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Feeding Ecology Helps Predict Patterns in Avian Winter Range Shifts

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Abstract

Environmental changes such as urbanization and climate change have led to fluctuations in the geographic ranges of birds over the last century. For many species, population-level changes are poorly understood if catalogued at all. The Christmas Bird Count (CBC) is the United States' longest-running citizen science project. By using CBC data, it is possible to harness large amounts of information dating back as far as the early twentieth century to answer questions about how avian communities are changing over time. In this study, we examined long-term CBC data (number of birds counted per party hour) from 1955-2014 for a suite of bird species from different feeding guilds native to North America. For each species, we compared the geographic center of abundance between the Atlantic and Mississippi flyways from 1955 - 2014. We downloaded CBC data for each species, and separated the data by latitude for what we determined to be the Atlantic and Mississippi flyways. This allowed us to calculate the geographic center of abundance for each species for each year. The data were then plotted using regression analyses showing varying trends between flyways for species. Our results yielded seven distinct trends within the 14 species tested: A) Species shifting northward predominantly in the Atlantic flyway (n=5), B) Species shifting northwards equally in both flyways (n=2); C) Species shifting northward predominantly in the Mississippi flyway (n=1), D) Species shifting north in the Atlantic flyway, and shifting south in the Mississippi flyway (n=1), E) Species shifting north in the Mississippi flyway, but shifting south in the Atlantic flyway (n=1), F) Species shifting south in both flyways (n=2), and G) Species that do not appear to be shifting their range latitudinally (n=2). Further, we found that feeding ecology was a good predictor of range shift patterns for many species. This understanding may improve future studies and aid researches in anticipating avian range shifts based on species feeding guild.

Keywords: avian range shifts, Christmas Bird Count, climate change

1. Introduction

Climate change is a far-reaching anthropogenic force on ecosystems worldwide, and its effects on complex ecological relationships have been well documented[1] The consequences of this environmental change are increasingly apparent; average temperature increases have led to spring plants blooming earlier[1,2], phenological changes across taxa, as well as distributional changes in reptiles, invertebrates, mammals, amphibians, and birds[2].

There is growing concern about how avian winter distributions may be changing in response to a rapidly changing environment. Avian ranges are dynamic and subject to contractions and expansions caused by a variety of factors, including disease, competition, predation, and anthropogenic influences[3]. Increasing average temperatures has been linked to changes geographic distributions of both breeding and non-breeding birds[4]. Anecdotal evidence has placed many bird species far north of their winter ranges, indicating that climatic changes are leading to shifting ranges of bird populations. Some of these range changes might include contraction, expansion, shifts northward, or shifts southward.

In North America, bird populations can make use of four major flyways during migration or when shifting range: the Pacific, Central, Mississippi, and Atlantic[5]. Populations of the same species that utilize different flyways are sometimes distinct behaviorally or morphologically due to differing environments. Some populations of the same species may be experiencing different changes in its geographic distribution. For example, more extreme winters experienced in the Midwest may restrict northward expansion of bird populations, whereas hot summers and mild winters experienced along the Atlantic coast may allow populations to shift northward more noticeably.

In order to understand the complex nature of biogeographical patterns and processes associated with avian range fluctuations, it is critical to have data that covers a wide spatiotemporal range[6]. Logistical difficulty often limits this, but thanks to the growing popularity of citizen science, this is no longer a research impediment. The Christmas Bird Count (CBC) is the nation's longest-running citizen science project. Over a century's worth of avian distribution data collected by dedicated amateur naturalists is currently available to scientists worldwide. Counts are conducted annually between mid-December and early January by dedicated volunteer birders. Previous studies by Westphal, Niven et al, and Tirpak et al have successfully utilized CBC data to answer questions about avian populations and changing ecology[5,7,8].

For this study, we explored the spatiotemporal dynamics of winter range shifts for a suite of bird species that have a significant range in the continental US during the non-breeding season. We used CBC data to compare distributional shifts between the Atlantic and Mississippi flyway populations for each species. We expected to see more drastic shifts northward in geographic center of abundance associated with Atlantic flyway populations due to milder coastal winters, allowing for greater expansion in this region.

