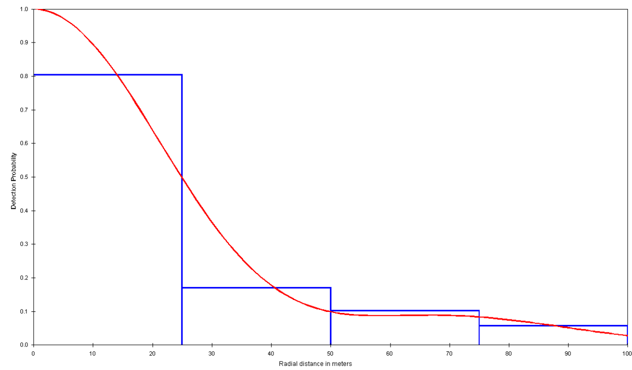


Savannah Sparrow – Uniform Cosine

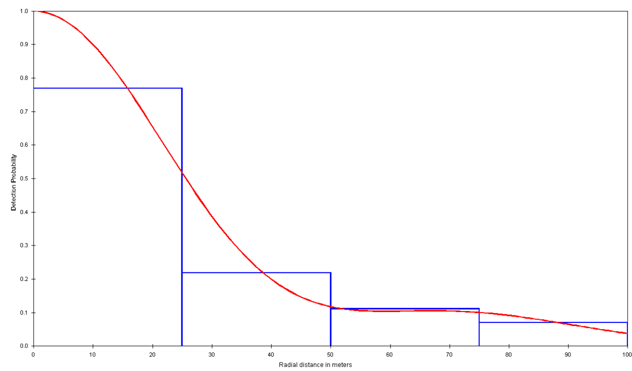


High-elevation Riparian (Continued)

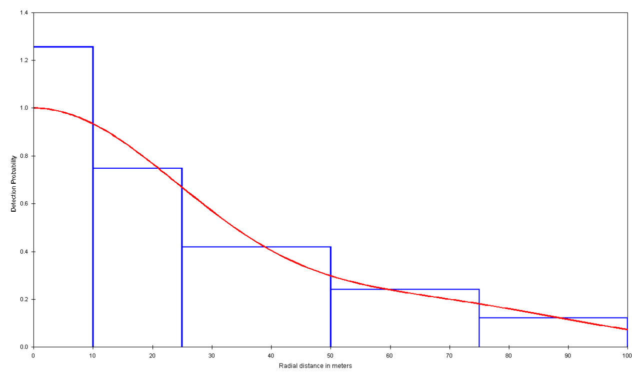
Song Sparrow – Half Normal Cosine with 1 adjustment term



Lincoln's Sparrow – Half Normal Cosine with 1 adjustment term

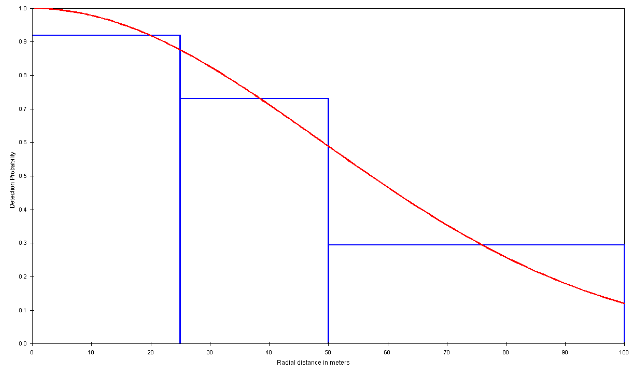


White-crowned Sparrow – Half Normal Cosine

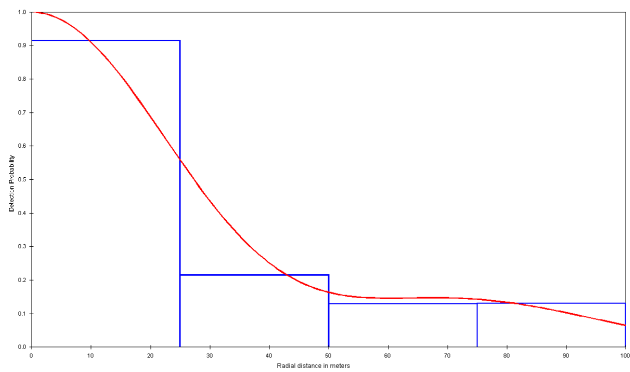


High-elevation Riparian (Continued)

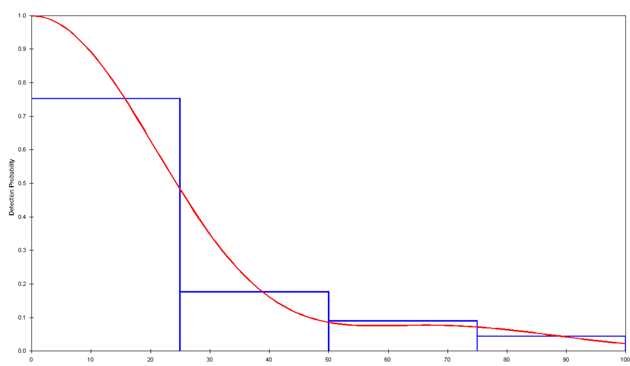
Dark-eyed Junco – Half Normal Cosine



Red-winged Blackbird – Half Normal Cosine

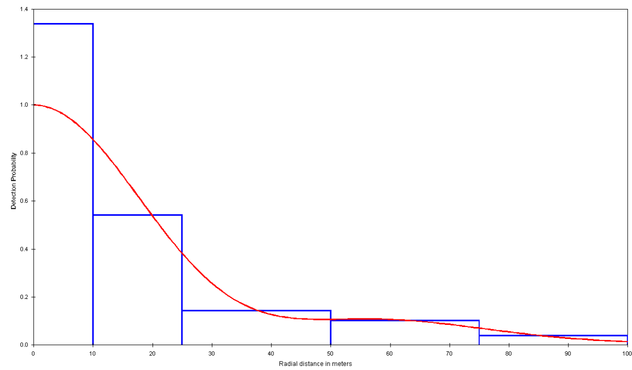


Brown-headed Cowbird – Half Normal Cosine



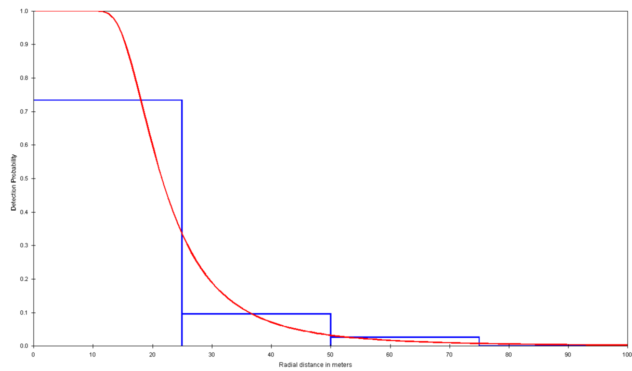
High-elevation Riparian (Continued)

Pine Siskin – Half Normal Cosine

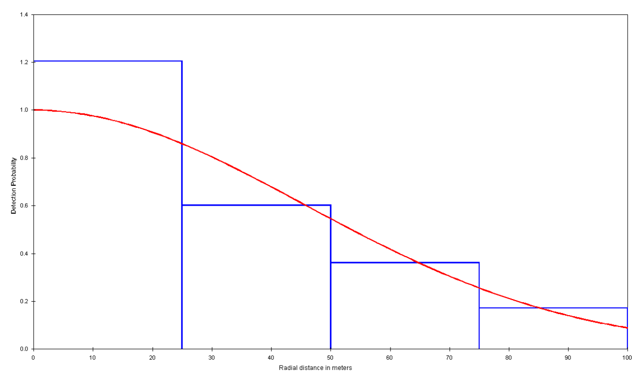


Lodgepole Pine

Broad-tailed Hummingbird – Hazard Cosine

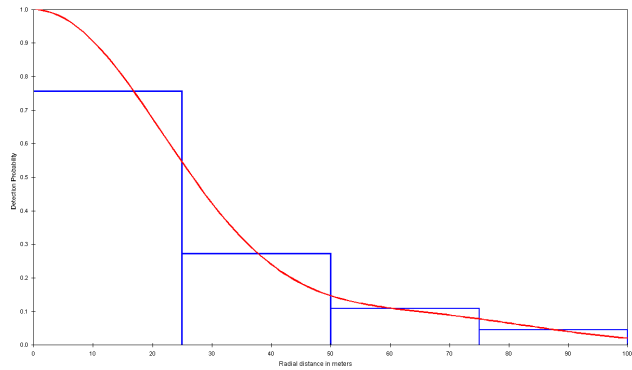


Warbling Vireo – Half Normal Cosine

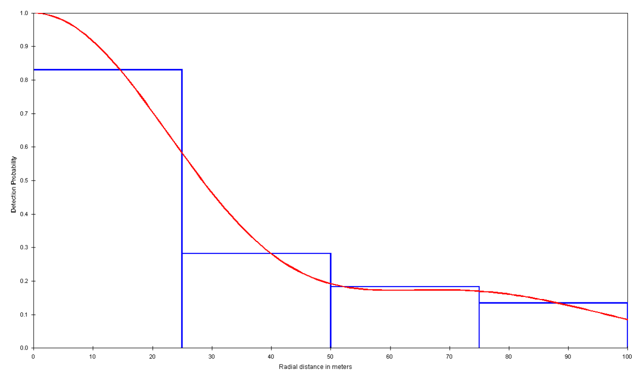


Lodgepole Pine (Continued)

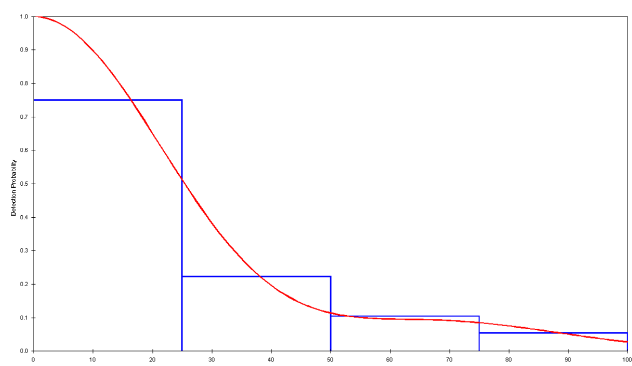
Mountain Chickadee – Half Normal Cosine



Ruby-crowned Kinglet – Half Normal Cosine

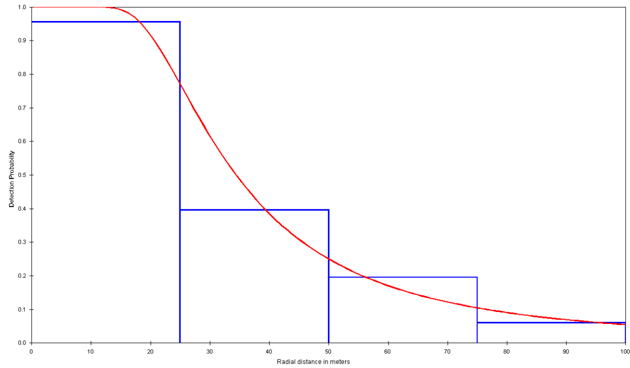


American Robin – Half Normal Cosine

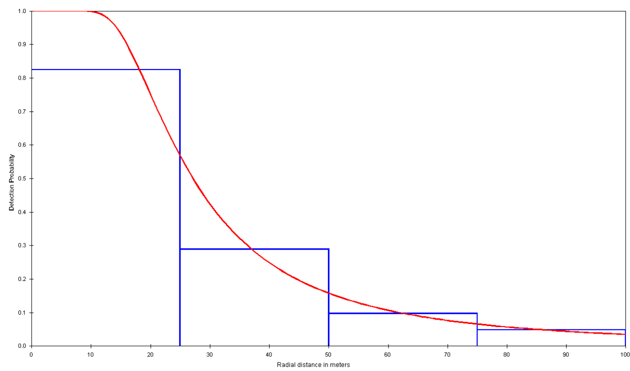


Lodgepole Pine (Continued)

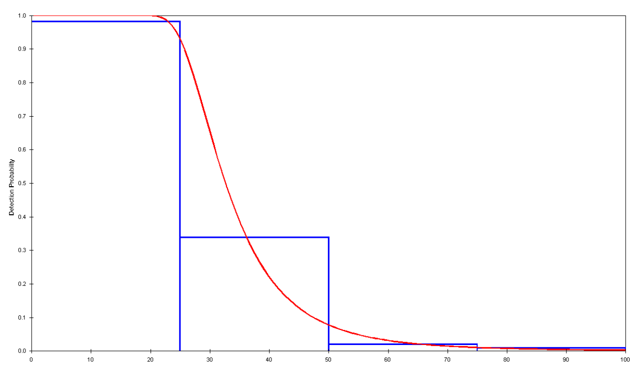
Yellow-rumped Warbler – Hazard Cosine



Dark-eyed Junco – Hazard Cosine

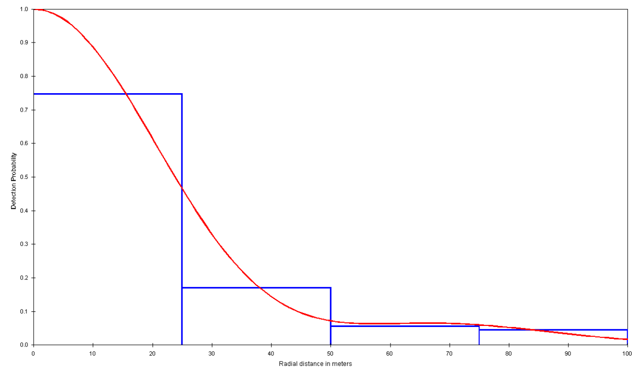


Pine Siskin – Hazard Cosine



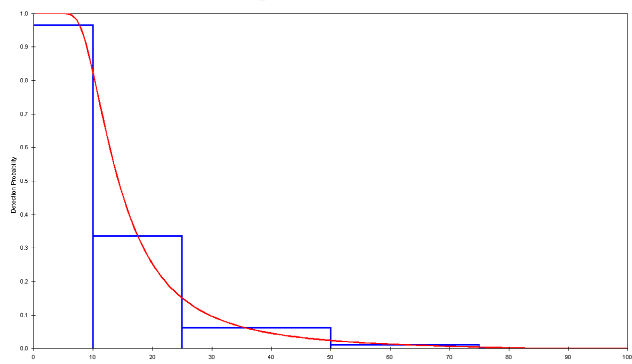
Lodgepole Pine (Continued)

Red Crossbill – Half Normal Cosine

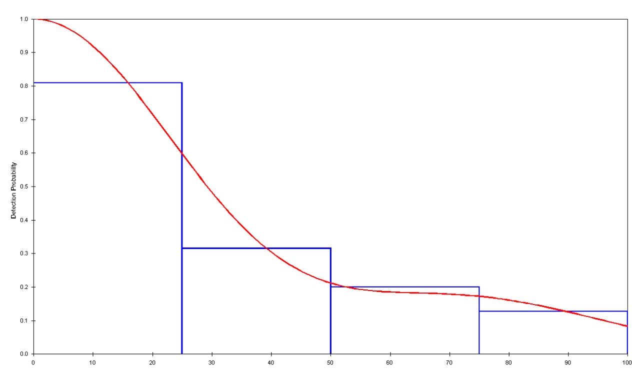


Ponderosa Pine

Broad-tailed Hummingbird – Hazard Simple

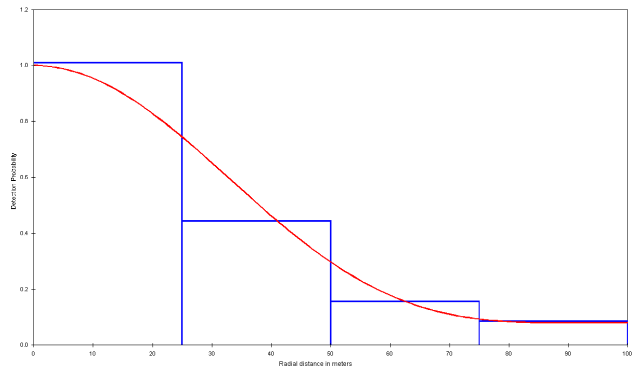


Western Wood-pewee – Half Normal Cosine

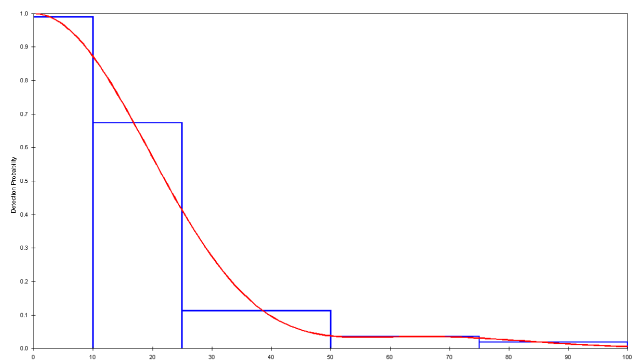


Ponderosa Pine (Continued)

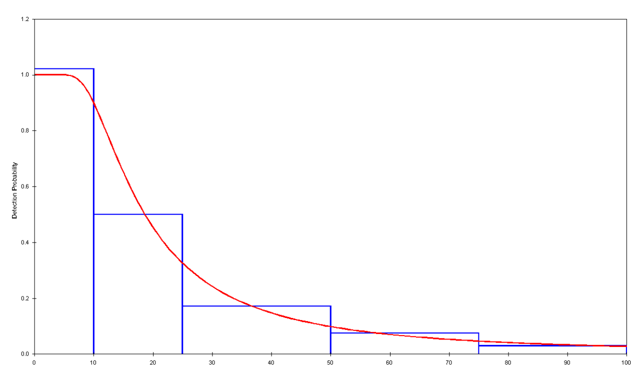
Hammond's Flycatcher – Uniform Cosine



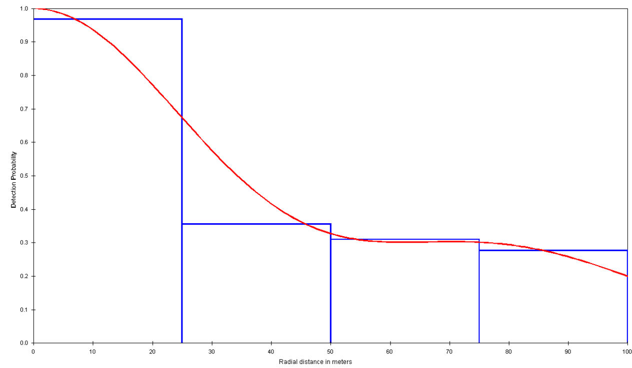
Dusky Flycatcher – Half Normal Cosine



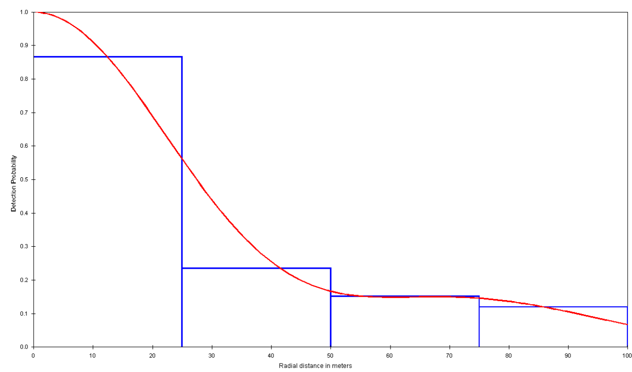
Cordilleran Flycatcher – Hazard Cosine



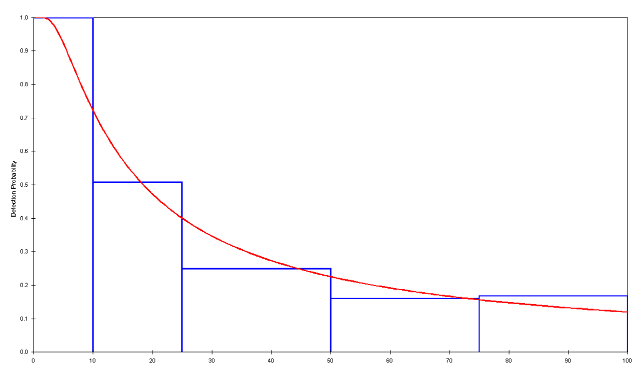
Warbling Vireo – Half Normal Cosine



Steller's Jay – Hazard Cosine

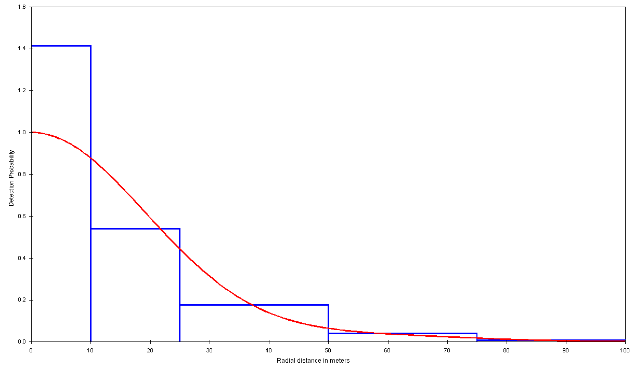


Black-billed Magpie – Hazard Cosine

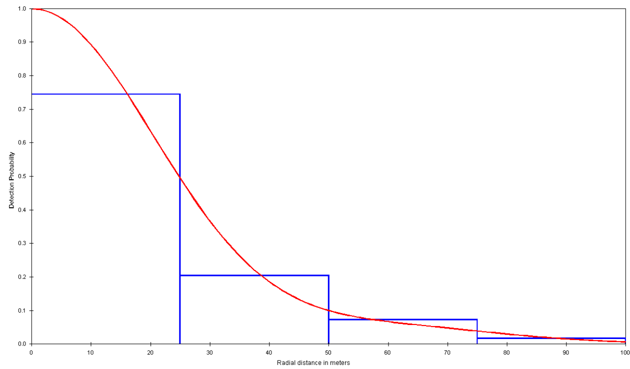


Ponderosa Pine (Continued)

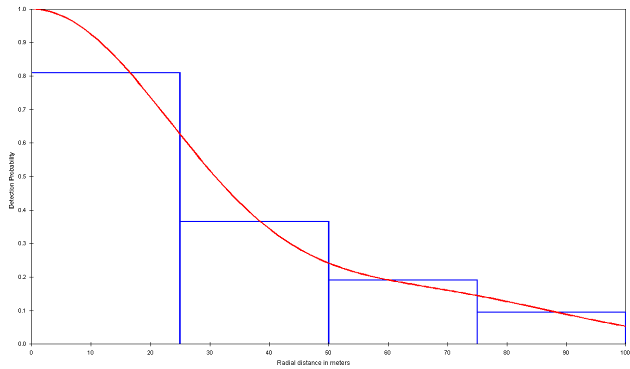
Tree Swallow – Half Normal Cosine



Violet-green Swallow – Half Normal Cosine

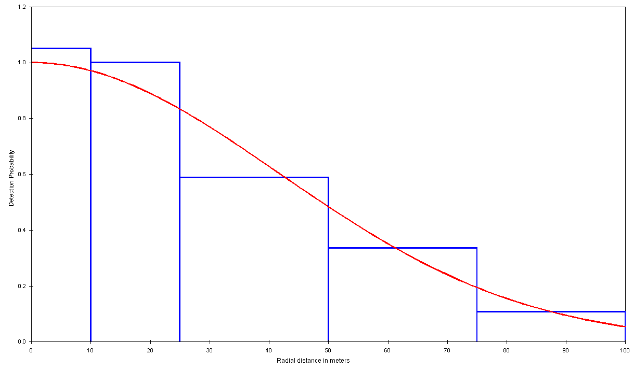


Mountain Chickadee – Half Normal Cosine

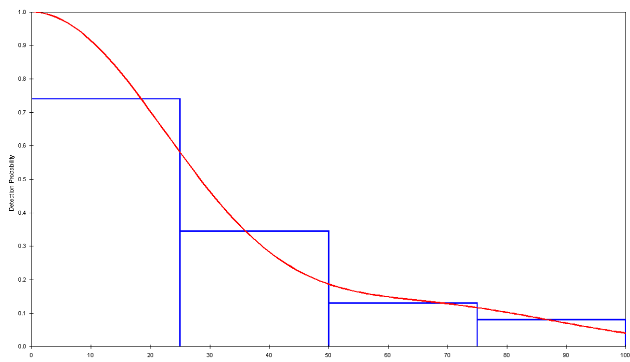


Ponderosa Pine (Continued)

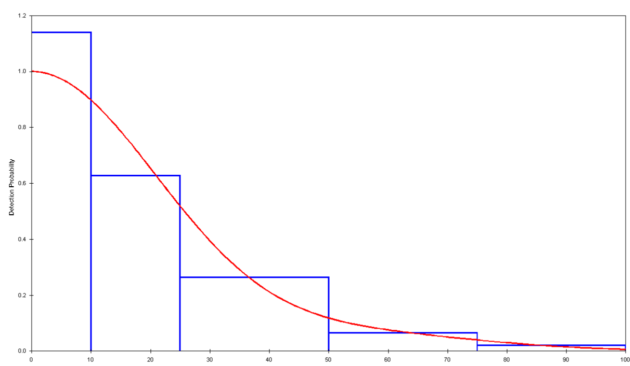
Red-breasted nuthatch – Half Normal Cosine



White-breasted nuthatch – Half Normal Cosine

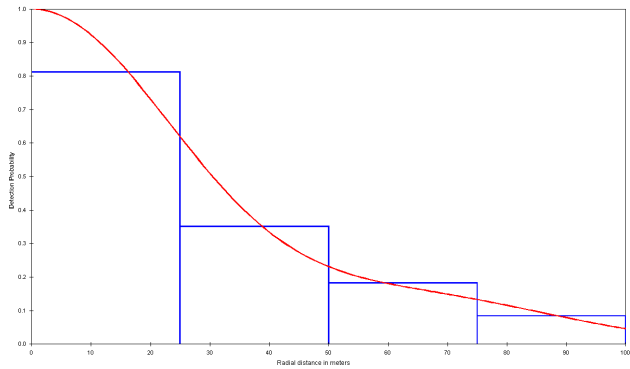


Pygmy Nuthatch – Half Normal Cosine

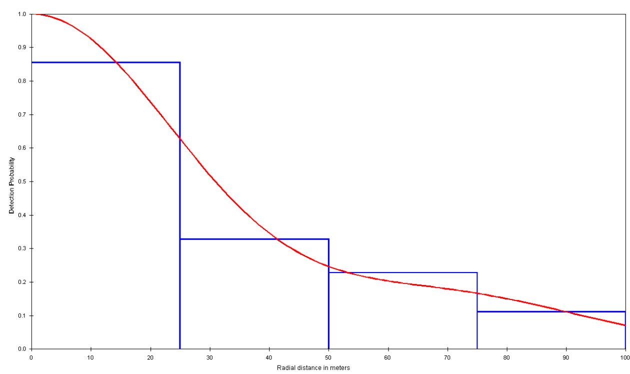


Ponderosa Pine (Continued)

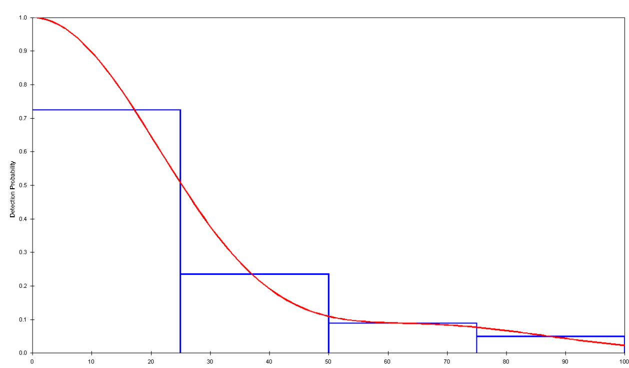
House Wren – Half Normal Cosine



Ruby-crowned Kinglet – Half Normal Cosine

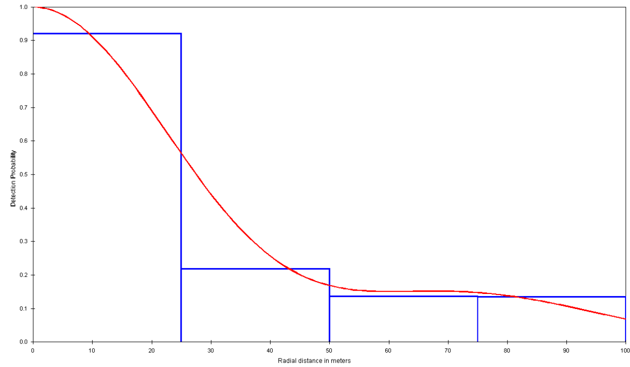


Mountain Bluebird – Half Normal Cosine

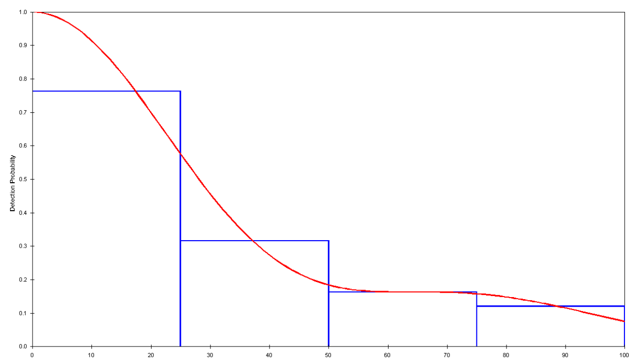


Ponderosa Pine (Continued)

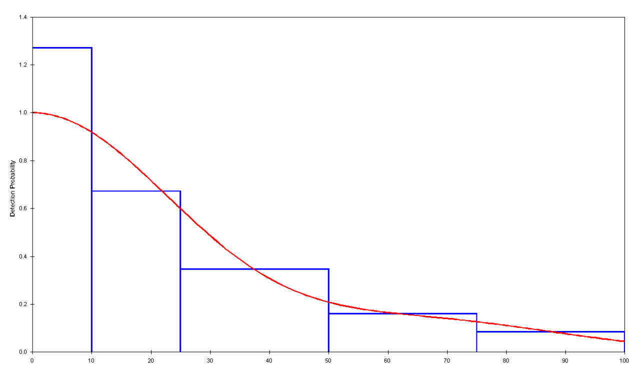
Townsend's Solitaire – Half Normal Cosine



American Robin – Half Normal Cosine

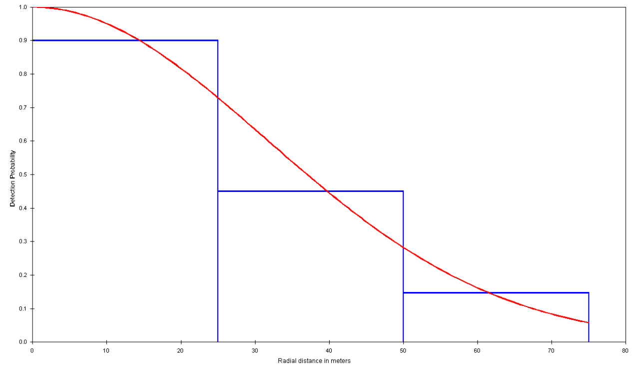


Yellow-rumped Warbler – Half Normal Cosine

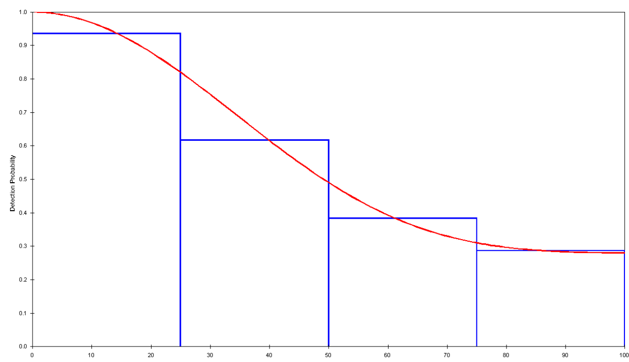


Ponderosa Pine (Continued)

