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Potential Impacts of Climate Change on the Distribution of Breeding Bird Populations in Great Smoky Mountains National Park

Kristin D. Anderson
University of North Carolina Asheville
One University Heights
Asheville, North Carolina 28804 USA

Faculty Advisor: Dr. Andrew Laughlin

Abstract

A growing body of evidence suggests that average global temperatures are increasing. In the southern Appalachians, forested regions are seeing higher average temperatures, more severe droughts, and more severe precipitation events. These climatic changes can lead to adaptive responses in some species. This study sought to determine whether changes in climate over the last twenty years have impacted the distribution of breeding bird populations in Great Smoky Mountains National Park (GSMNP). The expectation was that as temperatures increased, some species would move to higher elevations to remain within their preferred climate envelope. Overall declines in some species populations were also expected. Researchers from NC State performed breeding bird surveys throughout the GSMNP in the late 1990s. A selection of these point count surveys spanning different elevations were repeated in 2018. At each point, two researchers recorded all bird species detected aurally and visually over a ten-minute period. Points were placed into three different elevation categories. Ten points were selected from each elevational band for direct comparison between the historical surveys and the counts conducted in 2018. For each elevational band species richness and abundance were measured. Species composition was then compared to historical data. A decline in some species across all elevational bands were observed, in addition to shifts in elevation for other species. Further surveys are required for proper analysis of point count data, but preliminary results suggest that of those species that have shifted their distribution, most have shifted upslope and only three species have shifted downslope. Species abundance and richness remain high at all bands.

1. Introduction

Since the industrial revolution, the global climate has been changing due to anthropogenic causes[3,4]. Among these changes are an increase in extreme weather events, changes in long-term precipitation patterns, and increasing average temperatures in some areas[3,4]. As an adaptive response to these changes in climate, some species are shifting their ranges[,2,5,6,7,8,10,11,14,15,16,17]. A review of climate models and documented responses by some species has revealed that these adaptive responses have mirrored the predictions of most climate change prediction models[9]. Studies have suggested that rapid range shifts in some species can be attributed to temperature increases[2]. Birds are an excellent indicator taxon because of their mobility and reliability in their timing of phenological events. For this reason, their movements in response to changes in climate have been well-studied.

Most research on range shifts of avian species has focused on poleward shifts[1,5,6,8,14,15]. These studies have indicated that species are shifting their ranges north or south to avoid increasing temperatures[1,5,6,8,14,15]. Some studies have demonstrated similar behavior in birds that have the opportunity to shift their ranges altitudinally[5,7,8,10,11,15,16,17]. One study compared the results of point count surveys to climate data in the Adirondacks and found that some species were shifting their elevational ranges in areas with increased temperatures[7]. Several of these studies have shown some idiosyncratic results where some species shifted their ranges in unexpected ways, including downslope[1,2,15,16]. In another study, approximately 90% of bird species shifted their ranges to track their climatic niches[16]. While increasing temperatures are a strong driver for range shifts in some species, it is important to note that there may be other climatic factors that affect range shifts.

In the late 1990s, researchers from North Carolina State University conducted breeding bird surveys throughout Great Smoky Mountains National Park (GSMNP)[13]. This project provided a rich and detailed data set of bird species found along different elevational gradients within the park. In this study, we replicated a selection of these point counts for comparison to historical data. The research project investigated two questions: whether avian communities have shifted their ranges up or downslope in response to 20 years of climate change, and whether any species have seen population declines within this time frame. We hypothesized that some species distributions would shift upslope in response to warming temperatures, while others would see overall declines.

2. Methods

We mapped the points from the NC State study using Garmin's Basecamp software and loaded them into a Garmin Oregon 650t GPS unit. Between May 24th and June 29th, 2018, we repeated a section of these point counts in the eastern portion of the park. For each point, we recorded every individual bird seen or heard within ten minutes. These ten minutes were broken down into three sections: the first three, the next two, and the remaining five minutes. These timed sections will be used for later analyses to improve the accuracy of the counts with respect to detectability. For the purposes of this preliminary examination of the data, we left these distinctions out and only analyzed the raw individual counts.

For each point, we recorded the elevation as it was reported on the GPS at the time of the count and checked these measurements against elevation data on Google Maps to ensure accuracy. We then organized the points into three elevation categories: Low (<800m), Mid (800-1400m), and High (>1400m). Because of the limited sample size and to ensure that each elevational gradient was equally represented, we selected ten points from each elevational band for comparison to the data from 1999. We combined the individuals counted at all ten of the points within an elevational band into one grouping and considered them to be present at that elevation. In the same way, we grouped the data from the matching points counted in the NC State study and compared the species lists for all three elevational bands side-by-side. We also calculated species abundance and richness for each elevational band.

