

Climate disruption on avian species and communities in the southern Rocky Mountains

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ABSTRACT

Climate change is altering the phenology and distribution of organisms across taxonomic groups. Abiotic factors vary along elevational gradients, including those that are affected heavily by climate change, especially temperature. In high elevation environments, species distributions are often limited by temperature, and upward range shifts occur as a response to climate warming. Surveys along elevational gradients can act as a basis to assess these range shifts and enable further investigation of population declines and extinction risks. This study analyzes Gothic Breeding Bird Survey data conducted in 23 years since 1999 to determine long-term changes in species abundance in the southern Rocky Mountains and resurveys points along an elevational gradient (2,469-3,421m) to assess shifts in species elevation range and changes in community composition compared to 2011 survey data and historical ranges. Species abundance analyses of Breeding Bird Survey data indicate that there is a complex relationship between climate disruption and trends in species abundance. Point count survey observations suggest that species may be shifting their ranges upwards when compared to historical ranges, however, comparison to 2011 observations produced a variety of results and indicates that avian species are not uniformly responding to climate disruption with an upward range shift.

INTRODUCTION

Climate change is altering the phenology and distribution of organisms across taxonomic groups (Parmesan & Yohe, 2003). One way species can respond to a changing climate is through geographic range shifts (Parmesan & Yohe, 2003; Böhning-Gaese & Lemoine, 2004). Surveys along elevational gradients can act as a basis to assess range shifts, population declines, and extinction risks (McCain & Grytnes, 2010). Abiotic factors vary along elevational gradients, including those that are affected heavily by climate change, especially temperature (Liaolo et al., 2018). In high elevation environments, species distributions are often limited by temperature, and upward range shifts occur as a response to climate warming (Chamberlain et al., 2016). These range-restricted species are at greater risk of decline, and ultimately extinction, due to the fact that the amount of suitable habitat decreases as a species moves upslope, making them particularly vulnerable to climate change (Parmesan 2006; Freeman et al. 2018).

Global climate change is impacting the geographic ranges of birds and bird communities. In Britain, bird species shifted northward during a twenty-year period of climatic warming (Thomas & Lennon, 1999), and in the northern Andes many avian species across the region shifted their ranges upward (Medina et al. 2023). In the Fennoscandian mountain range in northern Europe, common montane birds declined in correlation with higher summer temperatures and precipitation compared to the preceding forty years (Lehikoinen et al., 2013). It is important to measure shifts in elevational ranges of montane bird species due to the accelerating influence of climate change on species distributions, and such insight can improve conservation assessments and aid in identifying which species are most vulnerable (Sekercioglu et al., 2007).

Avian species, including those in high-elevation environments, vary greatly in their life history traits, which can further affect each species' vulnerability to climate change. In the Sierra Nevada Mountains, species that were year-round residents, had small clutch sizes, and defended all-purpose territories were significantly more likely to shift their elevational ranges (Tingley et al. 2012). North American birds with large clutch sizes and more specialized diets expanded their ranges northward and uphill more than species with smaller clutch sizes that are diet generalists, suggesting that diet specialists may be more sensitive to climatic changes (Auer & King, 2014). These studies suggest that southern Rocky Mountain birds that are diet specialists might be more likely to have shifted their ranges upwards in response to climate changes, and that the relationship between clutch size and range shift is more complex.

The southern Rocky Mountains are an example of a montane ecosystem with well-documented climatic changes and avian species diversity. The diverse taxonomic groups in this high-elevation environment are responding in a variety of ways to different climate cues, creating the possibility for phenological mismatch among taxa and the environment (Prather et al., 2023). Upward shifts in the ranges of cold-adapted, montane mammals in the southern Rocky Mountains have been documented (McCain et al., 2021), but this has yet to be studied in avian species in the area. The Gothic Breeding Bird Survey is an annual one-day survey of breeding birds in Gothic, Colorado. This study analyzes survey data conducted in 23 years since 1999 to determine long-term changes in species abundance and community composition. In 2011, point count surveys along an elevational gradient in the southern Rocky Mountains were performed to assess changes in species elevation range compared to historical ranges (Liput, 2011). The 2011 survey observed six out of thirty-nine species above their documented ranges. This study aims to investigate whether avian species ranges have shifted along the same elevational gradient twelve years later, and how species abundance and community composition may have changed. If species are moving upwards in elevation, birds will be found at elevations above both historical ranges and ranges documented in the 2011 survey.

