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Breeding Bird Census to Compare Long-term Changes in the Avifauna of the Spruce-fir Forest on Mount Guyot, Great Smoky Mountains National Park 1967-2015

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by

Kevin Brooks

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Dr. Tom Laughlin

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ABSTRACT

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The high-elevation forests of the Southern Appalachian Mountains have been impacted and rearranged by a tiny introduced pest from Europe, known as the Balsam Woolly Adelgid (Adelges piceaea), creating a concern for conservation. Breeding bird censuses, along with botanical surveys, have been conducted periodically on an established 60-acre plot since 1967 on the virgin forested slopes of Mount Guyot, Great Smoky Mountains National Park, with the last census being completed in 2015. Breeding bird populations are shown to rise and fall in response to the forest's changes over the last 48 years. Comparisons are made between all studies in order to assess how bird populations are being affected by the changed forest dynamics.

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CHAPTER 1
INTRODUCTION

The Balsam Woolly Adelgid and the Southern Appalachian Mountains

The Balsam Wooly Adelgid (BWA), *Adelges piceae*, was first detected in the Southern Appalachians on Mount Sterling, North Carolina, in 1963 (Alsop 1968). A study on the life history of the BWA was done detailing the impact of these insects on fir trees (*Abies spp.*) over a short span of time done by Hollingsworth and Hain in 1991. According to Hollingsworth, this insect has significantly contributed to the devastation of fir populations across the Eastern United States of America. An infestation of the Adelgid can cause mature tree mortality in 2-5 years (Hollingsworth 1991) by essentially choking the tree, starving it of nutrients and water. In 1976, Galli, et al., proposed that the number of bird species in a habitat is greatly influenced by the size and integrity of that particular habitat. An interesting trait of these insects, is that in North America, they are entirely parthenogenetic. The pest requires a secondary host that does not occur in North America to produce males (Ragenovich 2006). Since the once characteristic Fraser Fir (*Abies fraseri*) forests of the Southern Appalachian highlands are now dying and/or fragmented, one would not expect the same abundance and diversity of avifauna to be found at these localities (Hollingsworth 1991). Adams and Hammond, also in 1991, discovered that a change in habitat caused by the Adelgid on Mount Mitchell in North Carolina, a similar habitat to that on Mount Guyot, resulted in the loss of four breeding birds at that elevation of around 6000 ft. between 1959 and 1985. Smith and Nicholas in 1991 could not locate enough mature Fraser Fir trees on Mount Guyot to make all of their desired iterations of Mixed Live Fir plots. There were only three canopy-level fir trees reported by Alsop and Laughlin 1991 on the Mount Guyot study area.

P.S. White in 1984 found that the BWA is a driving force of ecological change in the high elevation, boreal-type forests of the Southern Appalachians. Loss of the Fraser Fir as the dominant tree species has created a new biological dynamic (White 1984). Other factors include increased ozone damage to Red Spruce (*Picea rubens*), acidic precipitation, and of course, the looming threat of climate change (Melillo 1998; Weinstein et al. 1991). Red Spruce

has become the dominant tree species on the Mount Guyot study plot after the BWA destroyed 99% of the existing mature Fraser Fir (Alsop and Laughlin 1991). There have been numerous changes to the avifauna of the boreal zone forests of the Southern Appalachian mountains in the last 100+ years as evidenced in the 1886 article: *An Ornithological Reconnaissance in Western North Carolina* by William Brewster. It is important to professionals and amateurs alike to be aware of the ever fluid nature of bird populations as tied to habitat changes. Rabenold, et al., conducted a similar study on Mount Collins in 1998 in *Response of Avian Communities to Disturbance by an Exotic Insect in Spruce- Fir Forests of the Southern Appalachians*. Rabenold et al. had closely correlated results with Alsop and Laughlin 1991 over a 21- year period in both canopy tree cover assessment and avifauna censuses.

This study is significant in that it is the longest running census of the high elevation avifauna of the Great Smoky Mountains with a pre-disturbance baseline dataset and following ecological disturbance by BWA. Fred J. Alsop III gathered baseline data in 1967 as his Master's project, and the study was repeated twice more by Thomas Laughlin in 1985 and 1997 (1997 unpublished data). I, Kevin Brooks, have repeated the study during the summers of 2014 and 2015, creating a dataset that spans almost half a century. Interesting trends in bird and plant populations are shown after analyzing the composite data.

CHAPTER 2
METHODS

Mount Guyot Study Site

Mount Guyot lies at 35.705311, -83.257683 (Alsop 1968) between Sevier County, Tennessee and Haywood County, North Carolina and is the fourth highest peak east of the Mississippi River, just 63 feet below Mount Mitchell, the highest peak. Unlike the other lofty mountains mentioned, Mount Guyot is largely undisturbed by man due to its remote location. Only the Appalachian Trail, and a sparse few connecting trails, cuts through its slopes. On June 14th 2014, I hiked into the Great Smoky Mountains National Park via the Balsam Mountain Trail in Maggie Valley, NC in an area called Pin Oak Gap, and I used Snake Den Ridge trail on June 14th 2015 beginning from Cosby Campground in Cosby, TN to undertake the breeding bird census begun in 1967 by Fred Alsop. The Balsam Mountain Trail intersects with the historic Appalachian Trail on Mount Guyot where Tri-corner Knob shelter, my place of residence for the duration of the study, is only 150 feet downslope from the juncture of the Appalachian Trail and Balsam Mountain Trail, a total distance of little more than 10 miles with not much change in elevation. Snake Den Ridge is a rather arduous, uphill trek for nearly the entire journey of 8.8 miles. It also has a junction with the Appalachian Trail nearer to Cosby Knob shelter. Tri-corner Knob shelter was selected by Alsop in 1967 for its reliable water source and close proximity to Balsam Mountain Trail, the site of the study area, with its slopes of virgin spruce-fir forest.

The same "L" shaped 60-acre plot, subdivided into a grid of 40, 1.5 acre blocks used by Alsop in 1968 and Laughlin 1985 and 1997 was identified and reestablished with the aid of Thomas Laughlin on June 14-16, 2014, and by myself June 14-16, 2015. The intersections of these 40 blocks serve as 20 census points or "stations." All intersections (60) on the plot were used in vegetation analyses for comparison to previous years' studies.

Breeding Bird Census

The censuses were conducted as follows: At 6:00 AM (EDST) , I awoke and prepared to leave the shelter, weather permitting. It is well known that avian subjects tend to be silent if there is precipitation or excessive wind. The first census began at the first station at 6:30 AM. Each bird

observed is recorded for a period of exactly 3 minutes at each of the 20 stations. Each bird species seen or heard singing, sex (if determinable by plumage or behavior), distance and direction from observer, and any interesting behavioral observations are also recorded. All birds contacted were recorded, but more emphasis was given to singing males over birds contacted only by call notes or sight alone. This is because a singing male generally is advertising territory and is likely a breeding bird, the focus of these censuses. For a list of birds identified, but not holding territory in the study area, see Appendix A. Of special importance are observations of two or more males singing at the same time, because this way I can be sure that there is indeed more than one territory being defended in the area by a particular species. All birds that were seen or heard overhead during the census were also noted. I used the following notation to denote a bird's contact: "si"= singing; "c"=call; any vocalizations that were not a song, and "oh"= overhead, for those birds that were not holding territory on the plot but flying overhead.

The census was also taken beginning at 6:30 PM (EDST) daily. Censuses beginning later than 6:30 PM resulted in being in the forest with inadequate daylight remaining, insufficient avian activity, and greatly increasing risk of personal injury because of the undergrowth and unwanted contacts with American Black Bear. Avian activity, including vocalizations, was observed to be adequate in this time frame for meaningful data collection.

The census data were collected using the Williams Spot-mapping Method (Williams 1936). Each observation for each bird was plotted on a map of the study area. Individuals' territories can be deduced from the resulting composite of spots. *It is important to note that the aim of these points is not to define the boundaries of the territories, only the number of territorial males present.* For every initial singing male I used a simple darkened circle on the spot-map. If contacts were made with two males singing simultaneously, I used an "o" so that I was able to differentiate between territorial males on the spot-map. On rare occasions, I recorded three males singing at the same station, in which case, I used an "x" on the spot-map for the third territorial male. Where the spots on the composite map clump together, a territorial boundary can be drawn, keeping in mind that many passerines hold territories of approximately one acre.

Spot-maps were generated for every species thought to be holding territory within the study area.

The hours between studies I used to conduct botanical surveys, photograph the plot, and photograph wildlife and scenery as well as the other activities involved in maintaining a camp. Hikers along the Appalachian Trail often expressed great interest in the conservation of the high elevation habitats.

Botanical Survey

The forest structure was divided into three vertical layers in this study, as in Alsop 1968, excluding lichens and bryophytes. The three layers are: Forest crown- those woody plants that are greater than 25 ft. making up the canopy, Understory- the woody vegetation less than 25 ft. but over 3 ft., and Ground Cover- specimens that are at least one inch above the ground. Botanical surveys were conducted in the same manner as in Alsop 1968 by setting up 10-ft. diameter circular plots. I used rope attached to a tent stake, at each of the 20 stations, and the remaining 40 plot intersections, for a total of 60 vegetation plots. The abundance of each species of tree was totaled and the amount of canopy coverage was assessed. These surveys can be accomplished with accuracy due to the relatively low biodiversity at higher elevations. Results are displayed in Appendix B, Tables 5 and 6. All identifications were made in the field or from photographs taken in the field or back in the laboratory. The botanical surveys are invaluable in interpreting the flux in avifauna populations over time and the overall health of the forest. As in Alsop 1968, there were no ecotones in this study plot, the forest is contiguous for miles except for where Tri-corner Knob and its privy is located near the study area. Balsam Mountain Trail itself represents a small area of disturbance from stations 1-3 (Figure 1) where grasses and sedges (*Caryx* spp.) can grow along with Bluets (*Houstonia* spp.) that were observed to occur nowhere else on the plot.

CHAPTER 3
RESULTS

Precipitation Data

The climate is as much a defining characteristic of the high elevations of GSMNP as are the flora and avifauna. The summertime temperatures in high forests of the GSMNP are similar in climate to those in southern Hudson Bay, Canada (Alsop 1968). These forests receive a high amount of rainfall throughout the year. I obtained data from a nearby rain gauge, RG301 (35°42.331', 83°15.357' at around 6,570' ft. elevation, only 0.79 miles from the study area) for the duration of my studies. The entire year of 2014 averaged approximately 64 inches of rain from February 2, 2014- December 31, 2014. RG301 was overturned by a curious American Black Bear (*Ursus americanus*) in January 2014. During my occupation at Tri-corner Knob shelter, there was 3.74 inches of rainfall recorded in 2014 and 3.56 inches recorded in 2015 by RG301. (Barros 2014; Prat 2010; and Burns 1990 et al).

Botanical Discussion

All botanical survey results and statistics may be viewed in the tables and figures in Appendix B. This study is fortunate in having a baseline dataset established before the Balsam Woolly Adelgid invaded the Great Smoky Mountains National Park and destroyed the existing forest structure on Mount Guyot. Table 1 is a comparative chart that shows the vegetation analyses that have been completed since 1967. Alsop (1968) showed that the forest on Mount Guyot was a virgin, dark, and closed canopy structure with numerous mature Fraser Fir trees as the dominant canopy-level species.

Table 1: Combined Botanical Surveys

A Comparison of the Forest Crown Trees[a] on 18,852 Square Feet[b] of the Mount Guyot Study Area Before and After Adelgid Infestation 1967-2015

Tree Species	Number of Trees				Percent of Total Trees				Percent of Change			
	1967	1985	1997	2015	1967	1985	1997	2015	1967-1985	1985-1997	1997-2015	1967-2015
Abies fraseri	529	5	2	12	80.0%	2.6%	2.4%	15.4%	-99.5%	-60.0%	500.0%	-97.7%
Picea rubens	107	152	50	35	16.0%	80.0%	61.0%	44.9%	-15.0%	-67.1%	-30.0%	-67.3%
Betula alleghaniensis	26	28	28	25	4.0%	14.7%	34.0%	32.1%	-35.0%	0.0%	-10.7%	-3.8%
Acer spicatum	0	5	2	6	0.0%	2.6%	2.4%	7.7%	100.0%	-60.0%	200.0%	100.0%
Sorbus americana	0	0	0	2	0.0%	0.0%	0.0%	2.6%	0.0%	0.0%	100.0%	100.0%
Totals	662	190	82	78	100%	100%	100%	100%				

[a]Only living trees were scored in all studies

[b]Area was calculated by multiplying the number of survey plots(60) by 10 feet^2 x 3.142

Data from Alsop 1968, Alsop & Laughlin 1991, and Brooks 2014-2015

After the BWA invaded the park, Laughlin 1985 chronicles the forest's initial response to the adelgid's destruction of the vulnerable Fraser Firs. The forest's pure stand of Fraser Firs were preyed upon by the adelgid and the resultant mass die off of the trees allowed much more sunlight to reach the ground than in the past. With the firs dead and fallen by 1985 on the plot, the large Red Spruce trees were much more subject to wind destruction, and massive tangled windfalls are now common throughout the Mount Guyot study area. The open canopy allowed more plant species to colonize the forest interior, especially in the ground layer where many plants are less tolerant of shade. In the most recent two iterations, Brooks 2014 and 2015, the forest remains an open canopy and the adelgid damage is still obvious; however, the sub-canopy layer has gained enough height to shade out some of the thickest ground cover that was experienced by Laughlin during his 1985 and 1997 censuses.

