The effects of canopy cover and oak dominance on ground leaf litter and duff layers in the Long Island Central Pine Barrens

Abstract:

The Long Island Pine Barrens provide habitat for many unique and endangered species. This habitat also supplies ecosystem services to Long Island such as ensuring the stability of important watersheds. The internal threat of forest succession that isn't kept in check by frequent low-intensity wildfires (a natural disturbance in the area) is of great concern due to the possible loss of ecosystem services. As this forest shifts towards an increase in dominance of oak trees, the ground cover (litter and duff) depth should increase due to the annual dropping of leaves of deciduous trees. As canopy cover increases the ground cover depth should increase as well. Pitch pines prefer bare mineral soil for germination, and as leaf litter increases pitch pine recruitment will decrease. For this reason, this study is important because it links canopy cover and oak dominance to the potential of pitch pine recruitment based on germination requirements. Thus also linking these variables to the stability of the pine barren's historic natural species composition, which was pitch-pine dominant. The overstory and ground cover measurements for this study were collected within a variety of forest types, a total of 49 random stratified sampling plots (16×25 m) were measured. Within these plots, canopy cover was measured at four points around the center point and duff and leaf litter depth were measured at 40 random points along 25 m long line intercept transects on each plot. Plots were categorized by percent oak abundance based on basal area calculations using dbh measurements for each tree. From this data, no significant correlation was found between canopy cover and ground over, or percent oak overstory and ground cover. The results could have been affected by a low sample size and large variation in ground cover within plots- future research could benefit from a more accurate and standardized method of litter sampling and increasing the number of plots surveyed.

Introduction:

The Long Island Pine Barrens are a standout ecosystem characterized by their soil type and unique forest composition. The typical vegetation consists of pitch pine (*Pinus rigida*), white oak (*Quercus alba)*, scarlet oak (*Quercus coccinea*) and black oak (*Q. velutina*) in the overstory, while huckleberry (*Gaylussacia baccata*), blueberry (*Vaccinium pallidum* and *V.angustifolium*), scrub oak (*Q. ilicifolia*) and wintergreen (*Gaultheria procumbens*) dominate the understory[1]. The soils are usually sandy, acidic, and nutrient poor due to geologic properties, climatic characteristics and the microbiota (spring tails and other decomposers) of the Pine Barrens[1]. These pine woodlands are home to many unique species, such as the buck moth (*Hemileuca maia maia*); which is dependent on flora of the barrens to survive[2]. These woodlands also provide valuable ecosystem services to Long Island; for example, they serve as a recharge site to the Long Island aquifers, the only source of fresh drinking water on the island. Forested areas provide natural recharge centers for underground water supplies by increasing water infiltration into the soil and reducing soil compaction[3]. However, due to changes in the fire regime, invasion of Southern Pine beetle, invasive vegetation and other anthropogenic disturbances, large oaks such as black and scarlet oak (*Quercus veluntina* and *coccinea* respectively) are expected to out-compete the pitch pine and become more abundant in the pine barrens[1].

A possible cause of this shift from pine to oak dominated ecosystem could be linked to changes in leaf litter and duff, though in a complex and dynamic system such as this one many variables may be at play (e.g., greater shade tolerance of oak)[4]. Pitch pine (*Pinus rigida*) germinates most effectively and with greater success in acidic bare mineral substrate, and as leaf litter builds and the duff layer deepens, conditions become less conducive to pitch pine recruitment[5–7]. As humans shift the natural fire regime particularly via fire suppression, leaf litter and duff accumulate on the forest floor[8]. Due to this suppression of fire, and the species composition shift from pine to oak, there is immense concern that there has been a noticeable increase in leaf litter and soil duff that would further discourage pitch pine regeneration in the Long Island Central Pine Barrens.