METHODS

Gothic Breeding Bird Survey

a) Survey Methods

The Gothic Breeding Bird Survey is an annual one-day survey of breeding birds in mid-June in Gothic, Colorado. Five areas are surveyed from 6AM to 11AM by groups of observers led by at least one experienced birder. Each group recorded all birds observed by sight or sound.

b) Determining Changes in Abundance and Community Composition

Species abundance is the sum of all individuals observed by all survey groups each year. We performed linear regressions on each species with year as the independent variable and species abundance as the dependent variable to identify trends of increasing, decreasing, or no change over time in species abundances (R Core Team 2022). Only species that were observed in 10 or more survey years were analyzed, with the exception of the Orange-crowned Warbler because it is one of the avian species that visits sapsucker wells in the East River Valley (Daily & Ehrlich, 1987).

Point Count Surveys

a) Survey Methods

In this resurvey, we replicated the methods used in Liput 2011. We surveyed avian species at five weather stations managed by the Rocky Mountain Biological Laboratory (RMBL) located at Almont, Kettle Ponds, Judd Falls, Snodgrass Mountain, and Mexican Cut, in addition to a secondary accessible habitat at Almont greater than 100m from the weather station for a total of six survey areas within 2,469-3,421m elevation. Sampling points surrounded a focal point at each survey area generally associated with each weather station. Four sampling points were located approximately 50m or 100m from the focal point and 90° from each other. The secondary location at Almont is along a river, therefore sampling points were aligned linearly without a focal point. In 2011, the focal points and surveying points were mapped using a GeoXT unit equipped with Terrasync software and archived as spatial data in RMBL's spatial database. These points were located in the field using a Geo7X unit equipped with Terrasync software (Trimble Navigation, Sunnyvale, CA) or an iPhone SE using the GPS Tracks application (Morneault, 2023).

We visited each site three times between July 3 and July 29, 2023. Return visits were spaced at least three days apart, and point counts at each sampling point took place between 6:00AM and 9:20AM. Sampling point order was randomly determined to prevent bias. Each point count consisted of a one-minute waiting period for avian acclimation to human presence followed by two consecutive five-minute point counts. We observed birds equipped with binoculars (Nikon Action 8X42, Melville, NY) and an iPhone SE (Apple Inc., Cupertino, CA) and recorded all avian species detected by sight or sound, in addition to time observed, approximate distance, and direction. We also recorded approximate weather conditions in the form of temperature, wind (Beaufort scale), and cloud cover during each sampling period. No point counts were taken during moderate precipitation or wind greater than Level 5 on the Beaufort scale. We audio recorded each survey period using an iPhone SE within the Merlin application to confirm observations and identify any unknown avian vocalizations (Cornell University, 2023).

b) Survey Analysis

We identified approximate elevational ranges for each species observed from survey observations and compared them to survey data from 2011 and known historical ranges (Andrews and Righter, 1992). We plotted species accumulation curves for each survey area with the number of surveys as the independent variable and number of species observed as the dependent variable (R Core Team 2022). To examine how avian community compositions may have changed compared to 2011 survey data, we performed a nonmetric multidimensional scaling analysis (Oksanen, 2022). We then performed a permutational multivariate ANOVA to determine the statistical significance of communities between survey sites and between survey years (Wickham, 2016).

RESULTS

Gothic Breeding Bird Survey

Linear regressions performed on each species revealed 13 species with significantly significant trends over time (Appendix 1). Three species had a positive trend and 10 species had a negative trend (Table 4). Two species that visit sapsucker wells had no significant trend over time (Table 4).

Point Count Surveys

A total of 50 species were observed across all surveys and sites during a 26-day period in July 2023 (Table 1). Species accumulation curves indicate that point count surveys were reasonable in sampling all species at all six survey sites (Appendix 2). Fourteen species were observed above their documented ranges (Table 2), and fourteen species were observed outside of their observed 2011 ranges (Table 3).

The communities at each of the six survey sites in both 2011 and 2023 are significantly different (PERMANOVA, $F_{5,233}$, 0.37712, $p < 0.001$; Figure 1). The communities in 2011 and 2023 as a whole are significantly different (PERMANOVA, $F_{1,227}$, 0.01457, $p < 0.001$; Figure 1). An environmental vector representing elevation shows a significant correlation between elevation and higher elevation sites ($R^2 = 0.7844$, $p < 0.01$, Figure 1).