As previously mentioned, the dominant canopy tree in 2015 was Red Spruce. Many of these trees were easily over 100 ft. in height and several were more than 30 in. in diameter at breast height (DBH). Intermittent old-growth Yellow Birch (*Betula alleghaniensis*) dotted the study area. Many of these trees were large and wizened, over 25 in. DBH, and may be well over 200 years old or greater (Burns 1990). Few Fraser Fir specimens were found to be at canopy level. The individuals that were located seemed to be healthy and free from any impact of the adelgid upon inspection of the main stem and reachable boughs. In the more disturbed areas around

stations 1-3 where more sunlight is available, Mountain Ash (*Sorbus americana*) and Mountain Maple (*Acer spicatum*) were able to reach the canopy.

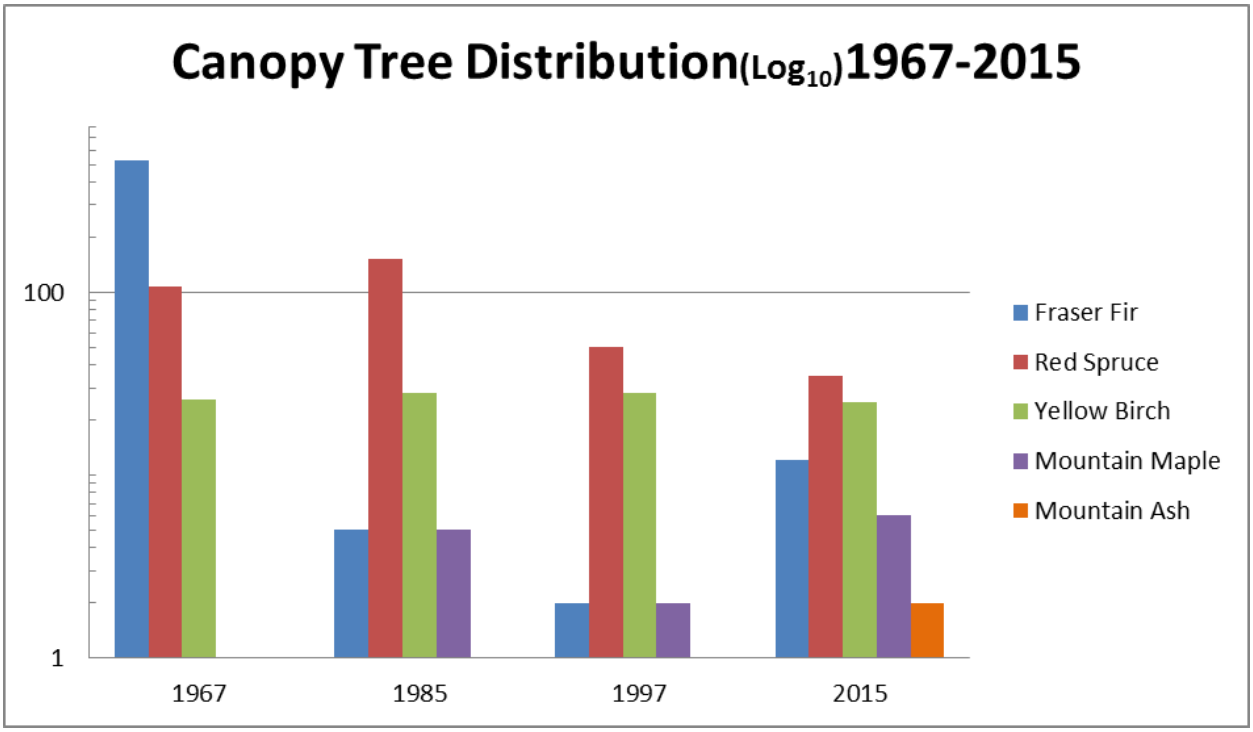

Figure 3: Canopy Tree Distribution 1967-2015

The sub-canopy zone was rich in young Red Spruce, and there was an obviously healthy population of the once-common Fraser Fir reaching toward the canopy. Scattered wherever there was enough sunlight were Yellow Birch, Mountain Ash, and Mountain Maple. A common shrub of the sub-canopy was Witch Hobble (*Viburnum alnifolium*). This woody plant had the propensity to form dense thickets through which it was difficult to maneuver. Mountain Cranberry (*Vaccinium erythrocarpum*) was in bloom at the time of the 2015 census and the docile Eastern Bumblebee (*Bombus* spp.) fed upon them along with a host of other invertebrates. The first Ruby-throated Hummingbirds (*Archilochus colubris*) for the study area were found to be feeding from the *Vaccinium*'s flowers in 2014. Some apparently sterile and colonial stems of *Vaccinium erythrocarpum* exceeded 6 ft. in height. Thornless Blackberry (*Rubus canadensis*) formed thickets wherever a Red Spruce windfall created a light gap in the canopy coverage and it could usually be found around the trail.

Table 2: Sub-canopy Growth 2015

Sub-canopy Trees (<25 ft.) of the Mount Guyot Study Plot in 2015		
Species	**Abundance**	**Percentage of Total Trees**
Picea rubens	163	49%
Abies fraseri	127	38%
Betula alleghaniensis	27	8%
Acer spicatum	13	4%
Sorbus americana	5	1%
TOTALS	335	100%

Non-woody plants made up the ground cover layer. Common Wood Sorrel (*Oxalis montana*) was present in fragmented patches throughout the study area. Alsop 1968 reported this species as "in greatest abundance," but *Oxalis montana* was not at all abundant in the 2015 study. Apparently this species has had trouble recovering from the excessive sunlight that penetrated the forest following the adelgid invasion. Lady Fern (*Athyrium filix-femina*) was the ground cover species in greatest abundance in this most recent iteration. Lady Fern was the dominant or co-dominant species on 70% of the 60 survey points. It was difficult to see the substrate at some stations; such was the abundance of Lady Fern. Lastly, Rugel's Ragwort (*Rugelia nudicaulis*) was common, especially along Balsam Mountain trail. It appeared in some numbers in every plot in the botanical survey and was the dominant ground cover in one census point. Clinton's Lily (*Clintonia borealis*) was found in only one survey point, E11 (Figure 2). Three stems of Indian Cucumber Root (*Medeola virginiana*) were found, and two Red Trilliums (*Trillium erectum*) were found growing near Balsam Mountain Trail.

In the original study, the forest was chiefly mature Fraser Fir as shown in Table 1. 2015 data shows that 45% of the canopy trees were Red Spruce and only 15% were Fraser Fir, but Table 2 shows that 49% of the sub-canopy trees were Red Spruce and 38% were Fraser Fir in the same 2015 study. There is a healthy understory of fir trees reaching for the canopy level on the Mount Guyot plot. It is my opinion, based on personal observation and the displayed data that, barring another round of adelgid infestation, the forest on Mount Guyot is transitioning back to a closed canopy predominantly Fraser Fir forest. In 2014 and 2015, I experienced a ground cover layer through which movement was not overly difficult, save for the occasional dense

jumble of fallen spruce-fir trees I encountered from stations 14-16 on a daily basis. This is due to the advanced state of the sub-canopy trees that are casting more shade than in Laughlin's studies in 1985 and 1997. Photos from Laughlin's 1997 study show a thick and wild layer of ground cover along with many woody stems of Thornless Blackberry, further supporting my hypothesis. Indeed the 1967 canopy tree dataset has more in common concerning species present with the 2014-2015 dataset than either of the middle two iterations as seen in Table 4.

Table 3: Jaccard Coefficient of Similarity for Canopy Tree Species

Jaccard Coefficient of Similarity for Canopy Tree Species 1967-2015	
1967-1985	0.75
1967-1997	0.75
1967-2015	0.6
1985-1997	1
1985-2015	0.8
1997-2015	0.8

Common indices of biodiversity and the coefficient of variation were calculated per year. Shannon Index shows minute increase between the first two studies, but as the canopy becomes more open in 1997 and ample time has passed for the maturation of trees; Shannon index increases from 1985-1997 and again from 1997-2015. Simpson Index shows a decreasing trend as tree distributions become more even. Coefficient of Variation also shows a strong decreasing trend.

Table 4: Plant Biodiversity Indices and Coefficient of Variance

Common Biodiversity Indices and Coefficient of Variation for Canopy Tree Species 1967-2015				
Assay	**1967**	**1985**	**1997**	**2015**
Shannon Index	0.6	0.66	0.85	1.3
Simpson Index	0.67	0.66	0.48	0.31
Coefficient of Variation	1.22	1.48	1.13	0.67

Breeding Bird Censuses Discussion

All data for the breeding bird censuses and statistics may be seen in the tables and figures comprising Appendix C, and a list of all birds identified on the mountain, but not breeding birds,

can be viewed in Appendix D. Most of the breeding birds on Mount Guyot are bound to these high elevation habitats that are provided by the Appalachian Mountains. The coniferous forest at this elevation attracts a suite of birds that normally breed much farther north in the Boreal forests of the northern-most reaches of the United States and Canada. The birds in the Mount Guyot study area are representative of these mountain-top "islands" of biodiversity.

Nesting Preference Guilds

To better show trends in avian populations, the birds of Mount Guyot were subdivided into 4 guilds by nesting site preference (Cornell Lab of Ornithology 2015) and can be seen in Table 7 and Figure 8. Nesting preference was used for guild determination rather than diet because most birds on the Mount Guyot study plot are primarily insectivorous at least during the breeding season, and therefore, there are no major dietary divisions. These guilds, by largest population, are: Ground- those species that nest on or near the ground itself, Cavity/Crevice- those species that either excavate their own cavity or utilize pre-existing cavities. Brown Creeper(*Certhia americana*) tends to nest in crevices created by old tree bark. Canopy/ Sub-canopy- those species that nest in the boughs of mature trees, and Shrub- those species that require shrub-layer for nesting.

Table 7: Breeding Bird Nesting Preference Guilds

Nesting Guild*	Species
Ground	Hermit Thrush, Veery, Canada Warbler, Dark-eyed Junco
Cavity/Crevice	Northern Saw-whet Owl, Hairy Woodpecker, Black-capped Chickadee, Brown Creeper, Red-breasted Nuthatch, Winter Wren
Canopy/ Sub-canopy	Blackburnian Warbler, Black-throated Green Warbler, Blue-headed Vireo, Golden-crowned Kinglet, American Robin
Shrub	Eastern Towhee, Chestnut-sided Warbler, Black-throated Blue Warbler, Ruby-throated Hummingbird
*Nest site preferences from Cornell Laboratory of Ornithology. Guilds arranged by most numerous.	

The Ground Guild was the most numerous during the 1967 study when the forest had a closed canopy of Fraser Fir trees. There was a dense layer of *Oxalis* and *Athyrium* that provided ample cover for ground nesting species. When the canopy was disturbed by BWA, ground cover

species declined in both 1985 and 1997, likely because familiar nest sites were destroyed and shrubs replaced much of the herbaceous ground cover. As the shrub layer became more shaded in the 2014-2015 studies, ground cover species began to recover in numbers.

Cavity/Crevice Guild nesters were not much affected by the BWA's disturbance. Their numbers remain relatively high throughout the decades, and actually show an increase in the most recent two iterations. The dead stands of Fir and wind-thrown Spruce trees provided additional foraging space for these birds and rotting wood is easier to excavate for nesting cavities. Winter Wren (*Troglodytes hiemalis*) is the major contributor to this nesting guild, and it is able to utilize the exposed root boles from wind-thrown Red Spruce as nesting sites.

The Canopy/ Sub-canopy Guild was the most affected by BWA's attack. In 1967, the pre-disturbed canopy was healthy and intact, but in the 1985 study, there were only three canopy-level Fraser Fir trees, the once-dominant canopy species, to be found. The extreme deficit of healthy canopy coverage for nesting and foraging caused the dramatic decline in this guild from 1985-1997. In the 2014-2015 studies, the sub-canopy had matured enough to support more members of this guild and numbers closer to pre-BWA infestation were recorded.