3. Results

Table 1 shows the complete list of species detected, their abundance within each elevational band, and the differences in their abundances between both data sets. Species richness and abundance have remained comparable, with only a marginal decrease in abundance in the low and mid elevational bands over the 20-year timeframe (Table 2). Several species have shifted their ranges upslope (Table 3), while a few have shifted their ranges downslope (Table 4). Some species showed notable declines in their overall populations (Table 5).

Table 1: Comparison of species abundance across elevational bands in 1999 and 2018. The numbers shown are raw counts of individuals within the specified elevational bands. The highlighted columns in the middle represent the difference between the number of individuals detected in 1999 and 2018. Increases are shown in green; decreases are shown in red, and darker shades of these colors indicate a larger difference between survey years.

1999				Difference between 1999 and 2018			2018			
Species	Low	Med	High	Low	Med	High	Species	Low	Med	High
Baeolophus bicolor	3	6	0	3	2	0	*Baeolophus bicolor*	6	8	0
Bonasa umbellus	0	0	0	0	0	1	*Bonasa umbellus*	0	0	1
Buteo platypterus	0	0	0	0	1	0	*Buteo platypterus*	0	1	0
Cardellina canadensis	0	1	0	0	-1	1	*Cardellina canadensis*	0	0	1
Cardinalis cardinalis	2	0	0	-2	2	0	*Cardinalis cardinalis*	0	2	0
Catharus fuscescens	0	1	3	0	-1	6	*Catharus fuscescens*	0	0	9
Certhia americana	0	0	6	0	3	-5	*Certhia americana*	0	3	1
Chaetura pelagica	0	1	6	1	1	-6	*Chaetura pelagica*	1	2	0
Colaptes auratus	0	0	1	0	0	-1	*Colaptes auratus*	0	0	0
Contopus virens	0	0	0	0	1	0	*Contopus virens*	0	1	0
Corvus brachyrhynchos	5	3	0	-2	0	0	*Corvus brachyrhynchos*	3	3	0
Corvus corax	0	0	0	0	0	2	*Corvus corax*	0	0	2
Cyanocitta cristata	1	1	0	-1	0	3	*Cyanocitta cristata*	0	1	3
Dryocopus pileatus	1	4	0	1	-2	1	*Dryocopus pileatus*	2	2	1
Empidonax minimus	0	1	0	0	-1	0	*Empidonax minimus*	0	0	0
Empidonax virescens	10	4	0	-4	1	0	*Empidonax virescens*	6	5	0
Helmitheros vermivorum	0	0	0	2	1	0	*Helmitheros vermivorum*	2	1	0
Hylocichla mustelina	6	2	0	-6	-1	0	*Hylocichla mustelina*	0	1	0
Junco hyemalis	0	4	21	0	-1	-5	*Junco hyemalis*	0	3	16
Leuconotopicus villosus	0	1	1	1	-1	-1	*Leuconotopicus villosus*	1	0	0
Mniotilta varia	2	2	0	0	1	0	*Mniotilta varia*	2	3	0
Parkesia motacilla	1	0	0	0	0	0	*Parkesia motacilla*	1	0	0
Picoides pubescens	0	0	0	1	1	0	*Picoides pubescens*	1	1	0
Pipilo erythropthalmus	1	1	1	0	1	1	*Pipilo erythropthalmus*	1	2	2
Piranga olivacea	1	1	1	-1	0	-1	*Piranga olivacea*	0	1	0
Poecile atricapillus	0	6	3	0	-6	-1	*Poecile atricapillus*	0	0	2
Poecile carolinensis	0	1	1	1	0	-1	*Poecile carolinensis*	1	1	0
Regulus satrapa	0	4	8	0	-4	6	*Regulus satrapa*	0	0	14
Seiurus aurocapilla	23	15	2	-14	-4	0	*Seiurus aurocapilla*	9	11	2
Setophaga americana	1	8	3	6	-4	-3	*Setophaga americana*	7	4	0
Setophaga caerulescens	1	17	4	-1	-12	-2	*Setophaga caerulescens*	0	5	2
Setophaga citrina	5	2	0	5	5	0	*Setophaga citrina*	10	7	0
Setophaga dominica	2	0	0	-2	0	0	*Setophaga dominica*	0	0	0
Setophaga fusca	0	0	2	0	0	3	*Setophaga fusca*	0	0	5
Setophaga pensylvanica	0	0	1	0	1	-1	*Setophaga pensylvanica*	0	1	0
Setophaga virens	13	7	4	4	9	1	*Setophaga virens*	17	16	5
Sitta canadensis	0	3	4	0	-3	0	*Sitta canadensis*	0	0	4
Thryothorus ludovicianus	0	0	0	2	1	0	*Thryothorus ludovicianus*	2	1	0
Toxostoma rufum	0	0	1	0	0	-1	*Toxostoma rufum*	0	0	0
Troglodytes hiemalis	1	2	3	-1	-1	-2	*Troglodytes hiemalis*	0	1	1
Turdus migratorius	0	0	0	3	2	2	*Turdus migratorius*	3	2	2
Vireo flavifrons	1	0	0	-1	0	0	*Vireo flavifrons*	0	0	0
Vireo olivaceus	14	10	3	0	-9	-3	*Vireo olivaceus*	14	1	0
Vireo solitarius	5	5	3	-3	4	5	*Vireo solitarius*	2	9	8

Table 2: Comparison of species abundance and richness in 1999 and 2018. The numbers shown are raw counts of individuals (abundance) and species represented (species richness).