DISCUSSION

Our analysis of Gothic Breeding Bird Survey data provided a detailed view at what changes are occurring in a single-elevation community of avian species in a location with documented climatic changes. In addition to climate disruption, human disturbance in Gothic, Colorado has increased over the 23 years the survey has taken place. Three species showed

significantly positive trends of abundance over time: American Crow (*Corvus caurinus*), Cordilleran Flycatcher (*Empidonax occidentalis*), and Ruby-crowned Kinglet (*Regulus calendula*). Results of a previous study of North American birds suggested that diet specialists may be more sensitive to climatic changes (Auer & King, 2014). Crows are diet generalists while flycatchers and kinglets have more specialized diets (Cornell Lab of Ornithology, 2019). The life history trait of diet specificity does not link these three species and differentiate them from other species that declined or had no significant change in abundance over time, signifying that factors such as climatic changes and human disruption of habitat have more complicated effects than hypothesized. Similarly, the group of 10 species with significantly negative trends of abundance over time display a variety of life history traits, again pointing to the possibility of other factors involved in climate disruption influencing the success of each species (Appendix 1). One species with a significant decline is the Red-naped Sapsucker (*Sphyrapicus nuchalis*), a keystone species of the East River Valley (Cruz, 2022). Many species rely on the sapsuckers for nesting cavities and sap from sapwells, contributing to their role as a double keystone species. Avian species including Broad-tailed Hummingbirds, Yellow-rumped Warblers, and Orange-crowned Warblers have been observed feeding from sapsucker wells (Cruz, 2022; Daily & Ehrlich 1987, Kannan & Tumilson, 2023). Neither Broad-tailed Hummingbirds or Orange-crowned Warblers show a significant change over time from the Breeding Bird Survey analysis, but Yellow-rumped Warblers did show a significant decline, a potential example of the cascading effects of range shifts on avian communities (Table 4, Appendix 1).

Elevational gradient surveys detected avian species above documented ranges from 1992 (Andrews & Righter), supporting our hypothesis that species are shifting their ranges upwards in elevation and consistent with previous studies (Thomas & Lennon 1999; Lehtikoinen et al., 2013). Comparisons between 2023 observed ranges and those observed in 2011 show that avian species are not uniformly responding to climate disruption with an upward range shift in the 12-year period between surveys. The variety of responses included downward range shift, lower limit extension, lower limit contraction, upper limit extension, and upward range shift, similar to findings in range shifts in montane mammals in the southern Rocky Mountains (McCain, 2021). This variation in responses indicates that there is a more complex relationship between avian species range shifts and climate disruption.

Our elevational gradient survey analysis indicates that avian species communities in the southern Rocky Mountains significantly differ in composition between survey sites at different elevations. This is supported by the fact that habitat type differs along the surveyed elevation gradient (Liput, 2011), creating niches for a variety of species. Avian communities surveyed in 2011 and 2023 are also significantly different from one another, indicating that community structure has been altered in the 12-year period between surveys. There is evidence that climate disruption is driving range expansion of generalist species, which is in turn increasing the homogenization of avian communities (Davey et al., 2011). This could be one explanation for the difference in communities between survey years, as the range expansion of some species into new communities may alter avian community structure and composition itself.

Another method of response to climate disruption in addition to geographic range shifts is shifts in phenology. Range shifts are driven by thermal niche tracking, however, species may also shift life history events to correlate with cooler temperatures, reducing the need for range shifts. California bird communities advanced their breeding phenology by approximately 1 week over the past century, reducing the average temperature during the nesting period (Socolar et al., 2017). Phenological timing of events has been affected by climatic changes in the southern Rocky Mountains, including snowmelt date (Prather et al., 2023). In Gothic, Colorado, snowmelt date occurred 12 days earlier in 2023 compared to 2011, and point count surveys were conducted 4 days earlier in 2023, meaning the two survey periods were separated by a phenological period of 8 days (barr, 2023). This separation could cause a difference in species detection during the surveys, however, surveys were conducted over a 26-day period in both 2011 and 2023, which is a sufficient amount of time to survey avian species across a range of phenological events during the summer season.

This study investigated avian species response to climate disruption through an analysis of species abundance trends at one elevation in Gothic, Colorado using 23 years of annual survey data in addition to a point count resurvey of avian species along an elevational gradient in the southern Rocky Mountains. Analysis indicates that avian species may be shifting their ranges upwards in elevation, however, there is a complex relationship between climate disruption and species response. Secondary analyses into life history traits of the different species may reveal trends in responses and provide valuable information when creating predictions for avian communities as the climate continues to change. Further research should continue to survey avian communities along elevational gradients to track range shifts, assess changes in species abundance and community composition, and expand our understanding of how avian species are responding to climate disruption.

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FIGURES AND TABLES

Table 1. Elevation and point count survey dates for five weather station sites.

