# Pinelands Biodiversity Study

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## Introduction

Although Pinelands habitats occur throughout the northeastern United States, the largest and most uniform area of such habitat is the New Jersey Pinelands (Forman 1998). The New Jersey Pinelands Area is 1,449 square miles, approximately 19% of the total area of New Jersey (New Jersey Pinelands Commission 2008). Within the New Jersey Pinelands, there occurs 299 species of birds, 28 of which are listed as State-Threatened or State-Endangered, and 850 species of plants (New Jersey Pinelands Commission 2008).

The New Jersey Pinelands is a unique pine-and oak-dominated ecosystem, situated on very sandy and acidic soils. Frequent burning, along with poor soils, acidity, and drought susceptibility shape this ecosystem. Despite the relatively low diversity, the Pinelands have the unmistakable character of a boreal, pine-dominated system: the pine and oak canopy is very open, allowing enough light to support the lush shrub layer, consisting of many ericaceous shrubs (*Vaccinium corymbosum*, *V. pallidum, Gaylussacia baccata,* etc.) and *Hudsonia ericoides*. Open patches are often colonized by sedges and grasses; some areas are dominated by mosses (*Polytrichum juniperum*) and lichens (several species of *Cladonia*) (Boerner1981; Ehrenfeld et al. 1995; Sedia and Ehrenfeld 2003).

The distribution of vegetation and the presence of large unbroken stretches of the forest create a habitat for many bird species, such as the ubiquitous Carolina Chickadee (*Parus carolinensis*) and the rare and endangered Loggerhead Shrike (*Lanius ludovicianus*). The native plants are well-adapted to the nutrient-poor condition and high acidity. Human disturbance and deforestation, along with sand mining as well as natural disturbance (fire) are hypothesized to affect the diversity of the native plants and animal species, along with promoting the invasion by non-native species.

Past land use and natural disturbance events have shaped the Pinelands and has lead to its unique flora and fauna. One of the most pressing ecological questions currently facing this region is what effect existing landuse practices are having on biodiversity and rare species. Development, forestry, and prescribed burning are among the most common landuse activities carried out in the Pinelands today. While it is clear that development has a negative impact on most natural communities (Saunders et al. 1991, Lovejoy 1997), forestry and prescribed burning can often be beneficial plant and animal communities (Whelan 1995, Summerville et al. 2004), especially in disturbance-driven ecosystems. Some studies have found that stands managed by selective cutting or prescribed burning have a higher biodiversity compared to other clear cut or unmanaged stands (Nummelin and Hanski 1989, Intachat et al. 1997, Summerville and Crist 2002). In a recent study, Thomas (2002) found that geometrid moth communities exhibited their lowest abundance, but highest species richness in forest stands with moderate harvest levels (equivalent to 30% bole removal). Unlogged and clear-cut stands had a significantly lower number of species. These findings are consistent with the intermediate disturbance hypothesis proposed by Connell (1978), which suggests that species diversity will be highest at intermediate levels of disturbance.

Forest management techniques, including those described above, can have dramatic, though often idiosyncratic, effects on avian biodiversity and habitat use (Dickson et al. 1983; Nappi et al. 2003; Haskell et al. 2006; Legrand et al. 2007). For example, snag retention in some clear-cut areas significantly increases species richness, bird abundance, bird species diversity and evenness (Dickson et al. 1983; Nappi et al. 2003). Another study, however, suggested that over-creation of shelterwoods can decrease species diversity at the landscape scale by selecting against mature forest and clear-cut specialists (King and DeGraaf 1999). Other management techniques, such as creation of tree plantations for bird habitat, have shown to, perhaps unexpectedly, lower biodiversity when compared to exurban areas (Haskell et al. 2006). Post-management factors such as tree-stand age, for instance, may also contribute to changes in avian biodiversity by favoring late-successional species in older stands over early-successional species and vice-versa (Legrand et al. 2007).

The New Jersey Pinelands, by virtue of being located along a major flyway, the Atlantic Flyway, can have very high seasonal avian biodiversity during the Spring and Fall migratory periods. Additionally, nearly half of the bird species that occur in North America can be found in New Jersey (approximately 450 of 914) (Leck 1984). Despite the relatively high migratory biodiversity, the biodiversity of the Pinelands is lower in the breeding season and lowest during the winter (Brush 1989).

Two state-endangered/threatened birds occur in the New Jersey Pinelands, the Redheaded

Woodpecker (*Melanerpes erythrocephalus)* and the Barred Owl (*Strix varia*), although they are both relatively uncommon (Walsh et al. 1999). Within New Jersey, the Barred Owl is found in particularly low densities in the Pinelands despite a moderate overall increase statewide (Sutton 1988; Walsh et al. 1999). The Red-headed Woodpecker displays the opposite distribution pattern: it is rare throughout the rest of the state, though more common within the Pinelands (Wander and Brady 1980; Walsh et al. 1999).

We undertook this study, therefore, to assess the effects of different forest management practices on the plant and avian biodiversity in the New Jersey Pinelands. Many plant and animal communities in the Pinelands are globally rare. One consequence of this rarity is that little research has been conducted to document how these communities respond to forestry activities, and yet forestry activities are commonly carried out in this region. The primary objective of this study was to assess the diversity of birds and plants (vascular) in stands with and without historic forestry activities.

# Methods

Surveys were conducted in eight, 20-acre plots located at four sites in Brendan T. Byrne State Forest and in Ocean County during the summer of 2007. Within each site, there were two plots: a study plot which had undergone recent forest management (e.g. thinning), and a control plot which had not undergone any recent (e,g. at least 10 yrs.) forest management. We assigned names to each of these sites (from west to east): Circle site, Woodpecker site, Plantation site and Parkway site. See FIGURE 1.

### *Vegetation Surveys*

Vegetation surveys were conducted at each site during June -October 2007. The vegetation was surveyed by establishing transects across study areas, along the longest dimension of each area. Each site was sampled at the study site and the associated control site by setting up at least three 30 meter long transects. A 1 $m^2$ quadrat was placed every 3 m along a transect and the shrubs, forbs, and graminoids within the 1 $m^2$ area were counted. All the trees with a diameter at breast height (dbh) of greater than 2.5 cm and located within 5 m on either side of each 30 m transect were identified and counted. Stem counts were determined for blueberry, pine, oak, sheep laurel, mountain laurel, bracken fern and greenbriar. Ground cover (bare ground and leaf litter) within each subplot was recorded as a percentage of total area. Percent cover estimates also were used instead of stem counts for moss, lichens, wintergreen, and grass.

### *Avian Surveys*

Avian surveys were conducted weekly, from 7 May 2007 to 1 September 2007, in each of the study areas using a hybrid point-count/transect method. Surveys were generally conducted within 3 hours of sunrise. Five survey points were assigned, on established trails when possible (to reduce aural disturbance from "bush-whacking"), within each plot. A 5-minute bird count was conducted from each of these survey points. Species encountered while the observer was in transit between survey points were also included. Bird species were identified by both sight and sound. We used multiple sightings (e.g. from different survey days) as a proxy for abundance.

Additionally, we recorded bird vocalizations on several occasions.

In addition to the general surveys, we conducted specific surveys for the Red-headed Woodpecker (*Melanerpes erythrocephalus*) and Barred Owl (*Strix varia*), both of which are listed as threatened in New Jersey. These surveys used standard play-callback procedures, which entails playing prerecorded vocalizations of each species and then monitoring the area for return vocalizations from the target species. Play-callbacks for Red-headed Woodpeckers was done in the mornings (within 3 hours of sunrise) and in the evenings (dusk) for barred owls. We also specifically recorded vocalizations of red-headed woodpeckers for analysis of habitat use.

## Data Analysis

### *Bird Surveys*

Survey data for birds were pooled into "habitat complexes," consisting of data from the study and control plots at each of the sites. This was necessary because birds were moving freely and actively between plots during the surveys. We calculated several standard measures of biodiversity for birds at each of the sites. These measures include: alpha-, beta-, and gamma-diversity, relative abundance, Shannon Indices and evenness.

Alpha-diversity is synonymous with species richness, or the total number of species which occur within a given area (each study site). Gamma-diversity is also synonymous with species richness, though at a larger spatial scale (the entire region encompassing all study sites). Beta-diversity is a measure of change in species richness across different sites thus allowing direct comparison between sites (Whittaker 1960).