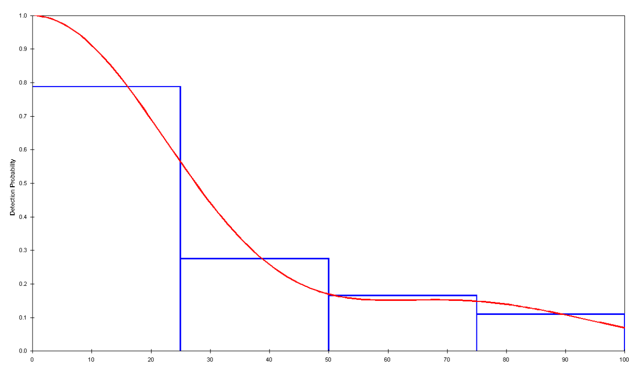
Western Tanager– Half Normal Cosine



Green-tailed Towhee – Uniform Cosine

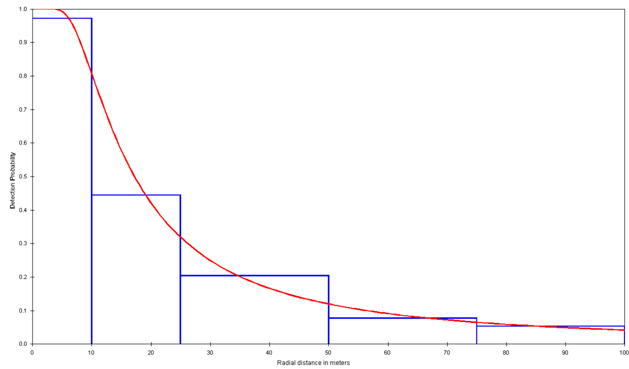


Chipping Sparrow – Half Normal Cosine

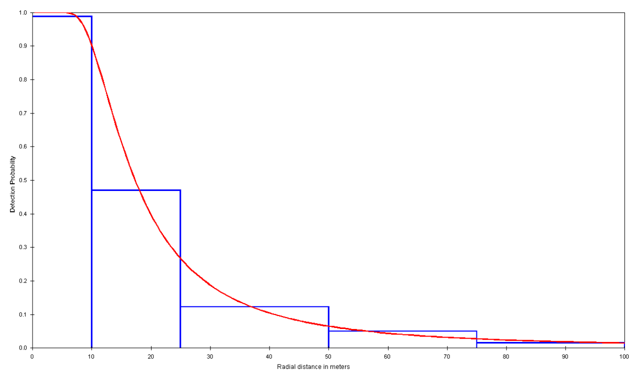


Ponderosa Pine (Continued)

Dark-eyed Junco – Hazard Cosine

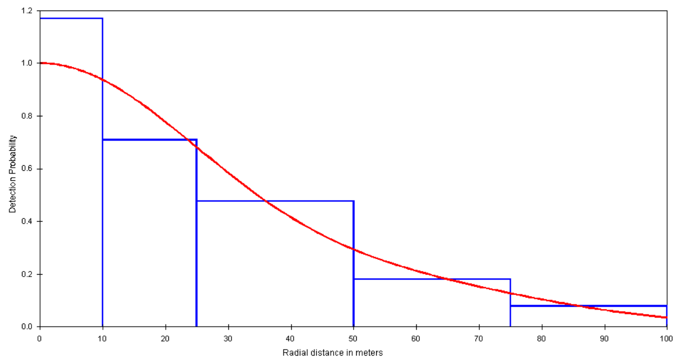


Pine Siskin – Hazard Cosine

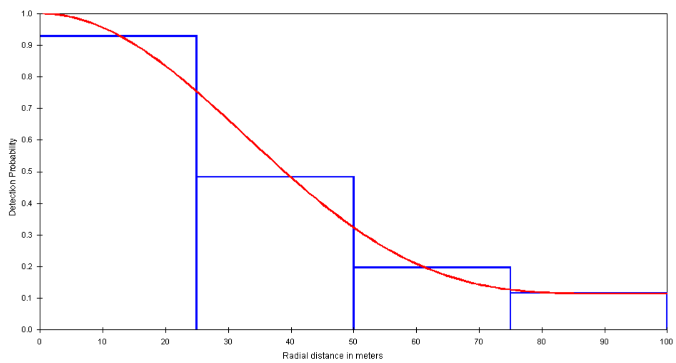


Spruce-fir

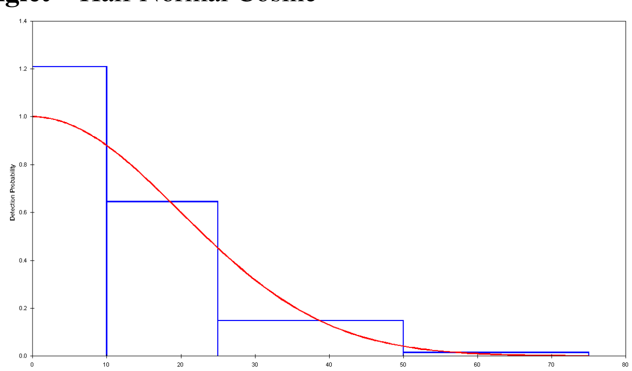
Mountain Chickadee – Half Normal Cosine



Red-breasted Nuthatch – Uniform Cosine

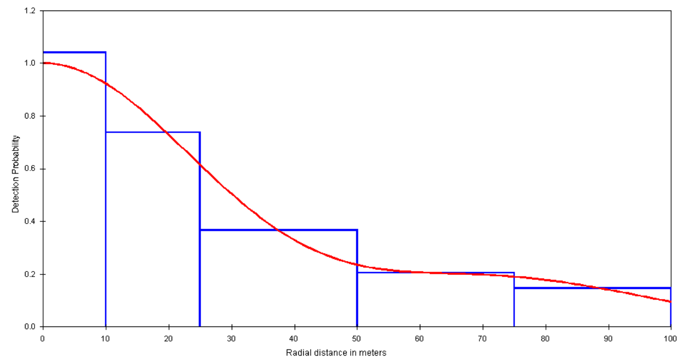


Golden-crowned Kinglet – Half Normal Cosine

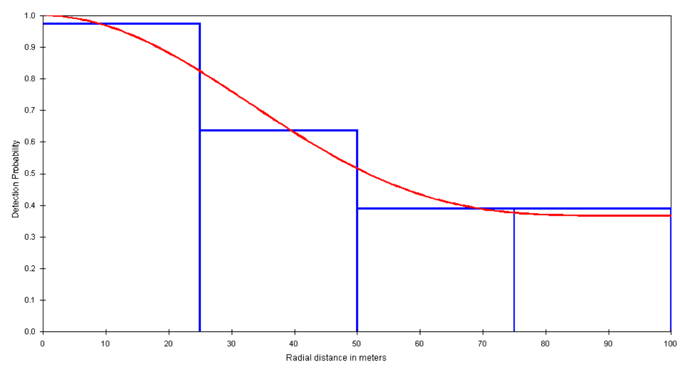


Spruce-fir (Continued)

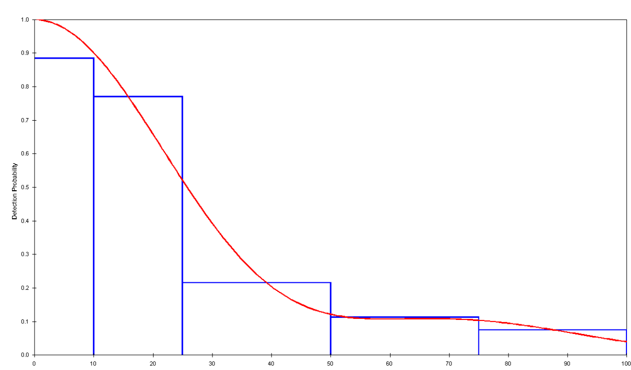
Ruby-crowned Kinglet – Half Normal Cosine



Hermit Thrush – Uniform Cosine

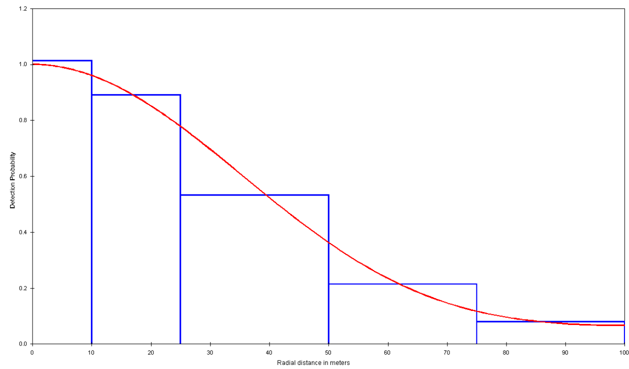


American Robin – Half Normal Cosine

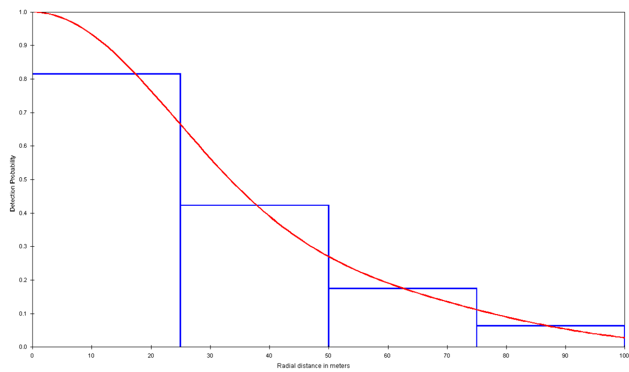


Spruce-fir (Continued)

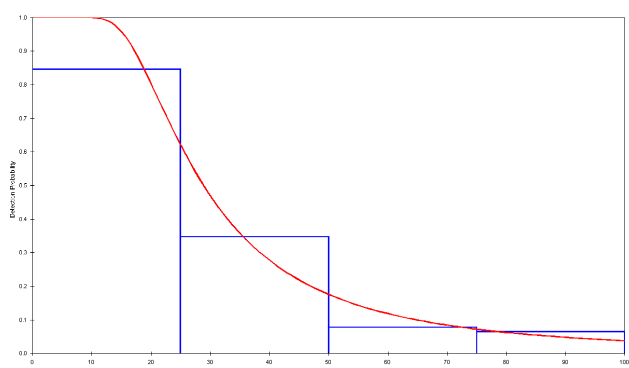
Yellow-rumped Warbler – Uniform Cosine



Dark-eyed Junco – Half Normal Cosine

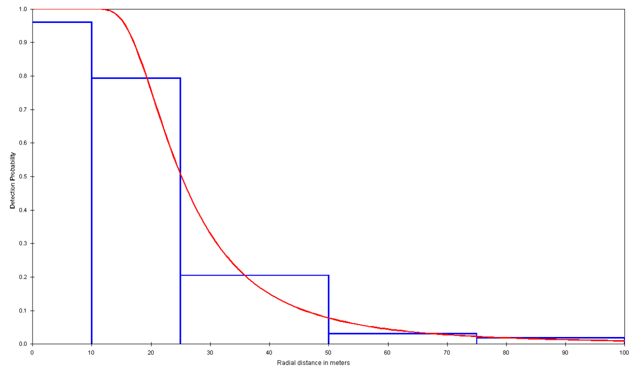


Pine Grosbeak – Hazard Cosine



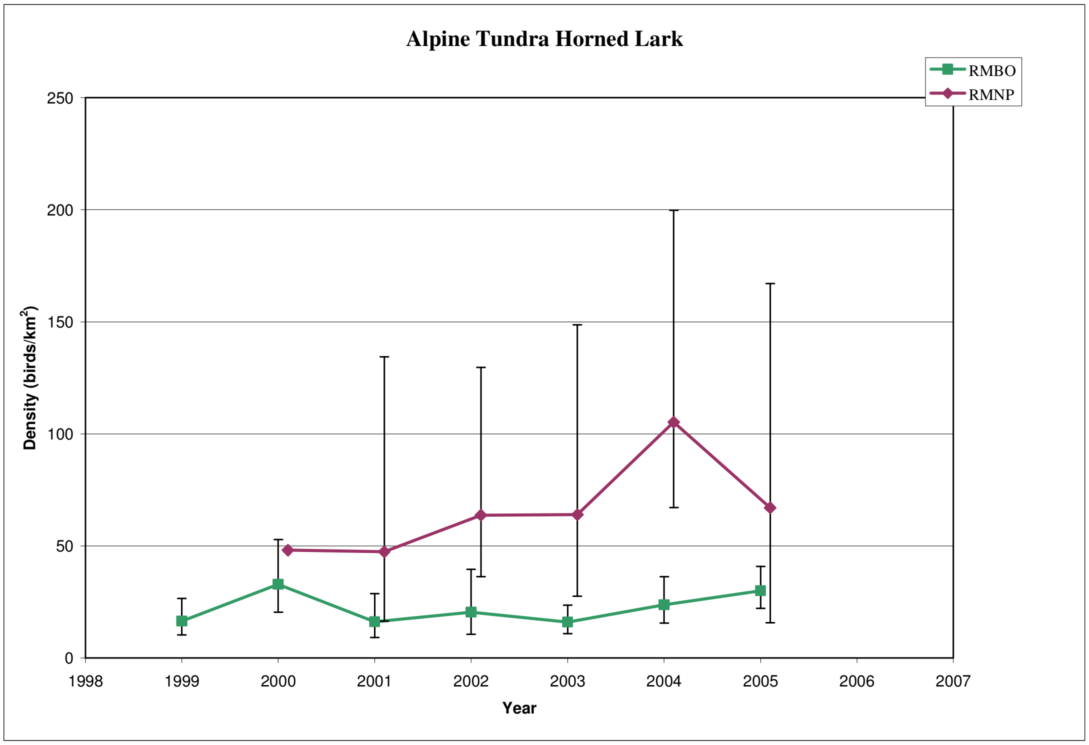
Spruce-fir (Continued)

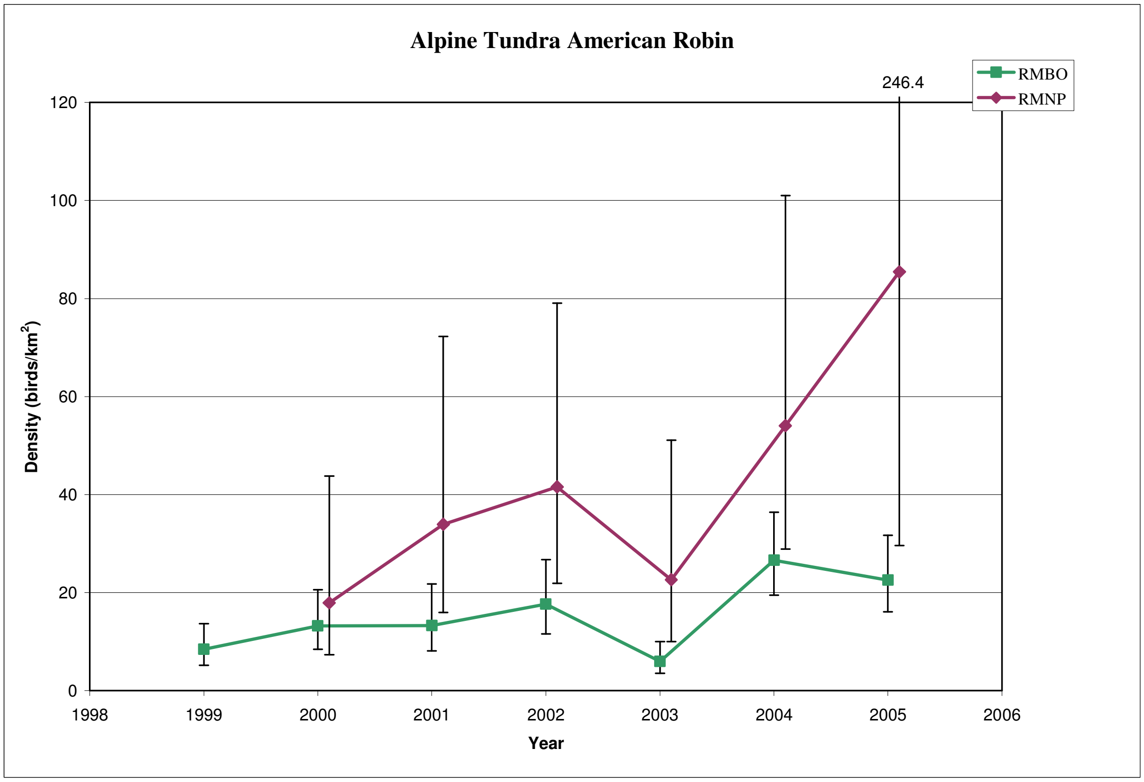
Pine Siskin – Hazard Cosine

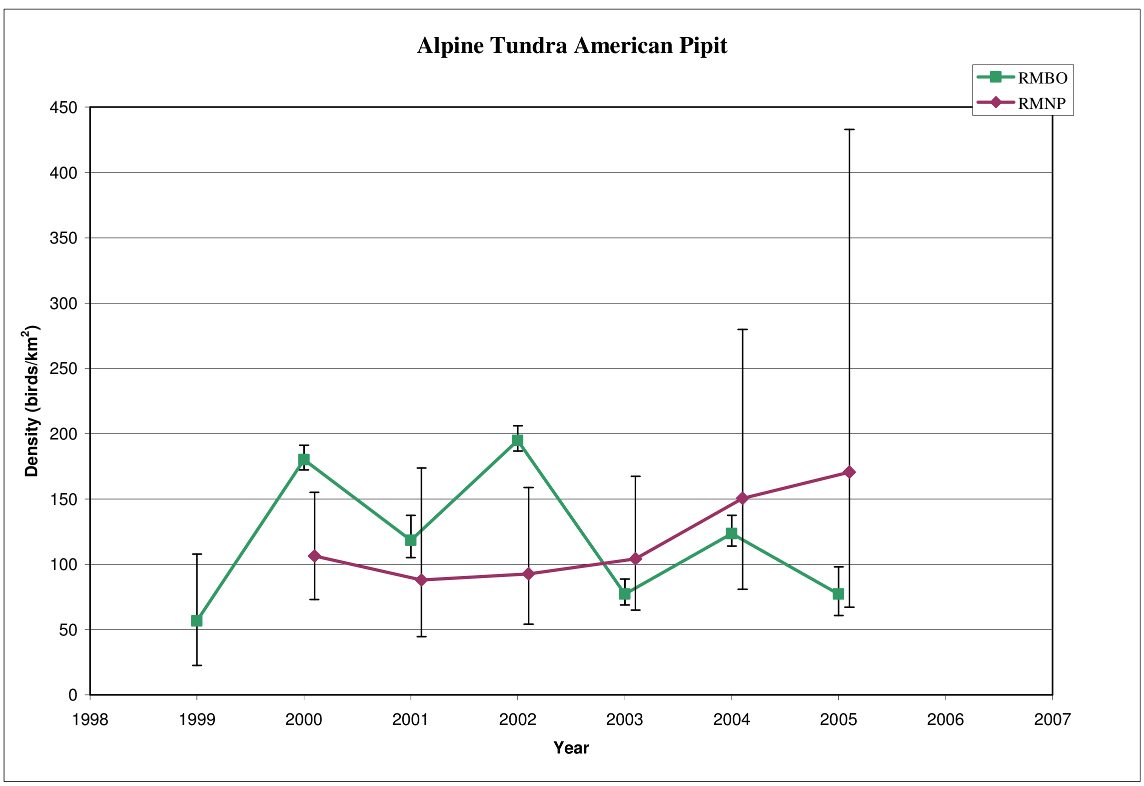


Appendix C – Trend Comparisons between RMBO and RMNP Density Estimates

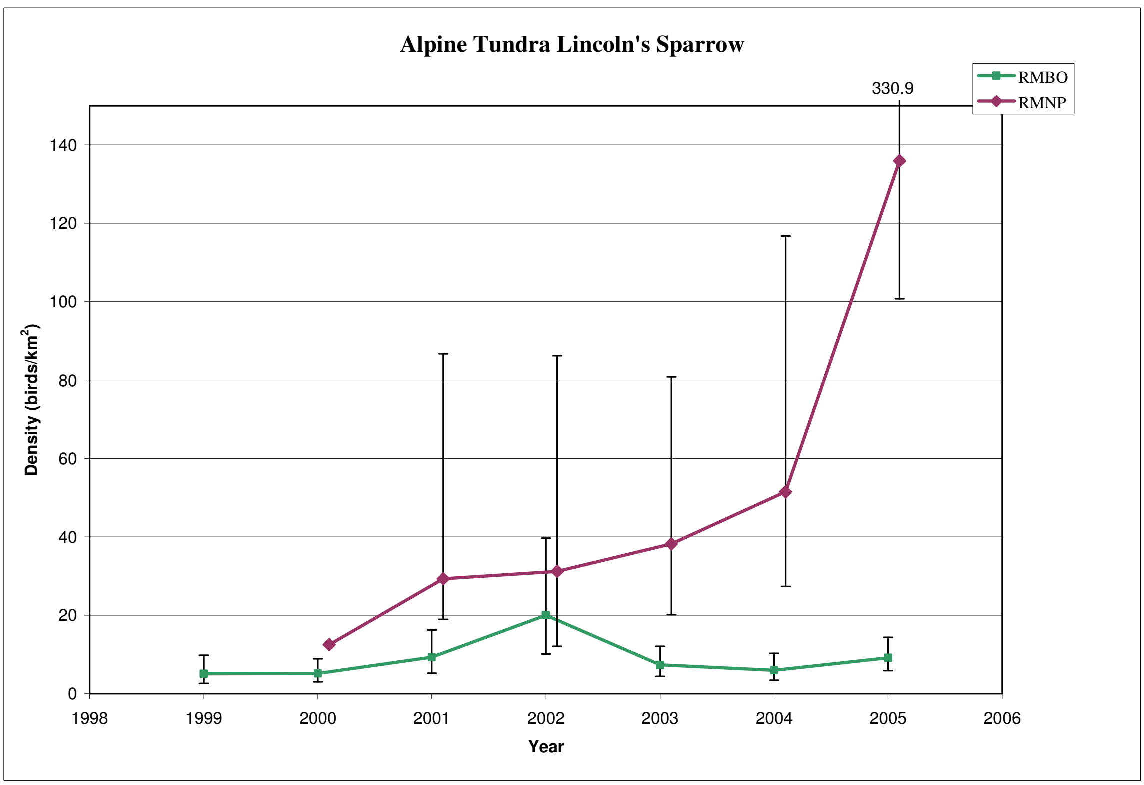
Alpine Tundra (Density = birds/km^2)

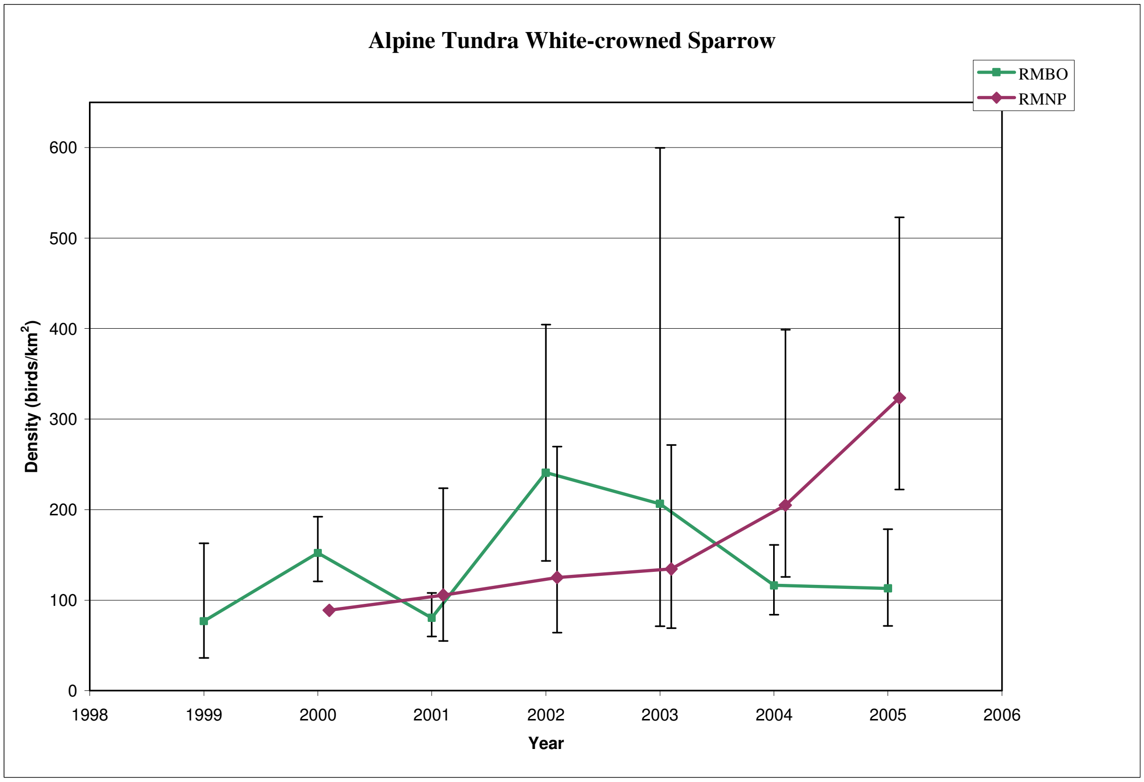


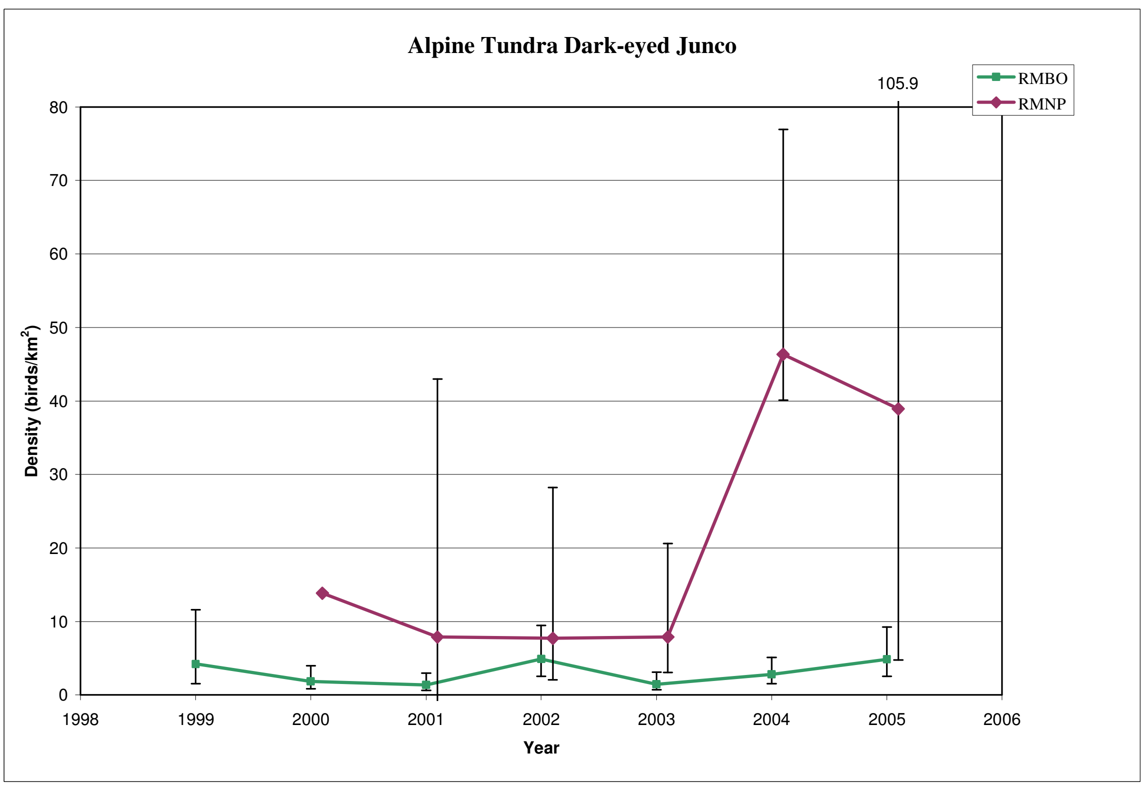

Alpine Tundra American Robin
RMBO
RMNP
246.4
Density (birds/km2)
0
20
40
60
80
100
120
1998
1999
2000
2001
2002
2003
2004
2005
2006
Year


Alpine Tundra American Pipit
RMBO
RMNP
Density (birds/km2)
0
50
100
150
200
250
300
350
400
450
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
Year

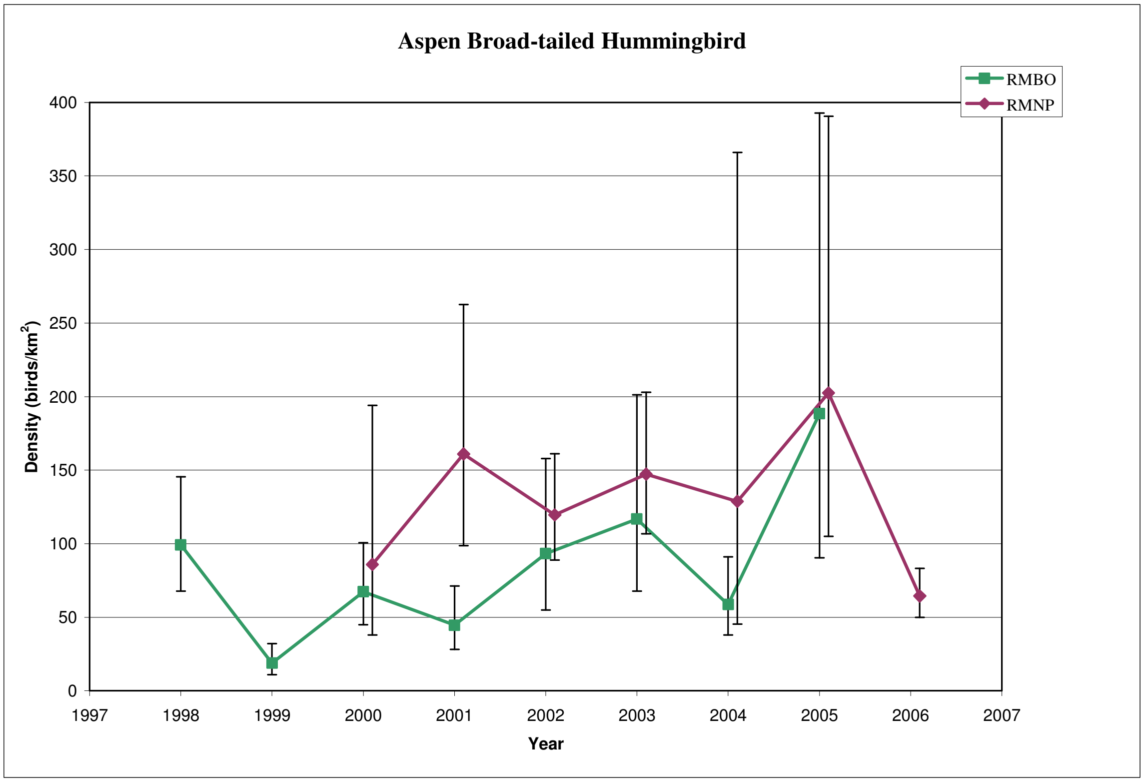

Alpine Tundra Wilson's Warbler
RMBO
RMNP
314.9
Density (birds/km2)
0
10
20
30
40
50
60
70
80
90
100
1998
1999
2000
2001
2002
2003
2004
2005
2006
Year

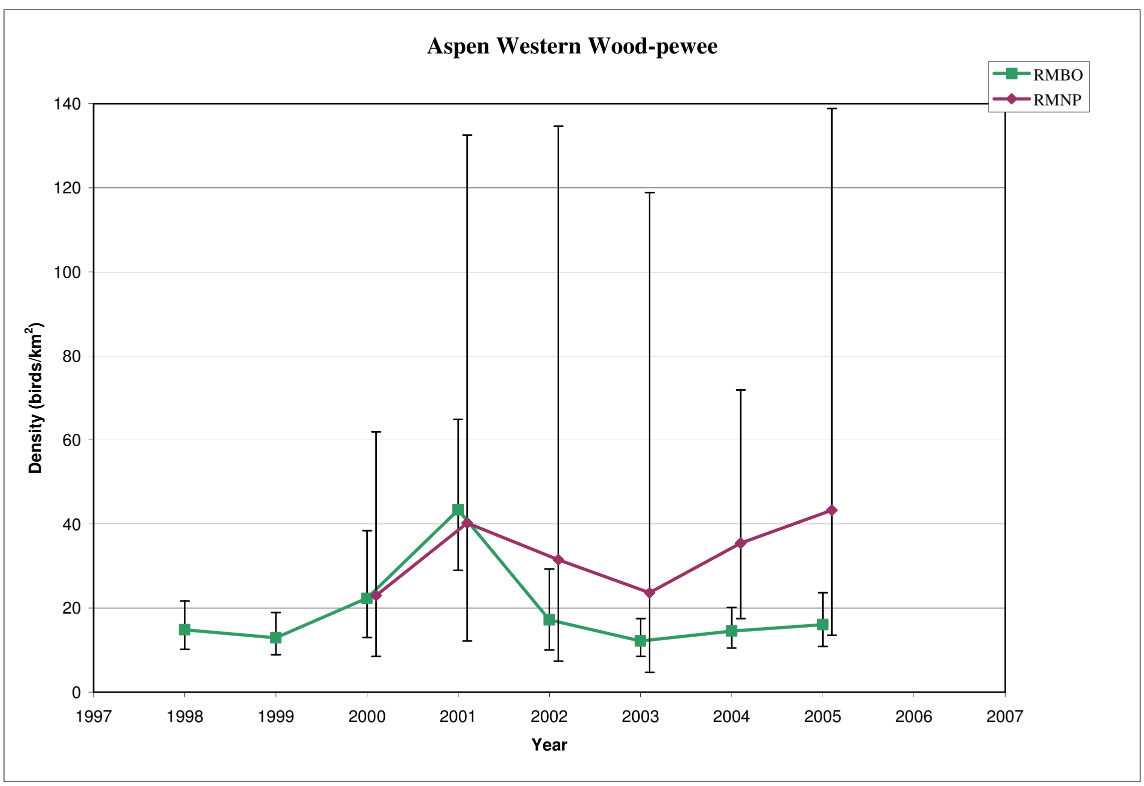

Alpine Tundra Lincoln's Sparrow
RMBO
RMNP
330.9
Density (birds/km2)
0
20
40
60
80
100
120
140
1998
1999
2000
2001
2002
2003
2004
2005
2006
Year