Site	Elevation (m)	Visit 1	Visit 2	Visit 3
Almont	2469	03-Jul-23	11-Jul-23	21-Jul-23
Kettle Ponds	2860	07-Jul-23	12-Jul-23	18-Jul-23
Judd Falls	3003	08-Jul-23	13-Jul-23	25-Jul-23
Snodgrass Mtn	3396	14-Jul-23	22-Jul-23	26-Jul-23
Mexican Cut	3421	20-Jul-23	24-Jul-23	28-Jul-23

Table 2. Comparison of observed and documented ranges for species observed above documented ranges.

Species	Documented Lower Limit (ft)	Documented Upper Limit (ft)	2023 Observed Lower Limit (ft)	2023 Observed Upper Limit (ft)	Comparison
Gray Catbird	1067	2134	2469	2469	Above
Mountain Chickadee	2438	3414	2469	3421	Slightly Above
Red Crossbill	1829	3353	3396	3421	Above
Cassin's Finch	1676	3353	3421	3421	Above
Lesser Goldfinch	1524	2438	2469	2469	Above
Broad-tailed Hummingbird	1768	3414	2469	3421	Slightly Above
Gray Jay	1676	3414	3396	3421	Slightly Above
Dark-eyed Junco	1798	3414	2860	3421	Slightly Above
Ruby-crowned Kinglet	2316	3414	2469	3421	Slightly Above

American Robin	1067	3414	2469	3421	Slightly Above
Western Tanager	1676	3200	2860	3421	Above
Hermit Thrush	2134	3414	2469	3421	Slightly Above
Yellow-rumped Warbler	2134	3353	3421	3421	Above
Hairy Woodpecker	1676	3414	3421	3421	Slightly Above

Table 3. Comparison of observed ranges in 2011 and 2023 point count surveys for species observed outside of observed 2011 ranges.

Species	2011 Observed Lower Limit (ft)	2011 Observed Upper Limit (ft)	2023 Observed Lower Limit (ft)	2023 Observed Upper Limit (ft)	Comparison
Brewer's Blackbird	2469	2860	2860	2860	Lower contraction
American Crow	2469	2469	3003	3003	Above
Northern Flicker	2469	3396	2469	3421	Upper extension
Olive-sided Flycatcher	2860	3421	3421	3421	Lower contraction
Pine Grosbeak	3396	3421	3421	3421	Lower contraction
Broad-tailed Hummingbird	2469	3396	2469	3421	Upper extension
Gray Jay	3003	3421	3396	3421	Lower contraction
Dark-eyed Junco	3003	3421	2860	3421	Lower contraction
Ruby-crowned Kinglet	3396	3421	2469	3421	Lower extension
Common Raven	2469	2469	3003	3396	Above
Red-naped Sapsucker	3003	3003	2860	2860	Below
Fox Sparrow	2860	2860	2469	2469	Below
Lincoln's Sparrow	2860	3421	3421	3421	Lower contraction
Violet-green Swallow	2469	3003	2469	3421	Upper extension

Table 4. Linear regression statistics for all species analyzed.

Species	Estimate +/- std. error	R ²	P-value
American Crow	5.303e-01 +/- 9.417e-02	0.5826	p < 0.001
Cordilleran Flycatcher	0.5059 +/- 0.1986	0.1197	p < 0.05
Ruby-crowned Kinglet	0.5452 +/- 0.1754	0.2825	p < 0.01
White-crowned Sparrow	-0.5213 +/- 0.2157	0.1803	p < 0.05
Warbling Vireo	-1.0052 +/- 0.3981	0.1963	p < 0.05
Yellow-rumped Warbler	-0.5551 +/- 0.1599	0.3343	p < 0.01

Red-naped Sapsucker	-0.6794 +/- 0.1916	0.3448	p < 0.01
Pine Siskin	-1.7676 +/- 0.4351	0.4143	p < 0.001
Cliff Swallow	-1.2278 +/- 0.3055	0.4079	p < 0.001
Tree Swallow	-0.4096 +/- 0.1389	0.2592	p < 0.01
Brown-headed Cowbird	-0.4193 +/- 0.1368	0.2762	p < 0.01
American Robin	-2.3877 +/- 0.4766	0.5228	p < 0.001
Pine Grosbeak	-0.19672 +/- 0.09002	0.1465	p < 0.05
Broad-tailed Hummingbird	0.1728 +/- 0.2584	0.08221	p = 0.099
Orange-crowned Warbler	0.02096 +/- 0.01216	-0.0257	p = 0.511