2. Methodology

In this study, we utilized Christmas Bird Count Data to analyze the geographic shifts of a suite of bird species. Every year, thousands of Audubon Christmas Bird Counts take place across the US and Canada at pre-determined, consistent locations, between December 15 and January 15. Each individual count spans a 15 mile radius. Volunteers track the number of species detected (heard and seen) per party hour "on foot" or "by vehicle"[9]. We selected species based on distribution and level of influence by anthropogenic factors. We chose both resident and migratory species that display a significant range within the US during winter months, and are unlikely to be influenced by the presence of feeders. We strove to select species from varied families; we chose predominantly passerines, but also included raptors, a woodpecker, and a grebe (Table 1). We compared trends in geographic center of abundance for these species among two differing flyways: the Mississippi flyway and the Atlantic flyway.

For each species, we used data from every CBC count from 1955-2014. We selected this time period because prior to 1955 CBC counts were less widespread and reliable. We then separated the data based on 'flyway'. For our purposes, we considered everything between -95 and -85 longitude within the Mississippi flyway, and everything east of -85 longitude and above 24 latitude within the Atlantic flyway. We divided the two flyways in order to compare trends in range shifts between differing populations and to discover whether the two are distinct as a result of differing environmental conditions between the two regions.

We used the R package Geosphere[10] to convert the number birds seen per 'party hour' (bph) for each year into a geographical center of abundance. We performed linear regressions using R to compare temporal trends between flyways, and to calculate the slope of the regression line which indicates the number of degrees latitude per year the geographic center of abundance shifts. Additionally, we used Pearson's product moment correlation tests using the function cor.test in R[11] to test for within-year correlations between flyways for each species.

3. Results

Our results yielded seven distinct trends within the 14 species tested: A) Species shifting north predominantly in the Atlantic flyway (n=5) B) Species shifting northwards equally in both flyways (n=2), C) Species that are shifting north predominantly in the Mississippi flyway (n=1) D) Species shifting north in the Atlantic flyway, and shifting south in the Mississippi flyway (n=1) E) Species shifting north in the Mississippi flyway, but shifting south in the Atlantic flyway F) Species shifting south in both flyways (n=2) G) Species that are not shifting their range latitudinally (n=2). See Table 1 for complete species list. To reiterate; the slope we calculated represents the changes in degrees of latitude of the geographic center of abundance per year.

A) The most prevalent trend exhibited among the species we examined was that of species shifting northward predominantly in the Atlantic flyway. Five species or 35% of species we examined displayed this trend. Most significantly, the Atlantic flyway population of yellow-bellied sapsuckers (*Sphyrapicus varius*) appears to be shifting northward at 18x the rate of the Mississippi population (Figure 1). Furthermore, American robins (*Turdus migratorius*) along the Atlantic flyway appears to be shifting northward at more than twice the rate as those along the Mississippi (Atlantic slope = 0.089 $P<0.01$, Mississippi slope = 0.041 $P<0.01$, see figure 1).) A positive slope represents an increase in latitude, and a negative slope represents a decrease in latitude. For example, the slope of the regression analysis for the American robins in the Atlantic flyway was calculated to be 0.089, meaning that the geographic mean for American robins in this region is shifting northward by 0.089 latitudinal degrees per year (Table 1).

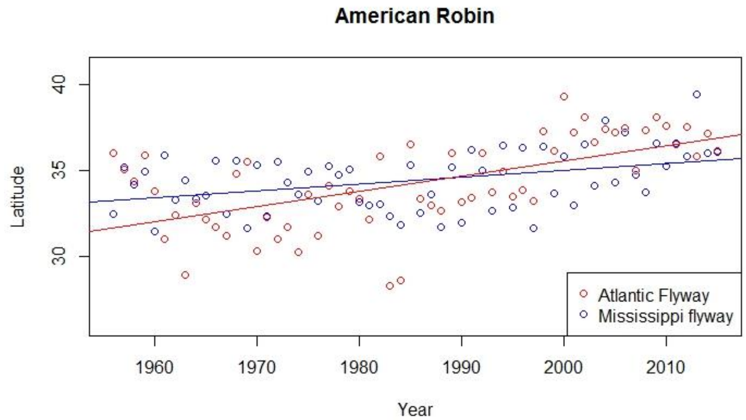

Figure 1. A representation of trend A by the American robin (*Turdus migratorius*). This species is shifting northward in both flyways, but significantly more so in the Atlantic flyway (Atlantic slope = 0.089, $P<0.01$, Mississippi slope = 0.041, $P <0.01$).