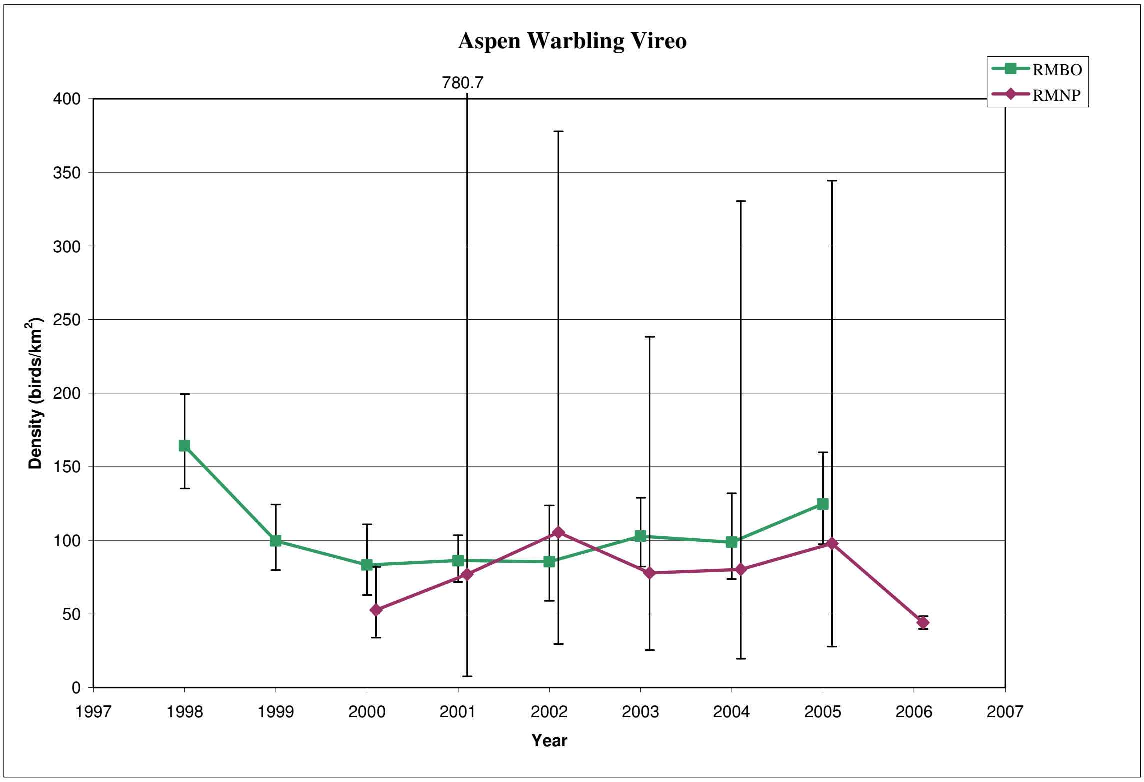

Alpine Tundra White-crowned Sparrow
RMBO
RMNP
Density (birds/km²)
0
100
200
300
400
500
600
1998
1999
2000
2001
2002
2003
2004
2005
2006
Year


Alpine Tundra Dark-eyed Junco
105.9
RMBO
RMNP
Density (birds/km²)
0
10
20
30
40
50
60
70
80
1998
1999
2000
2001
2002
2003
2004
2005
2006
Year

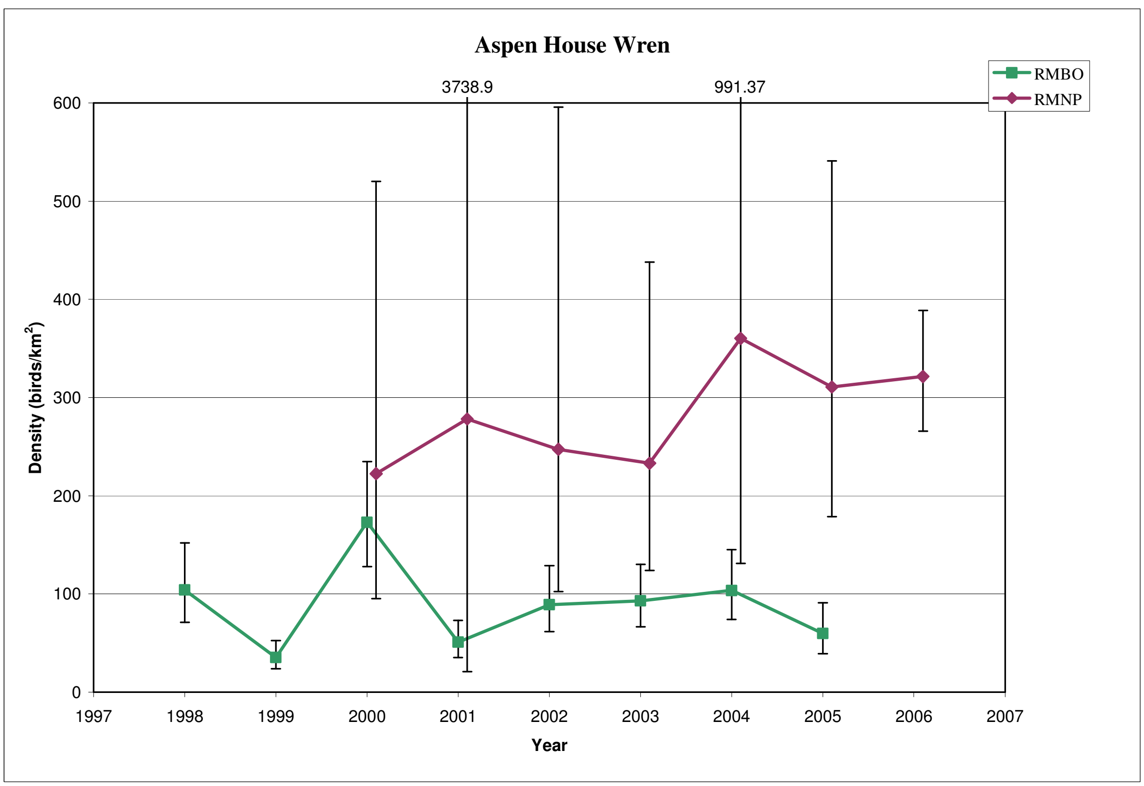
Aspen (Density = birds/km^2)



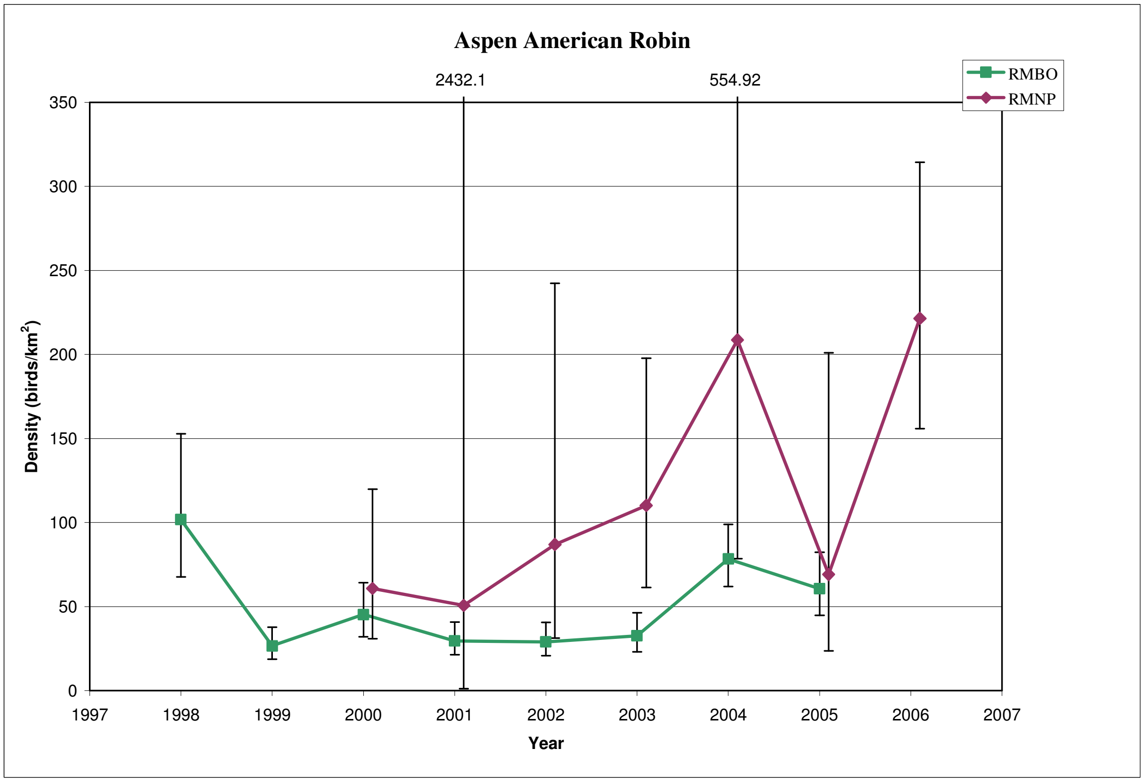




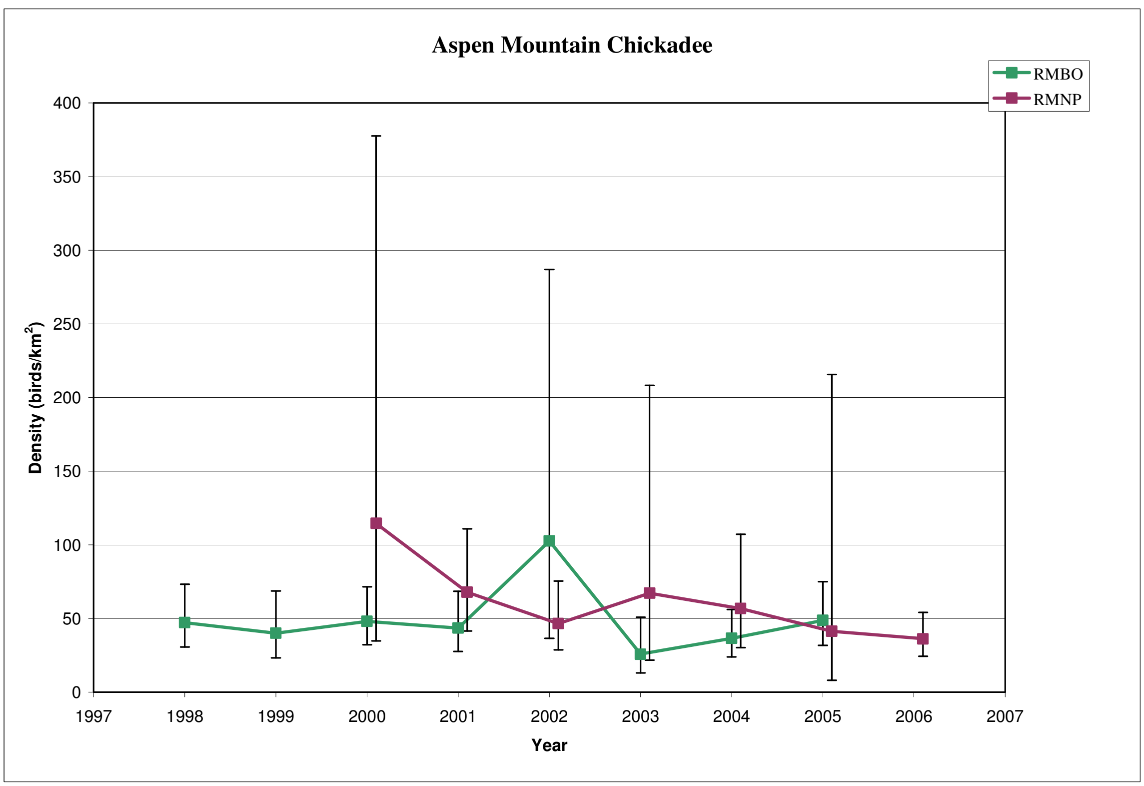
Aspen Warbling Vireo
RMBO
RMNP
780.7
Density (birds/km^2)
Year
0
50
100
150
200
250
300
350
400
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007



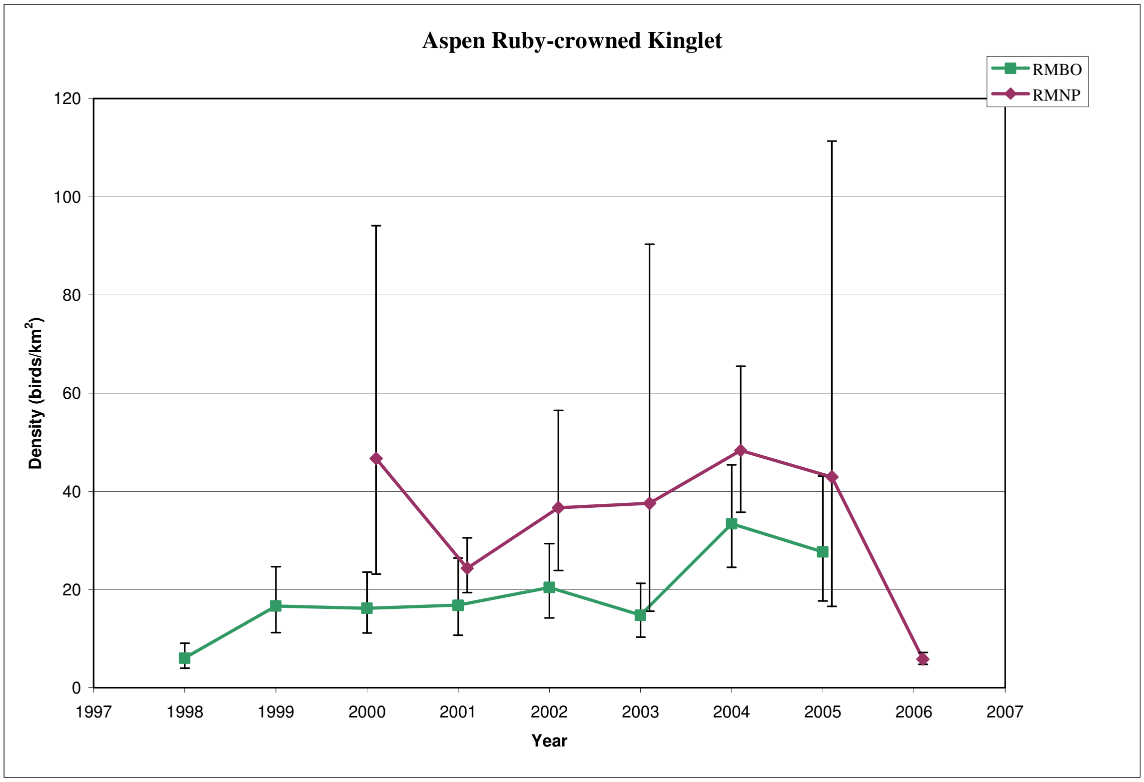
Aspen House Wren
RMBO
RMNP
3738.9
991.37
Density (birds/km^2)
Year
0
100
200
300
400
500
600
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007



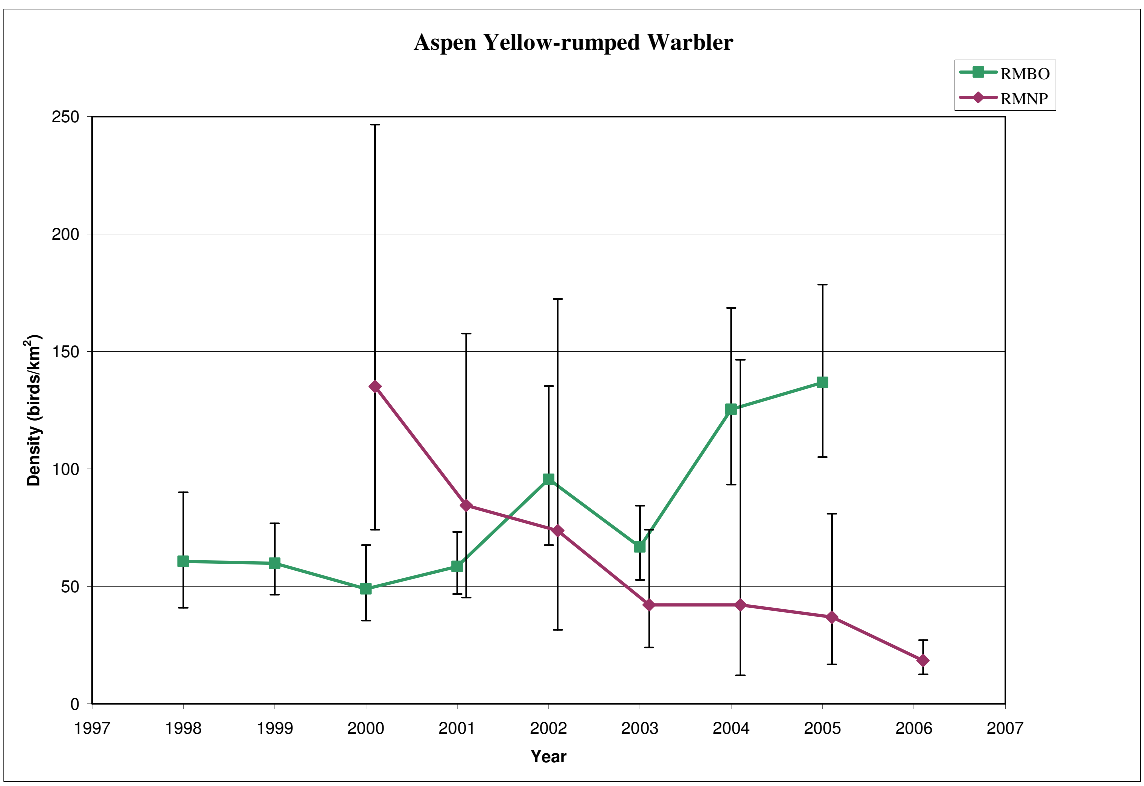
Aspen American Robin
RMBO
RMNP
2432.1
554.92
Density (birds/km²)
350
300
250
200
150
100
50
0
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
Year



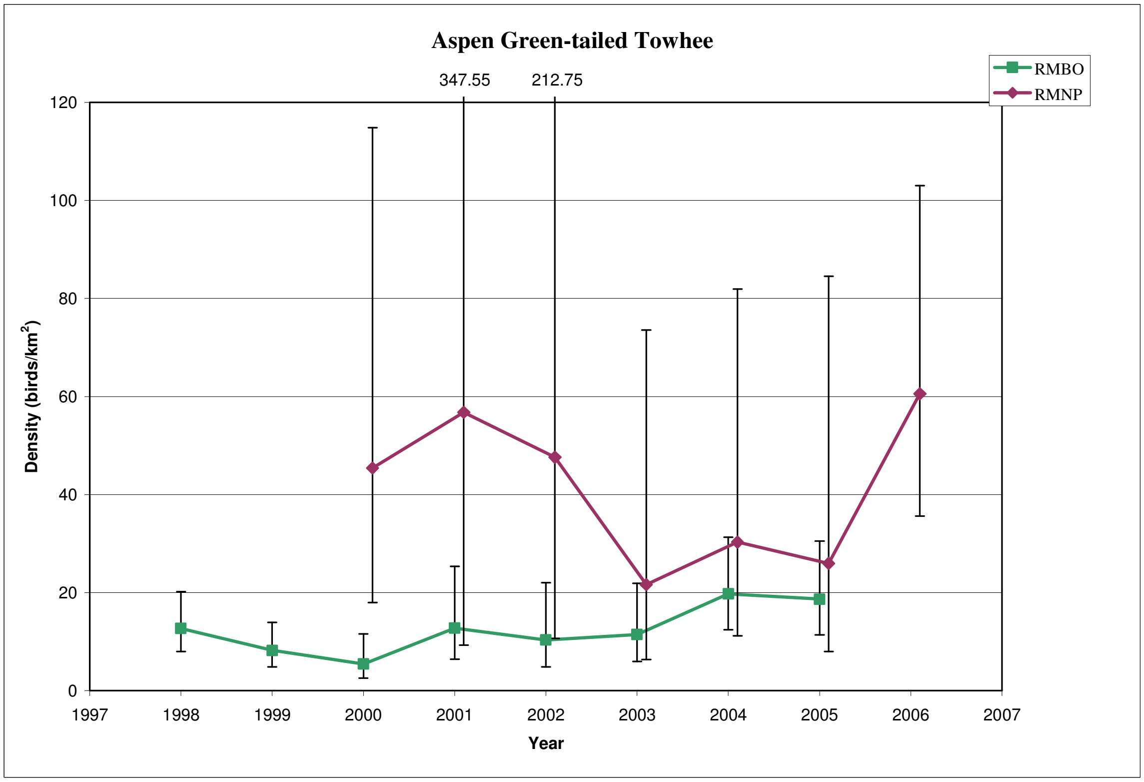
Aspen Mountain Chickadee
RMBO
RMNP
Density (birds/km²)
400
350
300
250
200
150
100
50
0
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
Year

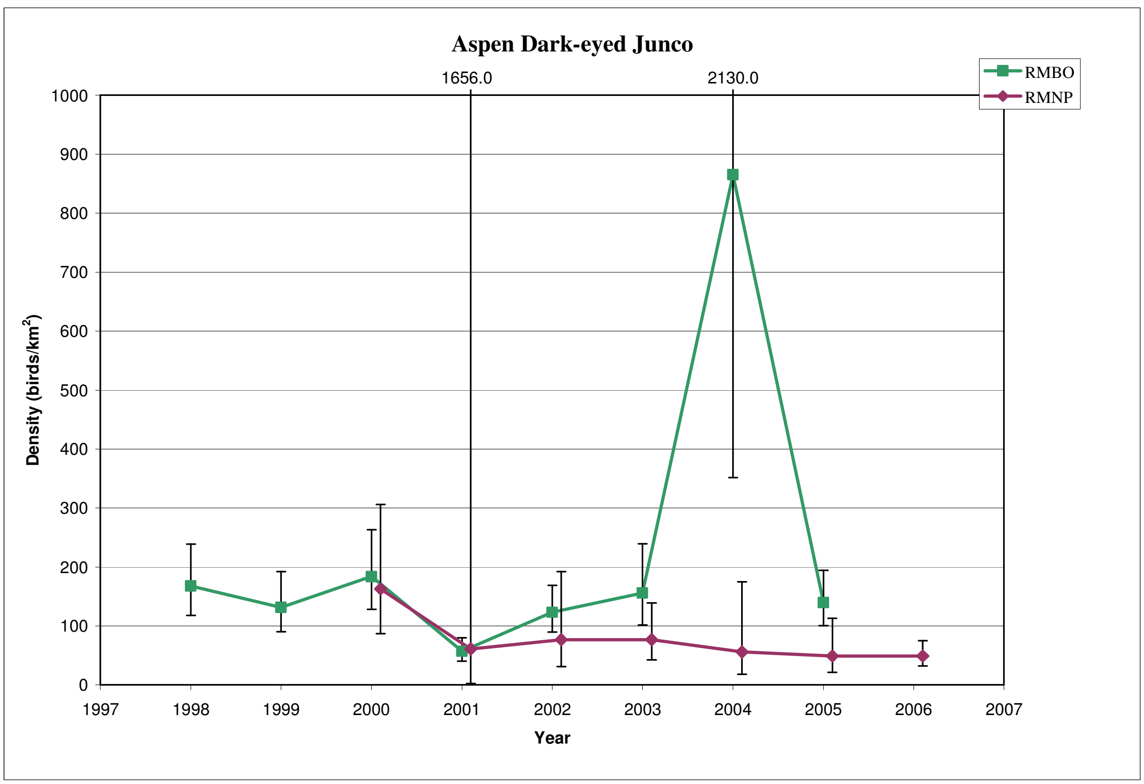


Aspen Ruby-crowned Kinglet
RMBO
RMNP
Density (birds/km2)
Year
120
100
80
60
40
20
0
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007

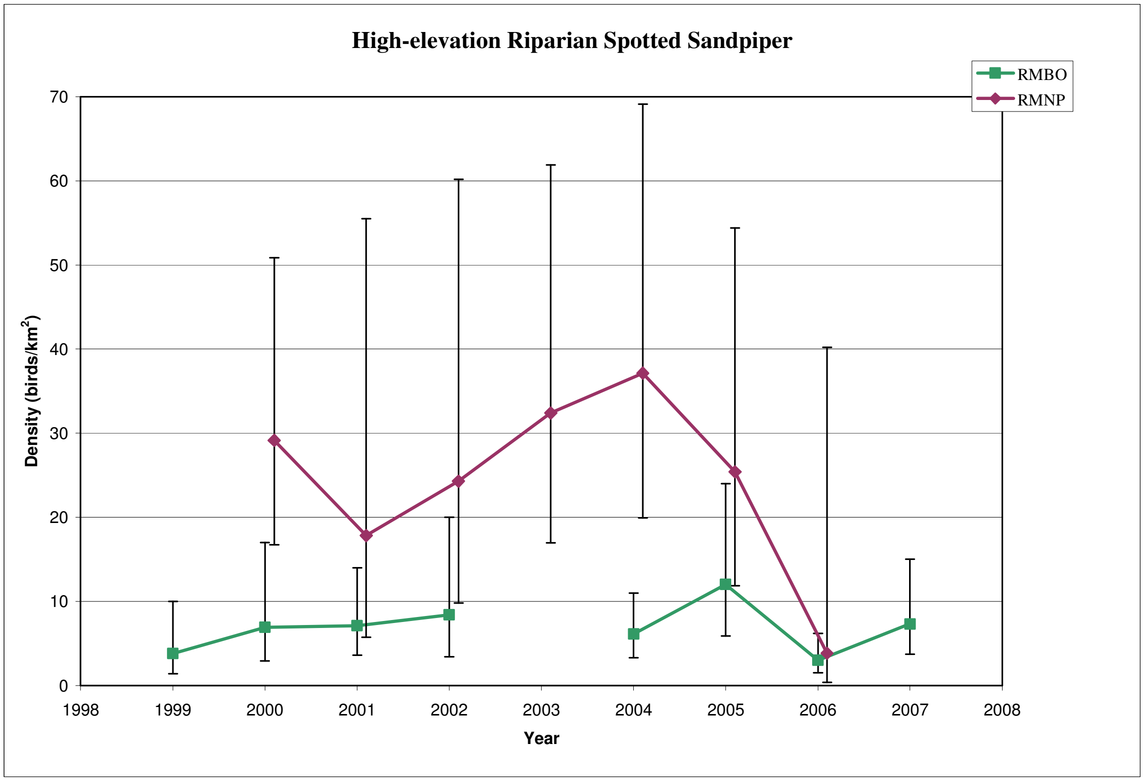


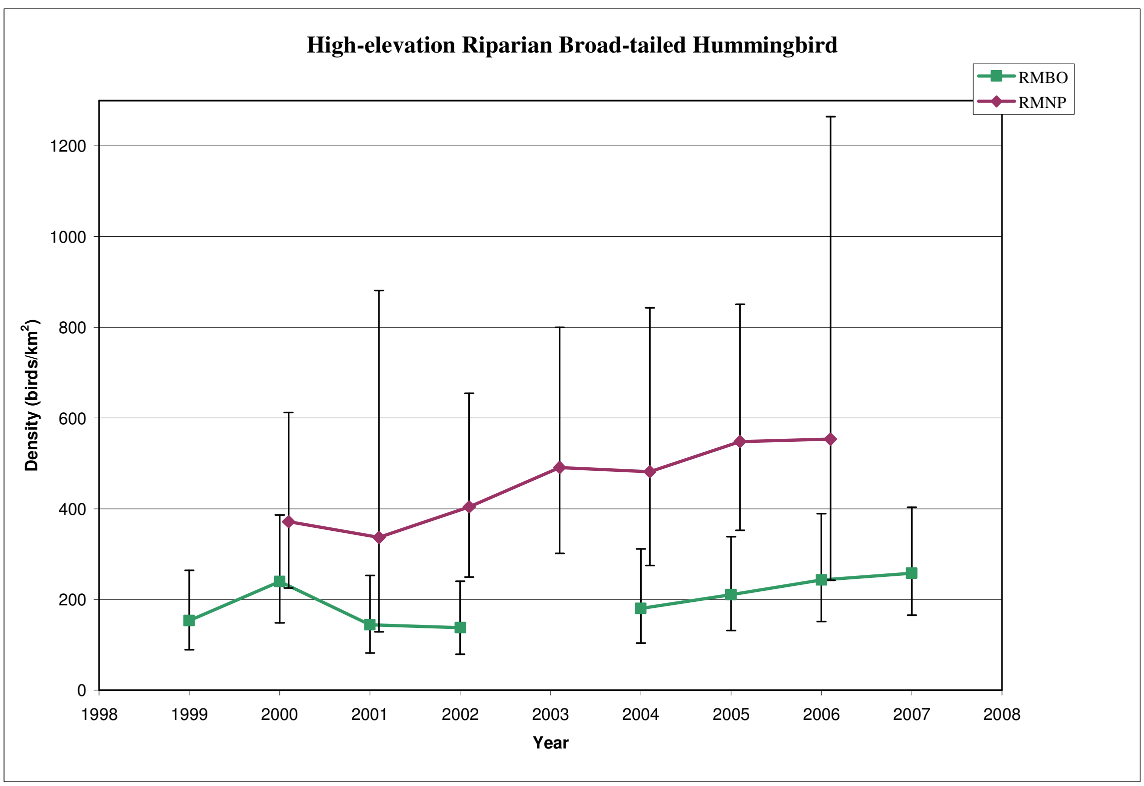
Aspen Yellow-rumped Warbler
RMBO
RMNP
Density (birds/km2)
Year
250
200
150
100
50
0
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007

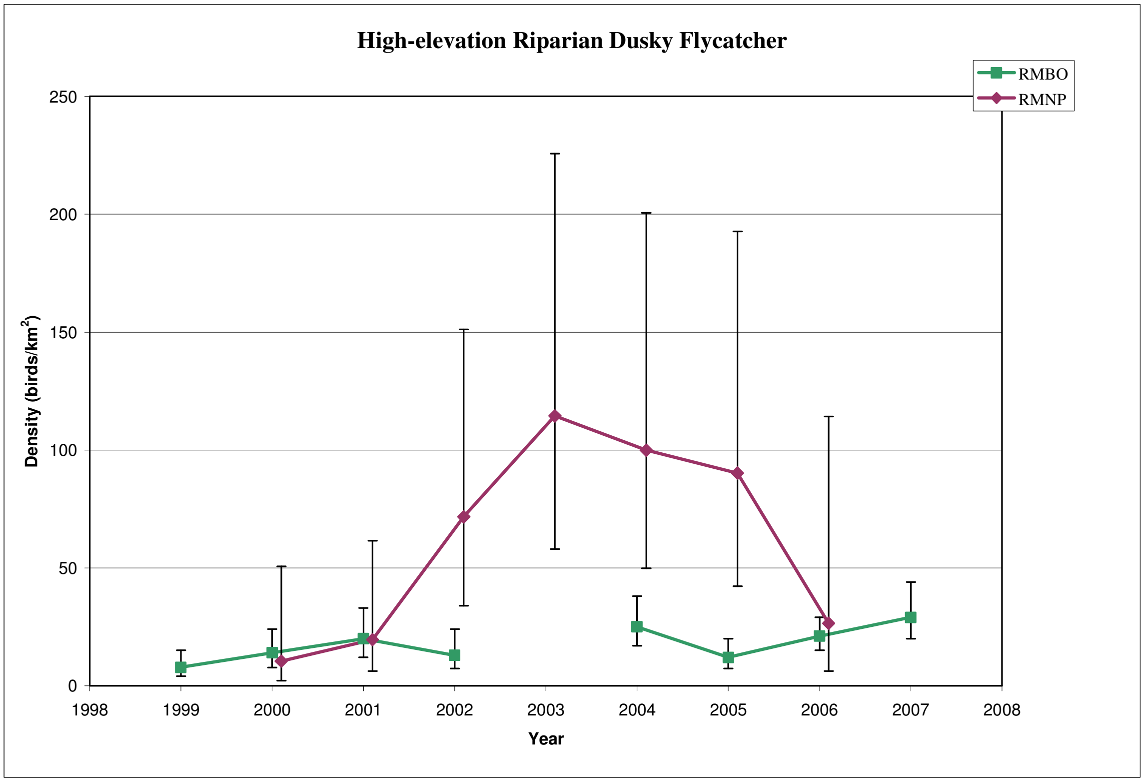

Aspen Green-tailed Towhee
347.55
212.75
RMBO
RMNP
120
100
80
60
40
20
0
Density (birds/km2)
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
Year