Relative abundance is simply a measure of species abundance that corrects for the contribution each species makes relative to the total abundance for all species. The Shannon Index,

$H'$, is defined by the formula:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where $S$ is the species richness (or alpha-diversity) and $pi$ is the relative abundance of each species (Shannon 1948). Finally, evenness, $E$, a measure of abundance/species equity is defined by the formula:

$$E = \frac{H'}{H'_{\max}}$$

Where $H'$ max = ln $S$, or the theoretical maximum species diversity, which occurs when all species are present in equal numbers.

*Plant Surveys*

The data obtained from the vegetation surveys was separated into managed-study and control groups for each of the four study sites. One-way ANOVA's, comparing the managed sites to the respective control site, were performed using SAS 9.1. Data were not normally distributed by symmetrical, so no transformation was necessary. Bar graphs were generated comparing Blueberry, grass, bare ground, litter, moss, pine, and oak. In the circle site and plantation site, data for lichen and high bush blueberry is also presented. F-values and P-values were determined for each plant type in each of the four sites. Additionally, we performed a Principal Component Analysis for the plant data.

## Results

*Bird Surveys*

We found a total of 39 bird species across all study sites. The Shannon Index across all sites was 3.08 with a theoretical maximum ( $H'_{max}$) of 3.66. The Circle site and the Parkway site had the lowest bird diversity (Shannon Indices of 2.65 and 2.67, respectively), while the Woodpecker and the Plantation site had the highest (Shannon Indices of 3.01 and 2.92, respectively). The mean species richness (alpha-diversity) across all sites was 25 species. The site with the greatest species richness, 31 species, was the Woodpecker site. The site with the lowest species richness, 19 species, was the Parkway site which had just 61% of the species richness of the Woodpecker site. See TABLE 2. The most abundant bird at the Circle site was the Eastern Towhee. The most abundant bird at the Woodpecker site was the Eastern Bluebird. The most abundant bird at the Plantation site was the Carolina Chickadee. The most abundant bird at the Parkway site was the Eastern Towhee. The most abundant birds across all sites were (in order of relative abundance): Eastern Towhee, Ovenbird, Carolina Chickadee, (Tie 3rd), Eastern Wood-Peewee (Tie 3rd), and Chipping Sparrow. See TABLE 3.

The play-callback surveys for Barred Owl and Red-headed Woodpecker had mixed results. No Barred Owls were observed during the study at any site. Red-headed Woodpeckers were observed only at the Woodpecker site. Analysis of vocalization recordings indicated a breeding pair of red-headed woodpeckers using the Woodpecker site. See APPENDIX 2.

*Plant Surveys*

There were clearly differences between the control and managed sites (FIGURES 3 -6) at each of the four locations. For the Parkway site, blueberry stem densities were higher in the experimentally manipulated plot (FIGURE 3). The site was also characterized by having significantly less grass, moss, and oak in the experimental site (FIGURE 3). There is also less pine present in this site, as well as slightly less leaf litter and bare ground. This site is in the early stages of regeneration, and it should be noted that this site contained a large number of small oak and pine seedlings. This relatively open site would be expected to have higher blueberry densities. The Plantation site (FIGURE 4) was characterized by having significant differences in the blueberry, grass, litter, moss, oak, and high bush blueberry. The experimental site lacked even small amounts of grass, moss, and high bush blueberry. The number of pine trees and amount of leaf litter was higher in the experimental plot. These differences might be attributed to the low lying aspect, and therefore more moisture present, in the control site. Moss promotes establishment of vascular plants (Sedia and Ehrenfeld 2003), so its lack could contribute to lack of the understory in the plantation site, along with closed canopy.

The Woodpecker Woods site showed significant differences in blueberry, bare ground, leaf litter, and oak. The management in this plot reduced the amount of leaf litter and nearly doubled the amount of bare ground present. Tree removal and girdling of trees has occurred recently in this plot and probably contributed to the increased bare ground. It is also important to note that management plan has resulted in higher numbers of dead snags in the pine and oak counts for the experimental site. The control site contained more scrub oaks than the managed site. The Circle site also had greater amounts of bare ground and decreased leaf litter in the experimental plots. In addition, there was a significant increase in the percent cover of lichen in the experimental site. These differences could be explained by recent logging activity at the experimental site. It is important to note that there is little evidence of dead snags at Circle site, in contrast to the Woodpecker woods site; yet, the patterns of vegetation cover are similar.

We also pooled the results of the plant and bird surveys to determine the overall (both plant and bird diversity) of each site. Our results indicate that the Woodpecker site was the most diverse, with an alpha-diversity of 45, followed closely by the Plantation site, with an alpha-diversity of 41. The Circle and Parkway sites had noticeably lower diversity, with alpha-diversity values of 34 and 31, respectively. See TABLE 5. Lists of all plants and birds seen across all sites is presented in APPENDIX 1.

## Discussion

In general, the amount of bare ground increased in the experimental plots, in particular the Woodpecker and Circle site. These sites both have had recent management including selective harvest and burn. Both of these would serve to open the canopy allowing more light penetration. It would be interesting to see the soil bacterial community response to these changes, as these communities are known to change in response to fire and timber harvest (Smith et al. 2008). Pine counts were similar among all four sites. It is interesting to recall that there were no significant differences between pine abundance between control and experimental treatments in any of the sites (see results section). This seems to indicate that management strategies are not creating areas where pine are unable to survive, an issue that could have the potential to create a shift in the ecosystem (Lawrence et al, 2007). Oak counts were highest in the control areas of the Plantation and Parkway sites. Both of these sites have not had any recent history of disturbance.

The Principal Component Analysis of plant data achieved a good separation of the sites (See FIGURE 2). Principal component 1 (PC1) was most important in separating Circle, Parkway, and Woodpecker sites, while Principal component 2 (PC 2) separated Plantation site from the rest. Looking at the loading of the principal components (TABLE 1), it appears that moss, pine and bare ground are positively and highly correlated with the PC 1, while oak is negatively correlated with it. PC 2 shows high positive correlation with grass and oak, and negative correlation with blueberry. This pattern indicates that the main differences we see between the managed sites also reflect the same variables as seen for within the sites ANOVAs --that is, the same vegetation components that most consistently differed between managed areas and controls also differed between the managed sites. This would indicate that management strategies affected primarily scrub oak, blueberry, litter accumulation and lichen-moss mats.

Comparisons to other studies: forest matrices (control sites) are similar to the sites described in Ehrenfeld et al. (1995, 1997) – many openings, spatial variation between dense stands of pine and scrub oak versus open areas dominated by ericoid shrubs. The revegetation after a disturbance occurs fairly quickly (Sedia and Ehrenfeld 2003, 2005, 2006), unless there is a specific management program in place.

We noticed that several of the sites looked fairly similar to the controls and the undisturbed sites, with the exception of the Woodpecker site and the Plantation site – both looked markedly different from the undisturbed area. Woodpecker site had a much more open character due to the site's management for Red-headed Woodpecker habitat (most standing trees were dead snags). Meanwhile, the Plantation site featured a high density of pine trees and created a closed canopy character which excluded the subcanopy of scrub oaks and ericoid shrubs we have observed in control sites.

For the purposes of comparison, site descriptions from Sedia and Ehrenfeld (2006) might be useful: All the experiments were conducted in the New Jersey Pinelands, a region of fire-maintained pitch pine (*Pinus rigida* Mills.)-dominated forests (Forman 1998). The soils (Lakewood and Lakehurst series, Spodic and Aquodic Quartzipsamments, respectively) are derived from the Cohansey Formation, a Miocene deposit of fine to coarse sands which produce very sandy soils. Mor humus horizons develop, with accumulations of 1 -3 cm (Ehrenfeld et al. 1995, 1997), and A horizons are usually 1-3 cm thick. The E horizon soils are very nutrient-poor (organic C <1%, Total Kjeldahl nitrogen (TKN) <0.1%, cation exchange capacity (CEC) <0.2 $mol_c$ / kg soil) and acidic (pH 3.5-4.0). The open pine canopy has an understory of *Vaccinium pallidum* Ait., *Gaylussacia baccata* (Wang) K. Koch., and other ericads. Areas that have been subjected to hot wildfires have frequent open patches with little or no tree canopy, sparse grasses (mostly *Schizachyrium scoparium* Nash. and *Panicum virgatum* Linn.), large patches of lichens, mosses and mixtures of the two cryptogams, and areas of bare soil. The lichen mats are composed of *Cladonia uncialis* (L.) F. H. Wigg., *Cladonia subtenuis* (Abbayes) Mattick, *Cladonia mitis* Sandst. and *Cladonia alpestris* (L.) Nyl. (taxonomy following Esslinger 1997). All lichens have green algae as phycobionts, and are not known to be nitrogen-fixing. Moss mats were composed of *Polytrichum juniperinum* Hedw. Cyanobacteria are not prominent components of these mats (Belnap 2007, pers. comm.) These openings are also characterized by the absence of O horizons, and reduced or buried A horizons (Ehrenfeld et al. 1995).