The Shrub Guild was comprised of only one species in 1967, the Black-throated Blue Warbler (*Setophaga caerulescens*), which was likely nesting in the *Viburnum* bushes and other woody shrub-later vegetation. After the BWA invaded and the canopy was opened, other species found the habitat suitable for nesting. Eastern Towhee (*Pipilo erythrophthalmus*) became a co-dominant species with Black-throated Blue Warbler in the Shrub Guild during the 1985-1997 time period. A small decline in this guild was recorded initially in 1985, because the Black-throated Blue population had been affected by the many fallen Fraser Fir and wind-thrown Red-spruce. This guild's peak followed in the 1997 study, when the shrub layer was most developed. Shrub Guild is shown to be in decline during the 2014 and 2015 studies due to a more developed sub-canopy tree community that has dampened the rapid expansion of the shrub layer.

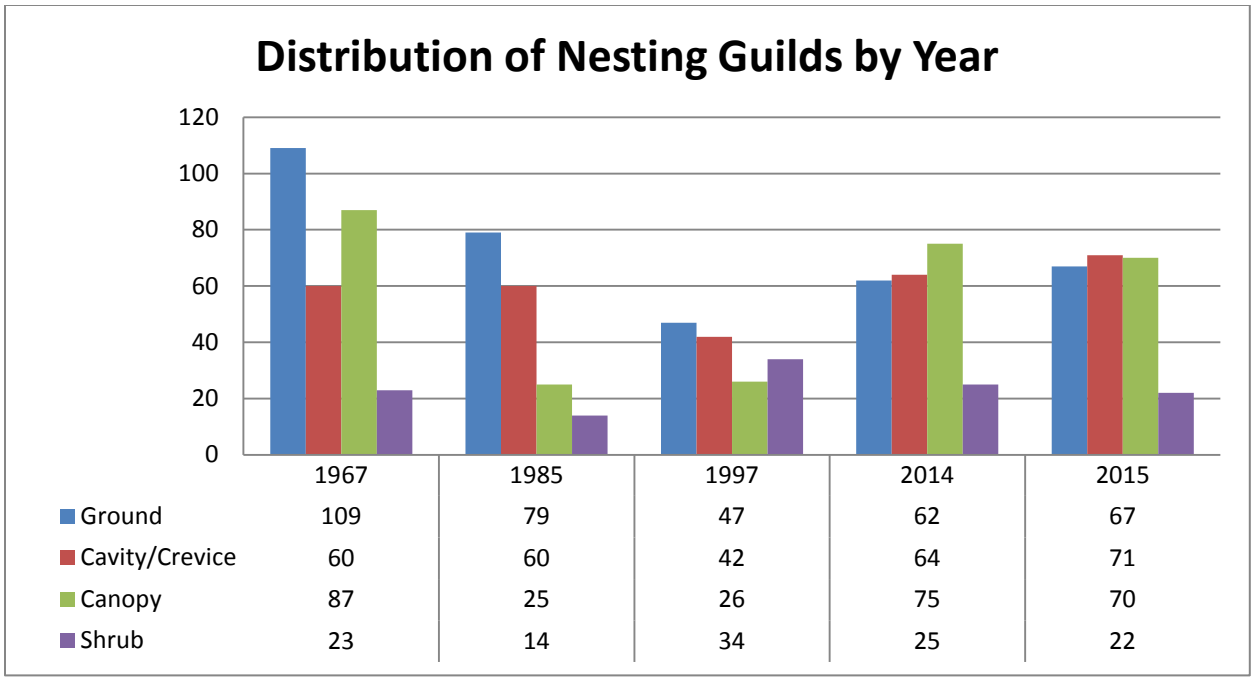

Figure 8: Nesting Guilds by Year

Individual Species Discussion

In the census conducted in the post-adelgid invasion in 1985, a sharp decrease can be seen in canopy-dependent species, such as Golden-crowned Kinglet (*Regulus setrapa*), Black-capped Chickadee (*Poecile atricapillus*), Black-throated Green Warbler (*Setophaga virens*. Blackburnian Warbler (*Setophaga fusca*) and American Robin (*Turdus migratorious*) found the habitat unsuitable and were no longer counted in subsequent censuses (except for 2 American Robin individuals calling in 2015). As the fir trees died, the canopy cover decreased drastically, and so did the birds which relied on that particular niche for food or nest building. Concurrently, species that rely on a more open forest interior such as Veery (*Catharus fuscescens*) and American Robin also suffered from a more open canopy. Three species did not seem to be much affected by the insect's invasion; indeed some species' populations were elevated. These include: Red-breasted Nuthatch (*Sitta canadensis*), Hairy Woodpecker (*Picoides villosus*), and Brown Creeper. These species' food and habitat preferences were not impacted significantly by the adelgid, in fact, the stands of dead fir timber would likely have provided more nesting and foraging space. The last few species exhibited a response closer to neutral and only showed a relatively small increase or decrease in population size. The Winter Wren, Dark-eyed Junco

(*Junco hyemalis*), and Blue-headed Vireo (*Vireo solitarius*) populations remained relatively stable in this time period of great ecological distress probably due to these birds' hardy nature and diet. Even though the original habitat was destroyed, habitat still remains of another variety.) New niches were created by the adelgid destruction which allowed for species like Chestnut-sided Warbler (*Setophaga pensylvanica*), Eastern Towhee, and Canada Warbler (*Cardellina canadensis*) to utilize the new and more open forest canopy structure along with the better developed shrub layer for nesting and foraging. Black-throated Blue Warbler numbers, though they nest in the shrub later, initially decreased with the initial disturbance but recovered in the 2014 and 2015 studies.

The 1985-1997 study period marks the period of time where the forest was in greatest ecological distress. Birds were adjusting to the new forest dynamic, and some birds managed to adjust better than others. Eastern Towhee and Black-throated Blue Warbler found the new shrubby and tangled ground layer, caused by increased sunlight, suitable for nesting. Eastern Towhee numbers increased sharply. Black-throated Green Warbler and Black-capped Chickadee began using the now suitably mature Red Spruce boughs to forage. Veery populations rose substantially because of the increased ground cover layer and shrub layer in which they nest. Blue-headed Vireo populations on the plot fell in this time period, possibly because of greatly reduced availability of suitable healthy branches in trees. Brown Creeper and Hairy Woodpecker also showed a small decrease in presence, as did Dark-eyed Junco and Winter Wren for similar nest site restriction reasons. Fewer nest sites translates into more competition for those nest sites that are available.

Interesting population shifts occurred in the period between 1997-2014. The forest's sub-canopy is now mature enough that the ground cover explosion has been slowed to a great extent. Birds that forage and nest on dead and dying timber like Hairy Woodpecker, Brown Creeper, and Red-breasted Nuthatch saw substantial population increases. The maturing understory spiked the abundance of Black-throated Green Warbler and Golden-crowned Kinglet, but also replaced suitable habitat for Eastern Towhee and Chestnut-sided Warbler, species which require a developed shrub layer for nesting. American Robin may still find the ground cover overly high for its foraging requirements. Three new species were added to the

breeding bird list in the 2014 study. These were: Ruby-throated Hummingbird, Hermit Thrush (*Catharus guttatus*), and Northern Saw-whet Owl (*Aegolius acadicus*). Ruby-throated Hummingbirds are easily overlooked and were probably present in past studies. I encountered them several mornings feeding on *Vaccinium* flowers near station markers along the Balsam Mountain Trail. Hermit Thrush did not occur on the mountain in the previous three studies, but has gone through a range extension southward in more recent years following the Appalachian Mountains' maturing spruce-fir forests (Laughlin 2013). Northern Saw-whet Owl is a species that has always been expected in the plot (Alsop 1968) but was not confirmed until the 2014 study. An effort was made in 2015 to contact Northern Saw-whet Owl, by imitating its call after dark on three nights as well as intermittently throughout the censuses but proved to be fruitless.

The 2015 study revealed little change in bird populations as expected, since it was only one year later than the previous foray. Chestnut-sided Warbler was observed to hold territory that only slightly encroached on the study plot. This species certainly had a nest in the more open and disturbed areas around Tri-corner Knob shelter. Two individuals of American Robin were heard giving "*pip pip"* notes on the southeast end of the study area at stations 14 and 15 on two census days. These birds may have been holding territory, but since no American Robin song was heard, I am not confident in this assessment. Overall, 10 species are showing a net decline in population numbers, while 6 species are increasing, and 3 species are absent on the plot since the baseline study conducted in 1967.

A Jaccard coefficient of similarity, along with common biodiversity indices were also calculated for bird species data. The Jaccard Coefficient of similarity can be seen in Table 8 with the most similar species present shared between the baseline dataset is the 2015 study. It is interesting to note that 1985 and 1997 were exactly the same in terms of species present.

Table 8: Jaccard Coefficient of Similarity for Birds

Jaccard Coefficient of Similarity for Breeding Bird Territories 1967-2015	
1967-1985	0.69
1967-1997	0.69
1967-2014	0.69
1967-2015	0.86
1985-1997	1.00
1985-2014	0.75
1985-2015	0.69
1997-2014	0.75
1997-2015	0.69
2014-2015	0.80

The data in Table 9 show Shannon Index dropping slightly as some species recorded in 1967 were not present in 1985. The Shannon Index then increases slightly in the following studies as the number of species present increases. Simpson index shows a minute increase in 1985. The coefficient of variation also shows a small increase between 1967 and 1985, but it then decreases in the following studies.

Table 9: Bird Biodiversity Indices and Coefficient of Variation

Common Biodiversity Indices and Coefficient of Variation for Breeding Bird Territories 1967-2015					
Assay	**1967**	**1985**	**1997**	**2014**	**2015**
Shannon Index	2.16	2.06	2.36	2.44	2.47
Simpson Index	0.15	0.19	0.11	0.097	0.095
Coefficient of Variation	1.34	1.61	1.07	0.98	0.91

CHAPTER 4
CONCLUSION

Conclusions

In conclusion, I found the virgin slopes of Mount Guyot, GSMNP to be in an advanced state of ecological change during the summers of 2014 and 2015. The introduction of the Balsam Woolly Adelgid has had profound effects on the high elevation spruce-fir forests of the Southern Appalachians, and the comparative indices and analyses highlight these changes. The initial forest upheaval was seen in Dr. Laughlin's studies, especially in 1985, when the canopy-level trees were greatly thinned and the ground cover layer was growing rapidly. In 2015, the spruce-fir forest seemed to be on a trajectory that will one day culminate in a closed canopy, predominantly Fraser Fir forest much the same found by Alsop (1968), assuming no further impact from the adelgid. Other impacting factors of which to be mindful are air pollution which causes acidic precipitation and climate change. If BWA is to continue on Mount Guyot, another round of Fraser Fir die-off is imminent, and further studies will be necessary to see how the forest's inhabitants can cope with further disturbance. The succession story of this high-elevation study plot is yet to be concluded.

Many species of avifauna of the Canadian Zone of the Southern Appalachian Mountains are surprisingly sensitive to disturbance in their preferred breeding niches. Few species of birds remain largely unaffected by the changes in the high elevation forest.

Long-term studies are a rarity in the literature, but this effort marks nearly a half-century of spot data that tells the story of a threatened ecosystem and its inhabitants' ability, or inability, to mitigate the changes. Future studies are necessary and important in order to fully understand how habitat disturbance in this remarkable forest biome affects the birds living in it.