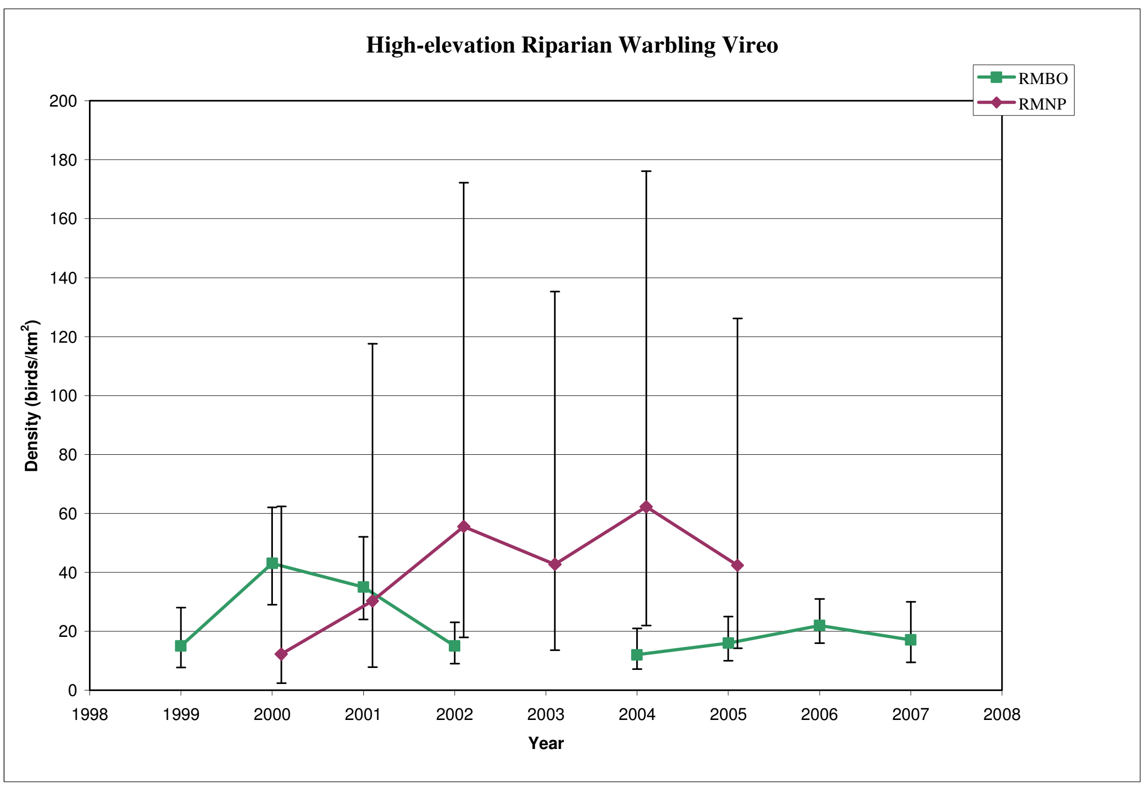

Aspen Dark-eyed Junco
1656.0
2130.0
RMBO
RMNP
1000
900
800
700
600
500
400
300
200
100
0
Density (birds/km2)
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
Year

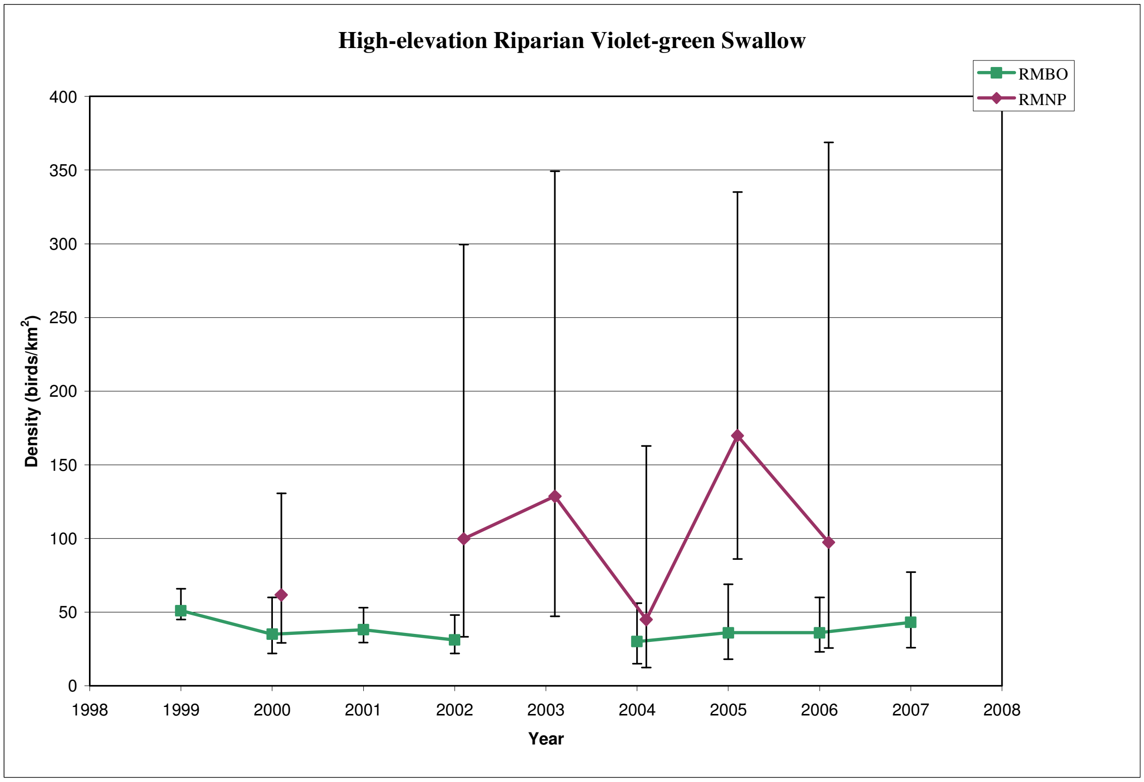
High-elevation Riparian (Density = birds/km^2)

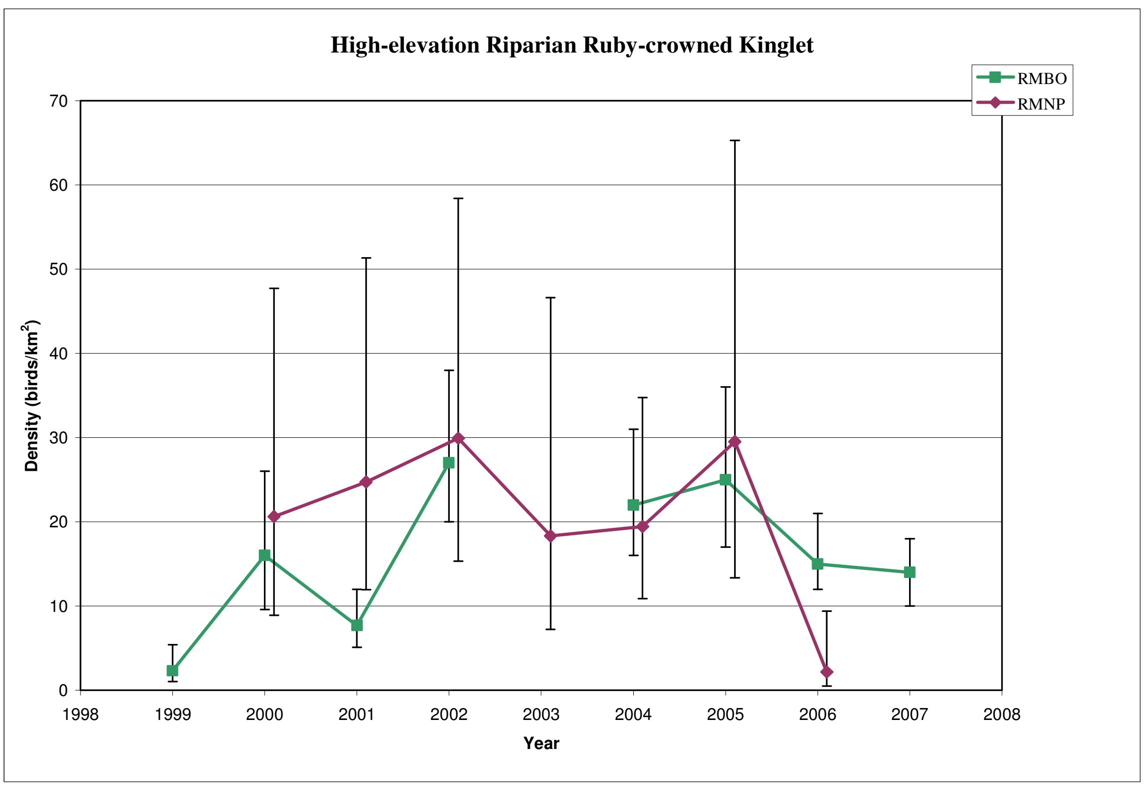


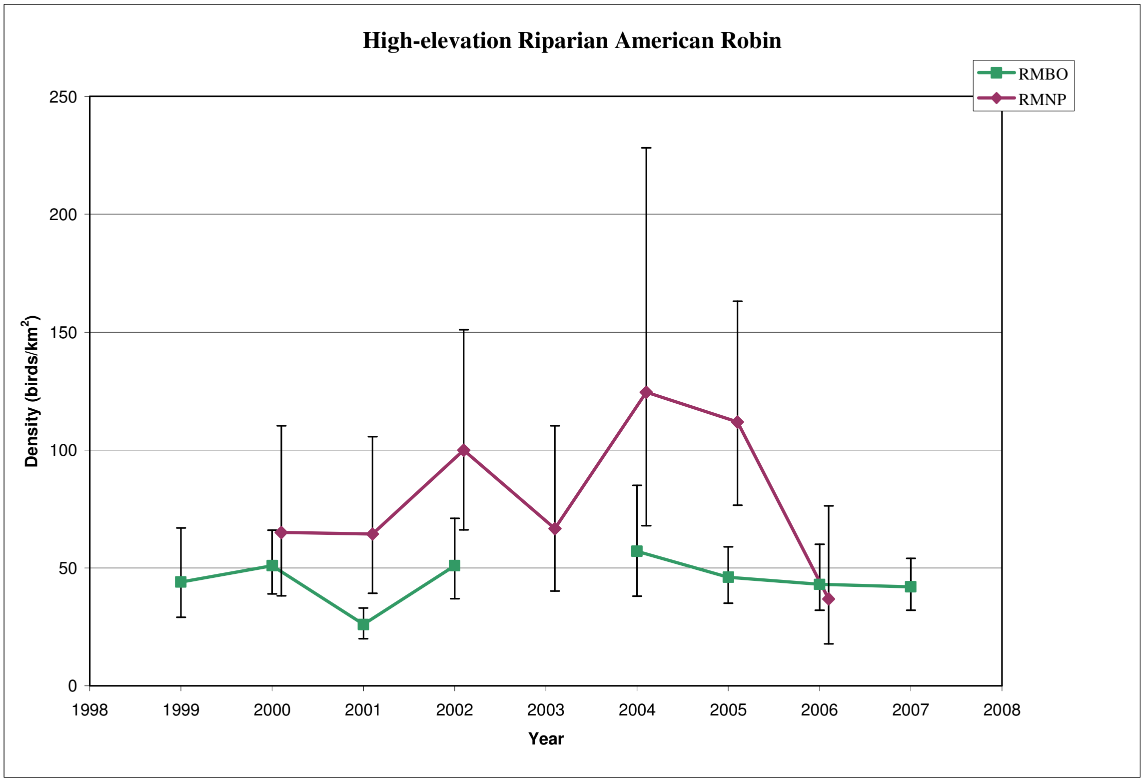


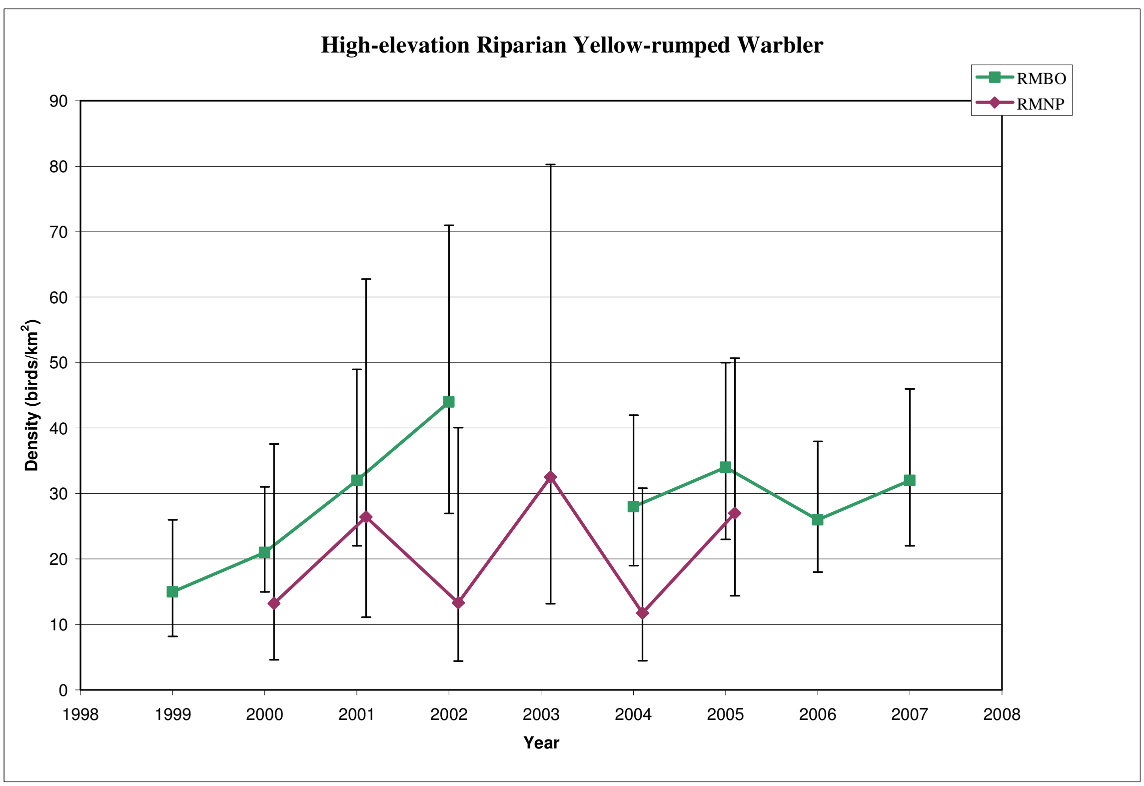

High-elevation Riparian Dusky Flycatcher
RMBO
RMNP
Density (birds/km^2)
250
200
150
100
50
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

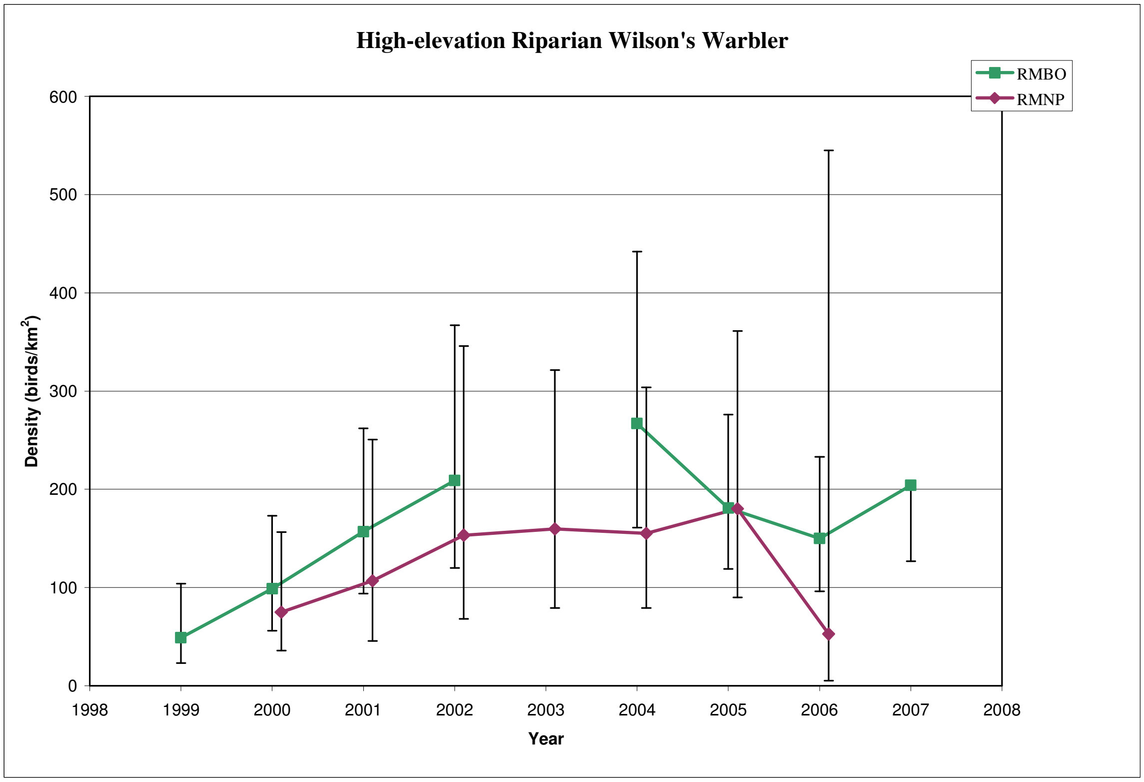

High-elevation Riparian Warbling Vireo
RMBO
RMNP
Density (birds/km^2)
200
180
160
140
120
100
80
60
40
20
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

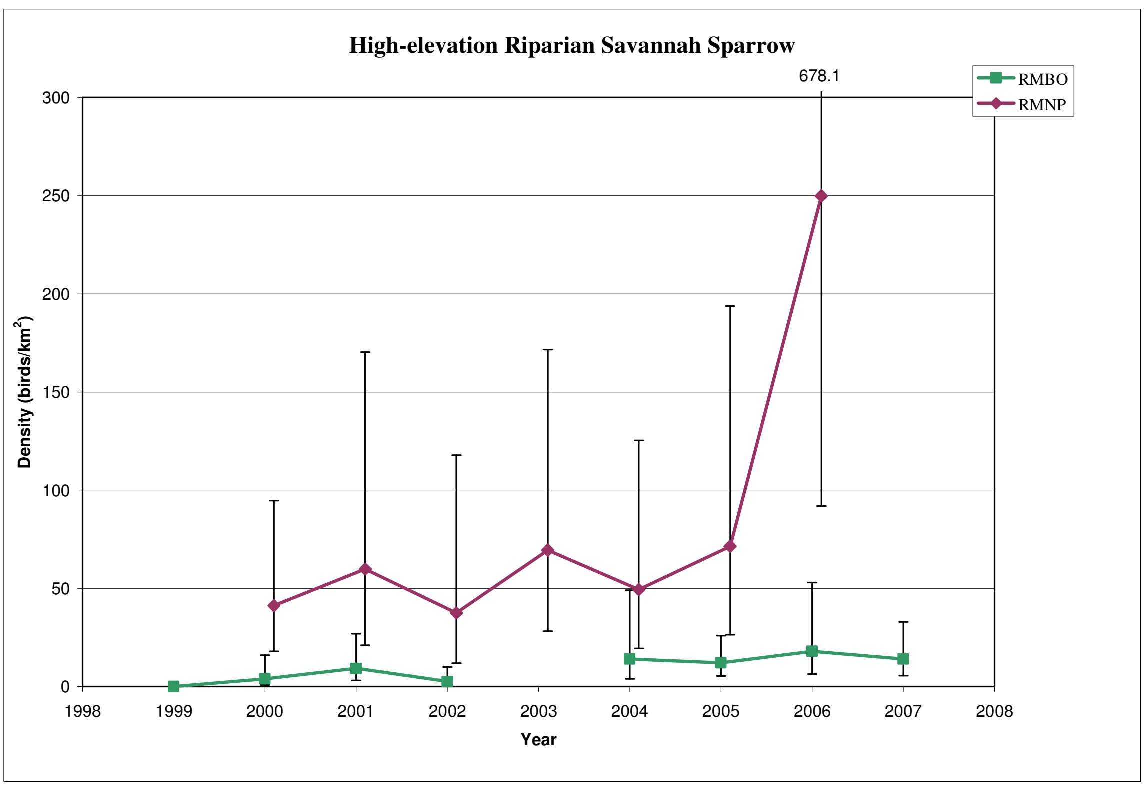

High-elevation Riparian Violet-green Swallow
RMBO
RMNP
Density (birds/km²)
0
50
100
150
200
250
300
350
400
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

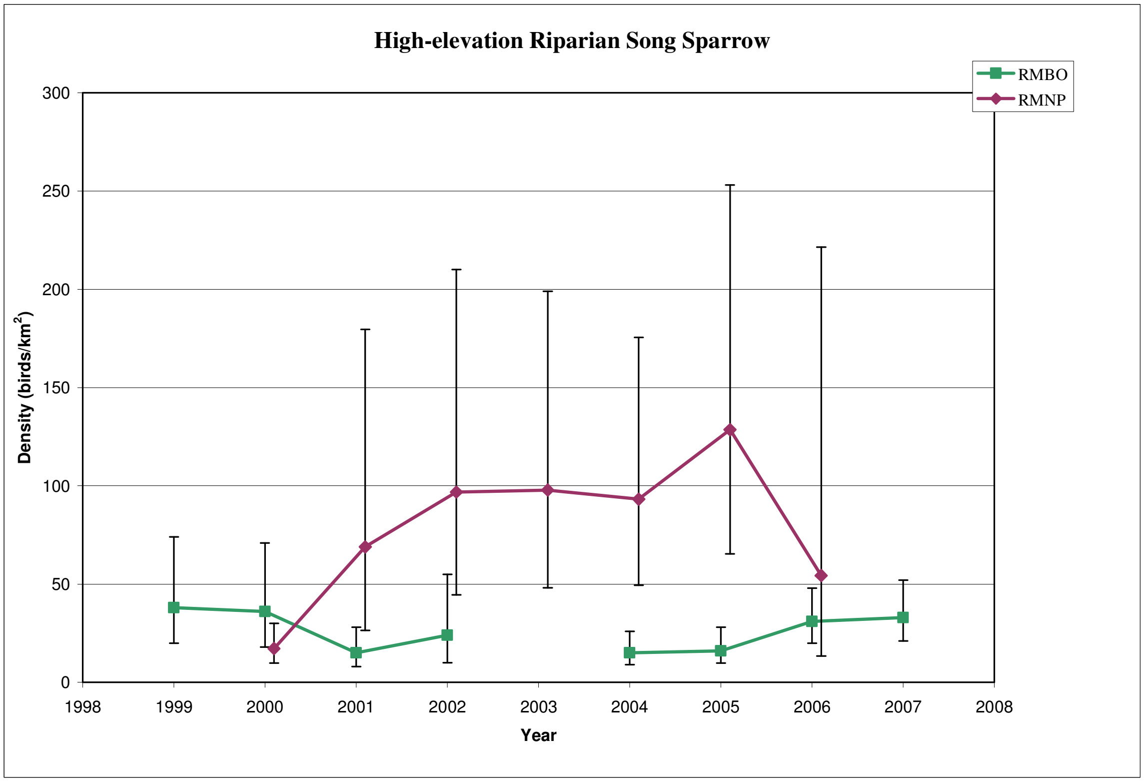

High-elevation Riparian Ruby-crowned Kinglet
RMBO
RMNP
Density (birds/km²)
0
10
20
30
40
50
60
70
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

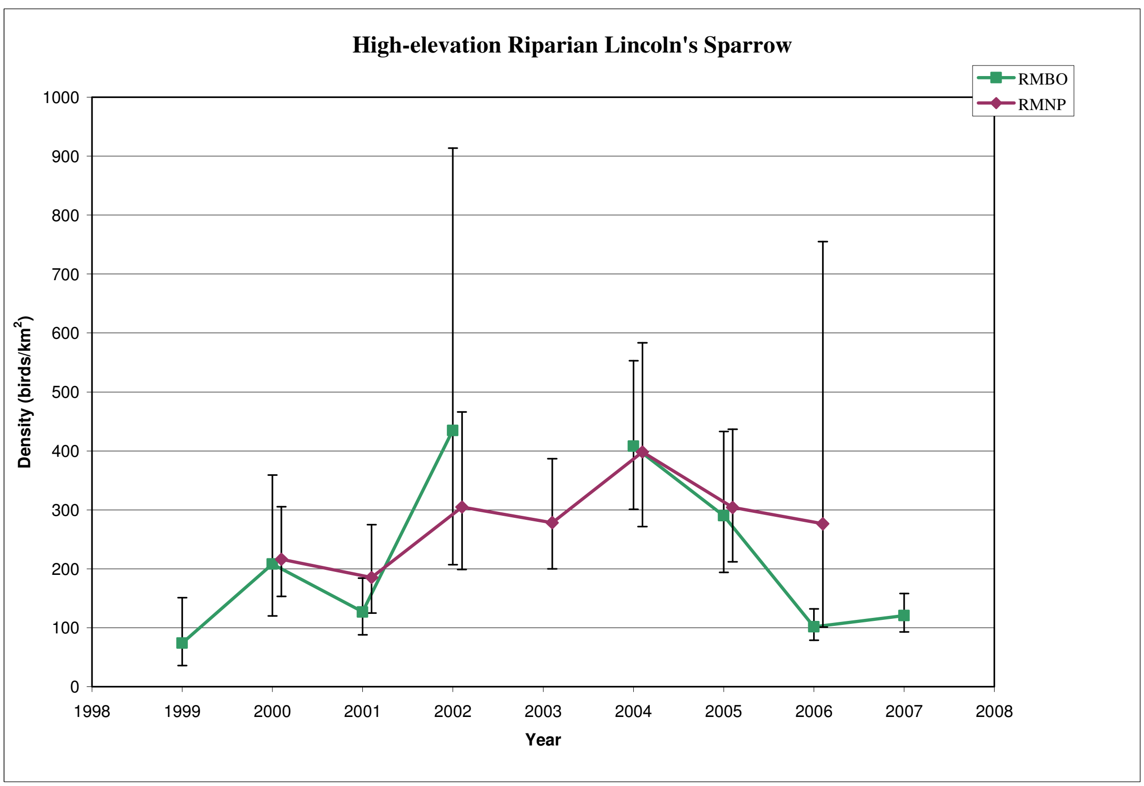

High-elevation Riparian American Robin
RMBO
RMNP
Density (birds/km²)
250
200
150
100
50
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

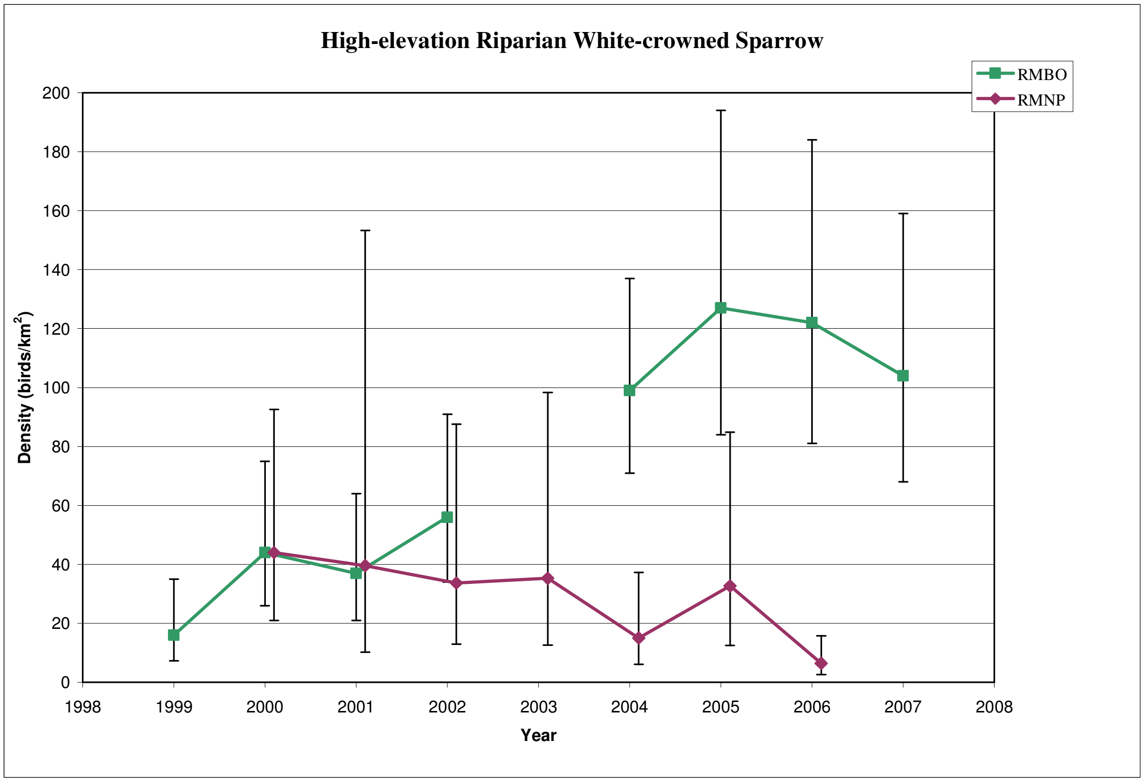

High-elevation Riparian Yellow-rumped Warbler
RMBO
RMNP
Density (birds/km²)
90
80
70
60
50
40
30
20
10
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

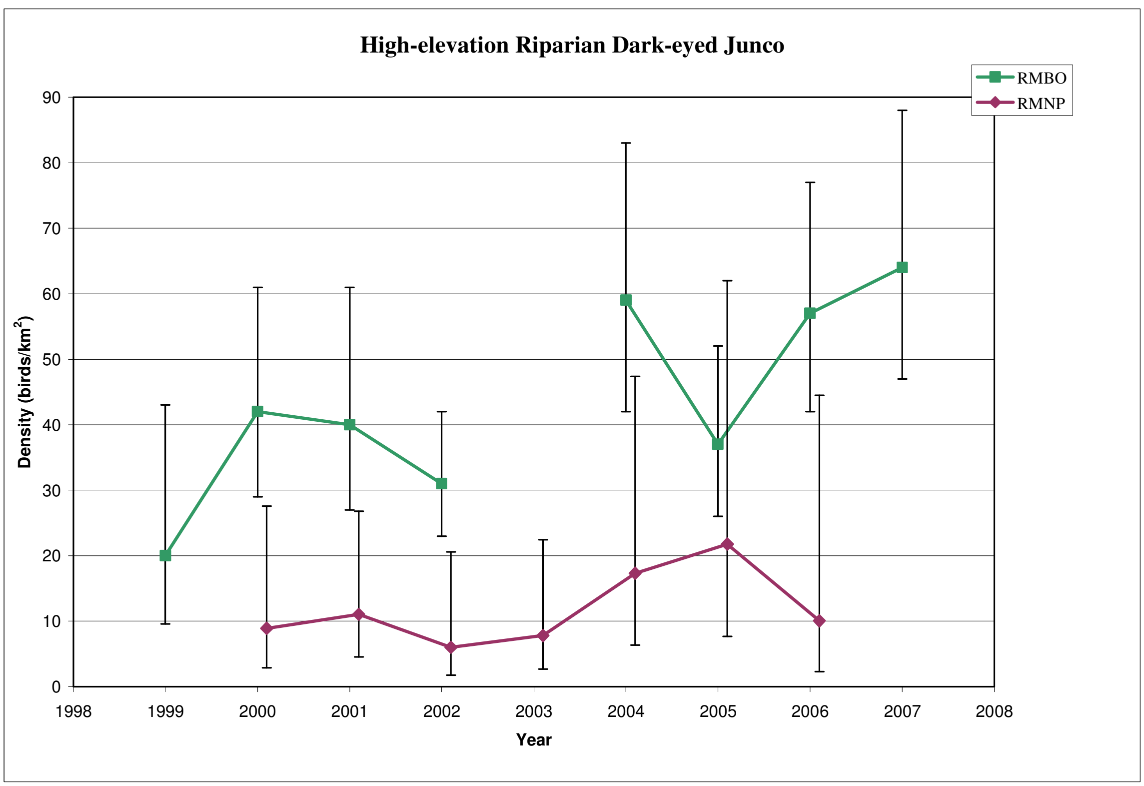

High-elevation Riparian Wilson's Warbler
RMBO
RMNP
Density (birds/km^2)
Year
0
100
200
300
400
500
600
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008