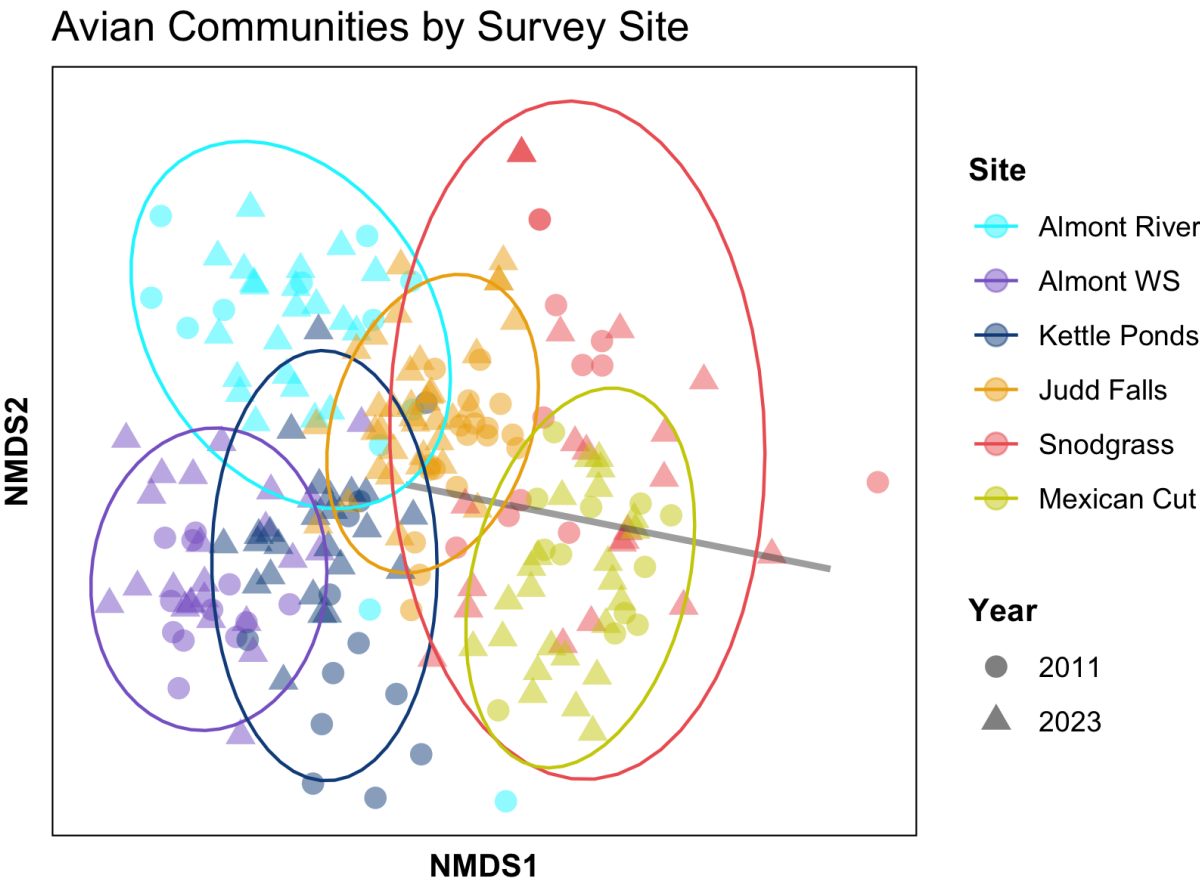
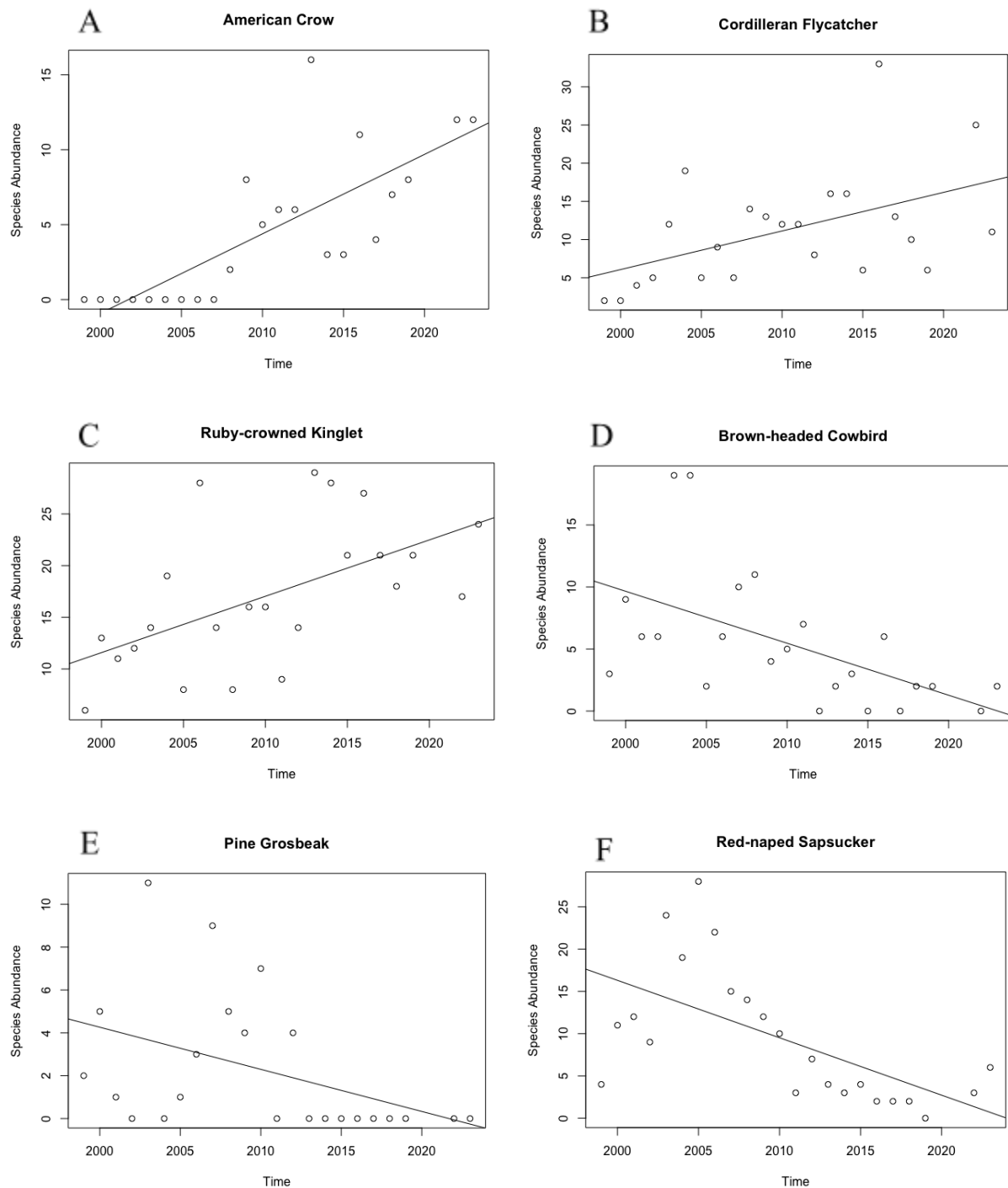
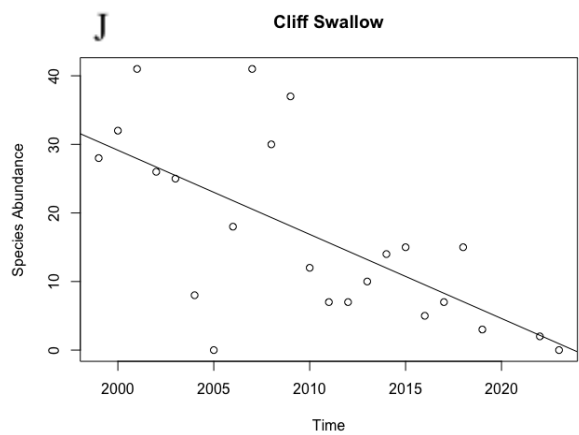
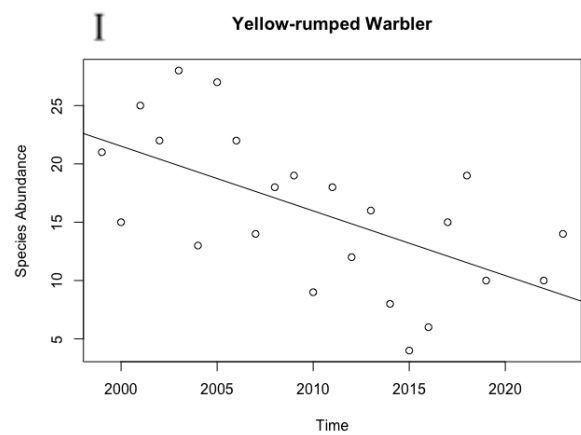
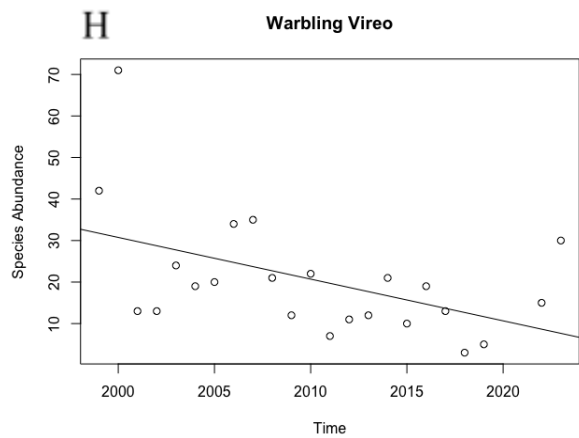