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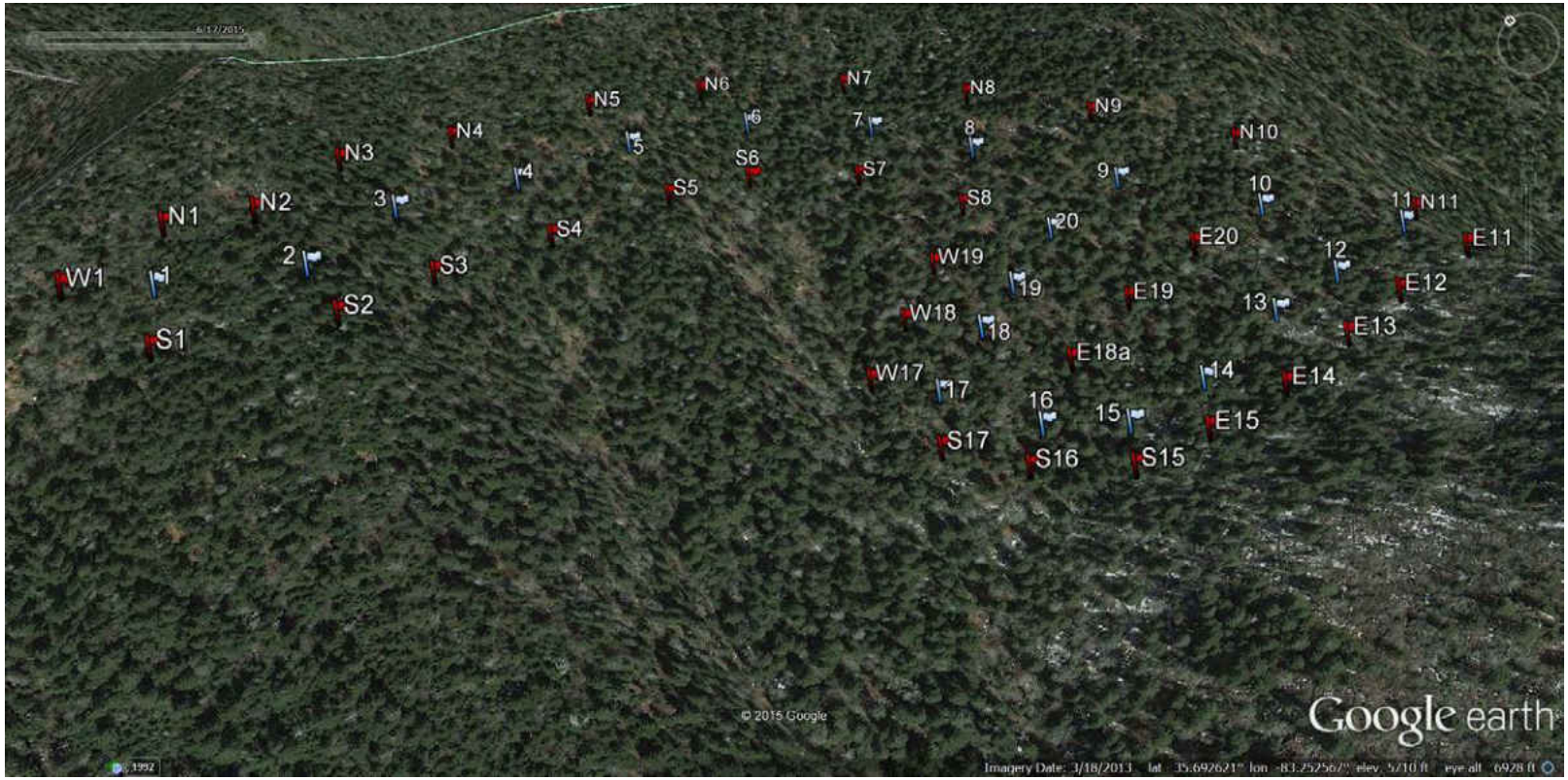
APPENDICES

Appendix A
Figures of the Study Area

Figure 1: Study Area Census Station 1-20

From Google Earth

Figure 2: Bird Census Stations As Well As Botanical Plots



From Google Earth

Appendix B
Botanical Surveys and Statistics

Vegetation Survey 1967- 2015

Table 1: Combined Botanical Surveys

A Comparison of the Forest Crown Trees[a] on 18,852 Square Feet[b] of the Mount Guyot Study Area Before and After Adelgid Infestation 1967-2015

Tree Species	Number of Trees				Percent of Total Trees				Percent of Change			
	1967	1985	1997	2015	1967	1985	1997	2015	1967-1985	1985-1997	1997-2015	1967-2015
Abies fraseri	529	5	2	12	80.0%	2.6%	2.4%	15.4%	-99.5%	-60.0%	500.0%	-97.7%
Picea rubens	107	152	50	35	16.0%	80.0%	61.0%	44.9%	-15.0%	-67.1%	-30.0%	-67.3%
Betula alleghaniensis	26	28	28	25	4.0%	14.7%	34.0%	32.1%	-35.0%	0.0%	-10.7%	-3.8%
Acer spicatum	0	5	2	6	0.0%	2.6%	2.4%	7.7%	100.0%	-60.0%	200.0%	100.0%
Sorbus americana	0	0	0	2	0.0%	0.0%	0.0%	2.6%	0.0%	0.0%	100.0%	100.0%
Totals	662	190	82	78	100%	100%	100%	100%				

[a]Only living trees were scored in all studies

[b]Area was calculated by multiplying the number of survey plots(60) by 10 feet^2 x 3.142

Data from Alsop 1968, Alsop & Laughlin 1991, and Brooks 2014-2015

Table 2: Sub-canopy Growth 2015

Sub-canopy Trees (<25 ft.) of the Mount Guyot Study Plot in 2015

Species	Abundance	Percentage of Total Trees
Picea rubens	163	49%
Abies fraseri	127	38%
Betula alleghaniensis	27	8%
Acer spicatum	13	4%
Sorbus americana	5	1%
TOTALS	335	100%

Figure 3: Canopy Tree Distribution 1967-2015

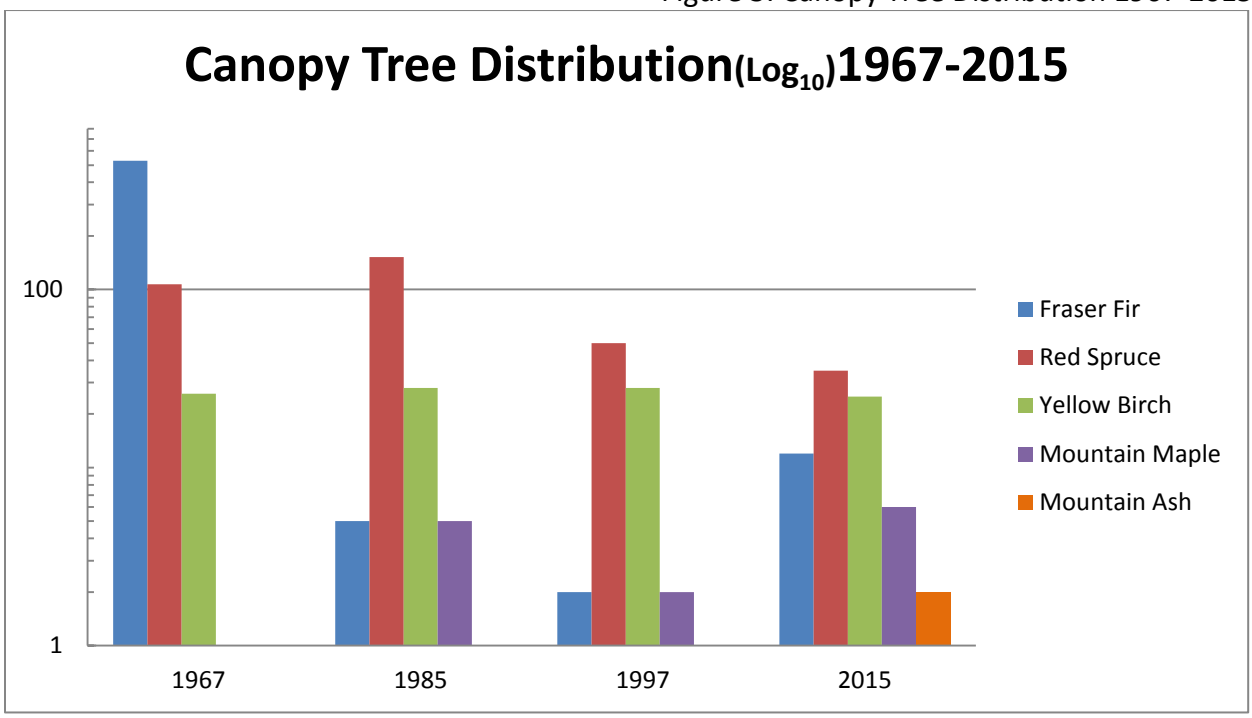


Table 3: Jaccard Coefficient of Similarity for Canopy Tree Species

Jaccard Coefficient of Similarity for Canopy Tree Species 1967-2015	
1967-1985	0.75
1967-1997	0.75
1967-2015	0.6
1985-1997	1
1985-2015	0.8
1997-2015	0.8

Table 4: Plant Biodiversity Indices and Coefficient of Variance

Common Biodiversity Indices and Coefficient of Variation for Canopy Tree Species 1967-2015				
Assay	**1967**	**1985**	**1997**	**2015**
Shannon Index	0.6	0.66	0.85	1.3
Simpson Index	0.67	0.66	0.48	0.31
Coefficient of Variation	1.22	1.48	1.13	0.67

Appendix C
Breeding Bird Surveys and Statistics

Table 5: Breeding Bird Survey Results 1967-2015

Number of males/ 100 acres on Mount Guyot Study Area[a]					
Species	**1967**	**1985**	**1997**	**2014**	**2015**
Ruby-throated Hummingbird	0	0	0	10	5
Hairy Woodpecker	3	5	3	7	7
Blue-headed Vireo	15	9	3	10	13
Black-capped Chickadee	6	1	3	7	10
Red-breasted Nuthatch	8	10	7	15	17
Brown Creeper	10	16	8	12	17
Winter Wren	33	28	20	23	20
Golden-crowned Kinglet	50	15	18	37	35
Veery	33	6	12	13	15
Hermit Thrush	0	0	0	12	10
American Robin	8	0	0	0	2
Blackburnian Warbler	3	0	0	0	0
Chestnut-sided Warbler	0	5	5	0	2
Black-throated Blue Warbler	23	8	17	15	17
Black-throated Green Warbler	11	1	5	28	22
Canada Warbler	0	6	3	2	0
Eastern Towhee	0	1	12	0	0
Dark-eyed Junco	76	66	32	37	42

[a]Birds arranged by 2015 A.O.U. taxonomic order

Table 6: Percent Change in Breeding Bird Populations 1967-2015

Percent Difference in Abundance of Territorial Males on Mount Guyot Study Area[a] 2015					
Species	**1967-1985**	**1985-1997**	**1997-2014**	**2014-2015**	**1967-2015**
Ruby-throated Hummingbird	0%	0%	100%	-50%	100%
Hairy Woodpecker	40%	-33%	100%	0%	122%
Blue-headed Vireo	-40%	-63%	200%	33%	-11%
Black-capped Chickadee	-88%	233%	100%	50%	67%
Red-breasted Nuthatch	20%	-33%	125%	11%	108%
Brown Creeper	37%	-48%	40%	34%	67%
Winter Wren	-16%	-29%	17%	-14%	-39%
Golden-crowned Kinglet	-70%	22%	106%	-5%	-30%
Veery	-82%	94%	14%	13%	-55%
Hermit Thrush	0%	0%	100%	-14%	100%
American Robin	-100%	0%	0%	0%	-120%
Blackburnian Warbler	-100%	0%	0%	0%	-100%
Chestnut-sided Warbler	100%	0%	-100%	100%	-60%
Black-throated Blue Warbler	-65%	108%	-10%	13%	9%
Black-throated Green Warbler	-92%	400%	460%	-24%	100%
Canada Warbler	100%	-44%	-50%	-100%	-100%
Eastern Towhee	100%	1067%	-100%	0%	-100%
Dark-eyed Junco	-13%	-52%	16%	14%	-45%