Oaks generally have thick, tough leaves and that have high levels of tannic acid that discourages the growth of bacteria and fungi that can aid in the decomposition of litter, but pine needles are high in lignin which is a tough cell structure making it hard to decompose[9,10]. This being said, studies have shown that oak leaves generally decompose faster than pitch pine needles[11]. The greater decomposition rate combined with the seasonal drop of leaves by oak trees causes a high rate of continual buildup of litter on the ground. This would negatively impact the recruitment of pine seedlings, because the continual addition of oak leaves without volatilization by fires leads to a large litter layer. The soils with thick oak litter layer do not favor pitch pine recruitment, partly because the leaf litter releases various phenols that inhibit pine growth[12]. With low recruitment of pines, oaks may come to dominate the ecosystem due to their high growth rates (and re-sprouting ability) that characterize their strategy for survival in fire-adapted ecosystems[13]. A study showed that as leaf litter depth increased the shrub layer became more dominant and pitch pine seedling recruitment decreased[14]. The same study found that *Q. alba* and *Q. coccinea* recruitment was unaffected by an increase in ground cover and shrub cover[14]. Shrubs are strong competitors for light in the understory and for a seedling to find its place among a dense shrub layer it must grow rapidly. Pitch pines grow slow in comparison to oaks, and thus they are easily overtaken by oak seedlings or shrubs[14].

Another possible consequence of the buildup of litter is an increased frequency of high intensity fires[15]. Although it's been shown that low intensity fires in post-fire dwarf pine plain communities help with pitch pine recruitment, intense crown fires have been shown to be detrimental in mature, full sized pitch pine forests[16]. Due to the lower percentage of serotinous cones in full sized pitch pine forests (compared to dwarf pines' 100% serotinous cones), later-successional full sized pitch pine forests show very low seedling recruitment after high intensity fires that damage tree crowns and unprotected seeds in non-serotinous cones[16].

A long-term shift of the pine barrens from pine to oak dominated forests could lead to a loss of the ecosystem services mentioned above, as well as a loss of biodiversity, and the disappearance of this unique ecosystem. This study is designed to get insight into the decreasing pitch pine abundance in the pine barrens by analyzing ground cover. We hypothesize that as the canopy cover of the forest increases, the combined litter and duff (ground cover) depth will increase. Furthermore, as the forest composition shifts from pine dominated to oak-dominated, there will also be an increase in ground cover depth. Studying the current ground cover can give conservationists and policy makers an insight to predict forest composition trends for future years and help them make management plans accordingly.

Methods:

In 2005/2006, 93 plots were established throughout the Central Pine Barrens. These plots were located in six different Pine Barren's forest types: coastal oak, oak-pine, pine-oak, pitch pine, pitch pine-scrub oak, and dwarf pine plains/shrub oak. The study was designed to detect vegetative shifts of 10% over the last 10 years using vegetative and ground cover surveys.

A total of forty-nine of the original 93, 16×25m, plots were resampled during 2019. In 28 plots, a densiometer (Spherical Crown Densiometer Convex Model A) was used to measure the canopy cover from four different points around the plot center marker. These measurements were taken at each point facing north and then facing south and an average of the north and south measurements from all four points represents the total forest cover within the plot.

In all of the 49 plots, litter and duff was characterized by laying out ten transect lines evenly spaced and parallel to the 25-meter edge of the plot. At four evenly spaced points along the transect, a soil core was taken that went deep enough to show the bottom extent of the duff layer; litter and duff depth were measured using a ruler[17].

Using excel, we created a regression model to compare the canopy cover percentage of plots to the average depth of litter and duff on each plot to see if there is a relationship between canopy cover and the ground cover depth (leaf litter, duff, and leaf litter + duff). Then using the basal area calculations of the trees in each plot, the plots were categorized into four forest community types, >75% oak, 75-50% oak, 25-50% pine, or <25% pine. Using the four different categories, an ANOVA test was run to calculate P values to test if there is a significant difference between the average ground cover depth within the four forest communities.

Results:

A positive correlation between overstory percentage and ground cover depth, as well as oak overstory percentage and ground cover depth was expected. First the relationship of overall forest canopy cover to duff depth, litter depth, and combined litter and duff depth was tested. A positive trendline comparing each of the three ground cover categories to canopy cover was revealed from this regression, demonstrating that as the canopy cover increased, duff, litter, and overall ground cover increased. However, each of the correlations had a small r-squared value (<0.1) indicating that the relationship is weak (Figures 1-3).