Results from our bird diversity studies are similar to results obtained from previous studies on avian diversity and distribution in the New Jersey Pinelands. Brady (1980) found that breeding-bird species diversity in Pine-Oak habitats was 34 and 40 in Oak-Pine habitats. Our species diversity (alpha-diversity) on a landscape-scale (e.g. the entire region containing all study sites), 39, was very similar to the previously published value. It is important to note that the time span between the surveys is approximately 30 years. During that time, many bird species have experienced declining numbers due to factors such as: habitat destruction/degradation, pollution and climate change, increased competition from invasives, etc. The New Jersey Pinelands, however, is relatively insulated from such factors by strict regulations. In effect, the Pinelands have been spared much of the habitat destruction that has been rampant elsewhere.

On a smaller scale (e.g. each site), we did observe differences in diversity between the sites, with a range of alpha-diversity values between 19 and 31. We found it was necessary to pool data between the managed and control areas within each site. This was due to several unavoidable factors, 1) birds were flushed into adjacent habitats by observers, 2) many of the observations were made by sound (e.g. bird vocalizations) that were difficult or impossible to definitively assign to either control or managed areas, 3) we observed birds preferentially using the edges created between the control and managed sites. The birds' preferential use of edges was consistent with previously published accounts; Yahner (1987) found that species richness was higher in edges than interiors of even-aged stands.

Despite having to pool the bird data, we observed some interesting differences between the sites. The Woodpecker site was, appropriately, the only site in which we observed Redheaded woodpeckers (see APPENDIX 2). The Parkway site was the most depauperate site for both plants (12 species) and birds (19 species). Beta-diversity values among the sites also differed. The Woodpecker site had approximately 60% less species turnover than did the Parkway site when both were compared to the overall regional diversity (e.g. Gamma diversity).

As described above, there were substantial differences in bird habitat between the sites (as expressed by differences in plant community structure). These differences were primarily due to differences in management practices among the sites. For instance, there were differences in stand ages, size and composition of shelterwoods (for the purposes of bird studies, this term is synonymous with other similar practices/terms - e.g., partial retention timer harvesting), as well as in the structure of stands adjacent to the managed sites (thus the aforementioned designation of these areas as "habitat complexes"). These differences can help explain the observed differences in avian biodiversity.

Lance and Phinney (2001 ??), for example, found that partial retention harvesting in sub-boreal conifer forests increased total bird diversity. Results from more detailed studies, however, are not so clear cut. Donald et al. (1998 ??) found that in the mixed forests of western England forest age was the most important variable in explaining avian diversity. Specifically, they found that tree size and tree species composition were positively correlated with alpha-diversity and overall abundance. DeGraaf et al. (1998 ??), however, found that stand size-class and forest cover-type were less important than forest structure (e.g. total foliage volume of large and midsize deciduous trees, density of mid-size trees, total woody stem density, total deciduous understory volume and total volume of large conifers) in northern New England managed forests. Another study done in the northern Rocky Mountains (Stuart-Smith et al. 2006) found that in managed stands ($\geq$ 7 years post-disturbance), changes in diversity between logged and burned stands were mainly due to differences in abundance not community composition. Furthermore, they suggest that management can influence the abundance of some species by manipulating the type and density of residual trees. The upshot of all these previous studies is that the results of forest management (with respect to birds) are highly idiosyncratic, with the possible exception of shelterwoods creation, and/or selective logging which are important predictors of avian species diversity (King and DeGraaf 1999; Heltzel and Leberg 2006). This is particularly valuable when integrated into larger landscape-scale management programs.

Perhaps not surprisingly, the site with the most biological diversity (plants and birds) was also the Woodpecker site. This site has been managed such that habitat complexity has been retained (e.g. creation of open areas with snags). The next most biodiverse site was the Plantation site. The study plot at the Plantation site was similar to that of the Circle site with the exception of the large plantation adjacent to it. We hypothesize that the habitat type (e.g. a relatively closed canopy in the plantation) and proximity (e.g. adjacent, across the road) of the surrounding areas (the "habitat complexes") were important factors contributing the increased biodiversity of this site. Similarly, the least diverse site, the Parkway Site was adjacent to many suburban structures (e.g. the Garden State Parkway, homes, other roads, etc.) and was highly fragmented.

We recommend that future studies focus on the landscape ecology of these habitat complexes on a larger scale (e.g. > 100 acres). We also recommend additional studies of habitat use of Red-headed Woodpeckers in the Woodpecker Site. Specifically, factors such as breeding success, foraging behavior, and phenology should be studied in a more detailed study.

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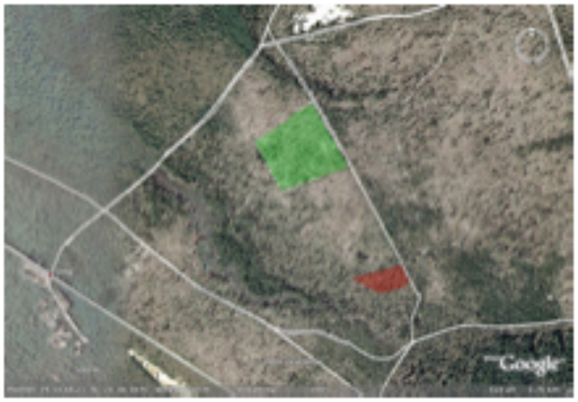
# Figures