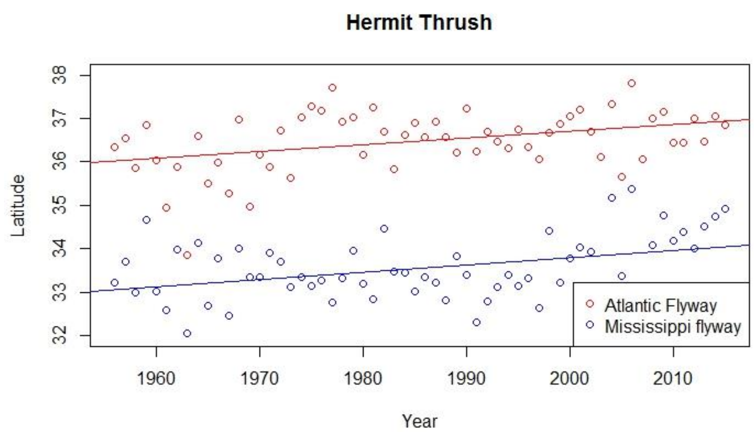

Figure 2**.** A representation of Trend B by the hermit thrush (*Catharus guttatus*). The Atlantic flyway population is shifting northward at almost an identical rate to the Mississippi flyway population (Mississippi slope = 0.017 $P<0.01$, Atlantic slope = 0.016 $P<0.01$).

B) Two species we examined appear to be moving north along both flyways at the same rate. The hermit thrush (*Catharus guttatus*) appeared to be shifting northward in both flyways almost identically (Mississippi slope = 0.017 $P<0.01$, Atlantic slope = 0.016 $P<0.01$, see figure 2). Similarly, the cedar waxwing (*Bombycilla cedrorum*) is experiencing near-identical northward shifts in both flyways.

C) Populations that were shifting northward predominantly in the Mississippi flyway were less common. This trend was represented solely by the red-breasted nuthatch (*Sitta canadensis*), which appears to be shifting northward in the Mississippi flyway at about 1.5x the rate of those shifting north in the Atlantic flyway (Mississippi slope = 0.054 P<0.001, Atlantic slope = 0.038 P<0.01).

D) Only one species appeared to be shifting southward along the Mississippi flyway while shifting northward along the Atlantic flyway, the white-crowned sparrow (*Zonotrichia leucophrys*). The linear model displayed a slope of -0.0083 for the Mississippi flyway and 0.0071 for the Atlantic flyway.

E) 2 of the species we examined appear to be shifting southward along the Atlantic flyway, and north along the Mississippi flyway. The Pied-billed grebe displays this trend most significantly (Mississippi slope =0,023 P<0.01, Atlantic slope = -0.022, P<0.01). The American kestrel (*Falco sparverius*) displays this trend less significantly. For the Atlantic flyway it exhibits a slope of -0.0022 (P>0.01) and a slope of 0.022 (P<0.01) in the Mississippi flyway.

F) 2 of the species we examined appear to be shifting south in both flyways. The red-shouldered hawk (*Buteo lineatus*) is shifting southward in the Mississippi flyway at a slope of -0.041 (P<0.01) and shifting southward less significantly in the Atlantic flyway at a slope of -0.012 (P>0.01). Similarly, the pine warbler (*Setophaga pinus*) displays this trend (figure 3) but is not shifting south significantly in the Mississippi flyway (P>0.01).

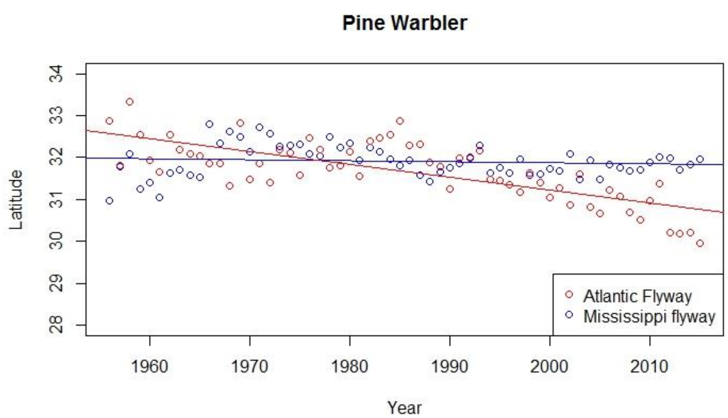

Figure 3. A representation of Trend F by the pine warbler (*Setophaga pinus*). This species is shifting south in both flyways, but not significantly in the Mississippi flyway (Mississippi slope = -0.0025 P>0.05, Atlantic slope = -0.031 P<0.01).