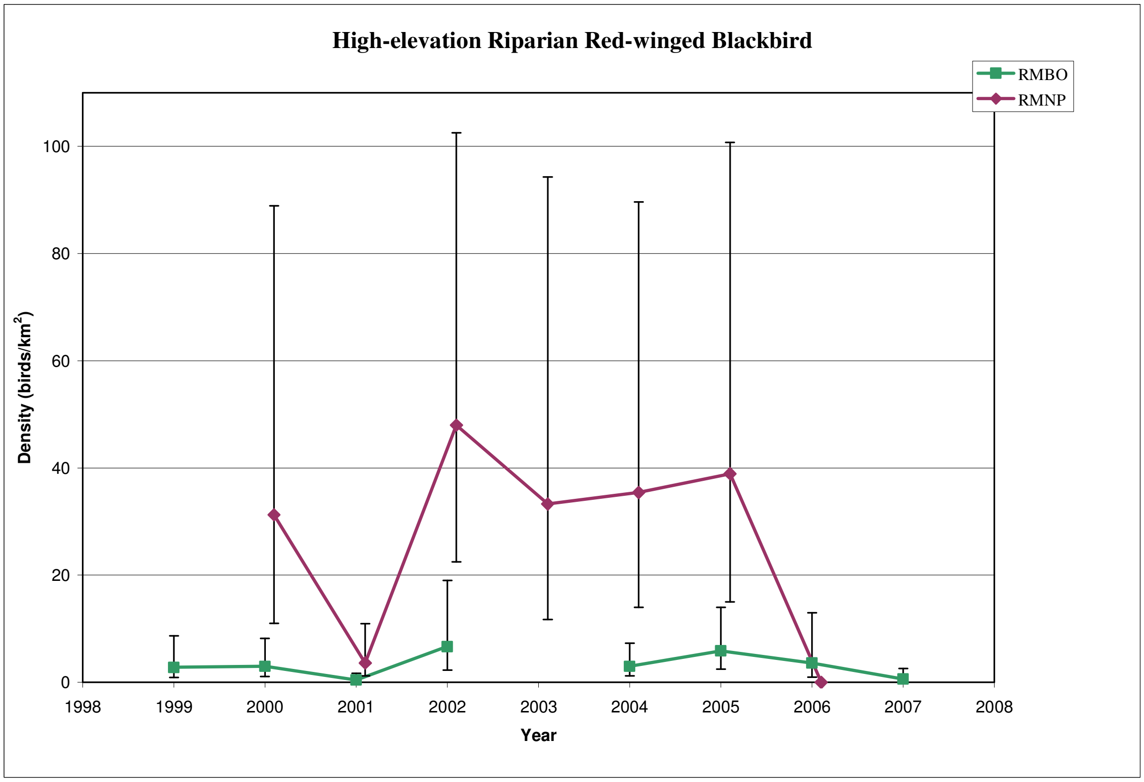

High-elevation Riparian Savannah Sparrow
678.1
RMBO
RMNP
Density (birds/km^2)
Year
0
50
100
150
200
250
300
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008

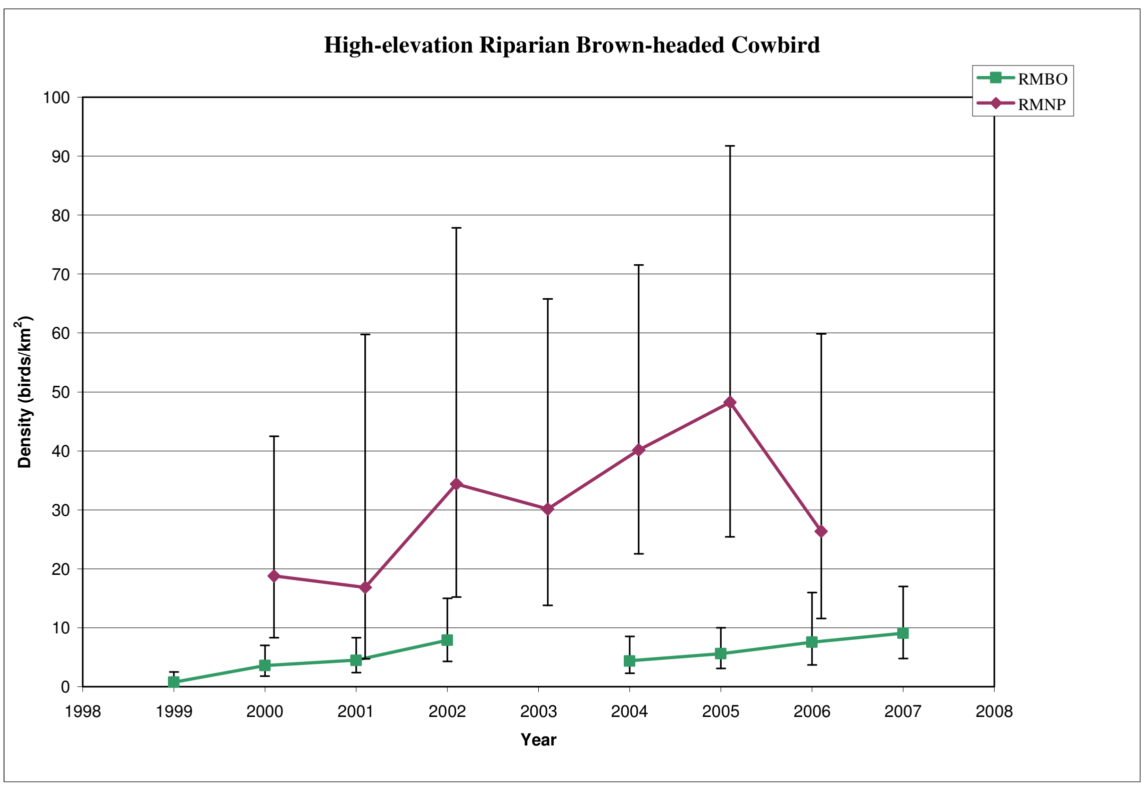

High-elevation Riparian Song Sparrow
RMBO
RMNP
Density (birds/km2)
300
250
200
150
100
50
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

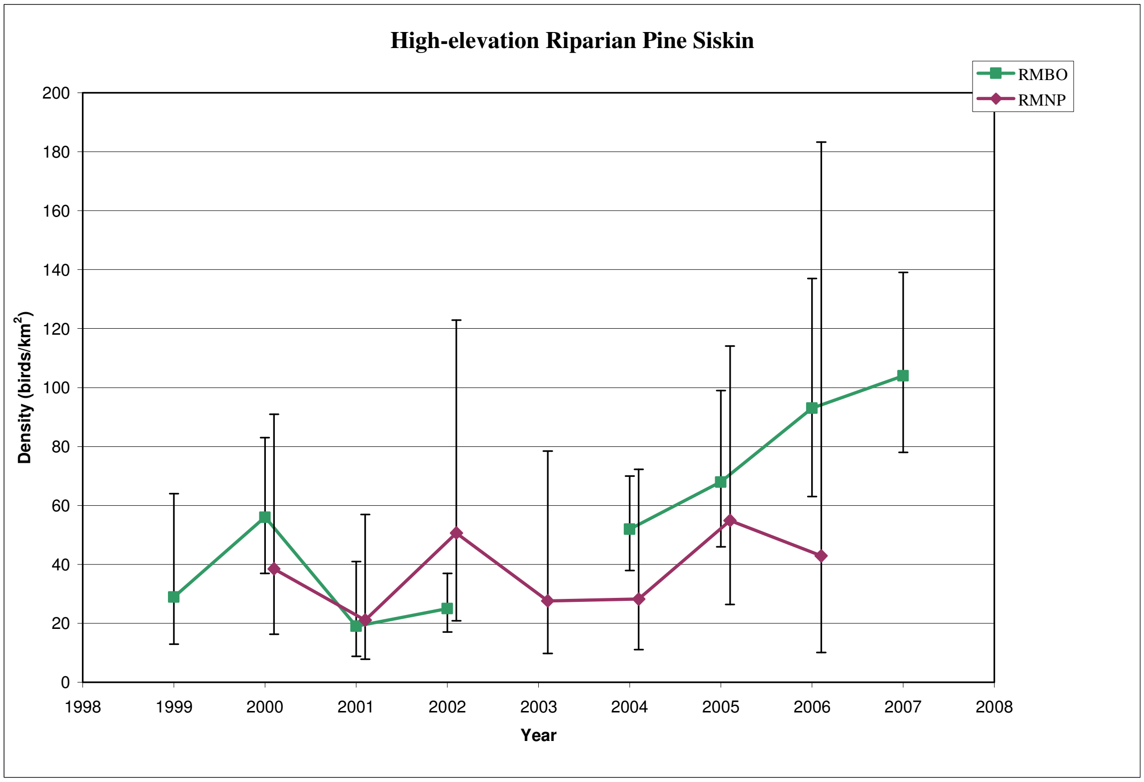

High-elevation Riparian Lincoln's Sparrow
RMBO
RMNP
Density (birds/km2)
1000
900
800
700
600
500
400
300
200
100
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year


High-elevation Riparian White-crowned Sparrow
RMBO
RMNP
Density (birds/km²)
0
20
40
60
80
100
120
140
160
180
200
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

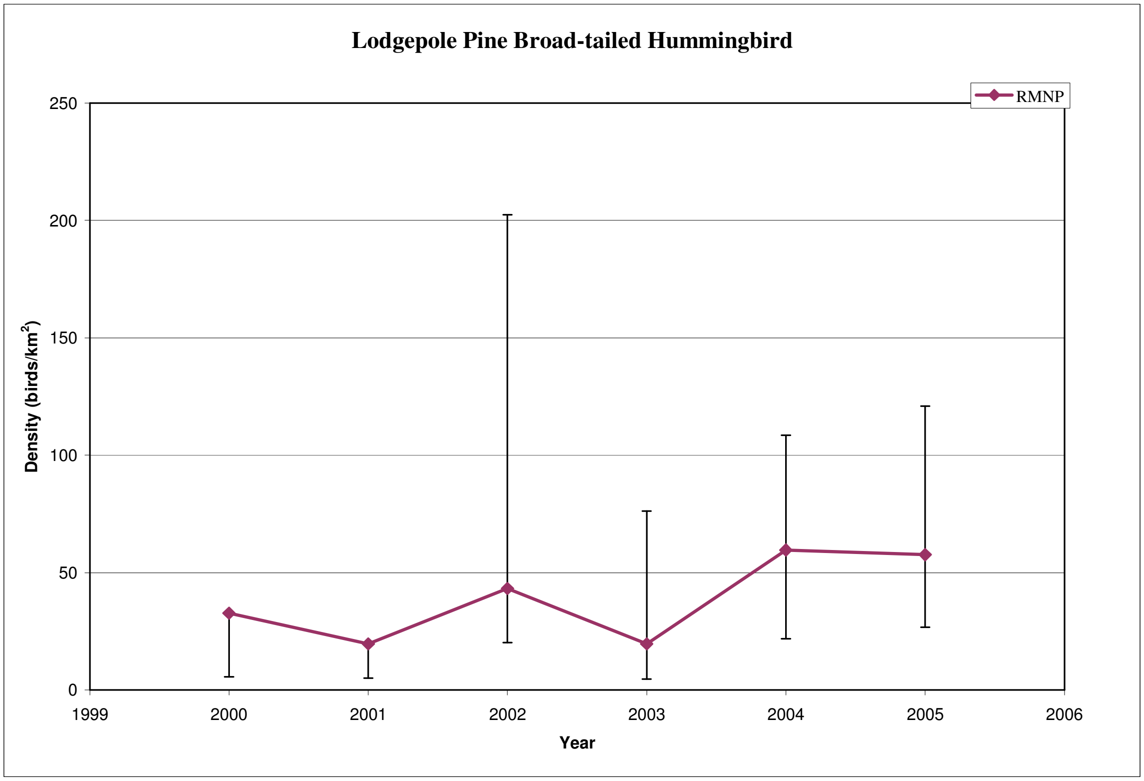

High-elevation Riparian Dark-eyed Junco
RMBO
RMNP
Density (birds/km²)
0
10
20
30
40
50
60
70
80
90
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

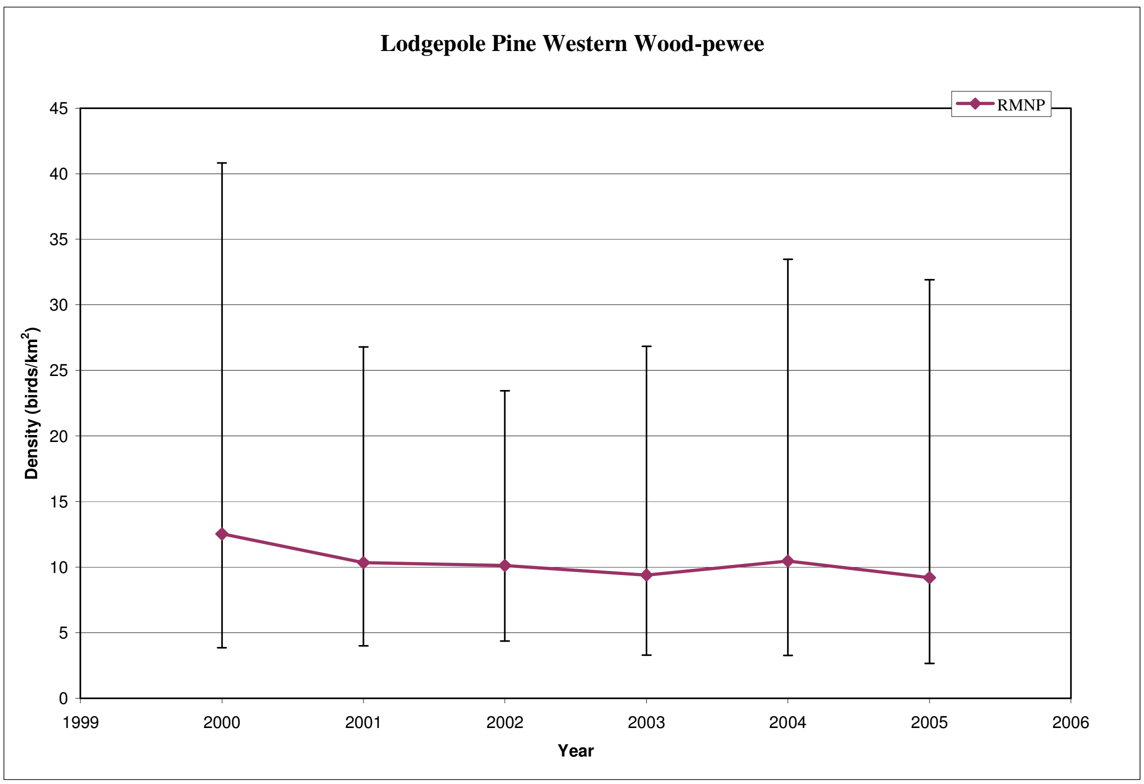

High-elevation Riparian Red-winged Blackbird
RMBO
RMNP
Density (birds/km²)
Year
0
20
40
60
80
100
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008

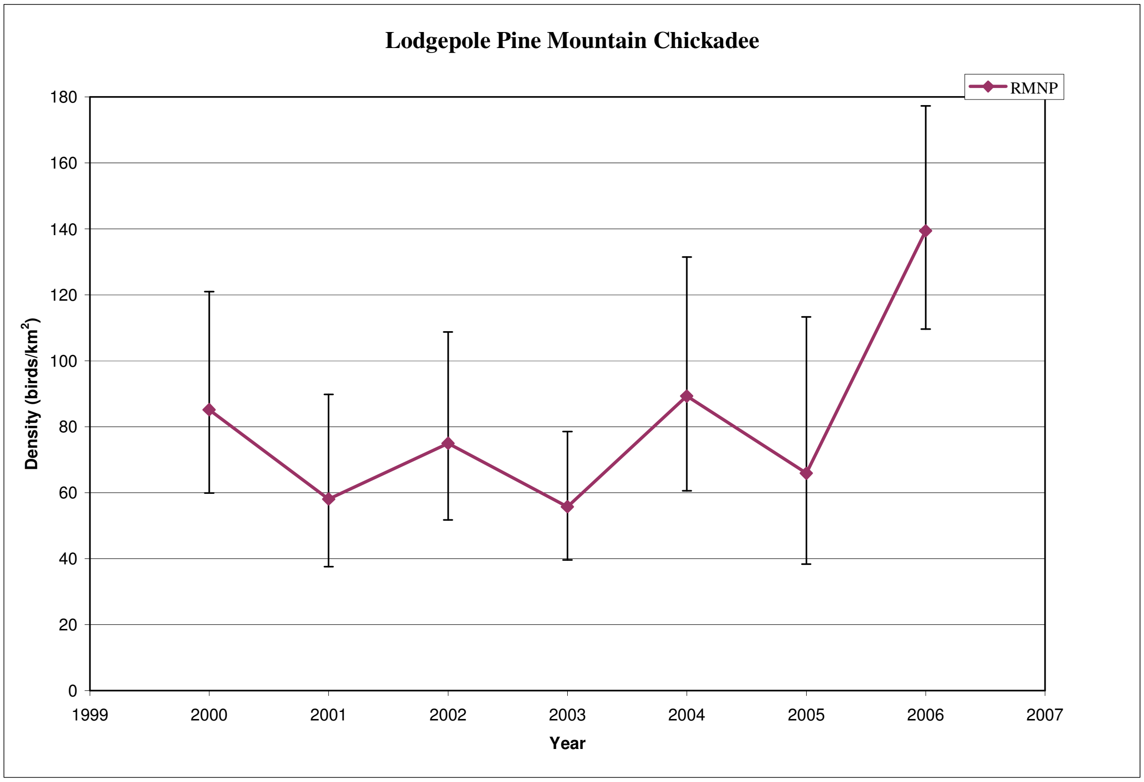

High-elevation Riparian Brown-headed Cowbird
RMBO
RMNP
Density (birds/km²)
Year
0
10
20
30
40
50
60
70
80
90
100
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008

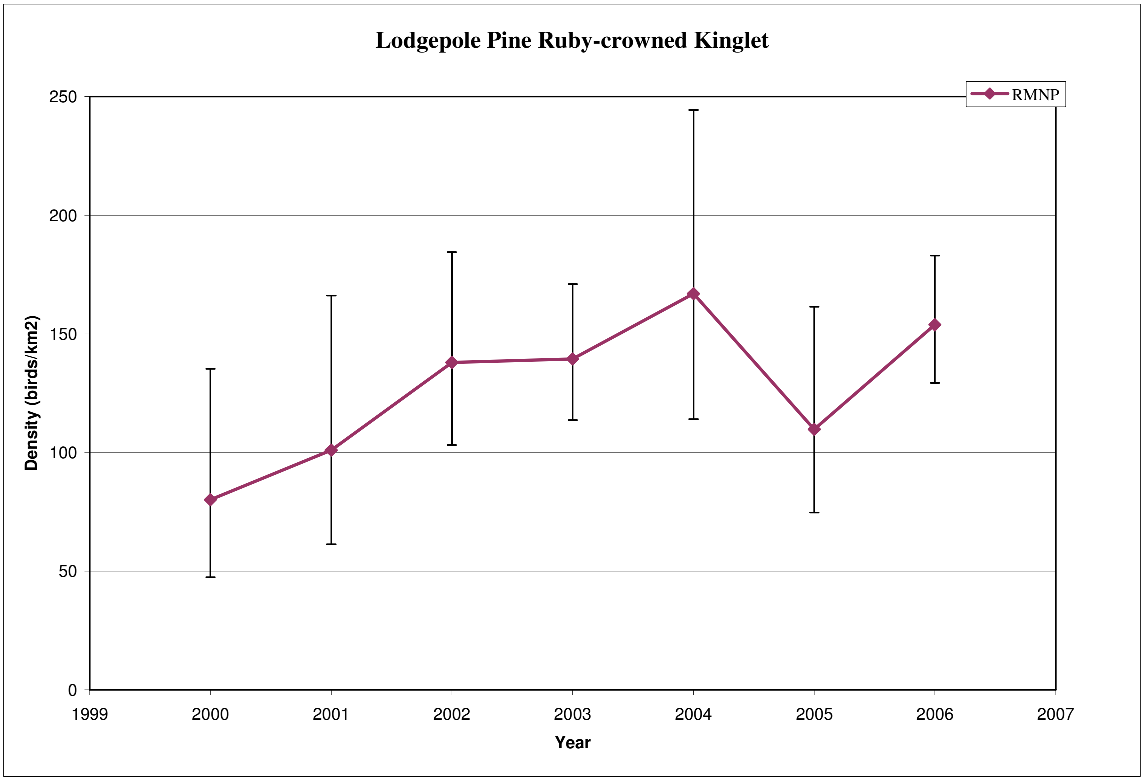

High-elevation Riparian Pine Siskin
RMBO
RMNP
Density (birds/km²)
0
20
40
60
80
100
120
140
160
180
200
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

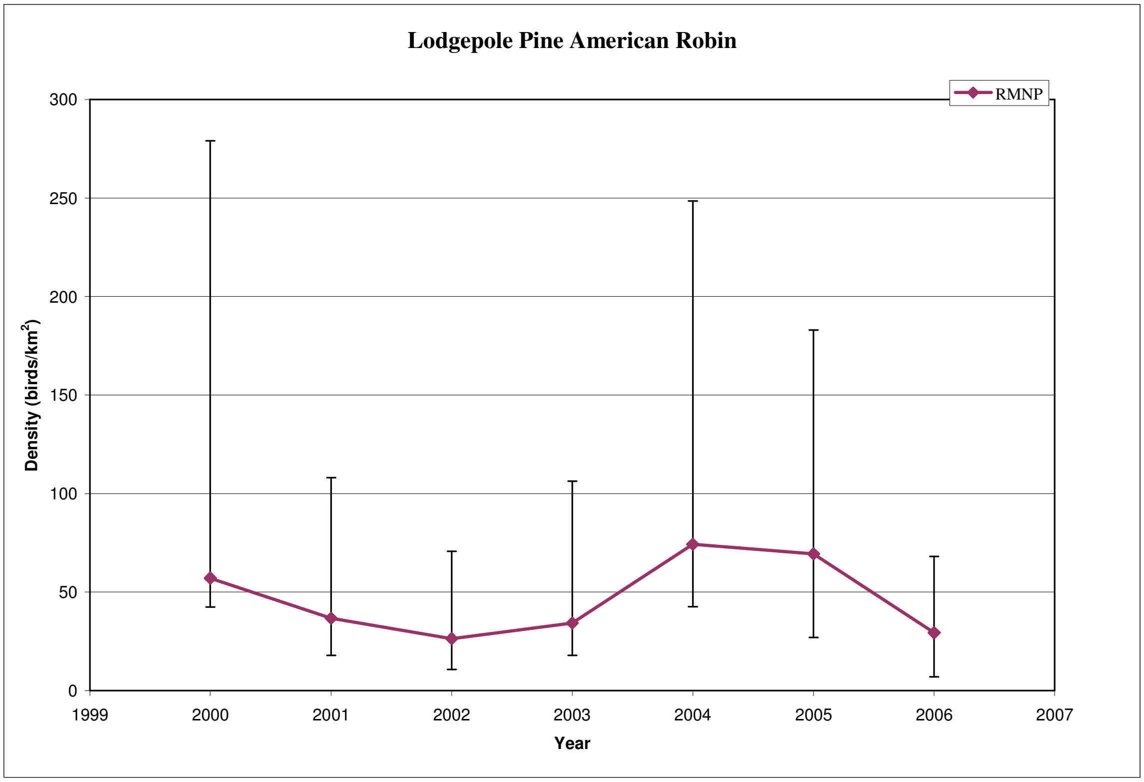
Lodgepole Pine (RMBO only surveyed lodgepole pine in 2000; Density = birds/km^2)

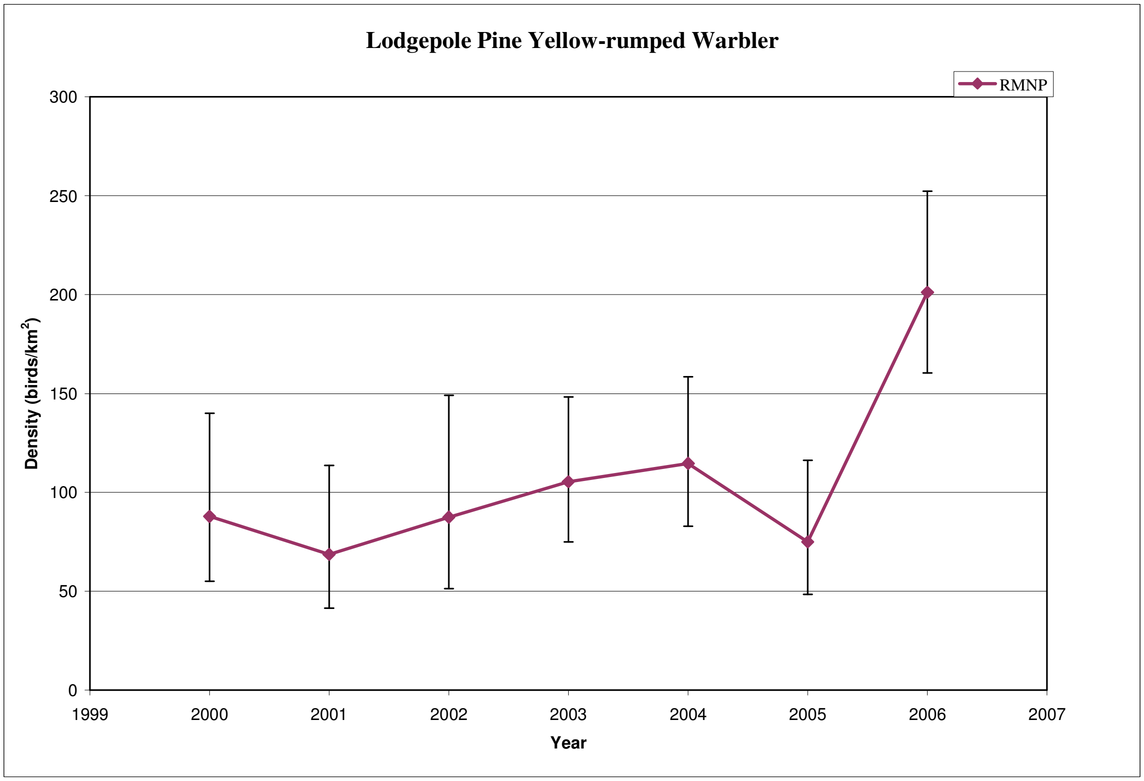


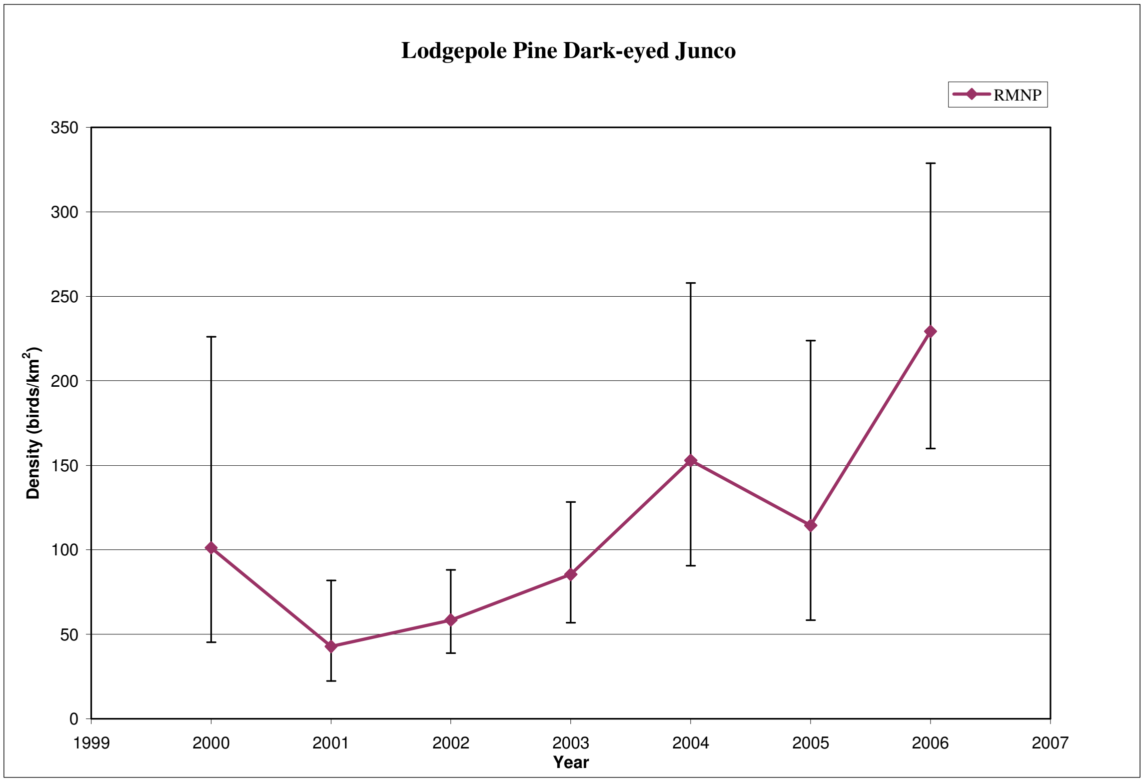


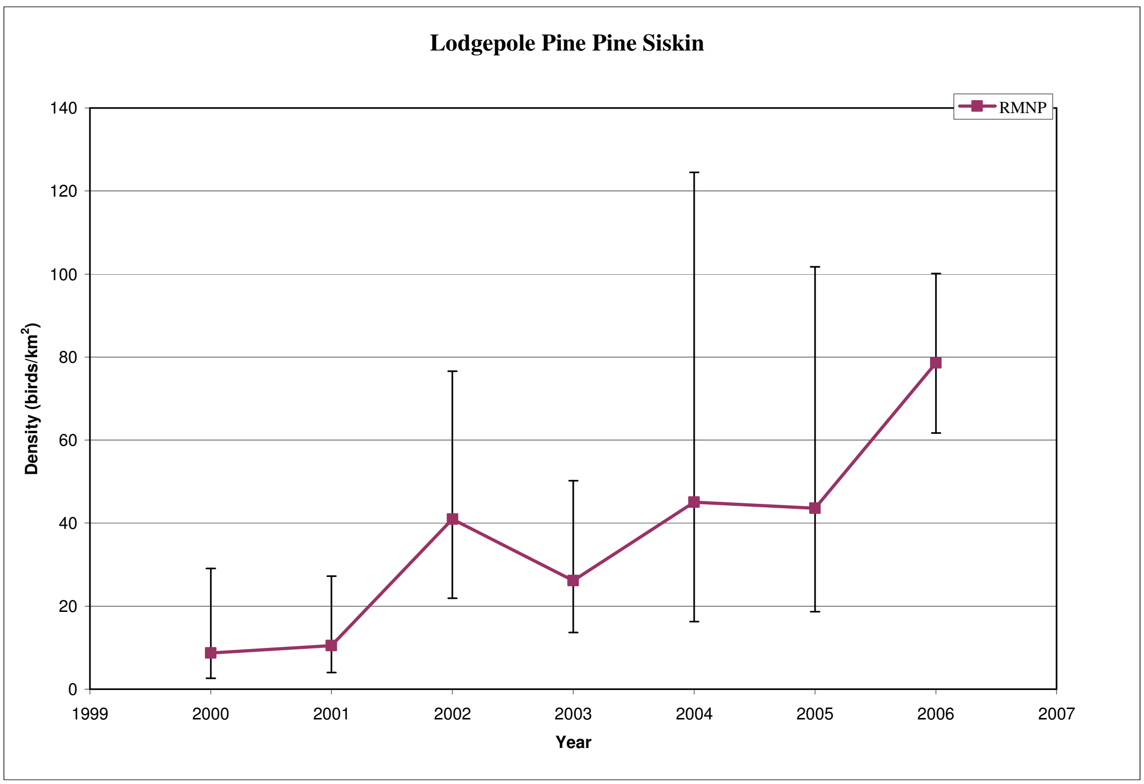

Lodgepole Pine Mountain Chickadee
RMNP
Density (birds/km^2)
0
20
40
60
80
100
120
140
160
180
1999
2000
2001
2002
2003
2004
2005
2006
2007
Year