FIGURE 1. Maps of Surveys Sites




i) Circle Site


ii) Woodpecker Site


iii) Plantation Site


iv) Parkway Site

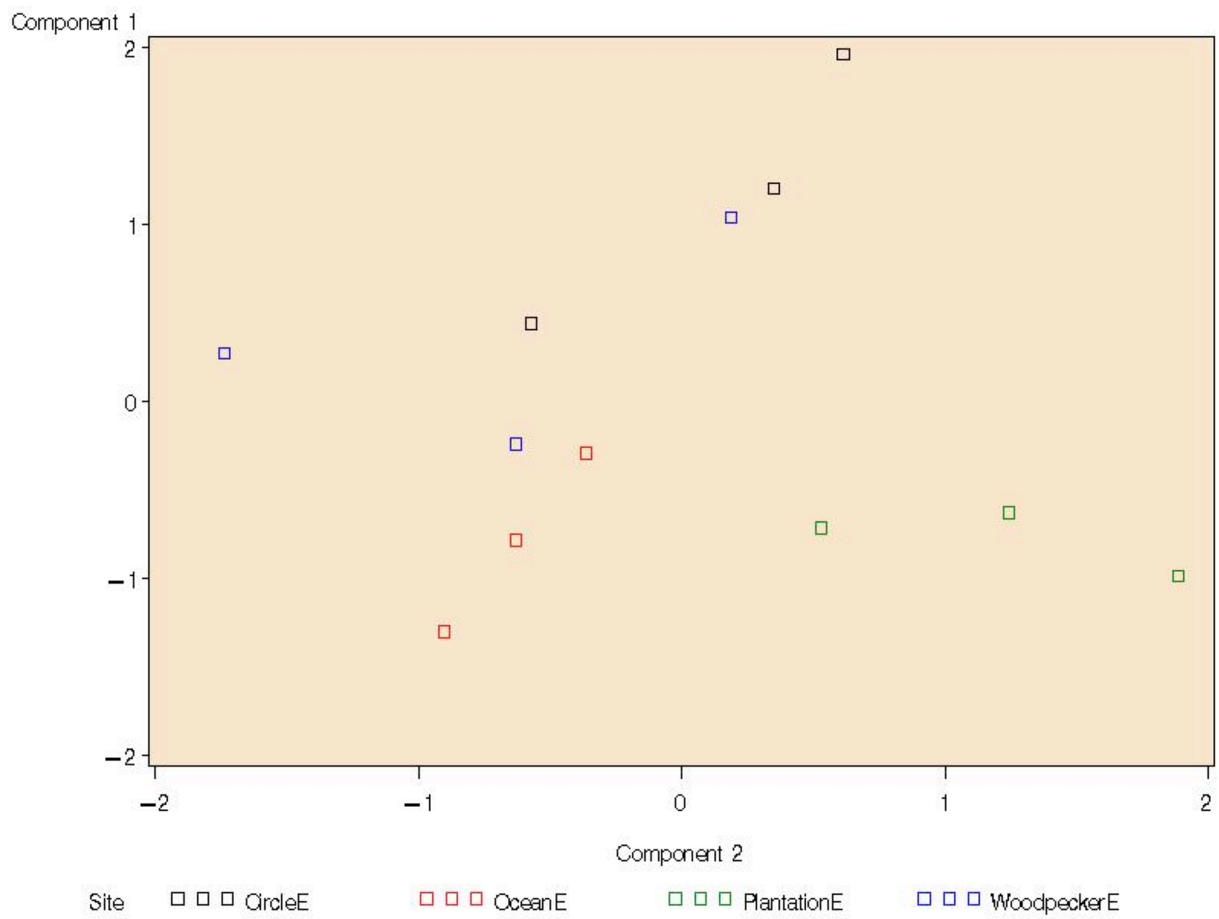
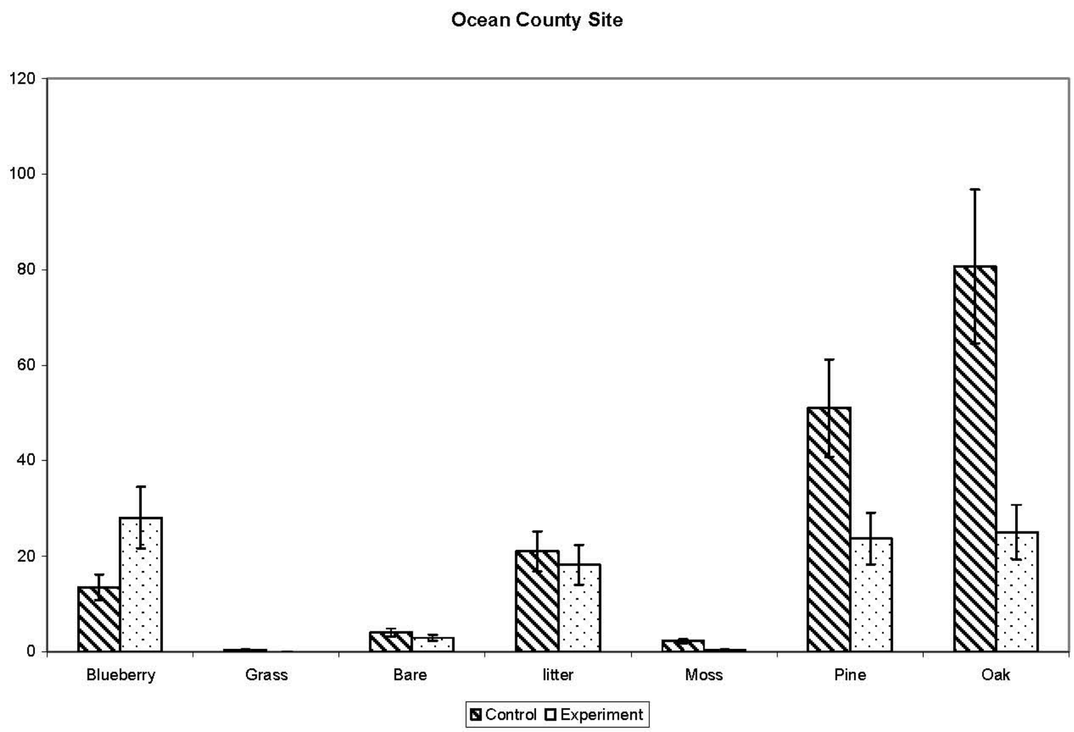



FIGURE 2. Principal Component Analysis for experimental sites, showing the separation of the sites along two principal component axes. Each square represents a single 30 m transect. Each of the survey areas is represented by a different color.

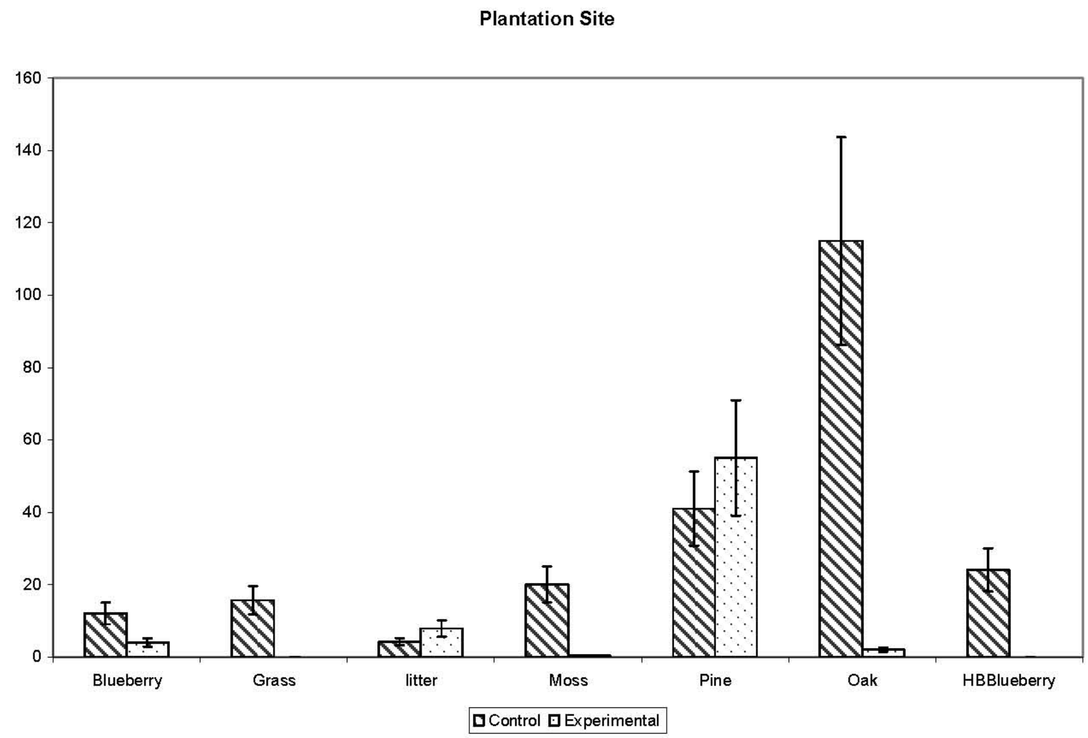
| | Eigenvectors | | |
|---|---|---|---|
| | **PC1** | **PC2** | **PC3** |
| Blueberry | -0.292479 | -0.389497 | 0.475526 |
| Grass | -0.000744 | 0.557787 | 0.432119 |
| Bare | 0.472367 | -0.263152 | 0.247575 |
| Litter | -0.291317 | -0.280236 | -0.519092 |
| Moss | 0.421595 | 0.102685 | -0.319102 |
| Pine | 0.424137 | 0.067696 | 0.199341 |
| Oak | -0.335866 | 0.592511 | -0.115335 |
| Lichen | 0.368807 | 0.152281 | -0.318642 |

TABLE 1. Correlation of vegetation variables with three eigenvectors. PC 1 and 2 are considered the most important for the analysis.