G) The only species that we examined does not appear to be making any significant range shifts was the tree swallow (*Tachycineta bicolor*) (Figure 4). (Mississippi slope = -0.00018 P>0.05, Atlantic slope = 0.0038 P>0.05).

Seven of the fourteen species we examined showed significantly positive correlations between years (See table 1): American Robin Pearson's Coefficient = 0.45, Blue-headed Vireo = 0.40, Carolina Wren =0.59, Cedar Waxwing =0.38, Hermit Thrush =0.50, Red-breasted Nuthatch =0.79, Red-shouldered Hawk =0.58.

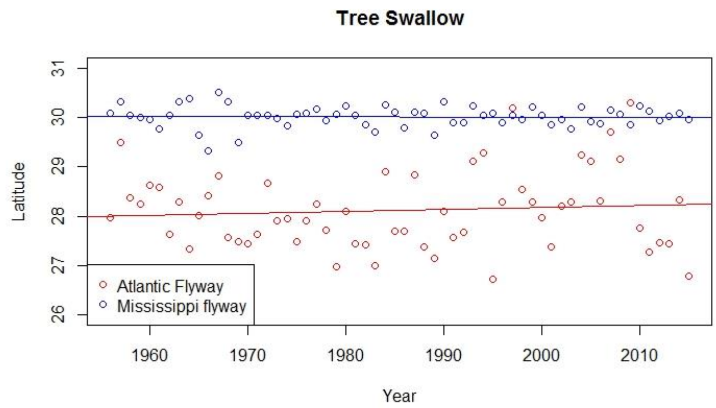

Figure 4. A representation of Trend G by the Tree Swallow (*Tachycineta bicolor*). This species is showing no trend in either flyway (Mississippi slope = -0.00018 P>0.05, Atlantic slope = 0.0038 P>0.05).

Table 1. Summary statistics for the fourteen North American birds we examined, comparing slope and R^2 between the Atlantic and Mississippi flyways. Pearson's Correlation Coefficients are also included to demonstrate correlation in movements between flyway populations. Feeding guild is represented in abbreviated terms: I= insectivore, WF = winter frugivore, O= omnivore, P= predator. * =P <0.05, ** = P<0.01

	Species		**Mississippi**		**Atlantic**		
		Guild	*Slope*	R^2	*Slope*	R^2	Cor Test
A	**American Robin**	I	0.041**	0.15	0.089**	0.35	0.45**
A	**Blue-headed Vireo**	I	0.0086**	0.32	0.054**	0.57	0.40**
A	**Eastern Phoebe**	I	0.0070**	0.14	0.042**	0.55	0.060
A	**Yellow-bellied Sapsucker**	I	0.0016	-0.015	0.030**	0.51	0.11
A	**Carolina Wren**	I	0.0068	0.0064	0.011**	0.096	0.59**
B	**Cedar Waxwing**	WF	0.027	0.11	0.021*	0.10	0.38*
B	**Hermit Thrush**	WF	0.017*	0.15	0.016**	0.14	0.50**
C	**Red-breasted Nuthatch**	I	0.054*	0.35	0.038**	0.26	0.79**
D	**White-crowned Sparrow**	O	-0.0083	0.020	0.0071*	0.12	-0.014
E	**American Kestrel**	P	0.02**	0.42	-0.0080	-0.0022	0.077
E	**Pied-billed Grebe**	P	0.027**	0.41	-0.022**	0.14	-0.025
F	**Red-shouldered Hawk**	P	-0.041**	0.20	-0.012	0.059	0.58**
F	**Pine Warbler**	O	-0.0025	-0.0043	-0.031**	0.55	0.065
G	**Tree Swallow**	WF	-0.00018	-0.017	0.0038	-0.010	0.18