[a]Birds arranged by 2015 A.O.U. taxonomic order

Figure 4: Territorial Males 1967-2015

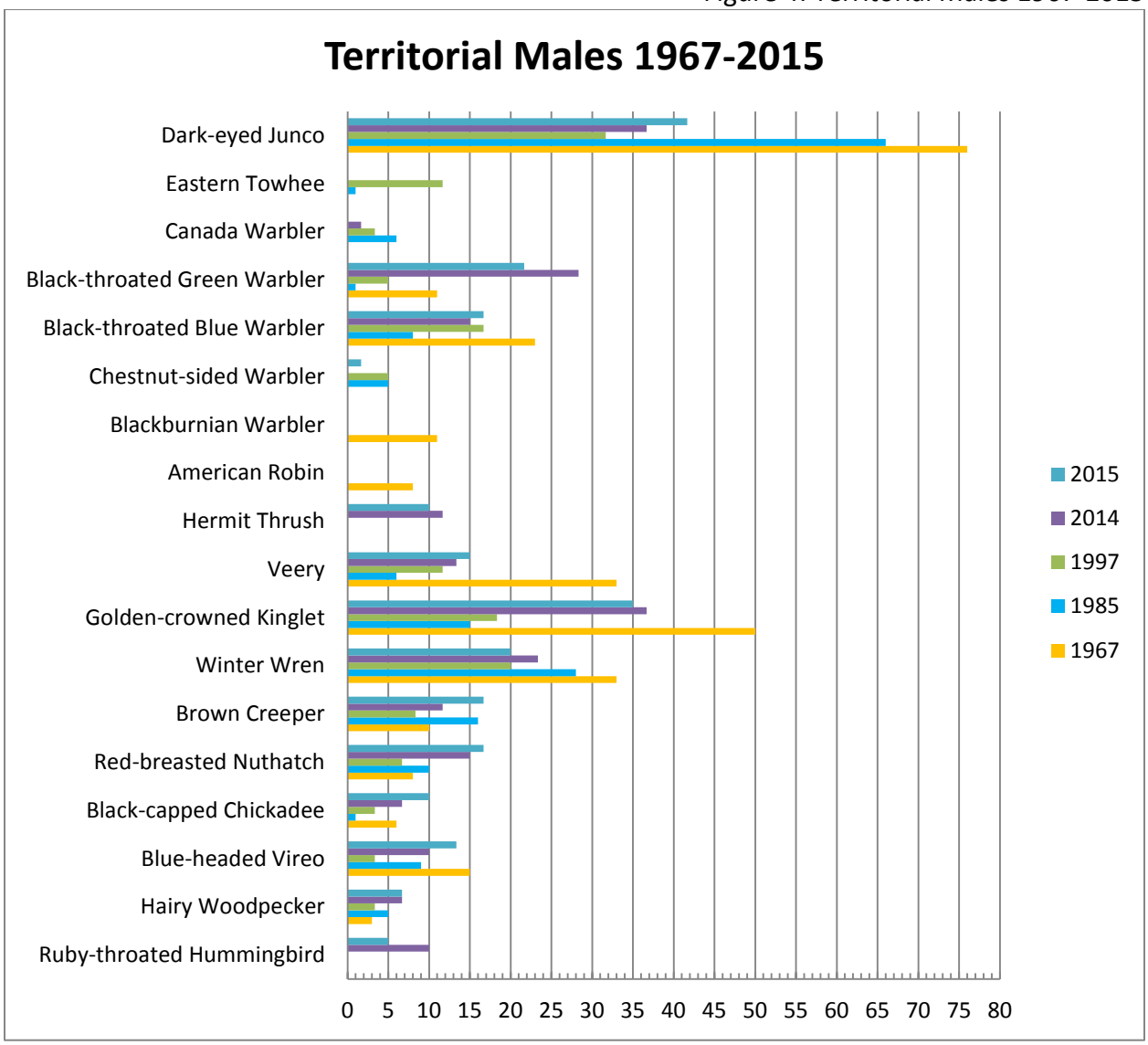


Figure 5: Territorial Males per 100 Acres 1967 & 2015

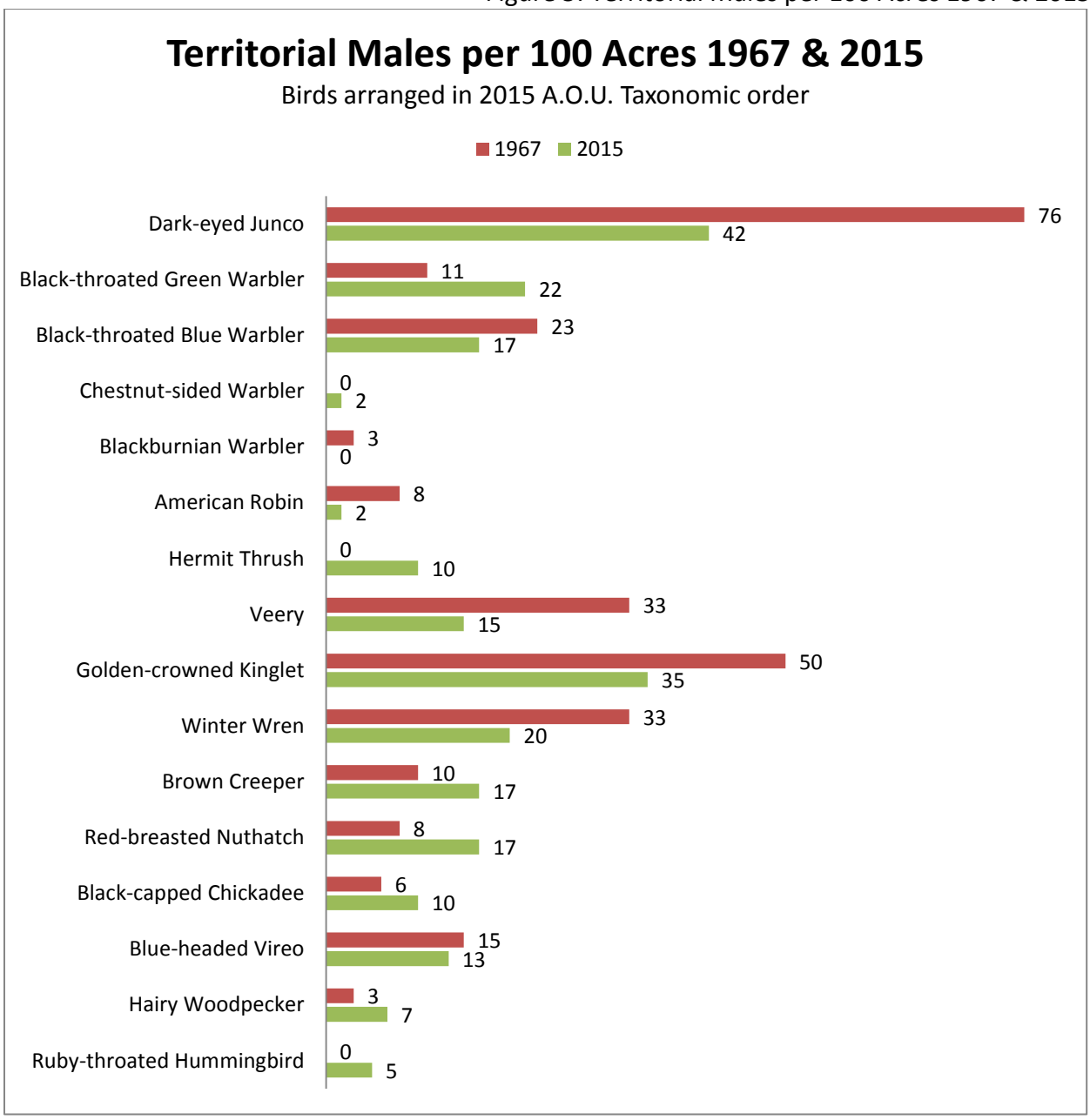


Figure 6: Total Territorial Males 1967-2015

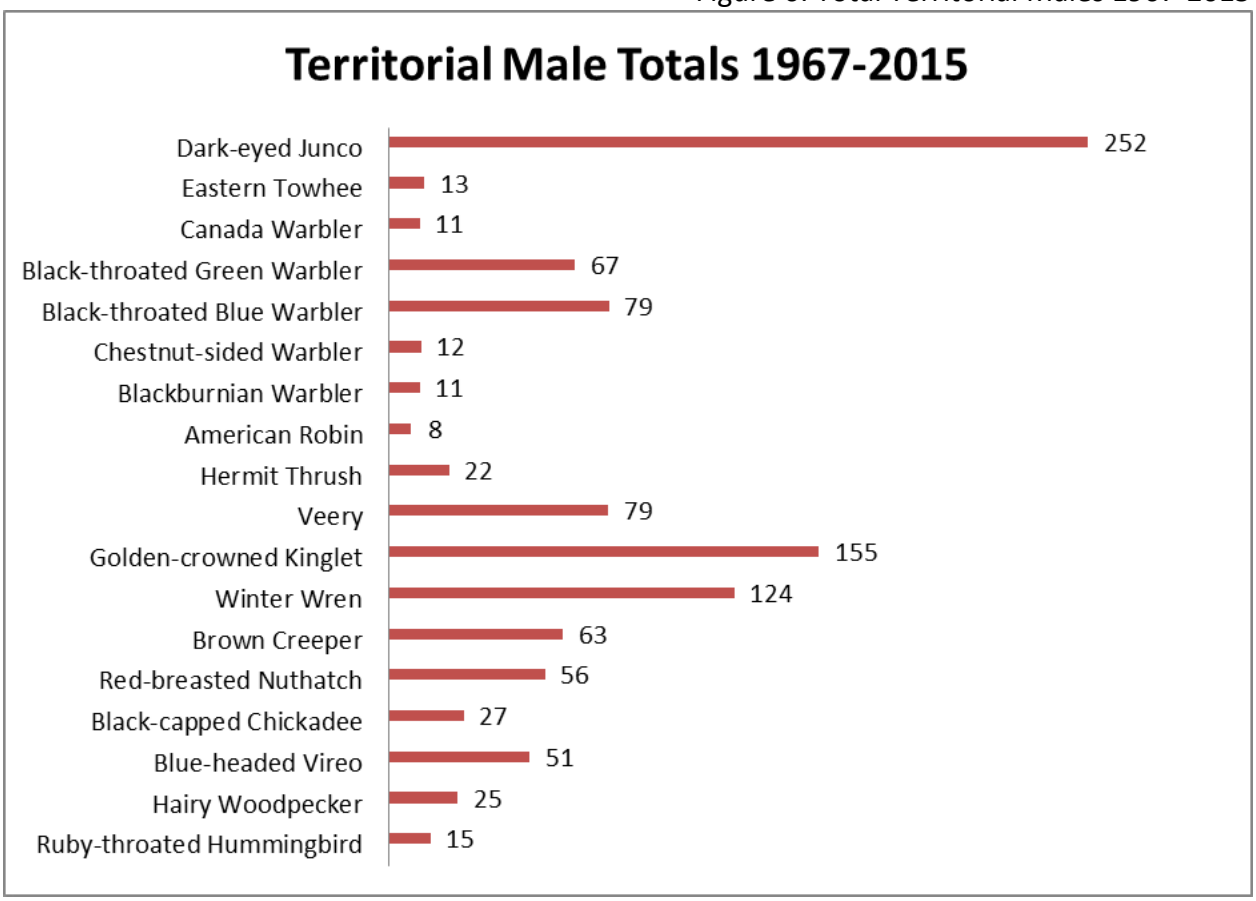


Figure 7: Species Occurrence by Year

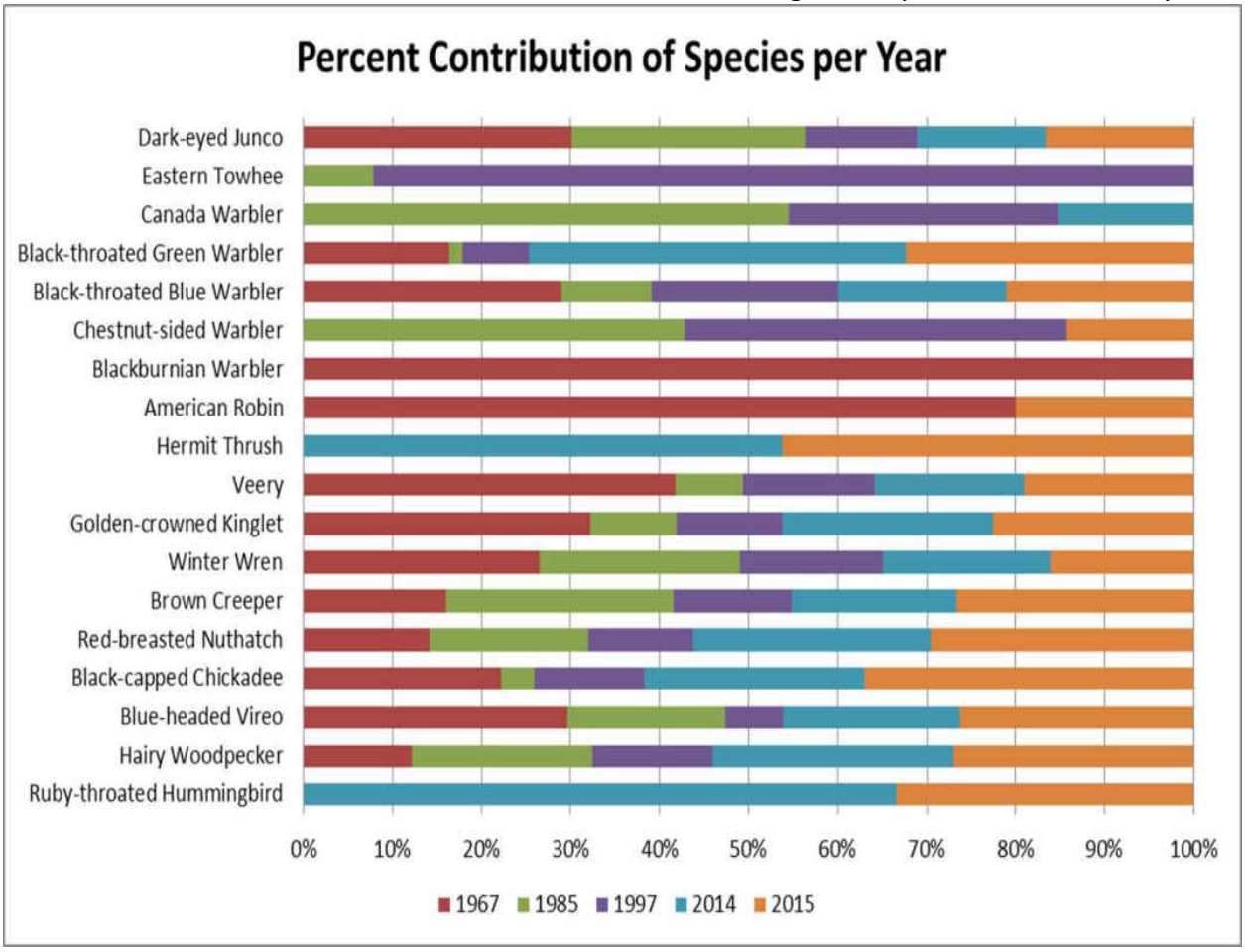


Table 7: Breeding Bird Nesting Preference Guilds

Nesting Guild*	Species
Ground	Hermit Thrush, Veery, Canada Warbler, Dark-eyed Junco
Cavity/Crevice	Northern Saw-whet Owl, Hairy Woodpecker, Black-capped Chickadee, Brown Creeper, Red-breasted Nuthatch, Winter Wren
Canopy/ Sub-canopy	Blackburnian Warbler, Black-throated Green Warbler, Blue-headed Vireo, Golden-crowned Kinglet, American Robin
Shrub	Eastern Towhee, Chestnut-sided Warbler, Black-throated Blue Warbler, Ruby-throated Hummingbird
*Nest site preferences from Cornell Laboratory of Ornithology. Guilds arranged by most numerous.	