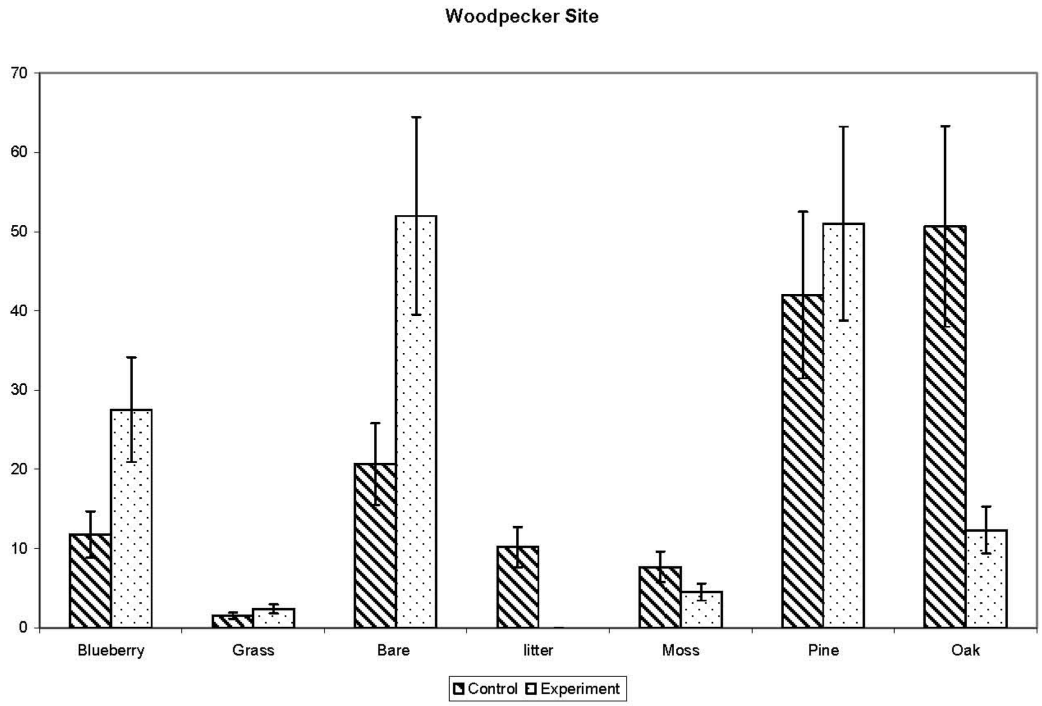

| Ocean County | | F Value | P value |
|---|---|---|---|
| | Blueberry | 25.25 | <0.0001 |
| | Grass | 5.09 | 0.0278 |
| | Moss | 4.64 | 0.0355 |
| | Oak | 15.03 | 0.0179 |

FIGURE 3. A comparison of vegetation types in the managed and control plots at the Parkway (Ocean County) site. The numbers represents stem counts or percent cover for the plant or ground cover listed. Error bars are shown for each vegetation type. The vegetation type having significant differences between the sites are listed the in table below the figure including the corresponding F- and P-value.



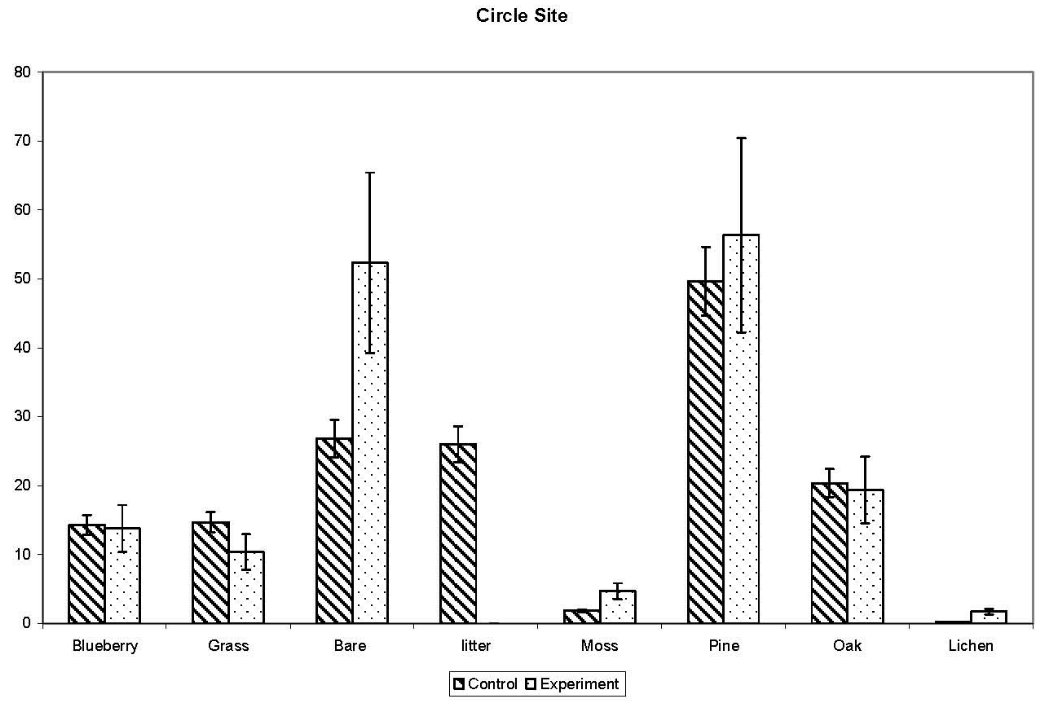

| Plantation | | F Value | P value |
|---|---|---|---|
| | Blueberry | 29.13 | <0.0001 |
| | Grass | 14.33 | 0.0004 |
| | Litter | 31.41 | <0.0001 |
| | Moss | 10.56 | 0.0314 |
| | Oak | 32.83 | 0.0046 |
| | HB Blueberry | 35.81 | <0.0001 |

FIGURE 4. A comparison of vegetation types in the managed and control plots at the Plantation site. The numbers represents stem counts or percent cover for the plant or ground cover listed. Error bars are shown for each vegetation type. The vegetation type having significant differences between the sites are listed the in table below the figure including the corresponding F- and P- value.




| Woodpecker | | F Value | P value |
|---|---|---|---|
| | Blueberry | 17.12 | 0.0001 |
| | Bare | 38.27 | <0.0001 |
| | Litter | 30.24 | <0.0001 |
| | Oak | 4.68 | 0.0347 |

FIGURE 5. A comparison of vegetation types in the managed and control plots at the Woodpecker site. The numbers represents stem counts or percent cover for the plant or ground cover listed. Error bars are shown for each vegetation type. The vegetation type having significant differences between the sites are listed in the table below the figure including the corresponding F- and P- value.




| Circle | | F-value | P |
|---|---|---|---|
| | Litter | 29.82 | <0.0001 |
| | Bare | 10.76 | 0.0018 |
| | Lichen | 7.78 | <0.0001 |

FIGURE 6. A comparison of vegetation types in the managed and control plots at the Circle site. The numbers represent stem counts or percent cover for the plant or ground cover listed. Error bars are shown for each vegetation type. The vegetation type having significant differences between the sites are listed in the table below the figure, including the corresponding F- and P- value.

| Site | α Diversity | β Diversity | γ Diversity | Shannon Index | Evenness |
|---|---|---|---|---|---|
| **Circle** | 21 | 1.86 | n/a | 2.65 | 0.87 |
| **Woodpecker** | 31 | 1.26 | n/a | 3.01 | 0.88 |
| **Plantation** | 28 | 1.39 | n/a | 2.92 | 0.88 |
| **Parkway** | 19 | 2.05 | n/a | 2.67 | 0.91 |
| **All Sites** | n/a | n/a | 39 | 3.08 | 0.84 |

TABLE 2. Diversity measures for birds occurring at study sites in the New Jersey Pinelands. Diversity measures presented are: alpha-diversity (local species richness), gamma-diversity (regional species richness), beta-diversity (change in species composition between sites), the Shannon Index ($H'$), and species evenness ($E$).

| Site | Most Abundant | 2nd Most Abundant | 3rd Most Abundant | 4th Most Abundant | 5th Most Abundant |
|---|---|---|---|---|---|
| **Circle** | Eastern Towhee | Carolina Chickadee (Tie 2nd) | Chipping Sparrow (Tie 2nd) | Eastern Wood-Peewee (Tie 2nd) | Ovenbird (Tie 2nd) |
| **Woodpecker** | Eastern Bluebird | Eastern Wood-Peewee | Ovenbird | Chipping Sparrow | Carolina Chickadee, Eastern Towhee, Pine Warbler (Tie 5th) |
| **Plantation** | Carolina Chickadee (Tie 1st) | Eastern Towhee (Tie 1st) | Ovenbird | Chipping Sparrow (Tie 4th) | Eastern Wood-Peewee (Tie 4th) |
| **Parkway** | Eastern Towhee | Carolina Chickadee (Tie 2nd) | Grey Catbird (Tie 2nd) | Ovenbird (Tie 2nd) | Eastern Wood-Peewee |
| **All Sites** | Eastern Towhee | Ovenbird | Carolina Chickadee (Tie 3rd) | Eastern Wood-Peewee (Tie 3rd) | Chipping Sparrow |