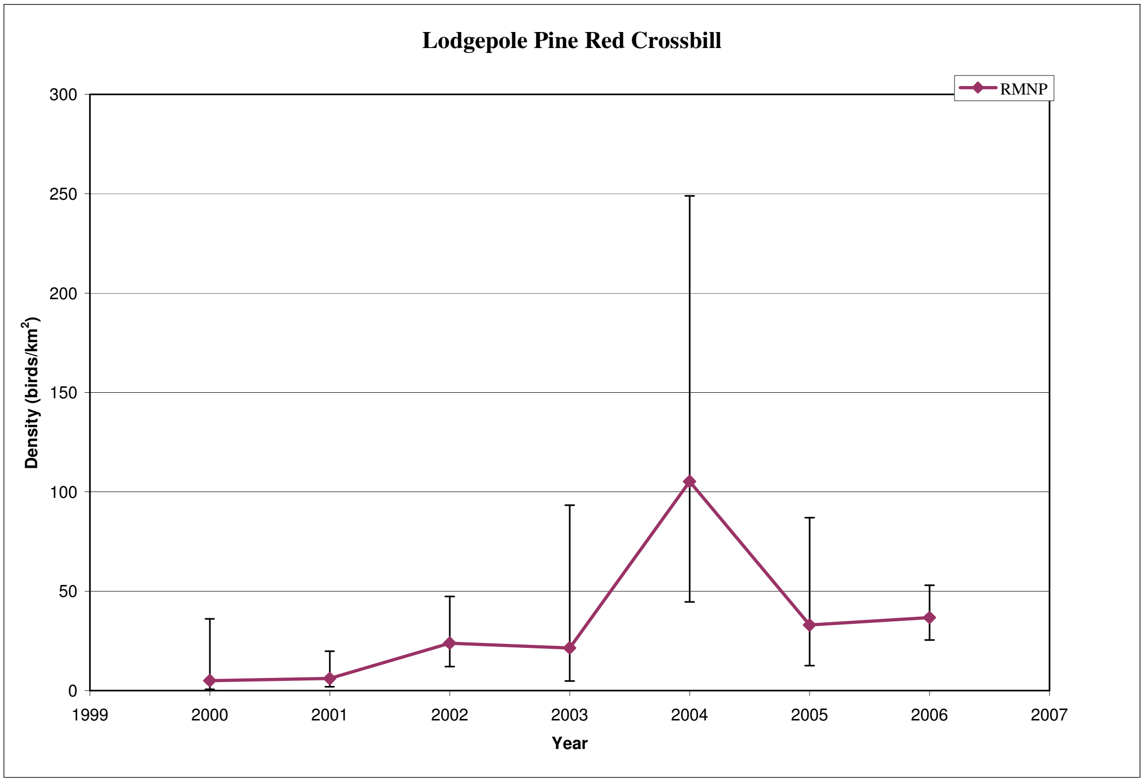

Lodgepole Pine Ruby-crowned Kinglet
RMNP
Density (birds/km2)
0
50
100
150
200
250
1999
2000
2001
2002
2003
2004
2005
2006
2007
Year


Lodgepole Pine American Robin
RMNP
Density (birds/km²)
300
250
200
150
100
50
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
Year

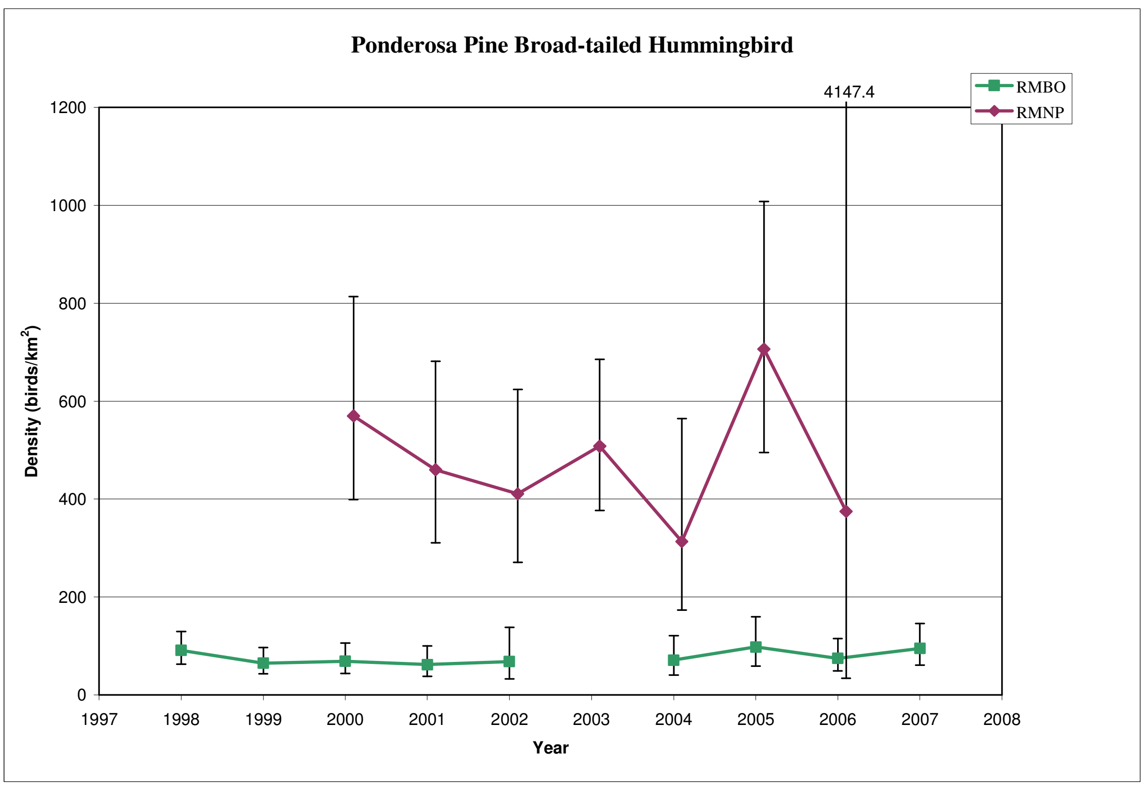

Lodgepole Pine Yellow-rumped Warbler
RMNP
Density (birds/km²)
300
250
200
150
100
50
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
Year

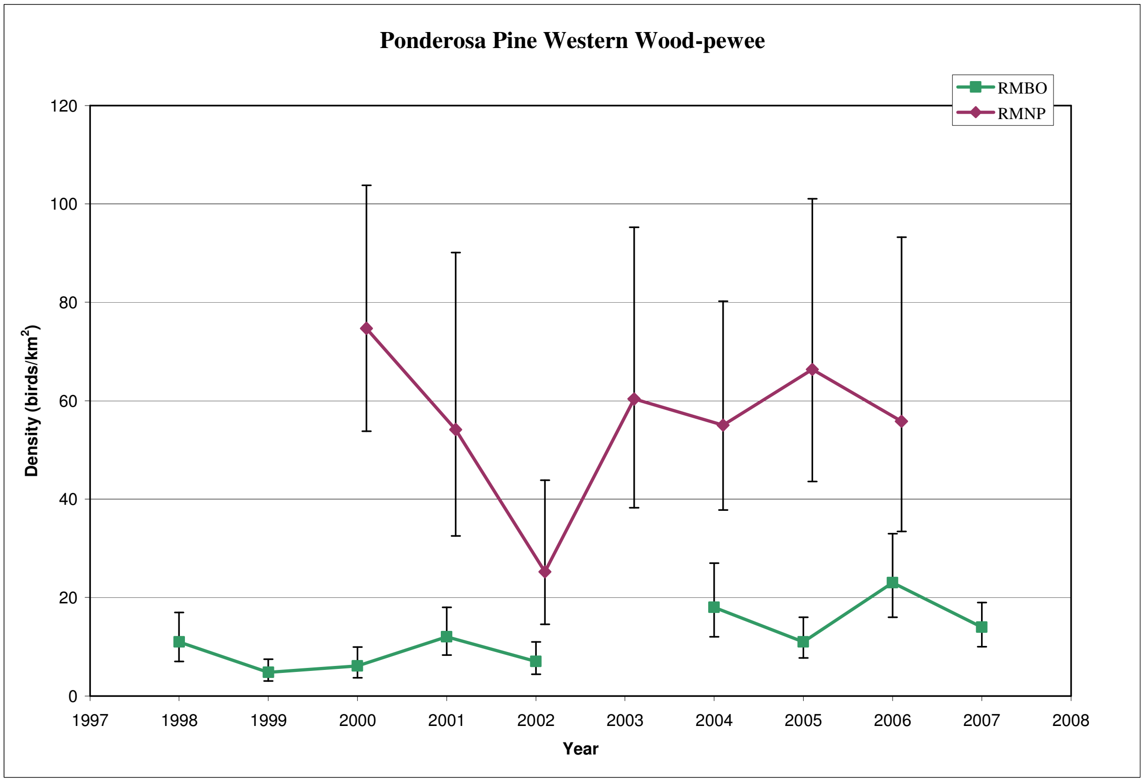

Lodgepole Pine Dark-eyed Junco
RMNP
Density (birds/km²)
0
50
100
150
200
250
300
350
1999
2000
2001
2002
2003
2004
2005
2006
2007
Year

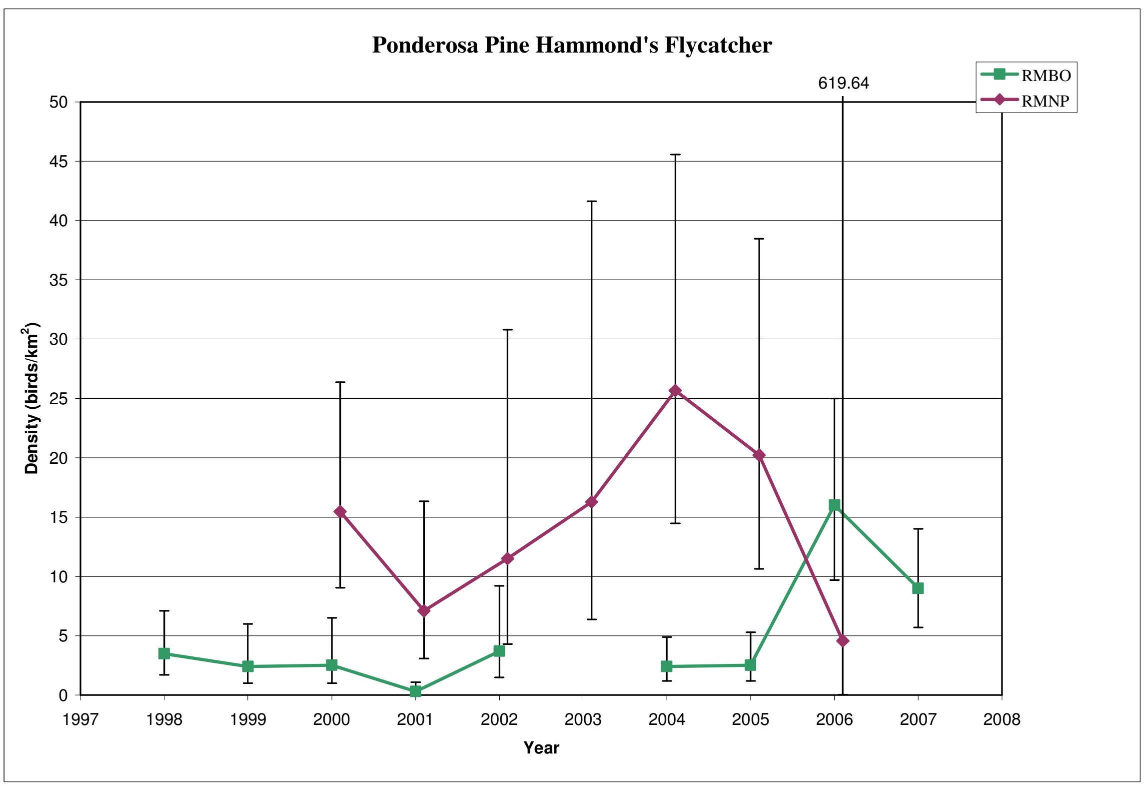

Lodgepole Pine Pine Siskin
RMNP
Density (birds/km²)
0
20
40
60
80
100
120
140
1999
2000
2001
2002
2003
2004
2005
2006
2007
Year



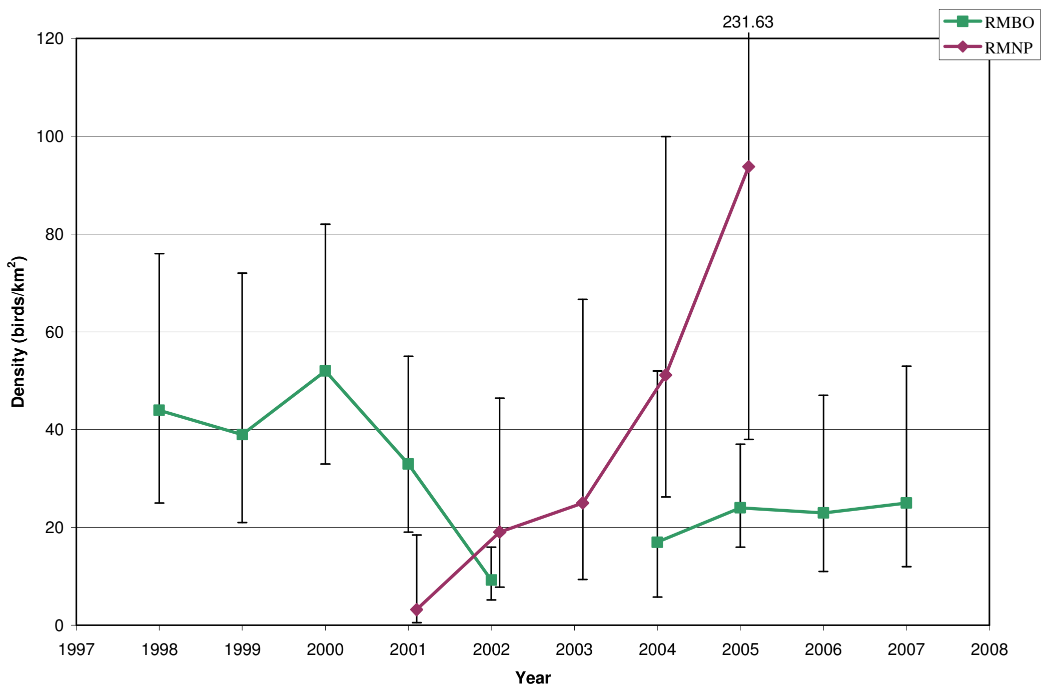
Ponderosa Pine (Density = birds/km^2)



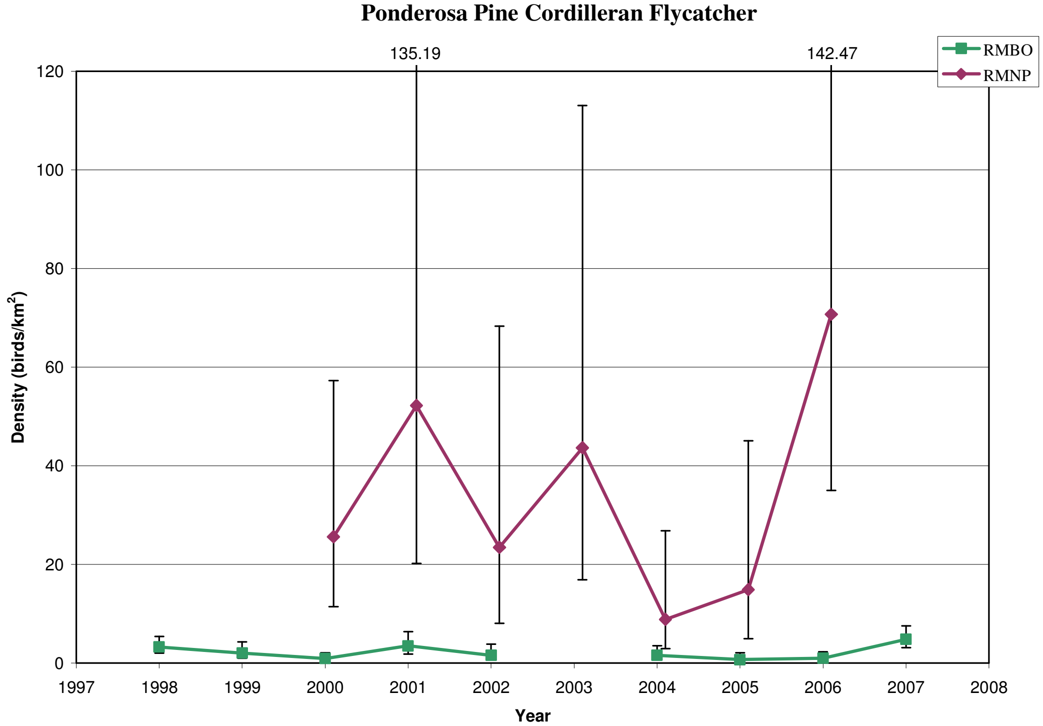

Ponderosa Pine Western Wood-pewee
RMBO
RMNP
Density (birds/km^2)
0
20
40
60
80
100
120
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

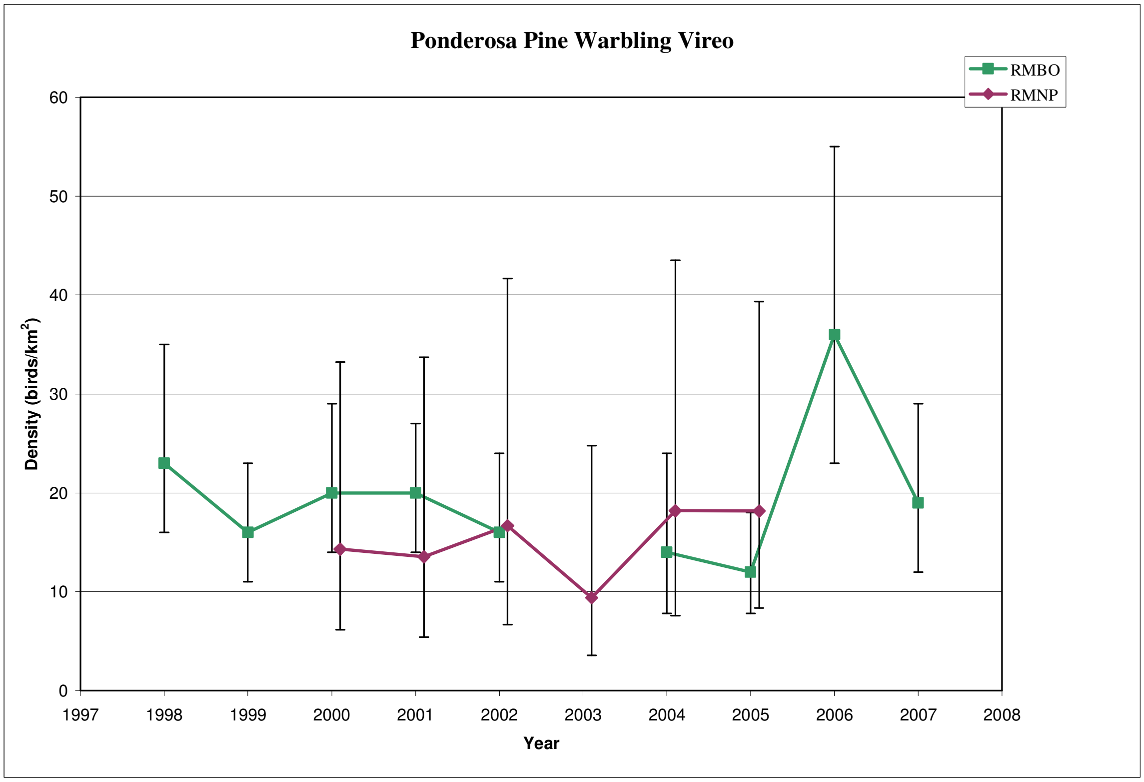

Ponderosa Pine Hammond's Flycatcher
RMBO
RMNP
619.64
Density (birds/km^2)
0
5
10
15
20
25
30
35
40
45
50
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

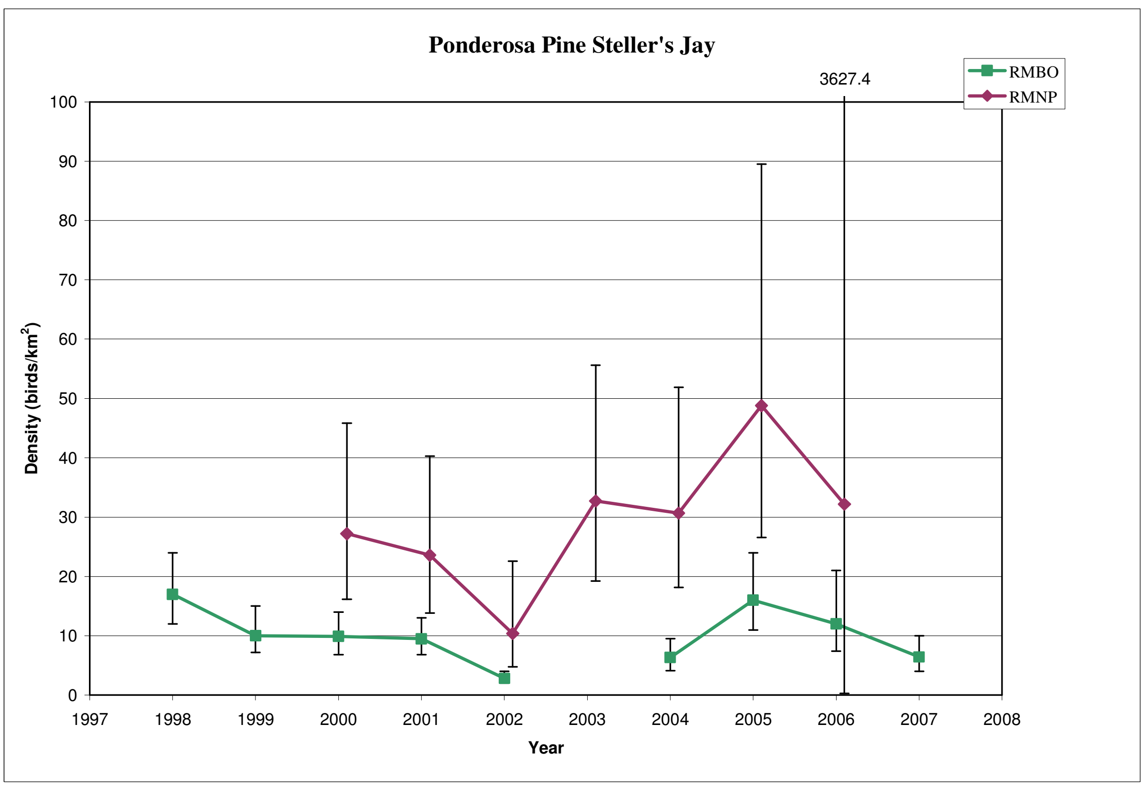
Ponderosa Pine Dusky Flycatcher

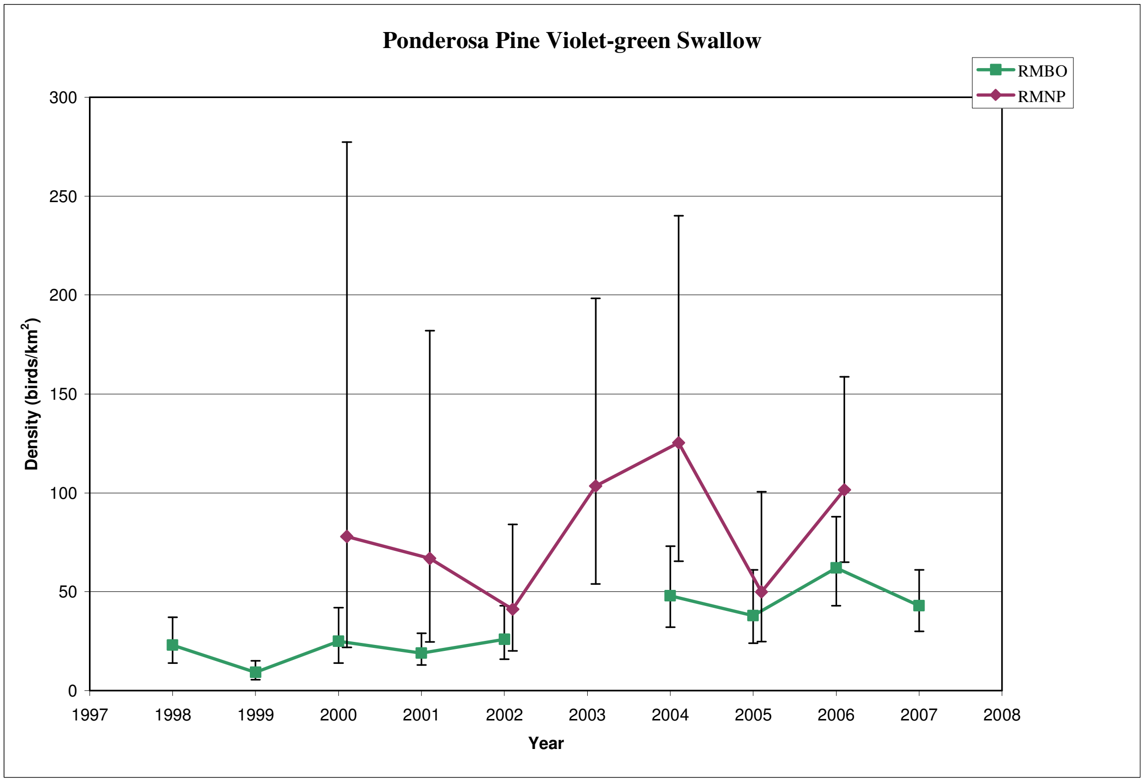


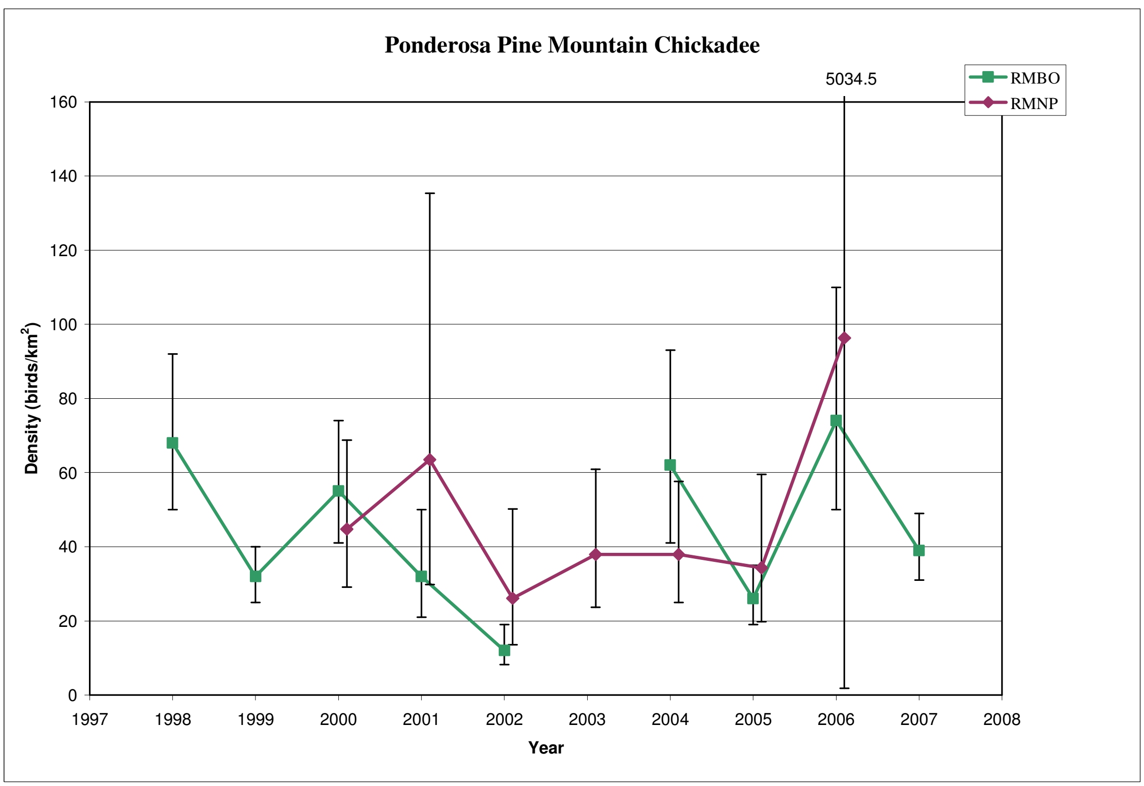
Ponderosa Pine Cordilleran Flycatcher

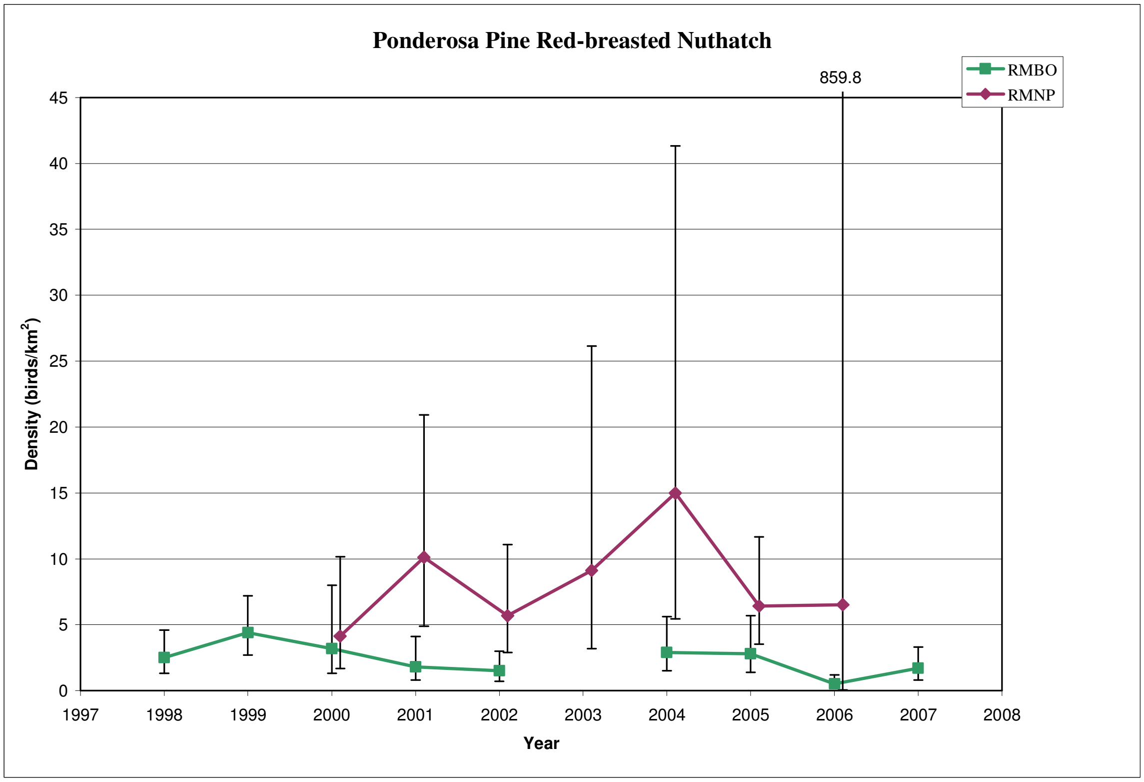



Ponderosa Pine Warbling Vireo
RMBO
RMNP
Density (birds/km²)
Year
0
10
20
30
40
50
60
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008

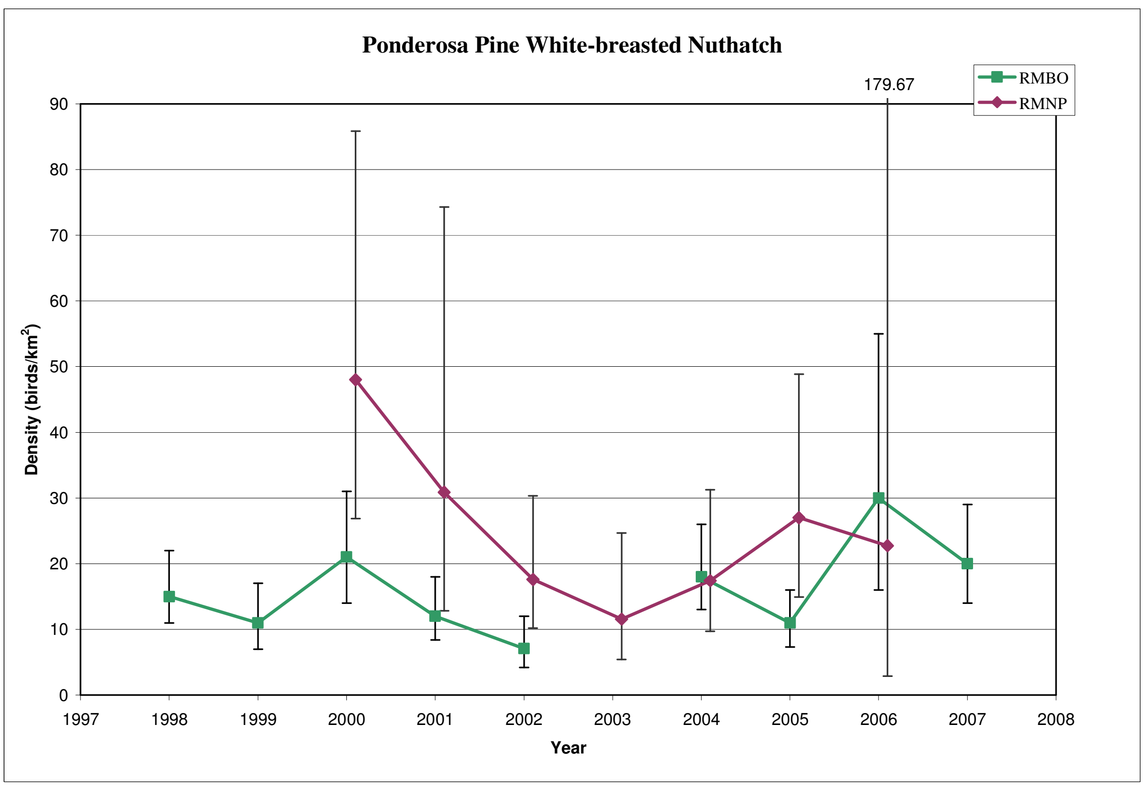

Ponderosa Pine Steller's Jay
3627.4
RMBO
RMNP
Density (birds/km²)
Year
0
10
20
30
40
50
60
70
80
90
100
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008