Figure 8: Nesting Guilds by Year

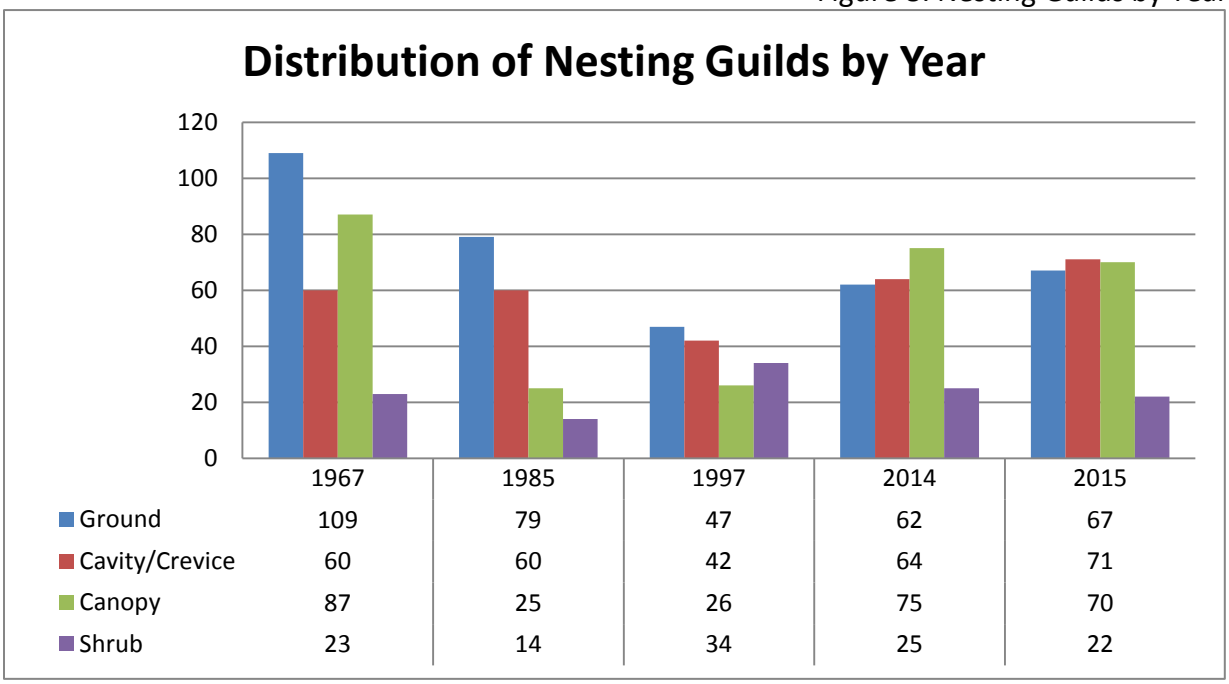


Figure 9: Ground Guild Trend

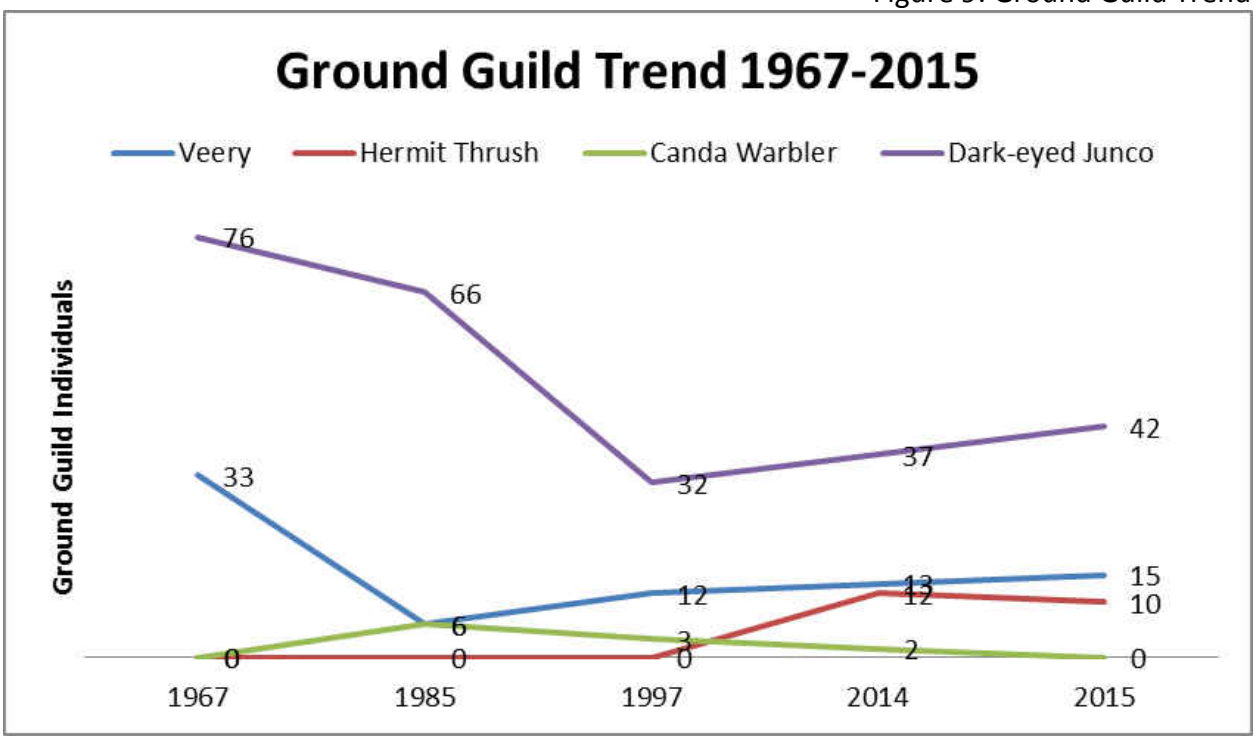


Figure 10: Cavity/ Crevice Guild Trend

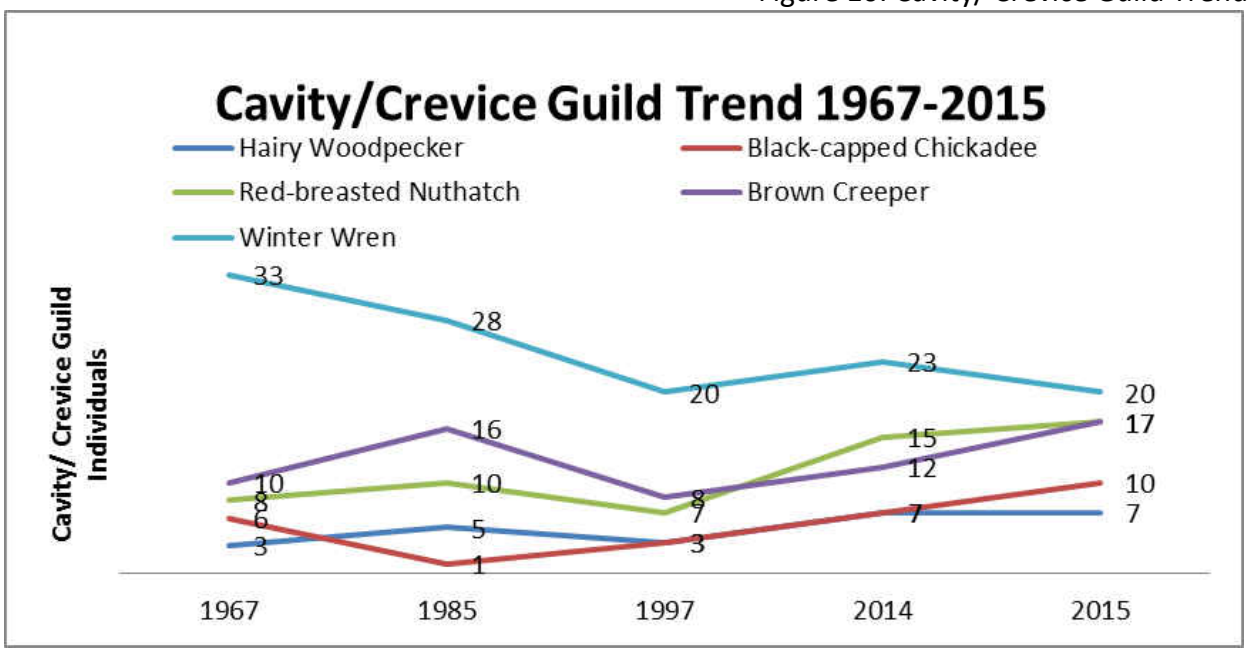


Figure 11: Canopy/ Sub-canopy Guild Trend

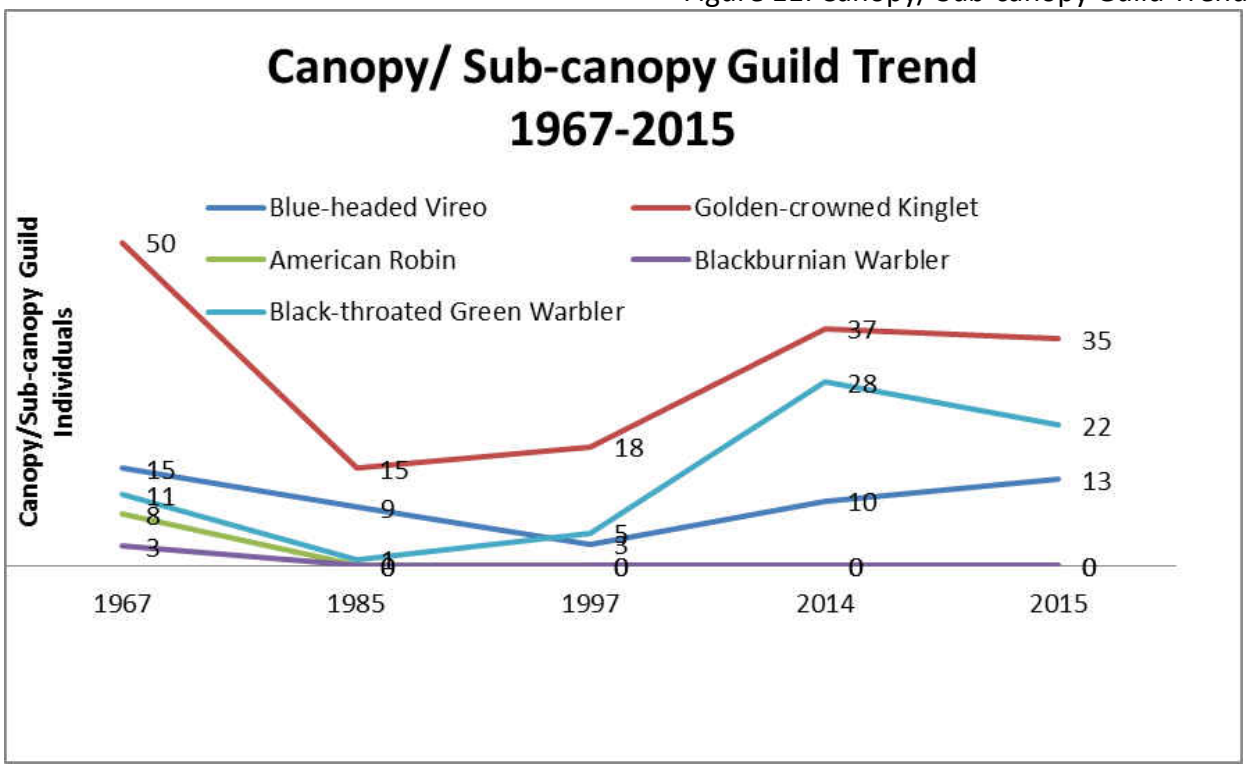


Figure 12: Shrub Guild Trend

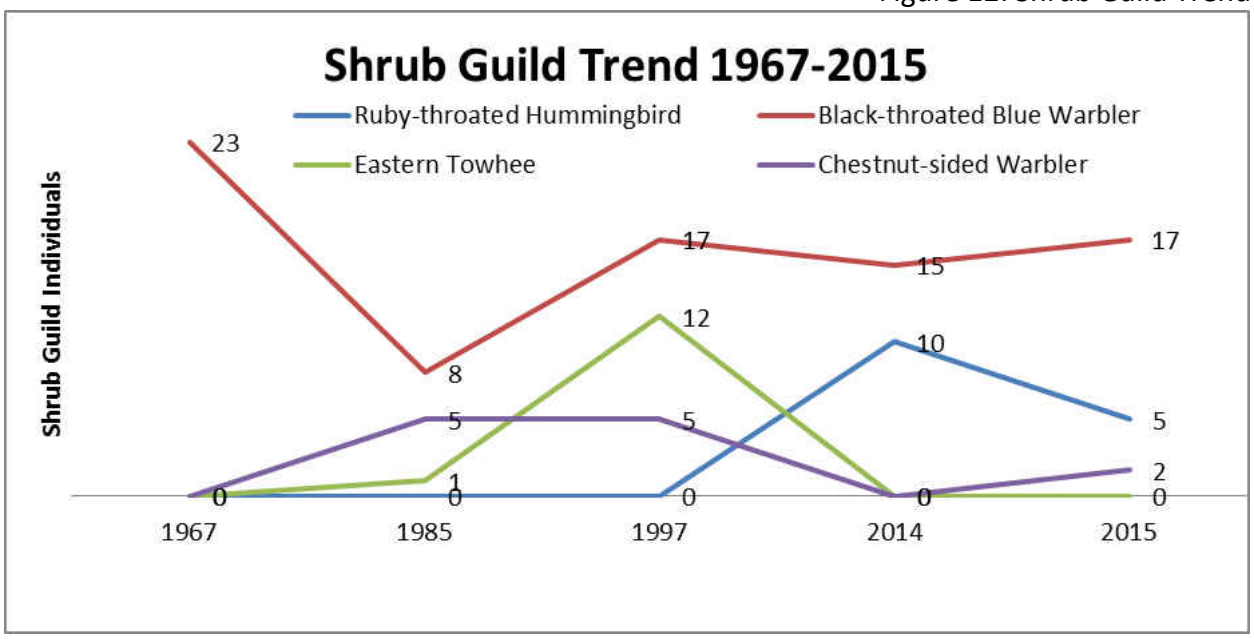