TABLE 3. Species composition (of the five most abundant species) for each of the study sites. Species are listed in order of abundance.

| Site | α Diversity | β Diversity | γ Diversity |
|---|---|---|---|
| **Circle** | 13 | 1.46 | n/a |
| **Woodpecker** | 14 | 1.36 | n/a |
| **Plantation** | 13 | 1.46 | n/a |
| **Parkway** | 12 | 1.58 | n/a |
| **All Sites** | n/a | n/a | 19 |

TABLE 4. Diversity measures for plants occurring at study sites in the New Jersey Pinelands. Diversity measures presented are: alpha-diversity (local species richness), gamma-diversity (regional species richness) and beta-diversity (change in species composition between sites).

| Site | α Diversity | β Diversity | γ Diversity |
|---|---|---|---|
| **Circle** | 34 | 1.71 | n/a |
| **Woodpecker** | 45 | 1.29 | n/a |
| **Plantation** | 41 | 1.41 | n/a |
| **Parkway** | 31 | 1.87 | n/a |
| **All Sites** | n/a | n/a | 58 |

TABLE 5. Diversity measures for birds and plants (pooled) occurring at study sites in the New Jersey Pinelands. Diversity measures presented are: alpha-diversity (local species richness), gamma-diversity (regional species richness), and beta-diversity (change in species composition between sites).

| Species | Abundance | Relative Abundance | Shannon Index |
|---|---|---|---|
| American Robin | 5 | 0.06 | -0.17 |
| Blue Jay | 7 | 0.09 | -0.21 |
| Carolina Chickadee | 9 | 0.11 | -0.25 |
| Chipping Sparrow | 9 | 0.11 | -0.25 |
| Downy Woodpecker | 1 | 0.01 | -0.05 |
| Eastern Bluebird | 1 | 0.01 | -0.05 |
| Eastern Phoebe | 1 | 0.01 | -0.05 |
| Eastern Towhee | 10 | 0.13 | -0.26 |
| Eastern Wood-Peewee | 9 | 0.11 | -0.25 |
| Finch | 1 | 0.01 | -0.05 |
| Goldfinch | 1 | 0.01 | -0.05 |
| Grey Catbird | 1 | 0.01 | -0.05 |
| Mourning Dove | 2 | 0.03 | -0.09 |
| Ovenbird | 9 | 0.11 | -0.25 |
| Pine Warbler | 6 | 0.08 | -0.19 |
| Red-Bellied Woodpecker | 1 | 0.01 | -0.05 |
| Tufted titmouse | 2 | 0.03 | -0.09 |
| Turkey Vulture | 1 | 0.01 | -0.05 |
| Whippoorwill | 1 | 0.01 | -0.05 |
| White-Breasted Nuthatch | 1 | 0.01 | -0.05 |
| Wood Thrush | 2 | 0.03 | -0.09 |
| **21** | **80** | **1.00** | **2.65** |

TABLE 6. Summary of avian diversity found at the Circle Site. The number below the species names represents the species richness for the site. Also presented are values for abundance, relative abundance, and species-specific intermediate values for the Shannon Index of the site.

| Species | abundance | relative abundance | Shannon Index |
|---|---|---|---|
| American Crow | 2 | 0.01 | -0.06 |
| American Robin | 4 | 0.03 | -0.10 |
| Back and White Warbler | 3 | 0.02 | -0.08 |
| Black Vulture | 1 | 0.01 | -0.03 |
| Blue Jay | 3 | 0.02 | -0.08 |
| Brown-Headed Cowbird | 3 | 0.02 | -0.08 |
| Carolina Chickadee | 10 | 0.07 | -0.19 |
| Chipping Sparrow | 12 | 0.08 | -0.21 |
| Downy Woodpecker | 2 | 0.01 | -0.06 |
| Eastern Bluebird | 13 | 0.09 | -0.22 |
| Eastern Phoebe | 2 | 0.01 | -0.06 |
| Eastern Towhee | 10 | 0.07 | -0.19 |
| Eastern Wood-Peewee | 13 | 0.09 | -0.22 |
| Finch | 1 | 0.01 | -0.03 |
| Goldfinch | 2 | 0.01 | -0.06 |
| House Finch | 1 | 0.01 | -0.03 |
| Northern Cardinal | 1 | 0.01 | -0.03 |
| Northern Flicker | 7 | 0.05 | -0.15 |
| Northern Oriole | 1 | 0.01 | -0.03 |
| Ovenbird | 13 | 0.09 | -0.22 |
| Pine Warbler | 10 | 0.07 | -0.19 |
| Red-Bellied Woodpecker | 9 | 0.06 | -0.17 |
| Red-Headed Woodpecker | 9 | 0.06 | -0.17 |
| Red-Tailed Hawk | 1 | 0.01 | -0.03 |
| Ruby-throated hummingbird | 1 | 0.01 | -0.03 |
| Summer tanager | 1 | 0.01 | -0.03 |
| Tufted titmouse | 2 | 0.01 | -0.06 |
| Turkey Vulture | 1 | 0.01 | -0.03 |
| Warbler | 1 | 0.01 | -0.03 |
| Whippoorwill | 1 | 0.01 | -0.03 |
| White-Breasted Nuthatch | 2 | 0.01 | -0.06 |
| **31** | **142** | **1.00** | **3.01** |

TABLE 7. Summary of avian diversity found at the Woodpecker Site. The number below the species names represents the species richness for the site. Also presented are values for abundance, relative abundance, and species-specific intermediate values for the Shannon Index of the site.

| Species | Abundance | Relative Abundance | Shannon Index |
|---|---|---|---|
| American Crow | 3 | 0.03 | -0.10 |
| American Robin | 8 | 0.07 | -0.19 |
| Back and White Warbler | 1 | 0.01 | -0.04 |
| Blue Jay | 3 | 0.03 | -0.10 |
| Carolina Chickadee | 12 | 0.11 | -0.25 |
| Chipping Sparrow | 10 | 0.09 | -0.22 |
| Common Yellowthroat | 1 | 0.01 | -0.04 |
| Downy Woodpecker | 1 | 0.01 | -0.04 |
| Eastern Phoebe | 2 | 0.02 | -0.07 |
| Eastern Towhee | 12 | 0.11 | -0.25 |
| Eastern Wood-Peewee | 10 | 0.09 | -0.22 |
| Finch | 2 | 0.02 | -0.07 |
| Goldfinch | 3 | 0.03 | -0.10 |
| Grey Catbird | 1 | 0.01 | -0.04 |
| Hermit Thrush | 2 | 0.02 | -0.07 |
| Mourning Dove | 3 | 0.03 | -0.10 |
| Northern Cardinal | 4 | 0.04 | -0.12 |
| Ovenbird | 11 | 0.10 | -0.23 |
| Pine Warbler | 6 | 0.06 | -0.16 |
| Prairie Warbler | 1 | 0.01 | -0.04 |
| Prothonotary warbler | 1 | 0.01 | -0.04 |
| Red-Tailed Hawk | 1 | 0.01 | -0.04 |
| Ruby-throated hummingbird | 1 | 0.01 | -0.04 |
| Tufted titmouse | 1 | 0.01 | -0.04 |
| Turkey Vulture | 3 | 0.03 | -0.10 |
| Warbler | 1 | 0.01 | -0.04 |
| White-Breasted Nuthatch | 2 | 0.02 | -0.07 |
| Wood Thrush | 1 | 0.01 | -0.04 |
| **28** | **107** | **1.00** | **2.92** |

TABLE 8. Summary of avian diversity found at the Plantation Site. The number below the species names represents the species richness for the site. Also presented are values for abundance, relative abundance, and species-specific intermediate values for the Shannon Index of the site.

