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Research Project Summary
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Pinelands Biodiversity Study: Survey of Flora and Fauna in Managed vs. Unmanaged Forests in Two Pinelands Habitats

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Abstract

Past land use and natural history in the New Jersey Pinelands have lead to the unique biodiversity of this ecosystem. Forestry management practices both past and present have shaped preserved State lands, and the specific effects of these practices with respect to changes in flora and fauna temporally have warranted investigation. Surveys by Richard Stockton College of New Jersey 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, two plots were examined: 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. Sites shown to be the most highly diverse (i.e. highest biodiversity value) with respect to birds and plants were the Woodpecker and Plantation sites (Shannon Indices of 3.01 and 2.92, respectively), where the theoretical maximum (H' max) is 3.66. These sites have been managed such that habitat complexity has been retained (e.g. creation of open areas with snags). Continual reintroduction of the early successional state through management and disturbance has contributed to the high biodiversity in managed areas. 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 to the increased biodiversity of these sites. However, areas in close proximity to infrastructure and suburban development can cause the opposite effect. 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 which may offer some insight. Renewal of open areas for species establishment greatly increases opportunities for colonization. We recommend that future studies focus on the landscape ecology of these habitat complexes on a larger scale (e.g. > 100 acres).

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. 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 land use practices are having on biodiversity and rare species. Development, forestry, and prescribed burning are among the most common land use 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 to plant and animal communities (Whelan 1995, Summerville et al. 2004), especially in disturbance-driven ecosystems. Unlogged and clear-cut stands have 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.

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.

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 quadrat was placed every 3 m along a transect, and the shrubs, forbs, and graminoids within the 1 m 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.

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. 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.

Table 1. 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	α Diversity	β Diversity	γ Diversity	Shannon Index (H')	Evenness (E)
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

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 (Table 1). 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. 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.

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.

Plant Surveys

There were clearly differences between the control and managed sites at each of the four locations (Table 2). For the Parkway site, blueberry stem densities were higher in the experimentally manipulated plot. The site was also characterized by having significantly less grass, moss, and oak in the experimental site. 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 sites (control and experimental) are characterized by having significant differences in the blueberry, grass, litter, moss, oak, and

Table 2. 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	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 3. Species lists (plants and birds) observed across all sites.

Plants	
Common name	**Scientific name**
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.
Birds	
Common name	**Scientific name**
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

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 this 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 3 for list of bird and plant species observed across all sites.

Conclusions

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. 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, however empirically pine numbers differed following regeneration after management. 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. Principal component 1 (PC1) was most important in separating Circle, Parkway, and Woodpecker sites, while Principal component 2 (PC 2) separated the Plantation site from the rest. Looking at the loading of the principal components, 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. The 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.

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.

The Woodpecker site was, appropriately, the only site in which we observed Redheaded woodpeckers. 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.

In summary, managed sites were found to exhibit higher biodiversity in the short term, as would be expected since species numbers and productivity are higher almost always in areas following disturbance. Conditions that mimic disturbance following natural causes (e.g. storms, fires, etc.) are always followed by increased pioneering activities by opportunistic species that define early successional stages, and thus flux in species is highest at this point. Temporally, as species are replaced, biodiversity decreases as longer-lived species and community stabilizers colonize. 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) and maintained in a pseudo-early successional stage. 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 to 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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RESEARCH PROJECT SUMMARY

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