Ponderosa Pine Violet-green Swallow
RMBO
RMNP
Density (birds/km²)
300
250
200
150
100
50
0
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

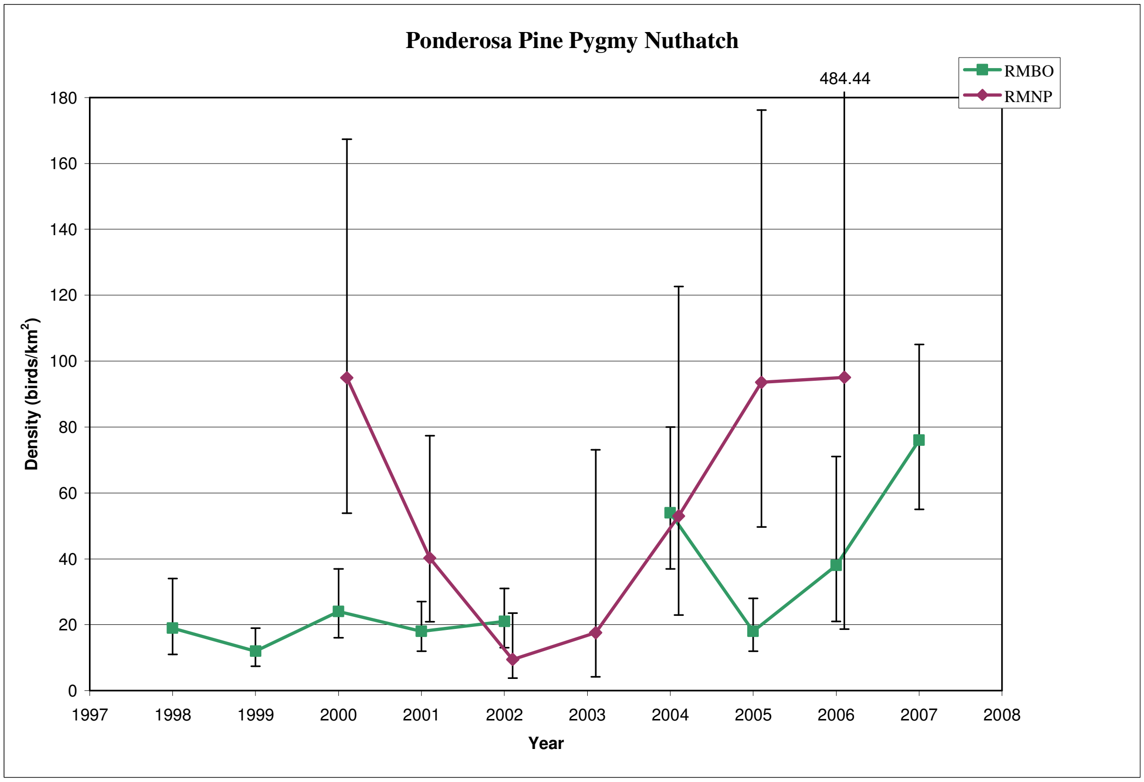

Ponderosa Pine Mountain Chickadee
5034.5
RMBO
RMNP
Density (birds/km²)
160
140
120
100
80
60
40
20
0
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

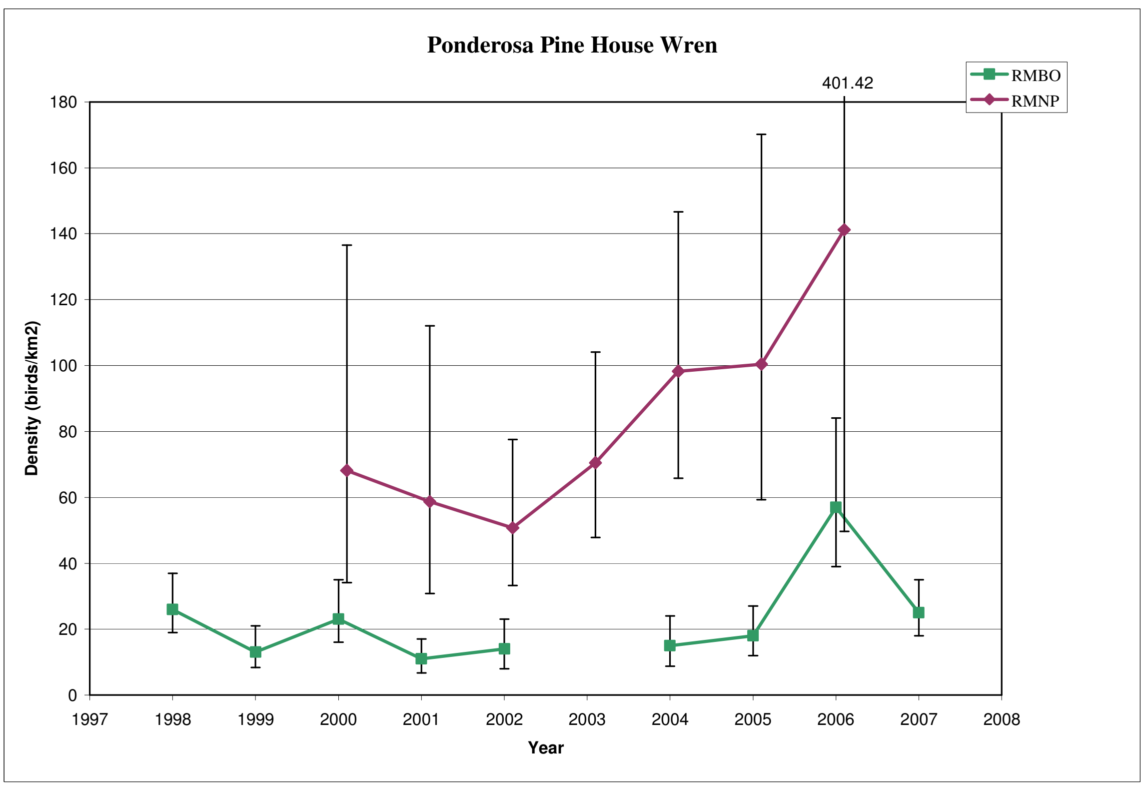


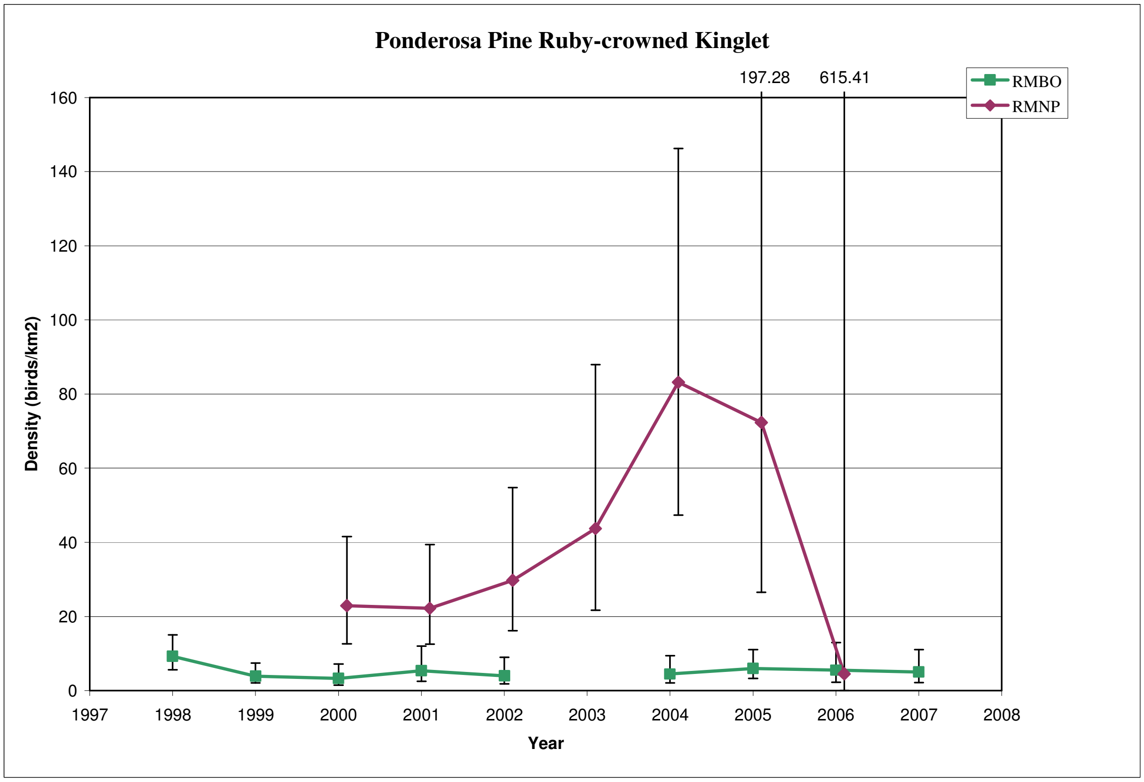
Ponderosa Pine Red-breasted Nuthatch
RMBO
RMNP
859.8
Density (birds/km²)
Year
0
5
10
15
20
25
30
35
40
45
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008

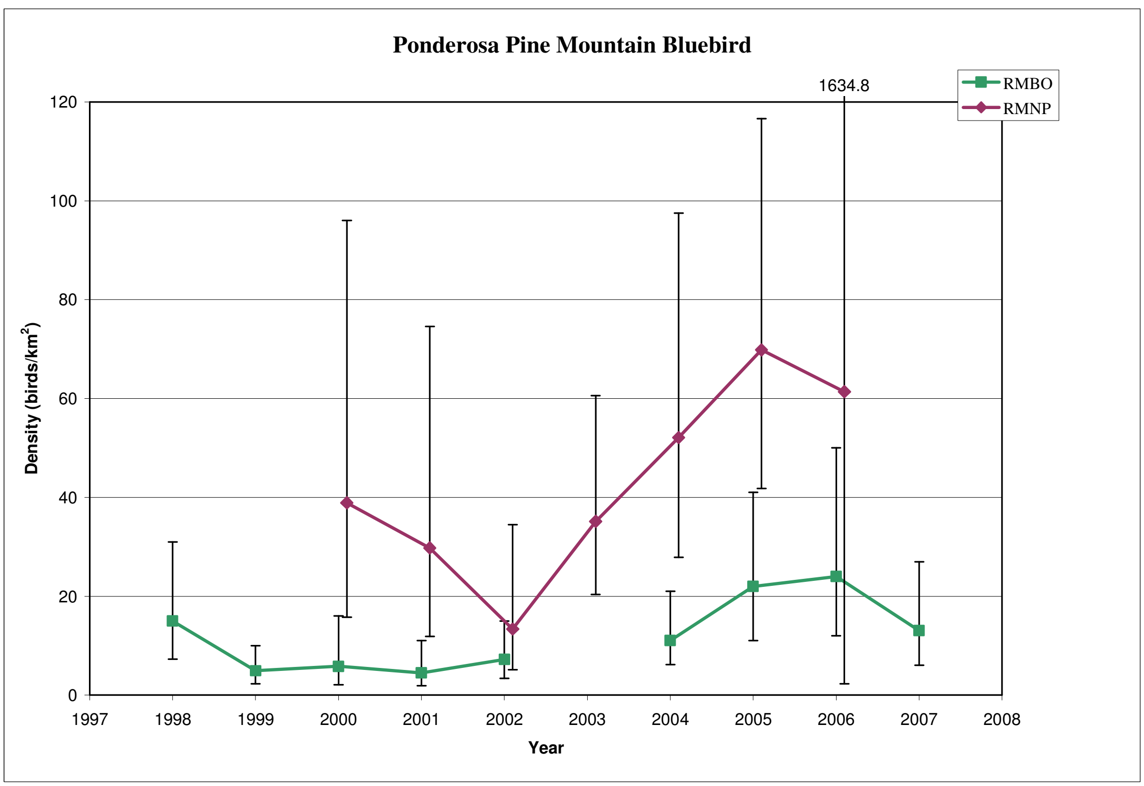


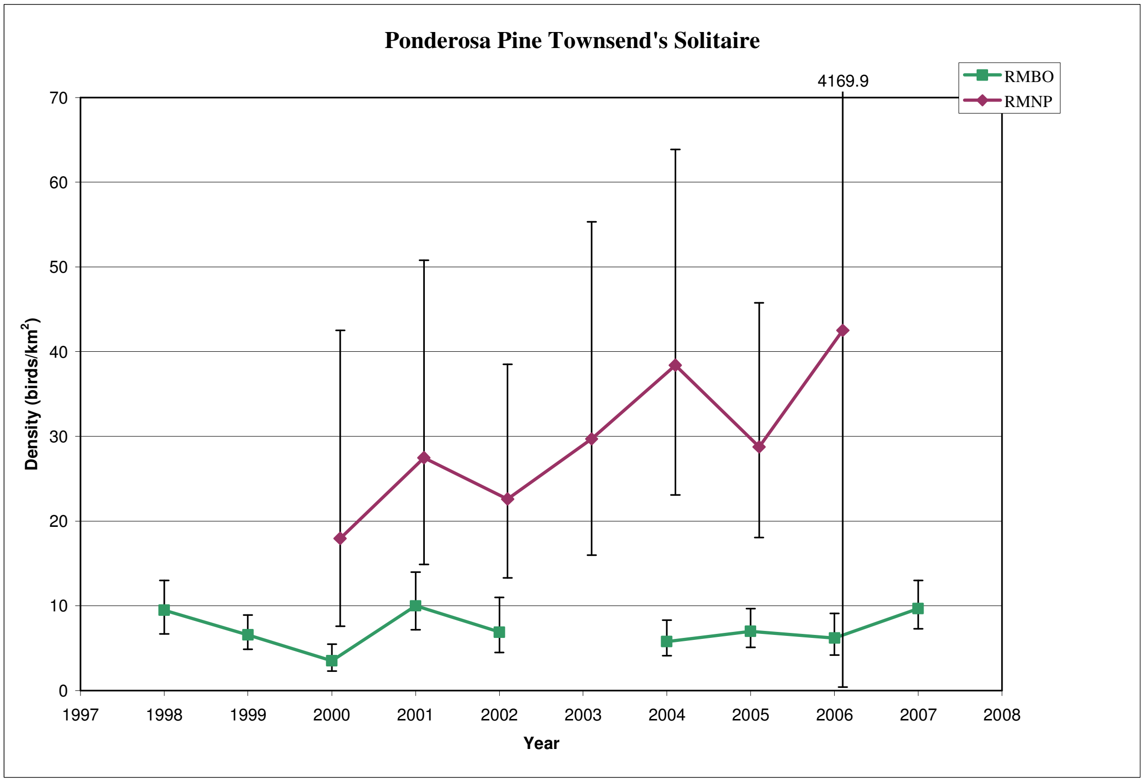
Ponderosa Pine White-breasted Nuthatch
RMBO
RMNP
179.67
Density (birds/km²)
Year
0
10
20
30
40
50
60
70
80
90
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008


Ponderosa Pine Pygmy Nuthatch
RMBO
RMNP
484.44
Density (birds/km^2)
0
20
40
60
80
100
120
140
160
180
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

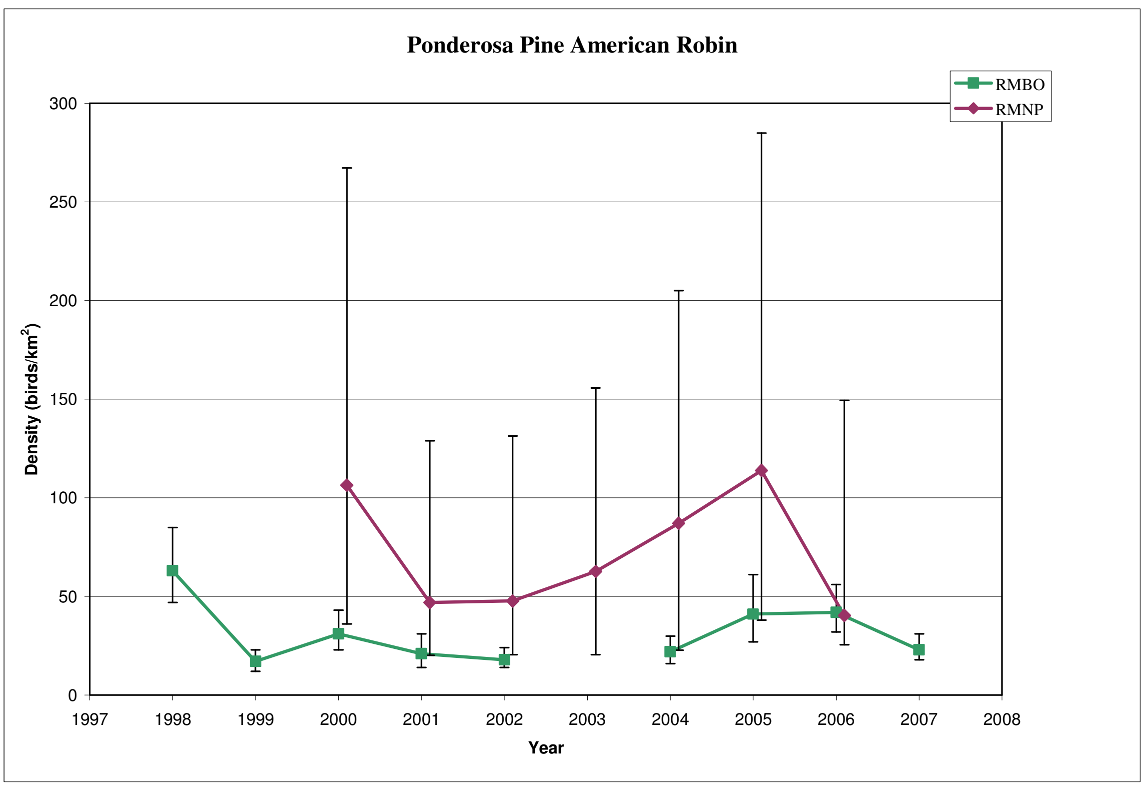

Ponderosa Pine House Wren
RMBO
RMNP
401.42
Density (birds/km2)
0
20
40
60
80
100
120
140
160
180
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year


Ponderosa Pine Ruby-crowned Kinglet
197.28
615.41
RMBO
RMNP
160
140
120
100
80
60
40
20
0
Density (birds/km2)
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

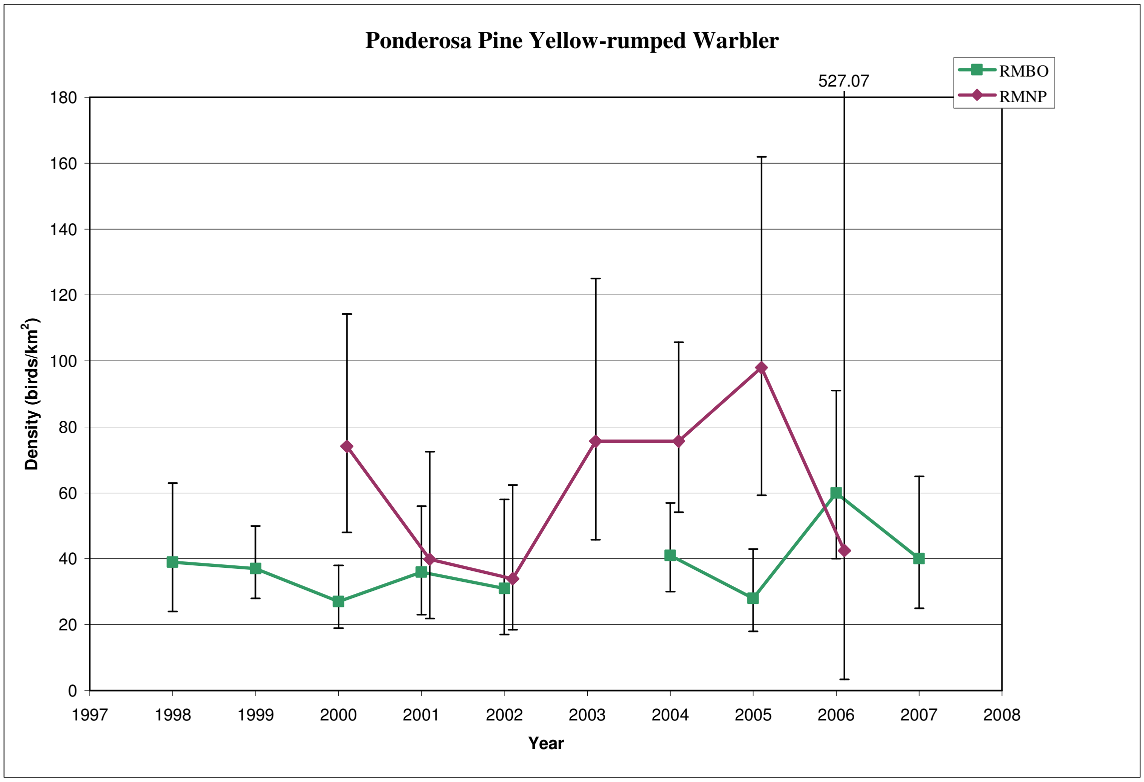

Ponderosa Pine Mountain Bluebird
1634.8
RMBO
RMNP
120
100
80
60
40
20
0
Density (birds/km^2)
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

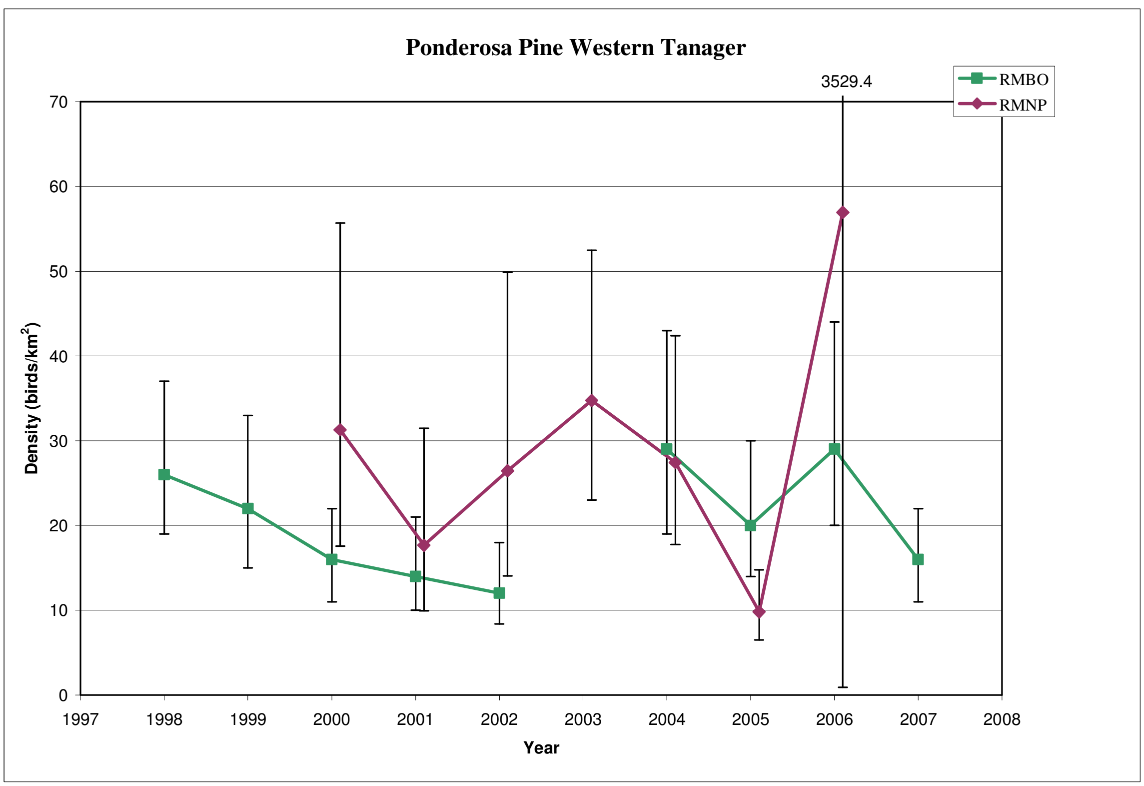


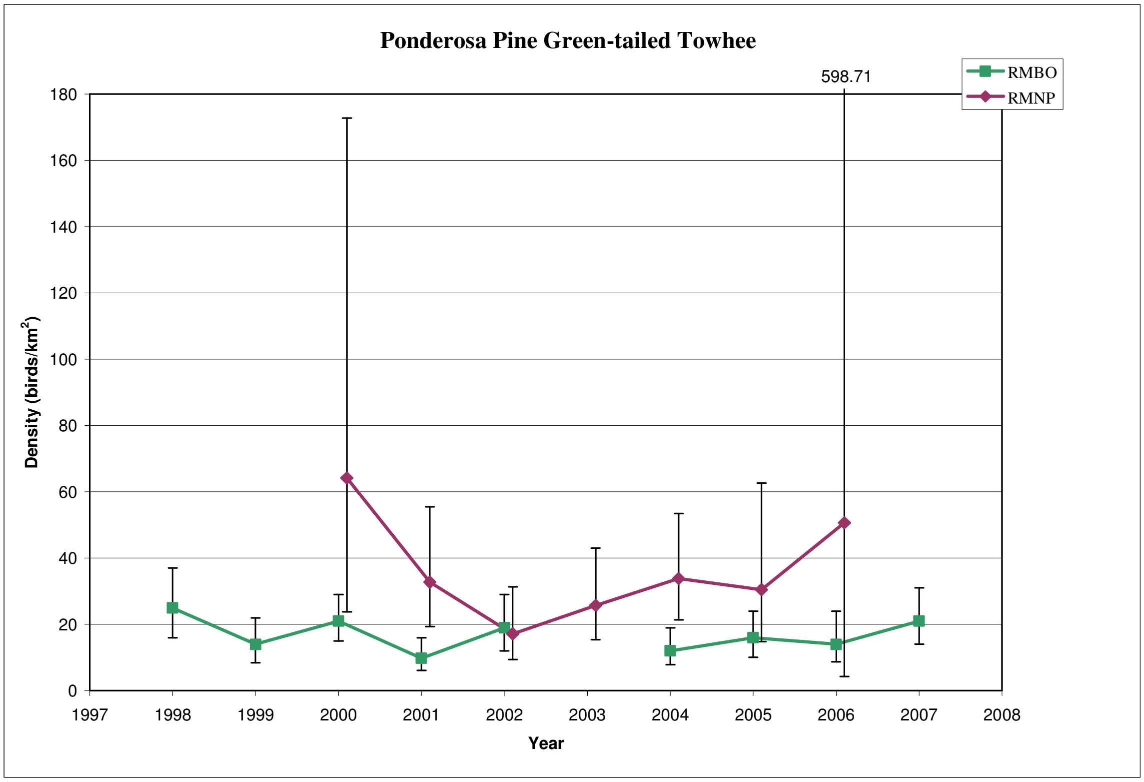
Ponderosa Pine Townsend's Solitaire
RMBO
RMNP
4169.9
Density (birds/km²)
0
10
20
30
40
50
60
70
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year



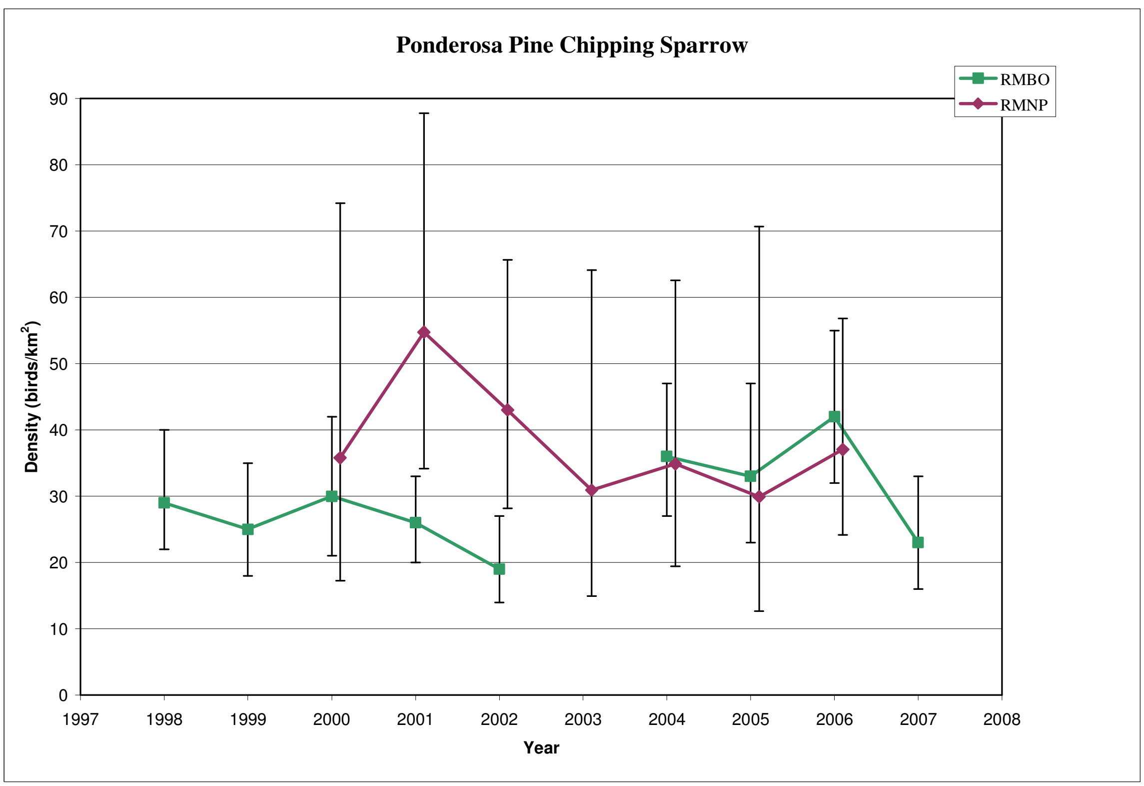
Ponderosa Pine American Robin
RMBO
RMNP
Density (birds/km²)
0
50
100
150
200
250
300
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year


Ponderosa Pine Yellow-rumped Warbler
RMBO
RMNP
527.07
Density (birds/km^2)
0
20
40
60
80
100
120
140
160
180
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

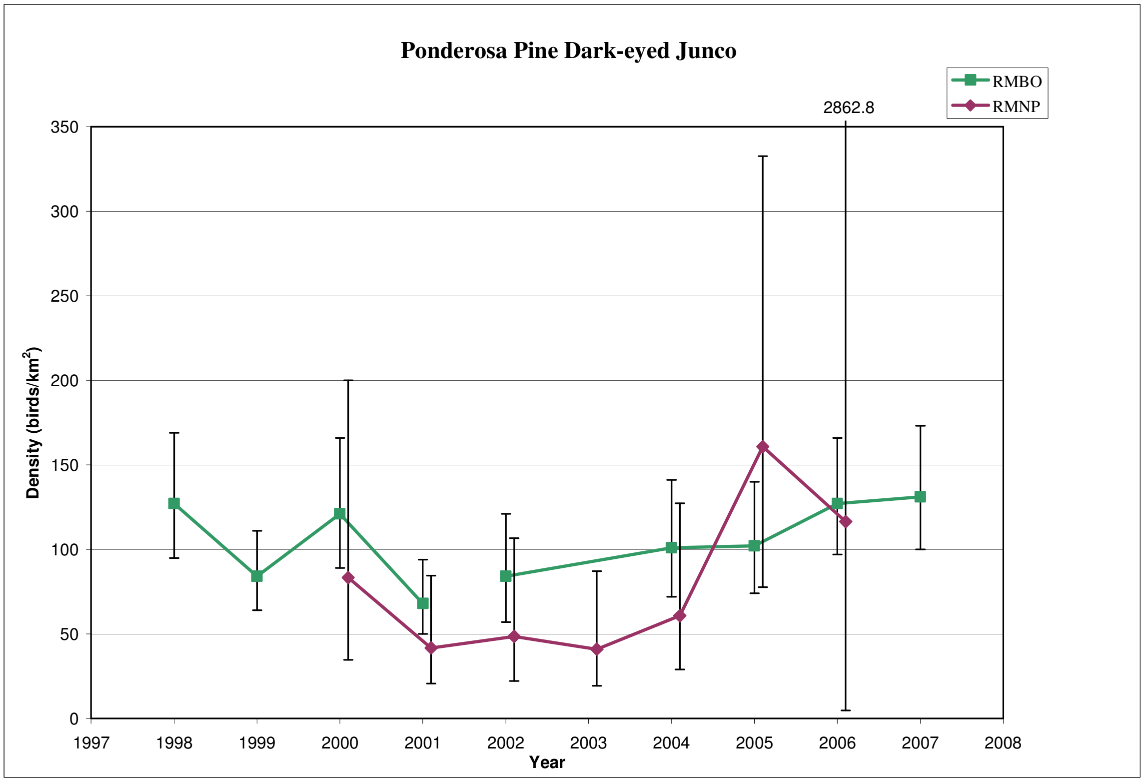

Ponderosa Pine Western Tanager
RMBO
RMNP
3529.4
Density (birds/km^2)
0
10
20
30
40
50
60
70
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