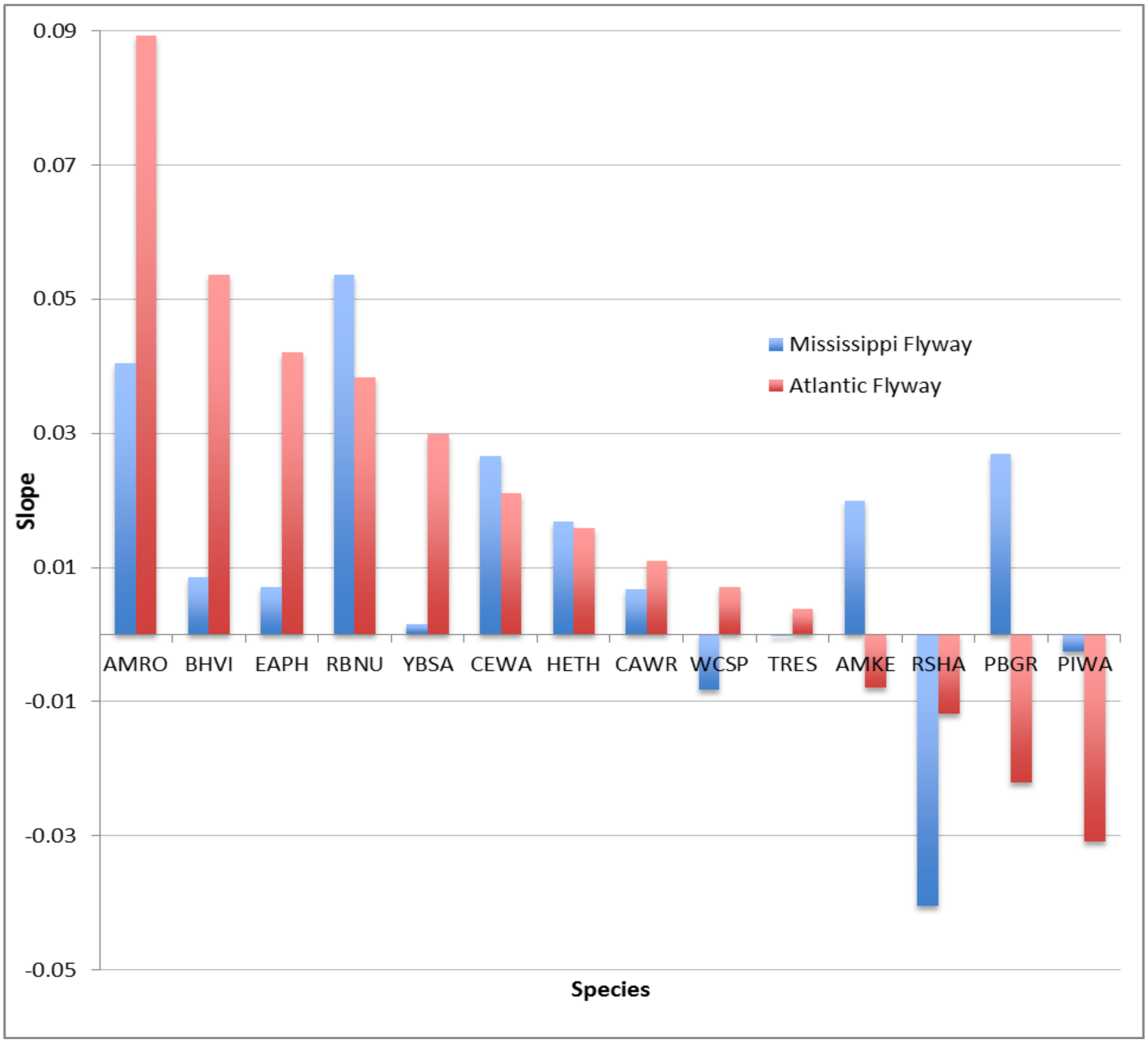

Figure 5. Summary of slopes of regression lines (number of degrees latitude per year of shift in geographic center of abundance) from 1955-2014 calculated for 14 bird species in descending order of Atlantic slope.

4. Discussion

Our results indicate that feeding guild helps predict the pattern of geographic winter range shifts for many species. More than half of the species analyzed (n=8) exhibited trends consistent with their feeding guild. Overall, the species we examined in this study exhibited more varied trends than we expected. However, we hypothesized that the most likely trend would be that species are shifting northward in both flyways, but doing so more significantly in the Atlantic flyway, and this trend was by far the most prevalent (n=5).

The five species experiencing the most drastic northward shifts along the Atlantic coast (American robin, blue-headed vireo, eastern phoebe, yellow-bellied sapsucker, and carolina wren) are all insectivores[12] (Table 2). The milder winters generally experienced along the Atlantic coast (compared with the interior) may allow populations of insects to survive the winter further north, providing incentive for wintering birds to shift north. Furthermore, insect populations may be shifting their geographic distributions northward, which would allow new areas to be colonized for these birds.