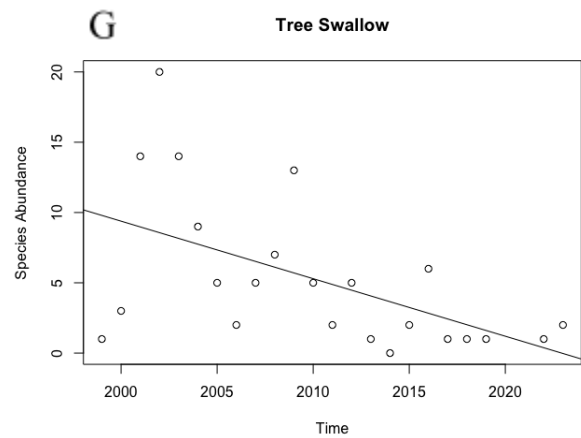
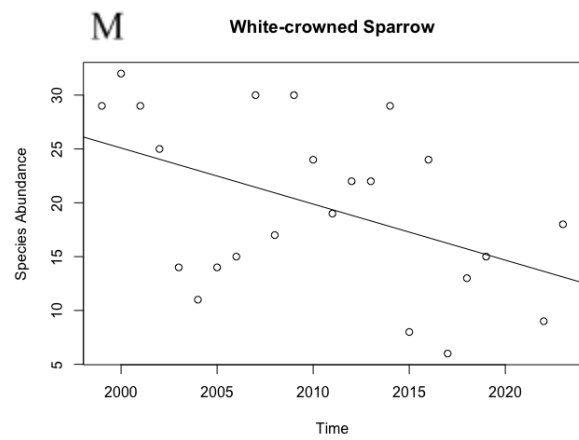
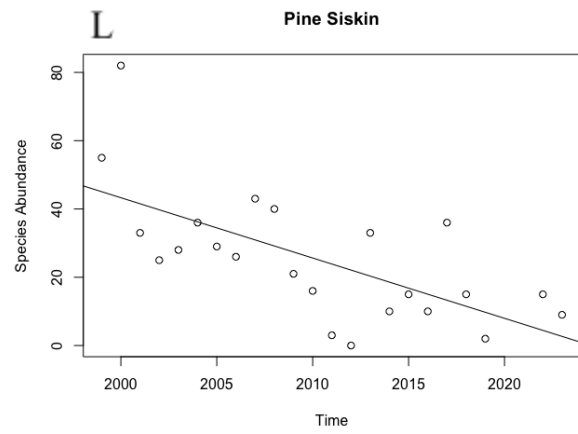
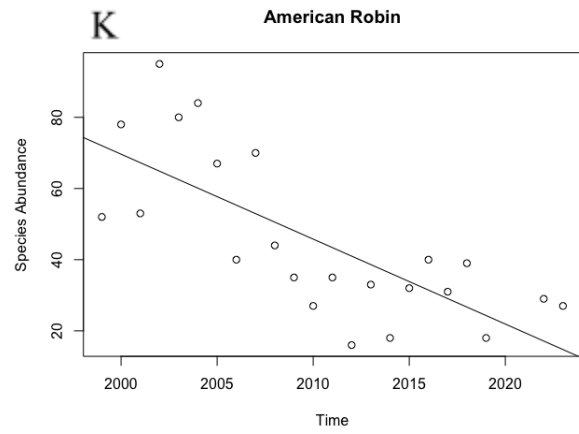