Figure 13 Ground Cover Guild Vs. Canopy Tree Cover

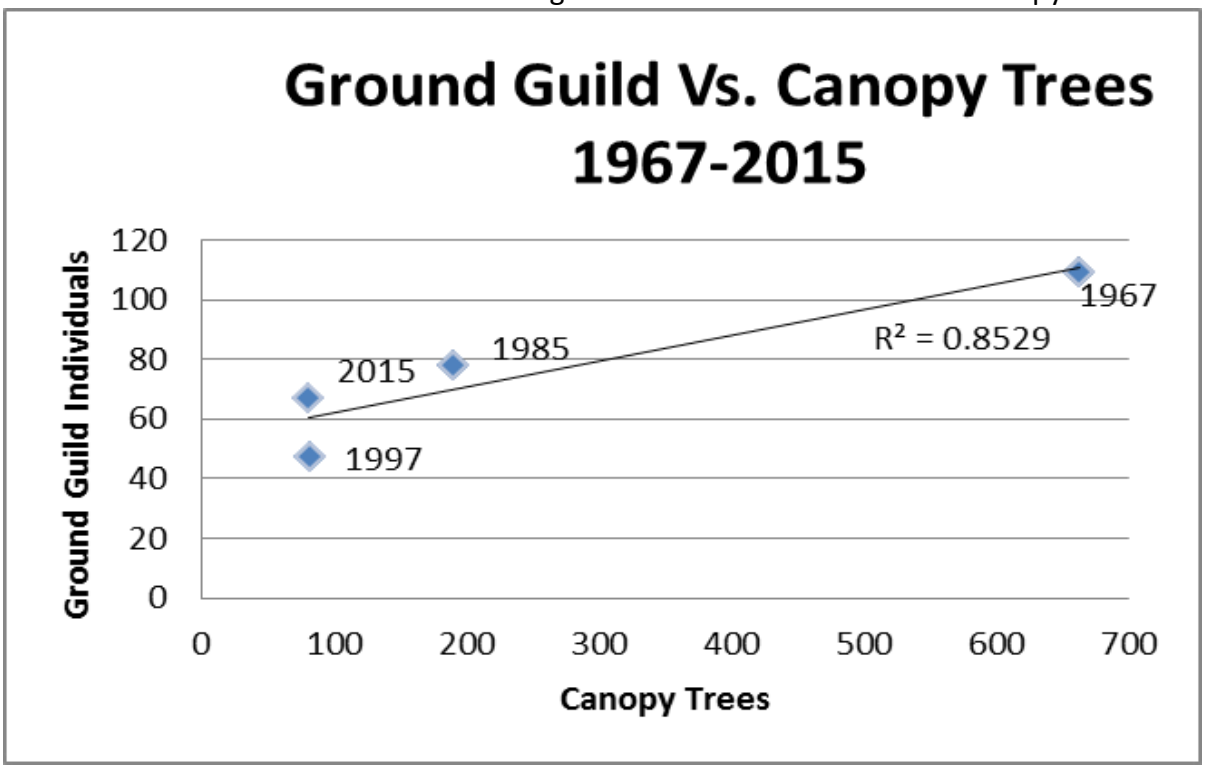


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Figure 14: Cavity/ Crevice Guild Vs. Canopy Tree Cover

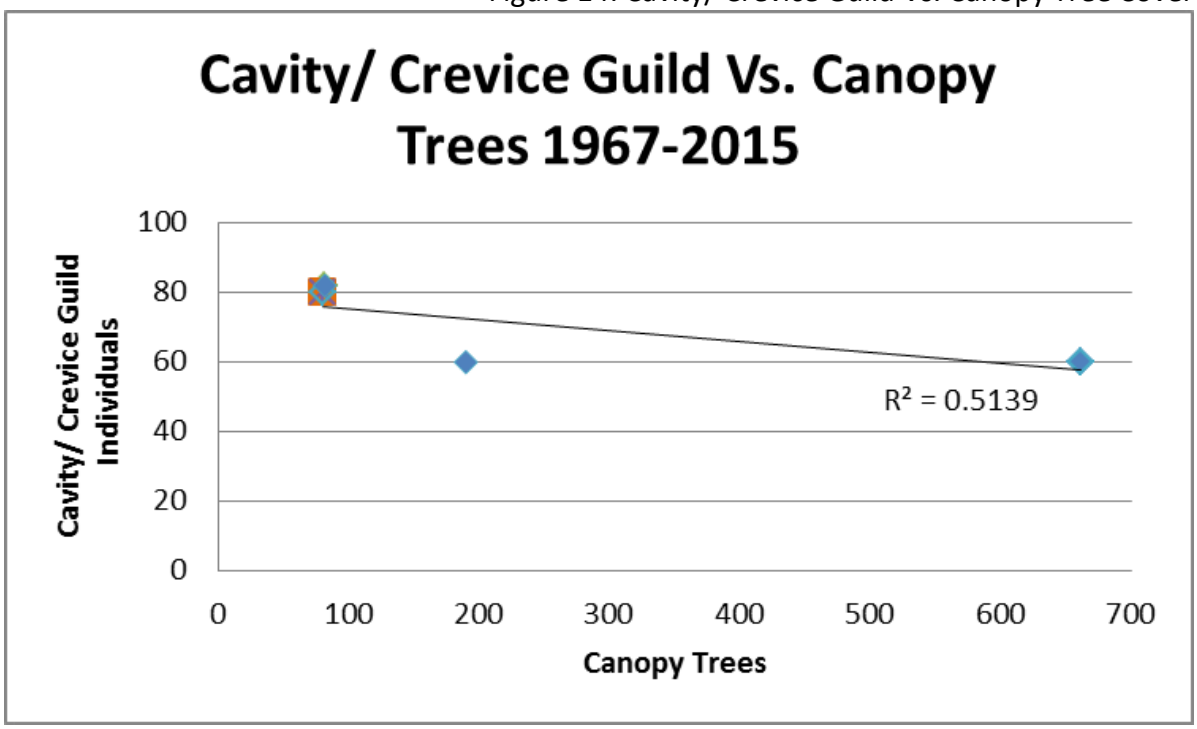


Figure 15: Canopy/ Sub-canopy Guild Vs. Canopy Tree Cover

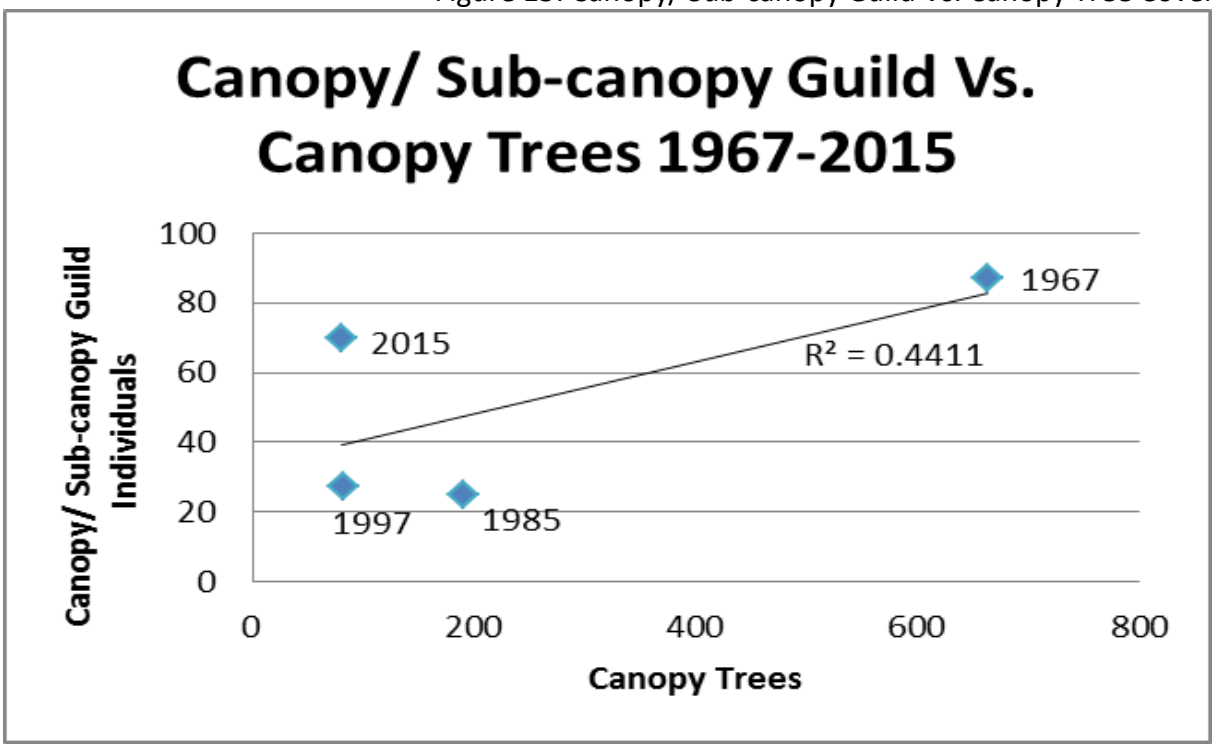
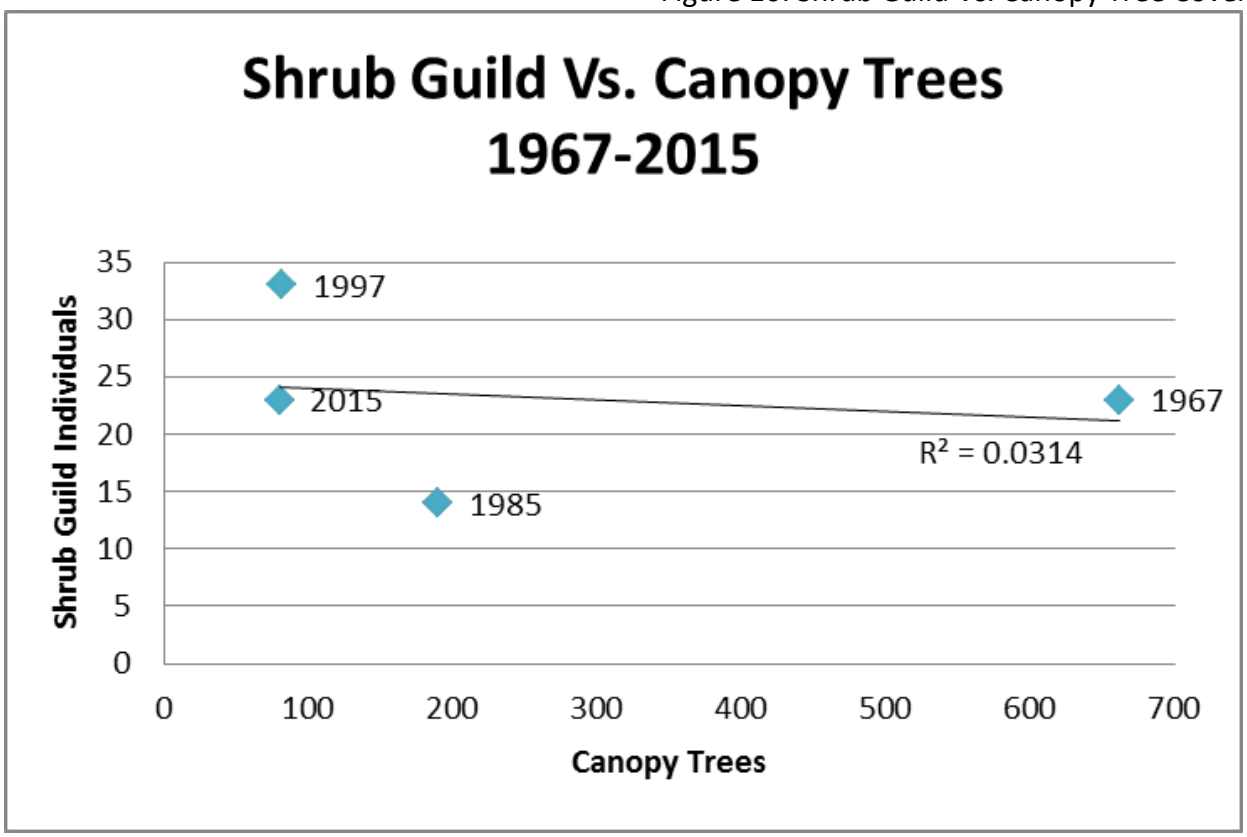