| Species | Abundance | Relative Abundance | Shannon Index |
|---|---|---|---|
| | | | |
| American Crow | 3 | 0.03 | -0.12 |
| American Robin | 7 | 0.08 | -0.20 |
| Back and White Warbler | 1 | 0.01 | -0.05 |
| Blue Jay | 3 | 0.03 | -0.12 |
| Carolina Chickadee | 9 | 0.10 | -0.23 |
| Chipping Sparrow | 7 | 0.08 | -0.20 |
| Downy Woodpecker | 1 | 0.01 | -0.05 |
| Eastern Towhee | 11 | 0.13 | -0.26 |
| Eastern Wood-Peewee | 8 | 0.09 | -0.22 |
| European Starling | 1 | 0.01 | -0.05 |
| Goldfinch | 2 | 0.02 | -0.09 |
| Grey Catbird | 9 | 0.10 | -0.23 |
| Mourning Dove | 5 | 0.06 | -0.16 |
| Ovenbird | 9 | 0.10 | -0.23 |
| Pine Warbler | 5 | 0.06 | -0.16 |
| Ruby-throated hummingbird | 1 | 0.01 | -0.05 |
| Turkey Vulture | 2 | 0.02 | -0.09 |
| Warbler | 1 | 0.01 | -0.05 |
| White-Breasted Nuthatch | 2 | 0.02 | -0.09 |
| **19** | **87** | **1.00** | **2.67** |

TABLE 9. Summary of avian diversity found at the Parkway Site. The number below the species names represents the species richness for the site. Also presented are values for abundance, relative abundance, and species-specific intermediate values for the Shannon Index of the site.

| Species | Abundance | Relative Abundance | Shannon Index |
|---|---|---|---|
| American Crow | 8 | 0.02 | -0.08 |
| American Robin | 24 | 0.06 | -0.16 |
| Back and White Warbler | 5 | 0.01 | -0.05 |
| Black Vulture | 1 | 0.00 | -0.01 |
| Blue Jay | 16 | 0.04 | -0.13 |
| Brown-Headed Cowbird | 3 | 0.01 | -0.04 |
| Carolina Chickadee | 40 | 0.10 | -0.23 |
| Chipping Sparrow | 38 | 0.09 | -0.22 |
| Common Yellowthroat | 1 | 0.00 | -0.01 |
| Downy Woodpecker | 5 | 0.01 | -0.05 |
| Eastern Bluebird | 14 | 0.03 | -0.11 |
| Eastern Phoebe | 5 | 0.01 | -0.05 |
| Eastern Towhee | 43 | 0.10 | -0.23 |
| Eastern Wood-Peewee | 40 | 0.10 | -0.23 |
| European Starling | 1 | 0.00 | -0.01 |
| Finch | 4 | 0.01 | -0.04 |
| Goldfinch | 8 | 0.02 | -0.08 |
| Grey Catbird | 11 | 0.03 | -0.10 |
| Hermit Thrush | 2 | 0.00 | -0.03 |
| House Finch | 1 | 0.00 | -0.01 |
| Mourning Dove | 10 | 0.02 | -0.09 |
| Northern Cardinal | 5 | 0.01 | -0.05 |
| Northern Flicker | 7 | 0.02 | -0.07 |
| Northern Oriole | 1 | 0.00 | -0.01 |
| Ovenbird | 42 | 0.10 | -0.23 |
| Pine Warbler | 27 | 0.06 | -0.18 |
| Prairie Warbler | 1 | 0.00 | -0.01 |
| Prothonotary warbler | 1 | 0.00 | -0.01 |
| Red-Bellied Woodpecker | 10 | 0.02 | -0.09 |
| Red-Headed Woodpecker | 9 | 0.02 | -0.08 |
| Red-Tailed Hawk | 2 | 0.00 | -0.03 |
| Ruby-throated hummingbird | 3 | 0.01 | -0.04 |
| Summer tanager | 1 | 0.00 | -0.01 |
| Tufted titmouse | 5 | 0.01 | -0.05 |
| Turkey Vulture | 7 | 0.02 | -0.07 |
| Warbler | 3 | 0.01 | -0.04 |
| Whippoorwill | 2 | 0.00 | -0.03 |
| White-Breasted Nuthatch | 7 | 0.02 | -0.07 |
| Wood Thrush | 3 | 0.01 | -0.04 |
| **39** | **416** | **1.00** | **3.08** |

TABLE 10. Summary of avian diversity found at the Parkway Site. The number below the species names represents the species richness for the site. Also presented are values for abundance, relative abundance, and species-specific intermediate values for the Shannon Index of the site.

# Appendices

# APPENDIX 1. Species lists across all sites.

## *Plants*

| Common | Latin |
|---|---|
| Pine | *Pinus sp.* |
| Oak | *Quercus sp.* |
| Blueberry (not Highbush) | *Vaccinium sp.* |
| Highbush Blueberry | *Vaccinium corymbosum* |
| Sheep’s Laurel | *Kalmia angustifolia* |
| Mountain Laurel | *Kalmia latifolia* |
| Wintergreen | *Gaultheria procumbens* |
| Braken Fern | *Pteridium sp.* |
| Greenbriar | *Smilax sp.* |
| Inkberry | *Ilex glabra* |
| Chokeberry | *Aronia sp.* |
| Staggerbush | *Lyonia mariana* |
| Sweet Pea | *Lathyrus odoratus* |
| Poverty Grass | *Hudsonia tomentosa* |
| Hudsonia Grass | *Hudsonia ericoides* |
| Panicum Grass | *Panicum sp.* |
| Other Grass | *Family Poaceae* |
| Moss | *Class Bryopsida* |
| Lichen | *Cladonia sp.* |

APPENDIX 1. Species lists across all sites. *(Continued)*

## *Birds*

| Common | Latin |
|---|---|
| American Crow | *Corvus brachyrhynchos* |
| American Robin | *Turdus migratorius* |
| Back and White Warbler | *Mniotilta varia* |
| Black Vulture | *Coragyps atratus* |
| Blue Jay | *Cyanocitta cristata* |
| Brown-Headed Cowbird | *Molothrus ater* |
| Carolina Chickadee | *Poecile carolinensis* |
| Chipping Sparrow | *Spizella passerina* |
| Common Yellowthroat | *Geothlypis trichas* |
| Downy Woodpecker | *Picoides pubescens* |
| Eastern Bluebird | *Sialia sialis* |
| Eastern Phoebe | *Sayornis phoebe* |
| Eastern Towhee | *Pipilo erythrophthalmus* |
| Eastern Wood-Peewee | *Contopus virens* |
| European Starling | *Sturnus vulgaris* |
| Finch | *Family Fringillidae* |
| Goldfinch | *Carduelis tristis* |
| Grey Catbird | *Dumetella carolinensis* |
| Hermit Thrush | *Catharus guttatus* |
| House Finch | *Carpodacus mexicanus* |
| Mourning Dove | *Zenaida macroura* |
| Northern Cardinal | *Cardinalis cardinalis* |
| Northern Flicker | *Colaptes auratus* |
| Northern Oriole | *Iceterus galbula* |
| Ovenbird | *Seiurus aurocapillus* |
| Pine Warbler | *Dendroica pinus* |
| Prairie Warbler | *Dendroica discolor* |
| Prothonotary warbler | *Protonotaria citrea* |
| Red-Bellied Woodpecker | *Melanerpes carolinus* |
| Red-Headed Woodpecker | *Melanerpes erthrocephalus* |
| Red-Tailed Hawk | *Buteo jamaicensis* |
| Ruby-throated hummingbird | *Archilochus colubris* |
| Summer tanager | *Piranga rubra* |
| Tufted titmouse | *Baeolophus bicolor* |
| Turkey Vulture | *Cathartes aura* |
| Warbler | *Family Parulidae* |
| Whippoorwill | *Caprimulgus vociferus* |
| White-Breasted Nuthatch | *Sitta carolinensis* |
| Wood Thrush | *Hylocichla mustelina* |

# APPENDIX 2: Student paper on Red-Headed Woodpecker

## Red-Headed Woodpecker Study

Matthew Niepielko

Supervised by: Daniel Hernandez, Ph.D.

**Abstract**

Research on the breeding phenology of the Red-headed Woodpecker (*Melanerpes erthocephalus*) was conducted during the summer of 2007. This study was designed to assess whether active conservation efforts for the New Jersey-Threatened Red-headed Woodpecker were succeeding at the Brendan T. Byrne State Forest Red-Headed Woodpecker Preserve. The objectives of this study were: finding the Red-headed Woodpecker, recording its vocalization, and analyzing the vocalizations and behaviors observed during the summer breeding season. By evaluating multiple sound spectrograms and observed visual behaviors, we concluded that a pair of Red-headed Woodpeckers was nesting and that current conservation efforts seemed to be successful.