Figure 1. Non-metric multidimensional scaling analysis of avian communities across all survey sites from 2011 and 2023.

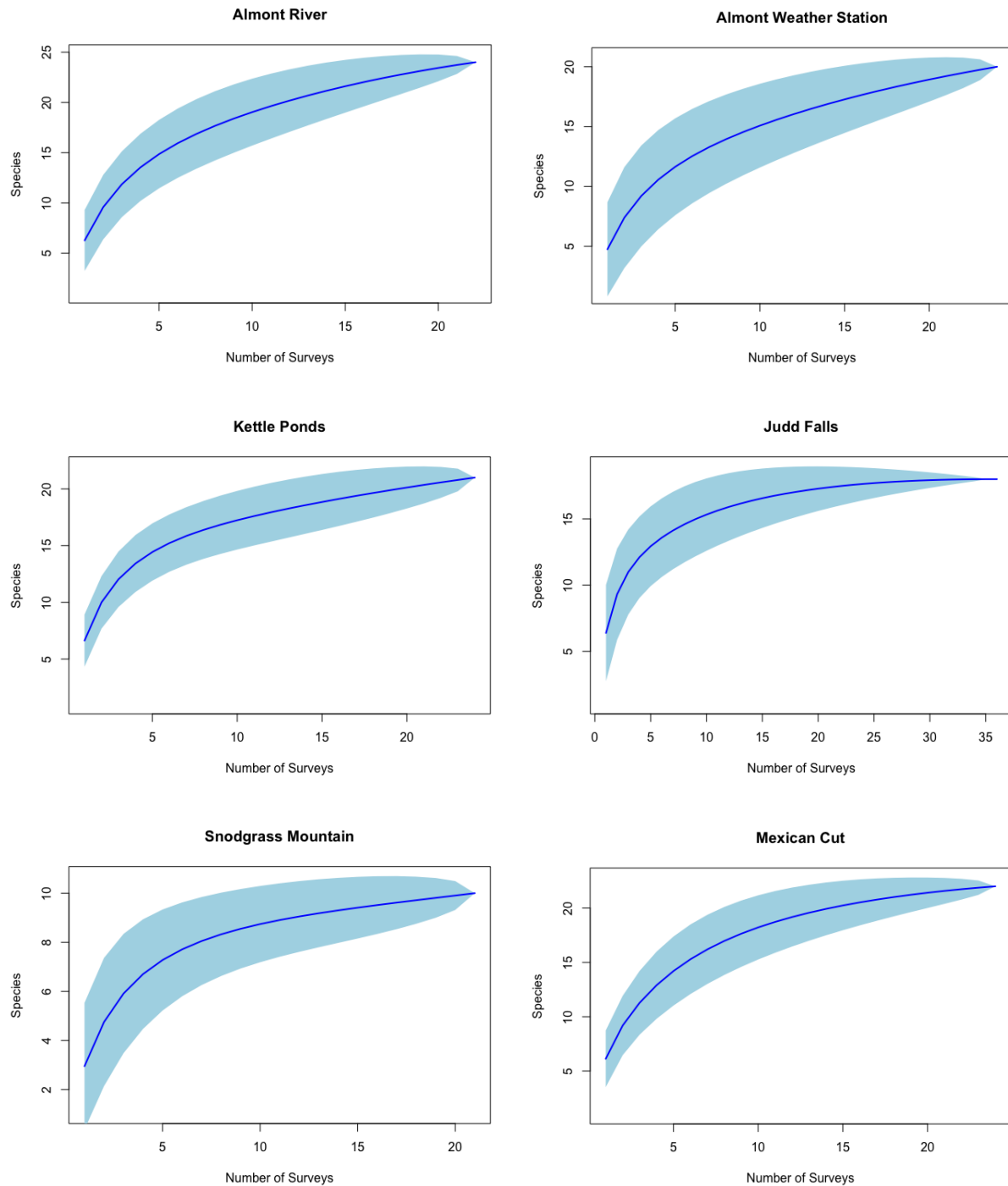
Appendix 1 - Linear regression plots for species observed during the Gothic Breeding Bird Survey with statistically significant trends of species abundance over time.