Figure 16: Shrub Guild Vs. Canopy Tree Cover



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1967-2014	0.69
1967-2015	0.86
1985-1997	1.00
1985-2014	0.75
1985-2015	0.69
1997-2014	0.75
1997-2015	0.69
2014-2015	0.80

Table 9: Bird Biodiversity Indices and Coefficient of Variation

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Simpson Index	0.15	0.19	0.11	0.097	0.095
Coefficient of Variation	1.34	1.61	1.07	0.98	0.91

Figure 17: Shannon Index Trend

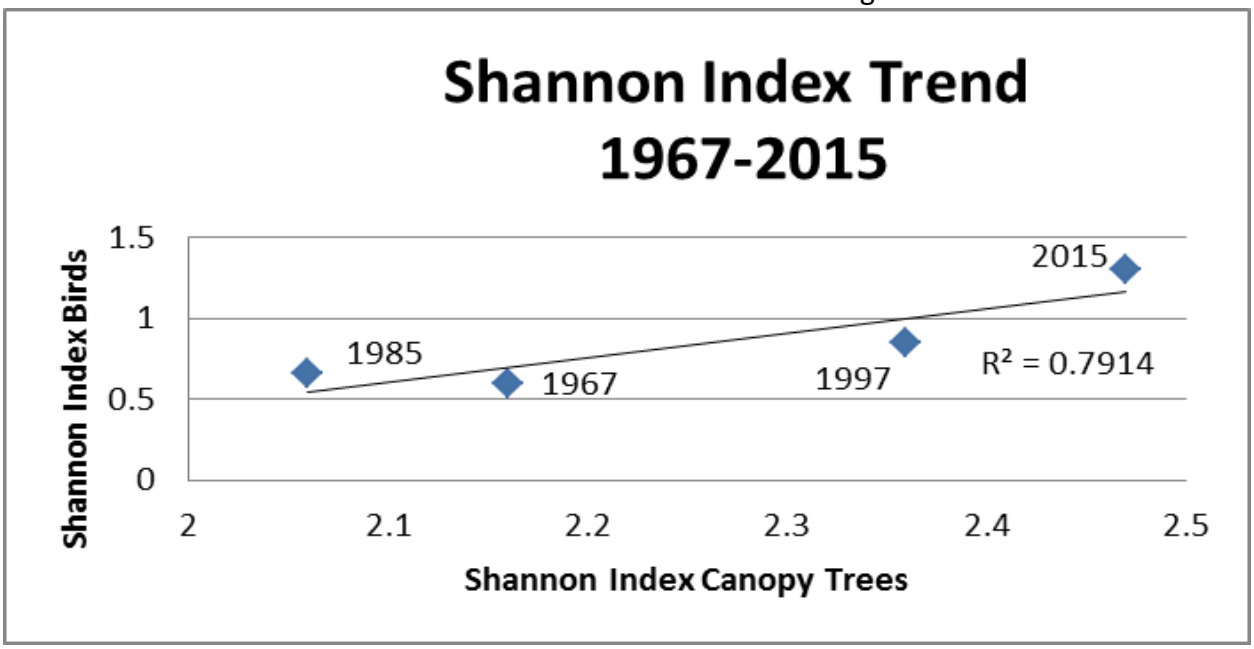
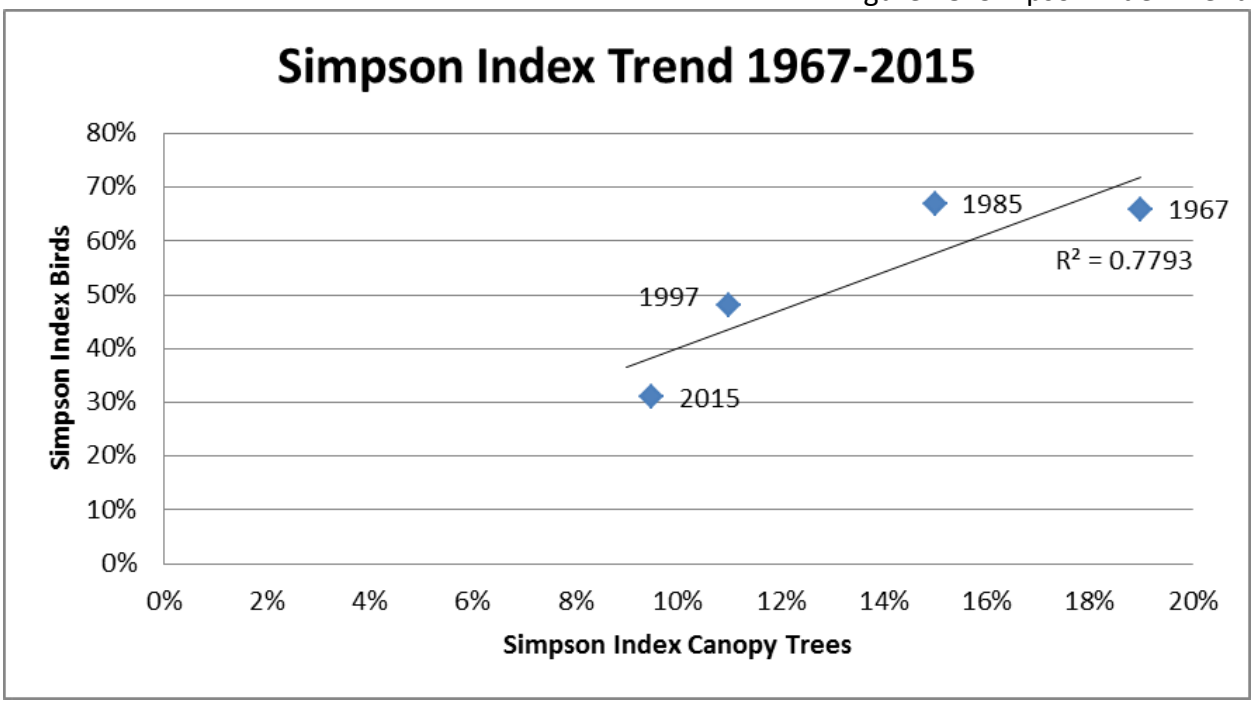


Figure 18: Simpson Index Trend



Appendix D

Additional Birds Detected but not Present in the Study Area(A.O.U. Taxonomic Order)

Ruffed Grouse (*Bonasa umbellus*) 2014 & 2015

Turkey Vulture (*Cathartes aura*) 2014 & 2015

Sharp-shinned Hawk (*Accipiter striatus*) 2014

Broad-winged Hawk (*Buteo platypterus*) 2014 & 2015

Peregrine Falcon (*Falco peregrinus*) 2014

Barred Owl (*Strix varia*) 2014

Chimney Swift (*Chaetura pelagica*) 2014 & 2015

Acadian Flycatcher (*Empidonax virescens*) 2014

American Crow (*Corvus brachyrhyncos*) 2014 & 2015

Common Raven (*Corvus corax*) 2014 & 2015

Cedar Waxwing (*Bombycilla cedrorum*) 2014 & 2015

Northern Parula (*Setophaga americana*) 2014

Magnolia Warbler (*Setophaga magnolia*) 2014

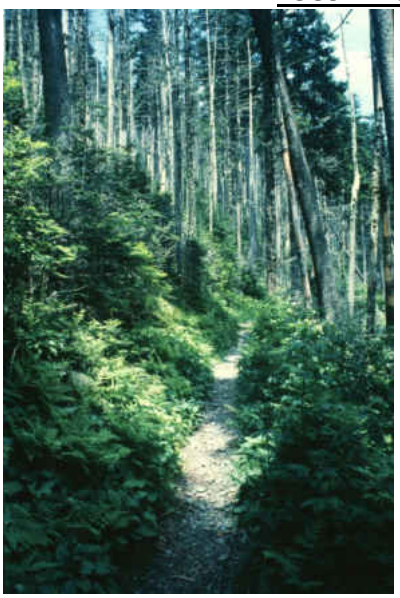
Yellow-rumped Warbler (*Setophaga coronata*) 2015

Red Crossbill (*Loxia curvirostra*) 2014 & 2015

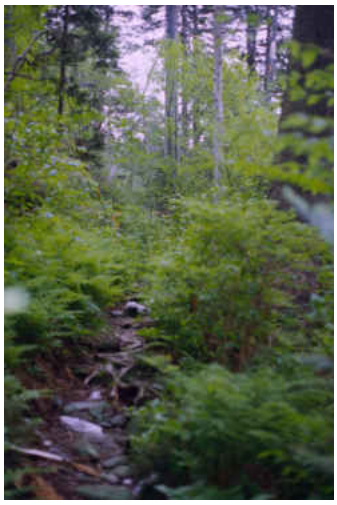
American Goldfinch (*Spinus tristis*) 2014

Appendix E
Photographs
1967- Photographs by Dr. Fred Alsop III

1985- Photographs by Dr. Thomas Laughlin

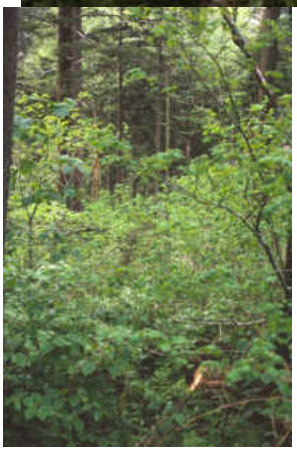


1997- Photographs by Dr. Thomas Laughlin

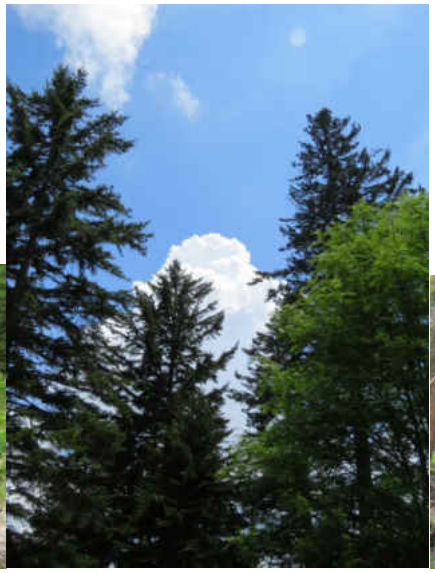








2014 & 2015- Photographs by Kevin C. Brooks



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