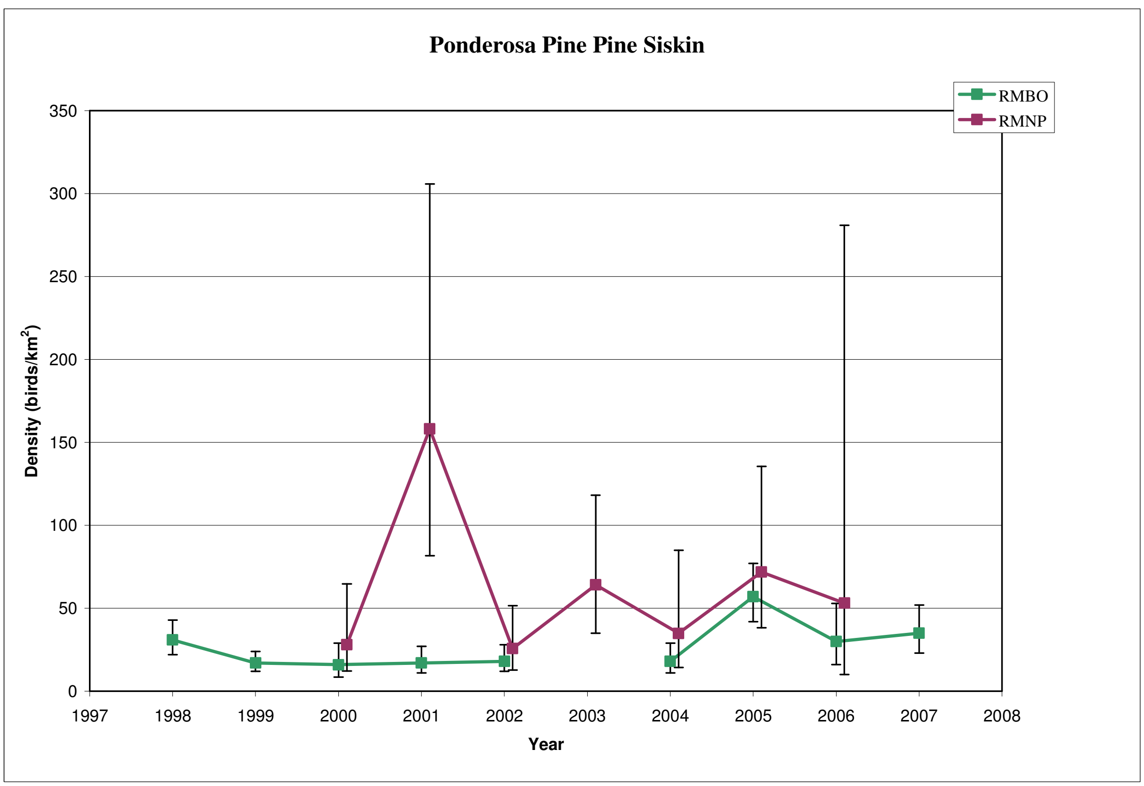


Ponderosa Pine Green-tailed Towhee
RMBO
RMNP
598.71
Density (birds/km2)
Year

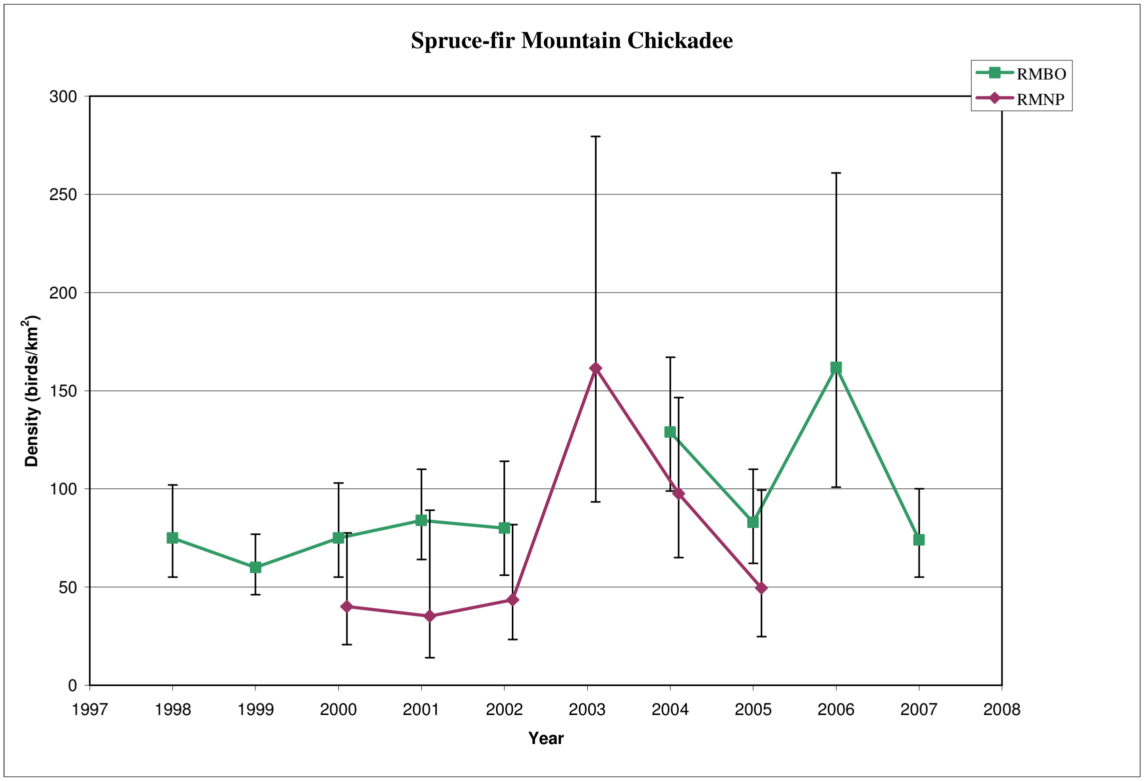


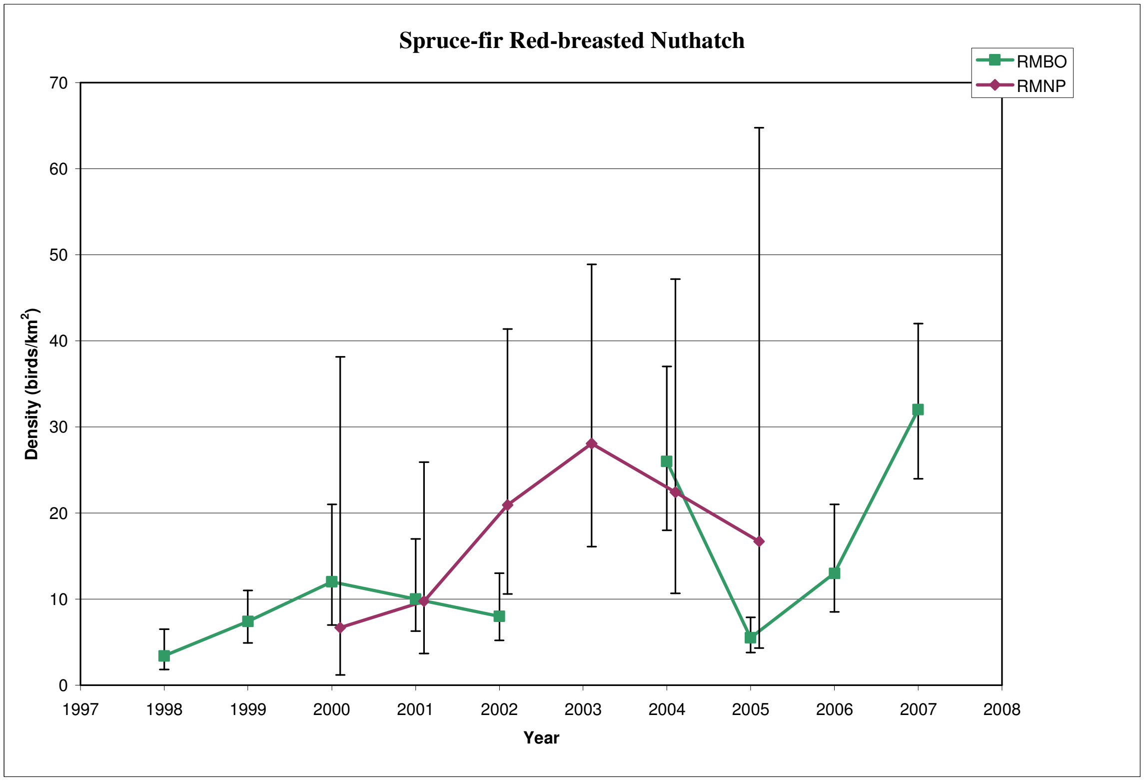
Ponderosa Pine Chipping Sparrow
RMBO
RMNP
Density (birds/km2)
Year

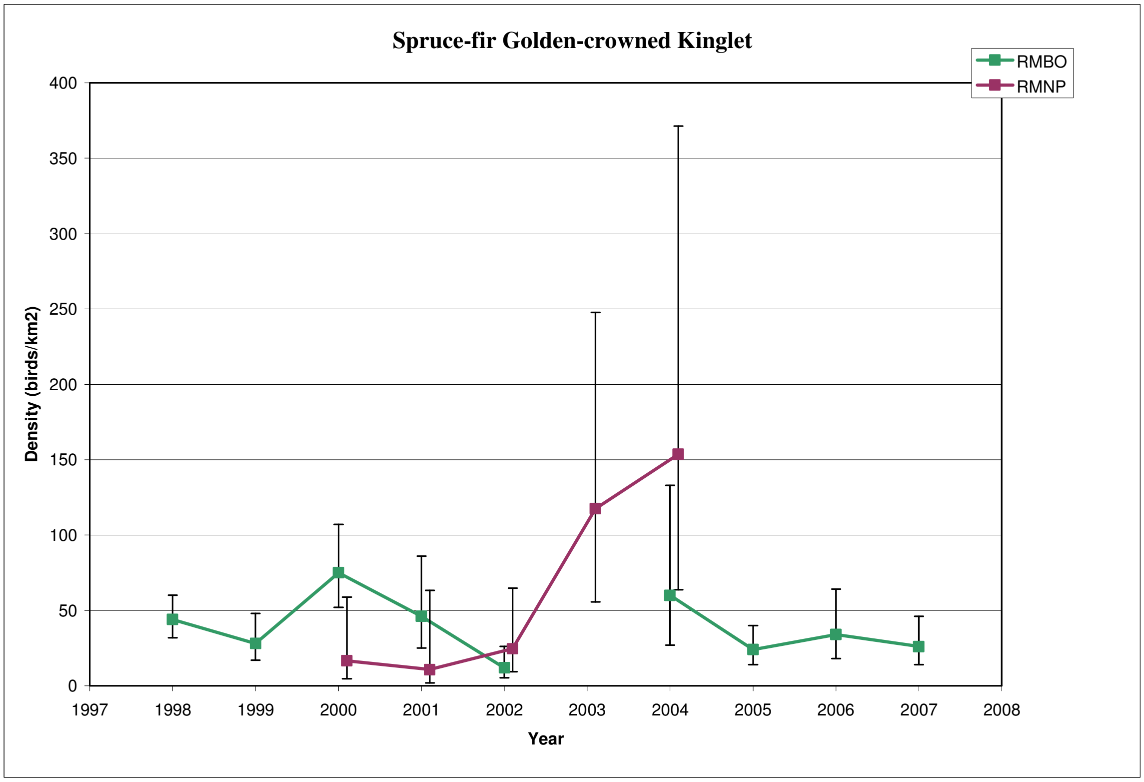

Ponderosa Pine Dark-eyed Junco
RMBO
RMNP
2862.8
Density (birds/km2)
Year
0
50
100
150
200
250
300
350
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008


Ponderosa Pine Pine Siskin
RMBO
RMNP
Density (birds/km2)
Year
0
50
100
150
200
250
300
350
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008

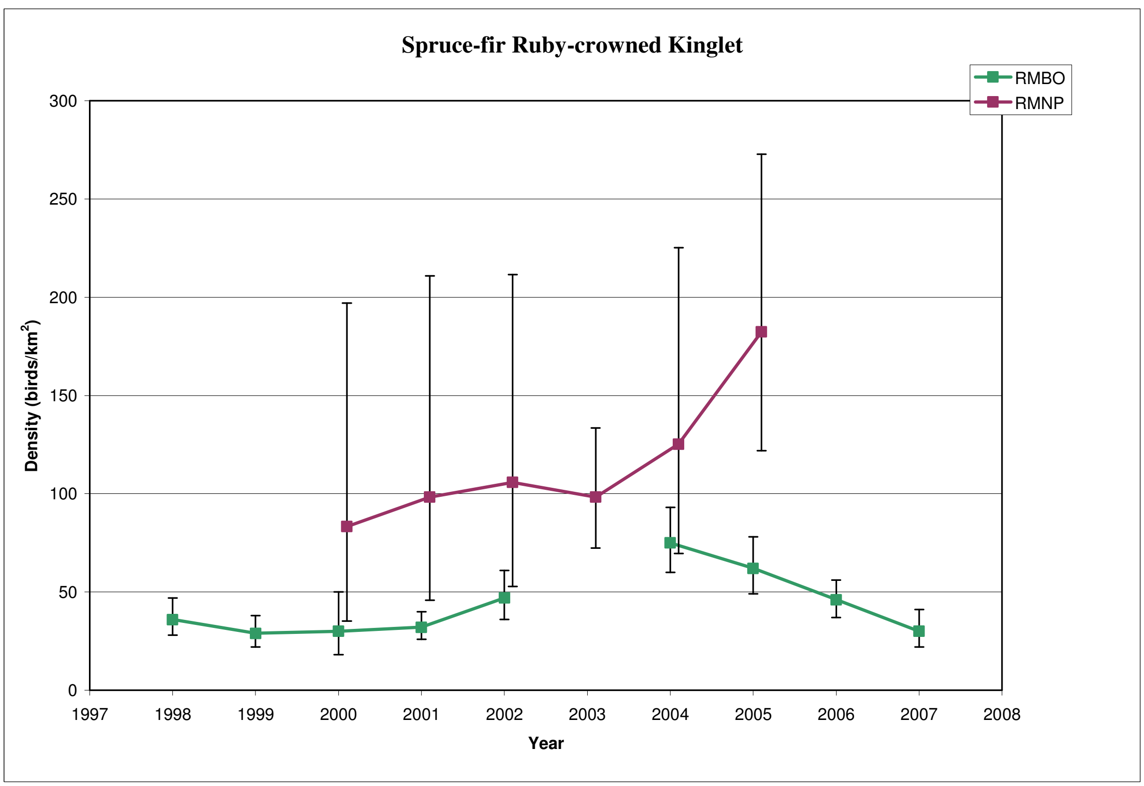
Spruce-fir (Density = birds/km^2)



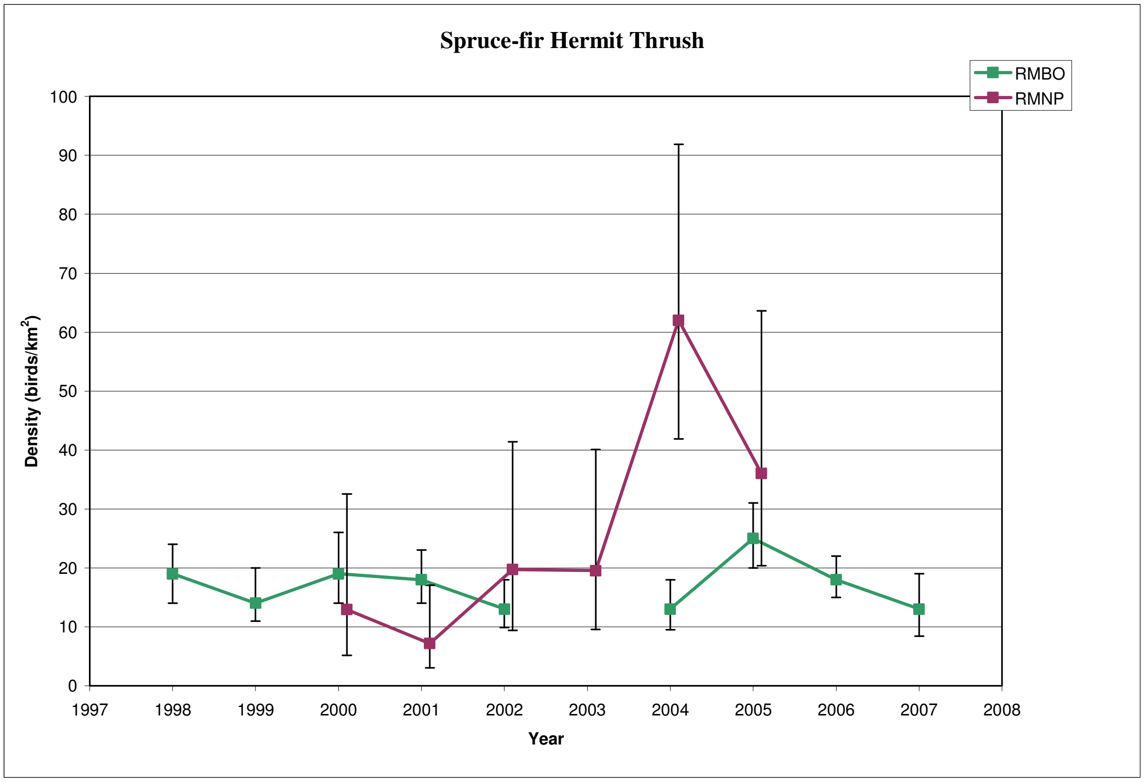




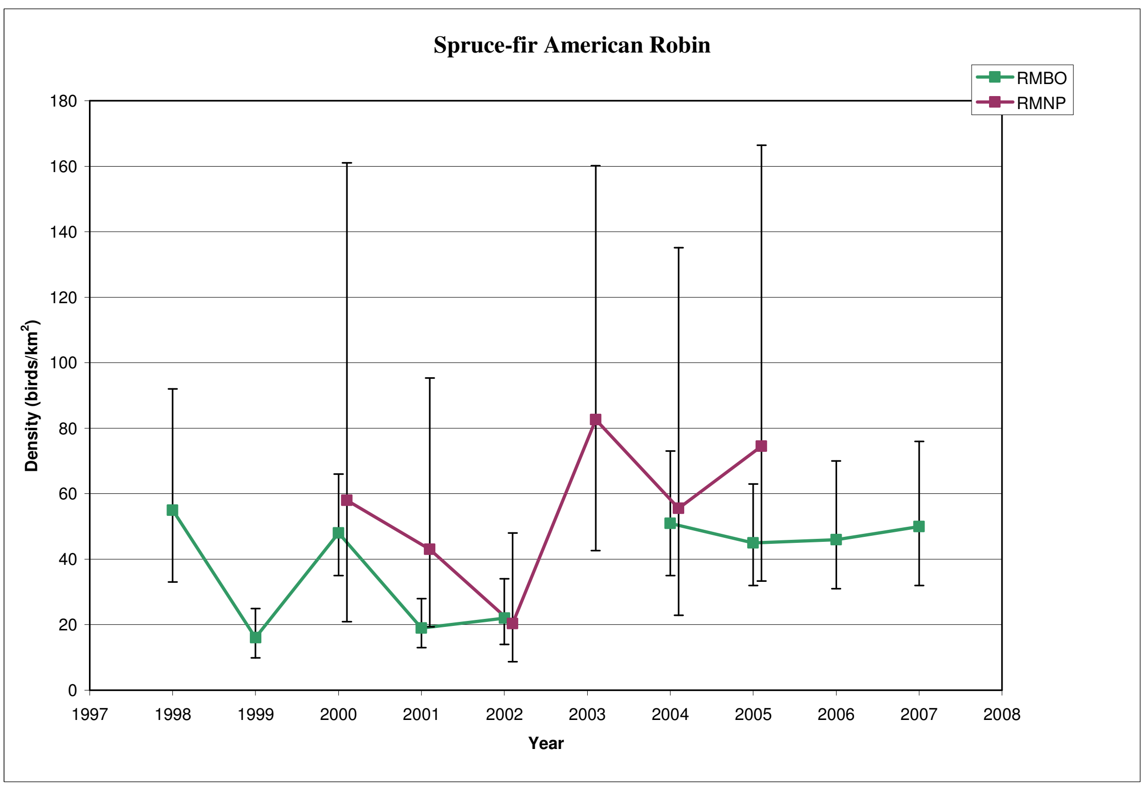
Spruce-fir Golden-crowned Kinglet
RMBO
RMNP
Density (birds/km2)
0
50
100
150
200
250
300
350
400
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year



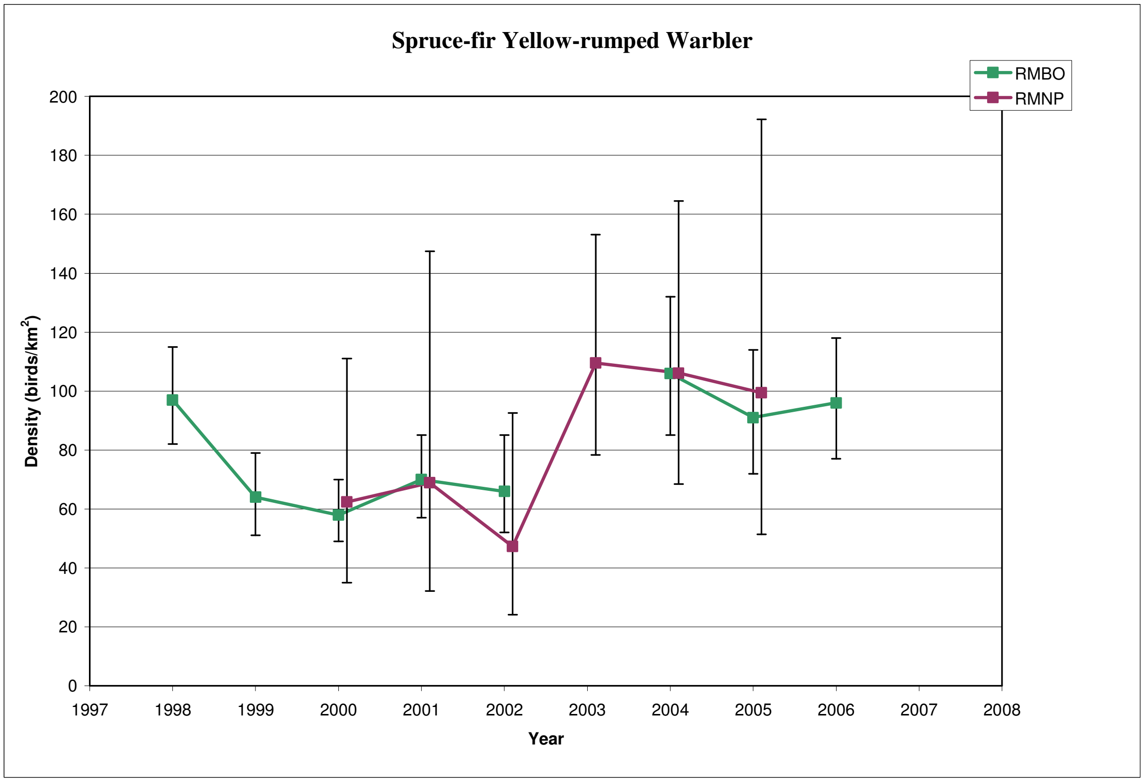
Spruce-fir Ruby-crowned Kinglet
RMBO
RMNP
Density (birds/km^2)
0
50
100
150
200
250
300
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

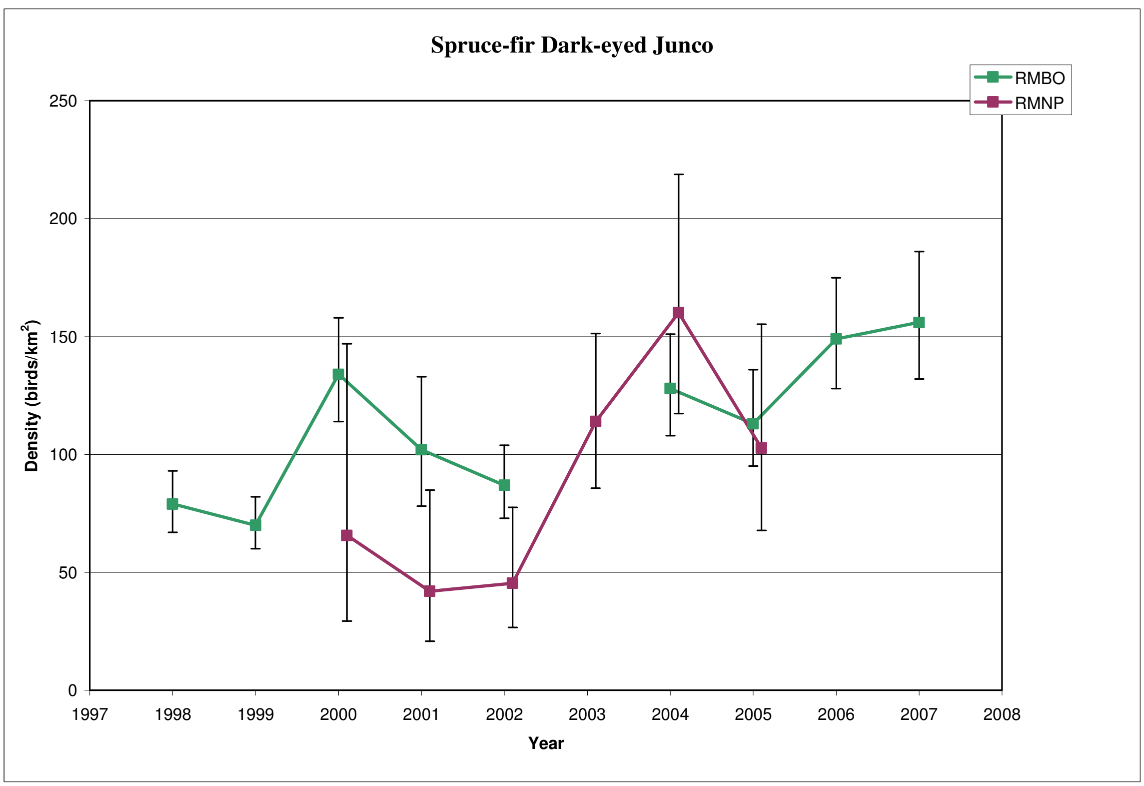


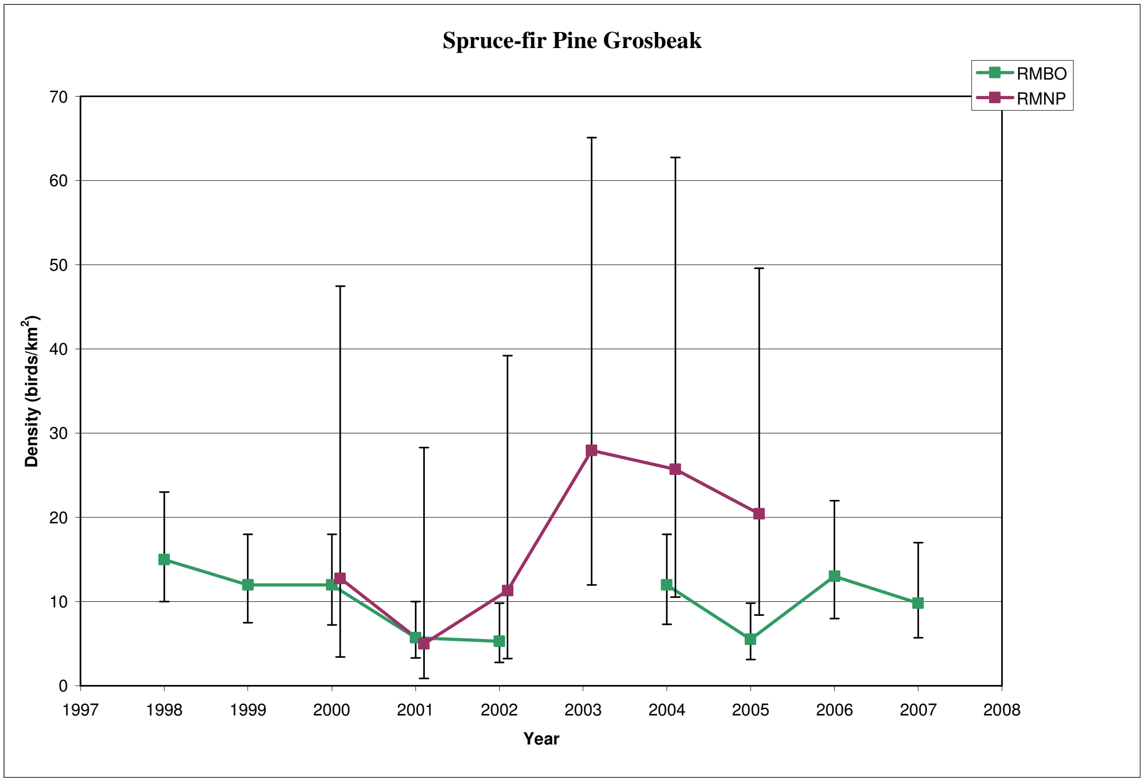
Spruce-fir Hermit Thrush
RMBO
RMNP
Density (birds/km^2)
100
90
80
70
60
50
40
30
20
10
0
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year



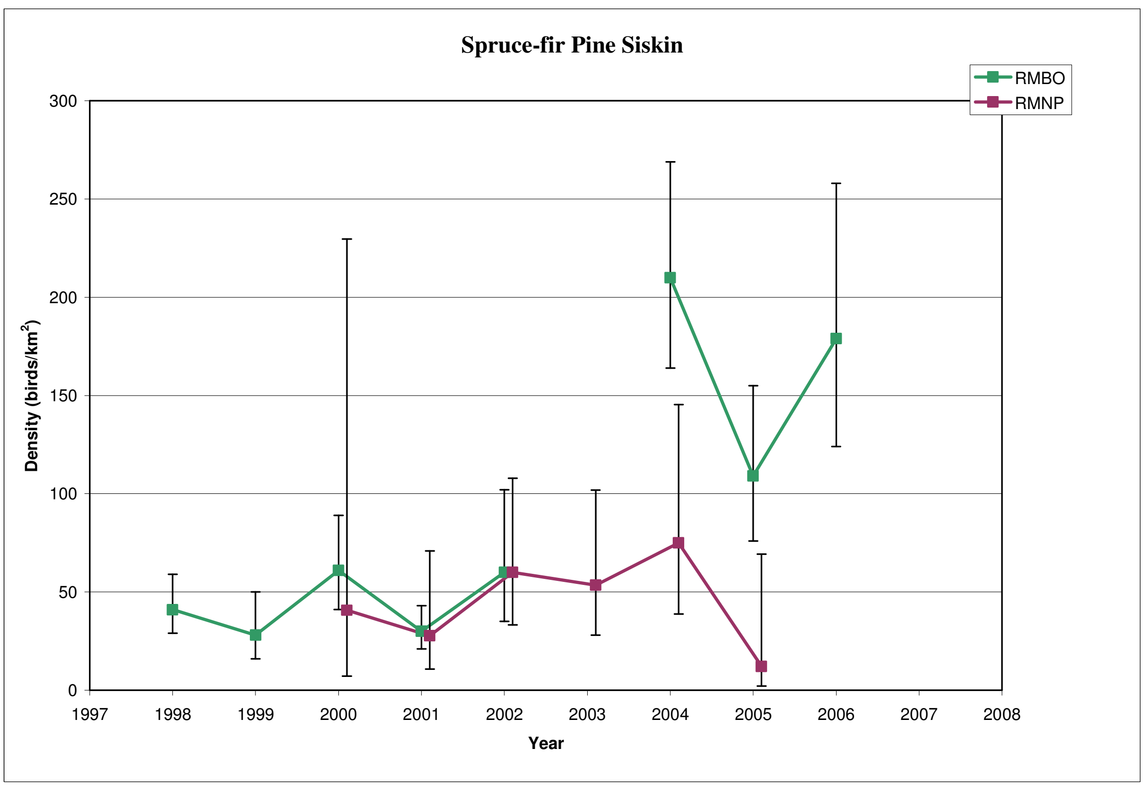
Spruce-fir American Robin
RMBO
RMNP
Density (birds/km^2)
180
160
140
120
100
80
60
40
20
0
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year


Spruce-fir Yellow-rumped Warbler
RMBO
RMNP
Density (birds/km²)
0
20
40
60
80
100
120
140
160
180
200
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year


Spruce-fir Dark-eyed Junco
RMBO
RMNP
Density (birds/km²)
0
50
100
150
200
250
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year



Spruce-fir Pine Grosbeak
RMBO
RMNP
Density (birds/km2)
0
10
20
30
40
50
60
70
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year



Spruce-fir Pine Siskin
RMBO
RMNP
Density (birds/km2)
0
50
100
150
200
250
300
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year