## Introduction

A study was conducted from May 7th 2007 to August 29th 2007 involving the survey and observations of birds in different woodland regions located at four sites. The main bird species actively searched for was the Red-headed Woodpecker. The Red-headed woodpecker was specifically searched for by playing its distinct calls through a loud speaker in hopes of a response. Red-headed Woodpecker responses were recorded for further comparative data analysis. Random recordings were also conducted during every visit in every region. Some questions to be answered from this study included: Are there any Red-headed woodpeckers at any site? Are Redheaded Woodpeckers selecting specific areas? What actions the Red-headed Woodpeckers taking? Is active wildlife management working in certain areas? Is the Red-headed woodpecker conservation effort working? Is nesting taking place?

## Field Research and Data Collection

All four sites were visited at least once a week from May 7th to August 29th during morning hours. A walk-through was conducted in two regions at each site for every visit. This walk-through was used to randomly collect sound samples of the Red-headed Woodpecker, record responses from imitated calls, and observe Red-headed Woodpecker behavior. These visual and sound observations were to be further analyzed to determine the success of actively managing a site specifically to conserve the Red-headed Woodpecker.

## Red-Headed Woodpecker Observations

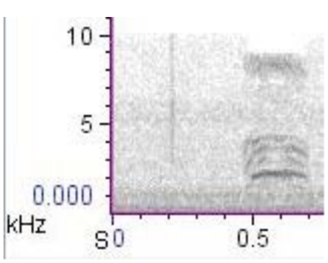
The Red-headed Woodpecker was only observed at one site, the actively managed Red-Headed Woodpecker Site located within Brendan T. Byrne Forest. The Red-headed Woodpecker was first observed on May 29th as a single individual responding to the imitated call note, and was last seen on August 16th as an individual. During each encounter with one individual, the Redheaded woodpecker was observed perched mid height on a dead oak or pine tree repeating its call note loud and frequently.

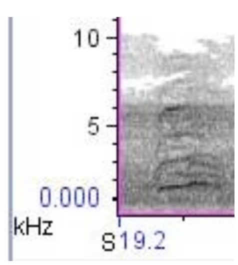
Distinct drumming was recorded on July 12th. Two Red-headed woodpeckers were observed calling and responding to each other on July 2nd and July 21st; one distinctly louder and more frequent than the other. Both were also observed perching and flying with one another from one side of the forest edge to the other side.

## Data Analysis

All field recorded Red-headed Woodpecker sounds were recorded onto a computer for evaluation. All Red-headed Woodpecker sounds were isolated and amplified from surrounding sounds to the best of my ability using a program called "*Raven Lite 1.0*." By using this program, I was able to create a visual spectrogram for each collected sound. These spectrograms allowed for the comparison of sound both visually as well as audibly. Sounds collected from the field were compared to known sounds. Known sounds and spectrograms were found using Cornell's accredited "Birds of North America Website" (1). By comparing sounds and spectrograms, it was determined that the individual Red-headed Woodpecker was frequently and relentlessly using a squeal-like "queer" call usually associated with attracting a mate. This frequently used call note was recorded during morning hours, the time in which a male will try to seek a female mate (2).

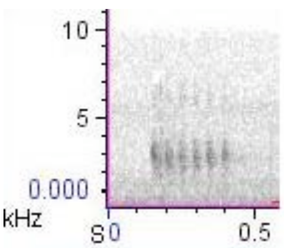
**Known Call Note Spectrogram Recorded Call Note Spectrogram**

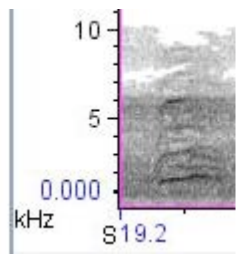


When analyzing the conversations recorded between two Red-headed Woodpeckers, no territorial calls were found. The audio and spectrograms did not match known calls used in defending a territory. This is particularly important since it is impossible to visually distinguish a male from a female Red-headed Woodpecker in the field. Because territory calls were not used in documented paired encounters, a possible male and female mating pair was suggested. Breeding grounds are guarded territories during the breeding season and would be associated with territorial calls when defended.

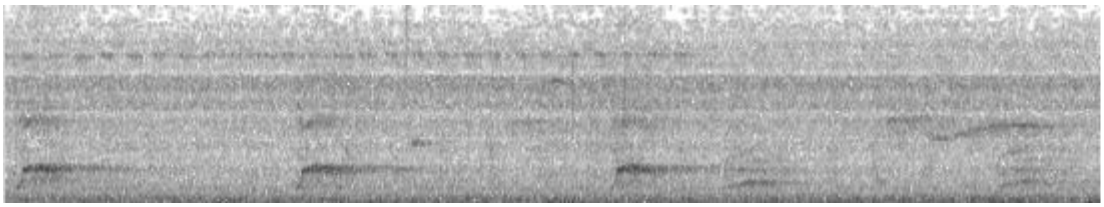
**Known Territorial Call Spectrogram  Recorded Call Note Spectrogram**




Further evidence suggesting a male and female pair came when analyzing the specific conversations between the two. During a two minute and eight second conversation, the louder Red-headed Woodpecker called forty-three times at a frequency of 2000 to 2300 Hz. The second bird responded at a much lower frequency of 1200 to 1500 Hz and only called twenty-three times. It was analyzed that all recordings of a solo bird performing male courtship behavior were only at 1200 to 1500 Hz. When comparing the solo calls with the calls in conversation, it was suggested that that one bird is deliberately increasing its pitch only during conversation with another. This why significant because females will use the same "queer" call as a male but less frequently and with less force (2). Accordingly, there was strong evidence that one male and one female were present during the conversation.

## Conversation Spectrogram



Behavior was also analyzed to conclude if this was a mating pair of Red-headed Woodpeckers. A courtship behavior often associated with Red-headed Woodpeckers is a "hide and seek" behavior game. This "hide and seek" behavior is described as a continuation of one bird flying and hiding while the other "searches." (3) This courtship behavior was documented and witnessed on July 21st 2007. Based on analyzed sound, spectrogram, and behavior data, it was concluded that the two Red-headed Woodpeckers were of the opposite sex and a mating pair (1).

## Discussion

Vocalization, spectrograms, and observed behaviors were used to suggest a nesting pair because of many difficulties involved with studying this bird. This study was not an easy study. For one thing, the male and female look exactly alike (1). Also, finding an actual nest would have been a difficult task since this study spent three fourths of the time investigating non-actively managed sites where no Red-headed Woodpeckers were documented. The final major difficulty was that Red-headed Woodpeckers are only in the act of mating for about seven seconds, so trying to witness this event would have been extremely difficult (1).

Another difficulty involved with this study involved understanding their mating season. Mating season for the Red-headed Woodpecker is normally between April and July. However, the Red-headed

Woodpecker is known for raising one nest while laying another nest. Furthermore, Red-headed Woodpeckers are known to mate again if a nest fails. This type of survival behavior can complicate, change, and extend the breeding season from one year to another year, and had to be taken in to consideration when studying this species(2).

Other difficulties in this study included the act of woodland birding. Unlike other types of birding such as shore birding, woodland birding consists of multiple obstacles that had to be overcome. Such obstacles include echoed sounds on trees, the frustration from the constant moving of birds from one tree to the other, finding birds in trees through dense canopy, and the ability to follow a bird from all parts of the forest including canopy, understory, and forest floor.

## Conclusion

The Red-headed Woodpecker was only found in one site out of the four. This suggests that something is attracting them to that site. Due to the specific qualities found, The Red-Headed Woodpecker Site in Brendan T. Byrne State Forest is actively managed for that specific species; wildlife management here can be deemed successful thus far. But are conservation efforts successful? In order for conservation efforts to be successful the species must be breeding. After analyzing the data, a male and female were found to be at the site, at the same time, on different occasions, during mating season, performing behavior associated with courtship. Drumming was also recorded suggesting possible nest building. Based on the evidence it can be concluded that there was at least one nesting pair of Red-headed Woodpeckers at the Red-Headed Woodpecker Site in Brendan T. Byrne forest during the summer of 2007. This nesting pair suggests that a conservation effort of the threatened Red-headed Woodpecker is working.

## Future Studies

Another study should be conducted during the breeding season in 2008. More time should be devoted to the actual managed site although other “potential” areas should still be studied. Time should be devoted to looking for nests and there should be close observations of possible population increases.

## Bibliography

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2 “Red-Headed Woodpecker Breeding Resource”, http://elibrary.unm.edu/sora/Auk/v094n02/p0231-p0239.pdf (accessed 2008) This article was used to understand the different breading behaviors of the Red-headed Woodpecker.

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