	1999				2018		
	Low	Mid	High		Low	Mid	High
Abundance	99	113	82		91	99	81
Species Richness	21	27	22		20	29	19

Table 3: A list of four species that demonstrated the most significant upslope shifts relative to their distribution in 1999. Numbers represent the difference in raw numbers of individuals detected in 2018 compared to 1999 survey data. Percentages represent percent change between survey years.

Species	Low	Mid	High
Regulus satrapa	No change	-4 (-100%)	+6 (+75%)
Vireo solitarius	-3 (-60%)	+4 (+80%)	+5 (+167%)
Catharus fuscescens	No change	-1 (-100%)	+6 (+200%)
Cyanocitta cristata	-1 (-100%)	No change	+3 (From 0)

Table 4: A list of three species that demonstrated the most significant downslope shifts relative to their distribution in the 1990s. Numbers represent the difference in the raw number of individuals detected in each elevational band in 2018 compared to 1999 survey data. Percentages represent percent change between survey years.

Species	Low	Mid	High
Setophaga Americana	+6 (+600)	-4 (-50%)	-3 (-100%)
Chaetura pelagica	+1 (From 0)	+1 (+100%)	-6 (-100%)
Certhia Americana	No change	+3 (From 0)	-5 (-83%)

Table 5: Notable overall population declines. Numbers represent the difference in the raw number of individuals detected in each elevational band in 2018 compared to 1999 survey data. Percentages represent percent change between survey years.

Species	Decline
Seiurus aurocapilla	-18 (-45%)
Setophaga caerulescens	-15 (-68%)
Vireo olivaceus	-12 (-44%)
Poecile atricapillus	-7 (-67%)
Hylocichlia mustelina	-7 (-86%)

4. Discussion and Conclusion

Although these results are preliminary, there appear to be some changes in avian distributions at these different elevational bands. As predicted, some species appear to be shifting upslope while others appear to be declining. As shown in Table 3, *Regulus satrapa*, *Vireo solitarius*, *Catharus fuscescens*, and *Cyanocitta cristata* all appear to be shifting upslope. A previous study has shown a correlation between temperature increases and elevational shifts in *R. satrapa, V. solitarius,* and *C. fuscescens,* so it is possible that these shifts may be related to changes in climate[7]. Table 4 shows that *Setophaga americana*, *Chaetura pelagica*, and *Certhia americana* all appear to be shifting downslope. While it is possible that these changes may be due to changes in climate, there may be other factors influencing these shifts.

Perhaps the most alarming results of this study are the observed declines in several species, highlighted in Table 5. *Vireo olivaceus* and *Seiurus aurocapilla* saw declines of 44 and 45%, respectively. *Setophaga caerulescens* declined by 68% and *Poecile atricapillus* by 67%. The decline in *P. atricapillus* is not an unexpected result if these declines are related to changes in climate, because a 2014 study showed that *P. atricapillus* has been shifting its range northward towards cooler temperatures[14]. This same study also discussed increased hybridization between *P. atricapillus* and *P. carolinensis* and a decreased survivability rate among the offspring of these hybridizations[14]. *Hylocichla mustelina* declined by 86%, another result that is largely consistent with current data on the decline of this species across the United States. According to the North American Breeding Bird Survey, *H. mustelina* has declined 62% between 1966 and 2015[12]. Some species that were recorded during the 2018 surveys that were not present during the previous study are species more closely related to disturbed areas, including *Turdus migratorius* and *Thyrothorus ludovicianus.* It is possible that these species are becoming more abundant in the area as a result of climate-related disturbances, but it is also possible that shifting plant ecology or other factors may be providing them with advantages over more sensitive species, like *H. mustelina*. These increases in disturbance-associated species may lead to competition for resources with less adaptable populations, further exacerbating some species declines.

These preliminary results suggest that more research is needed into avian population shifts within Great Smoky Mountains National Park. Repetition of many of these point counts, in addition to more statistical analyses that account for detectability will increase the robustness of these results. A larger sample size would also help rule out the possibility that these observed changes are the result of random variation. Examining climate data in these areas and how it has changed over the past 20 years would help clarify whether these population shifts can be attributed to changes in climate or other unrelated factors.

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