Cedar waxwings and hermit thrushes (which are experiencing a northward shift in both flyways) are mainly insectivorous, but forage for fruits during winter months[12] (Table 2). Range shifts may be supported by the presence of fall and winter fruits. Hermit thrushes are the only spotted thrushes that are not experiencing declines as a result of neo-tropical deforestation[12] and may not be restricted in either flyway in North America due to intact woodland.

Some species may be restricted by ecological factors. For example, tree swallows supplements their mostly insectivorous diet with wax myrtle (*Morella cerifera*) berries[13] during the winter. They are one of the few species that are capable of digesting wax in bayberries[11]. This may therefore restrict tree swallows from shifting their winter range beyond the distribution of wax myrtle as a result. Indeed, this species is showing no consistent latitudinal trend northward in either flyway, though annual variation in geographic mean is high (Figure 4).

Species that are shifting southward along both flyways like the pied-billed grebe and the pine warbler may simply be decreasing their migration distance from a southern natal site as resources become more plentiful year-round. The pine warbler is omnivorous and may only be restricted in its range by the distribution of pines in nesting locations[12]. Furthermore, the pied-billed grebe's range expands into Latin America, which may have skewed the data: What appears to be pied-billed grebes moving southward and increasing in the southern United States, may in fact be related to a shift of Latin American pied-billed grebes moving northward.

In summation, the trends exhibited by the fourteen species we examined in this study were more varied than expected. However, these behaviors support our hypothesis that populations of the same species that inhabit different flyways respond differently to environmental changes. Our results demonstrate that avian movements in North America are not uniform, and that we cannot assume that all species are shifting northward in abundance over time. Knowing the feeding ecology of a species may allow us to make more accurate predictions about its spatiotemporal movements in response to environmental changes. Finally, these trends may be supported by expanding this study in the near future.

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6. References

1. Sala, O. E., Chapin, F. S. III., Armesto, J. J., Berlow, R., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L. F., Jackson, R. B., Kinzig, A. (2000). Global biodiversity scenarios for the year 2100. *Science* 287, 1770-1774.
2. Parmesan, C. Yohe, G. (2003) A globally coherent fingerprint of climate change impacts across natural systems. *Nature*. Vol 421, 37-42.
3. Beaubien, E. Hamann A. Spring Flowering Response to Climate Change between 1936 and 2006 in Alberta, Canada. *BioScience*. Vol. 61, No. 7 (July 2011), pp. 514-524
4. La Sorte, F.A. Jetz, W. (2010) Avian distributions under climate change: towards improved projections. Journal of Experimental Biology. Vol 213: 862-869.
5. Niven, D. Butcher, G. Bancroft T. (2009) Christmas Bird Counts and Climate Change: Northward shifts in early winter abundance. *American Birds*. 10-15.
6. Galbraith, C.A. Jones, T. Kirby, J. Mundkur, T. Heredia, B. (2014) A review of migratory flyways and priorities for management. CMS Technical Series. Vol 27, 1-159.
7. Westphal, M. (2012) Spring Migration Counts in North Carolina. *The Chat*. Vol. 76:3, pp. 65-96.
8. Tirpak, J.M, Giuliano, W.M, Miller, C.A, Allen, T.J, Bittner, S, Buehler, D.A, Edwards, J.W, Harper, C.A, Igo, W.K, Norman, G.W, Seamster, M, Stauffer, D.F. (2006) Ruffed grouse population dynamics in the central and southern Appalachians. *Biological Conservation*. Vol. 133, pp. 364-378.
9. Yaukey, Peter H. (2010) Citizen Science and Bird-Distribution Data: An Opportunity for Geographical Research. *Geographical Review*. 100.2: 263-73. JSTOR. Web.
10. Hijmans, Robert. (2015) Geosphere: Spherical Trigonometry. R Package Version 1.5-1.
11. R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

12. Sibley, D.A. The Sibley Guide to Bird Life and Behavior. (Alfred A. Knopf, Random House LLC 2001). 1st Edition.
13. Piland, N.C. Winkler, D.W. (2015) Tree swallow frugivory in winter. *Southeastern Naturalist*. Vol 14:1, pp. 123-136.