Appendix 2. Species accumulation curves for each of the six elevational gradient survey sites with a confidence interval of 95%.



Appendix 3. Cumulative species list for all point count surveys conducted between 7/3/2023 and 7/29/2023.

American Crow
American Robin
Black-capped Chickadee
Brewer's Blackbird
Broad-tailed Hummingbird
Brown Creeper
Brown-headed Cowbird
Bullock's Oriole
Cassin's Finch
Cedar Waxwing
Chipping Sparrow
Common Raven
Cordilleran Flycatcher
Dark-eyed Junco
Downy Woodpecker
Dusky Flycatcher
Fox Sparrow
Golden-crowned Kinglet
Gray Catbird
Gray Jay
Great Blue Heron
Green-tailed Towhee
Hairy Woodpecker
Hermit Thrush
House Wren
Lazuli Bunting
Lesser Goldfinch
Lincoln's Sparrow

Mountain Bluebird
Mountain Chickadee
Mourning Dove
Northern Flicker
Olive-sided Flycatcher
Pine Grosbeak
Pine Siskin
Red Crossbill
Red-breasted Nuthatch
Red-naped Sapsucker
Rock Wren
Ruby-crowned Kinglet
Song Sparrow
Swainson's Thrush
Townsend's Solitaire
Vesper Sparrow
Violet-green Swallow
Warbling Vireo
Western Tanager
Western Wood-Pewee
White-crowned Sparrow
Yellow Warbler
Yellow-rumped Warbler