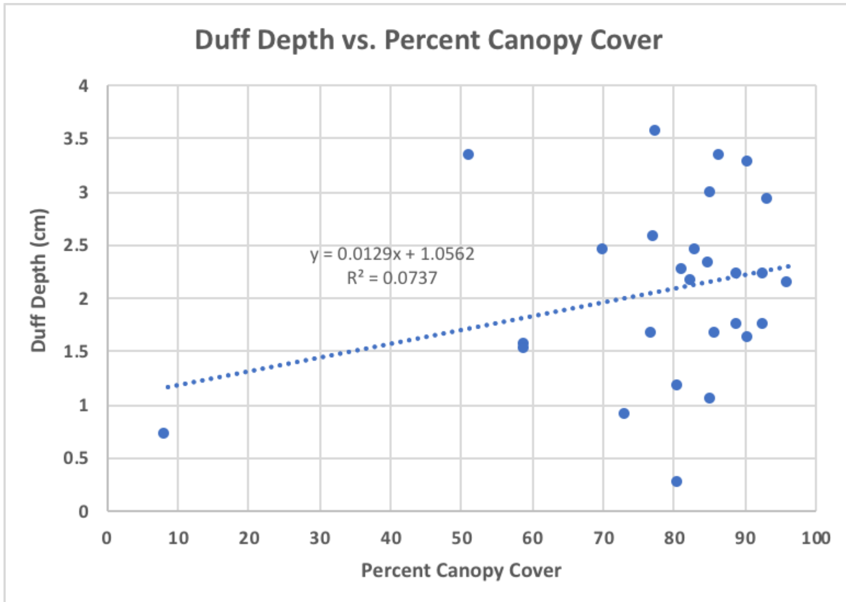

Figure 1: Scatter plot representing the average duff depth (y-axis) graphed against the percent canopy cover (x-axis) of each plot. Average plot duff is the average of 40 duff readings for each plot.

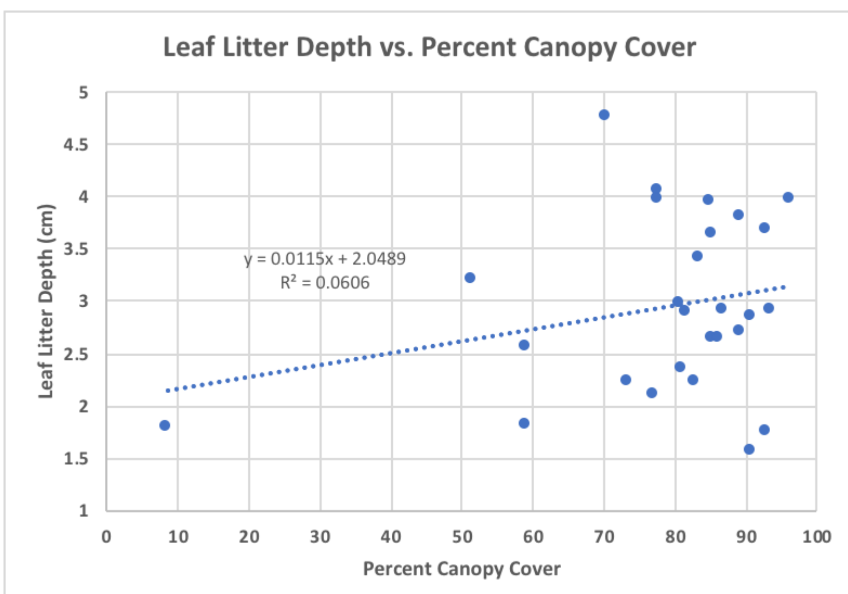

Figure 2: Scatter plot representing average leaf litter depth (y-axis) vs. percent canopy cover (x-axis) of each plot. Average plot leaf litter is the average of 40 leaf depth measurements throughout the plot.

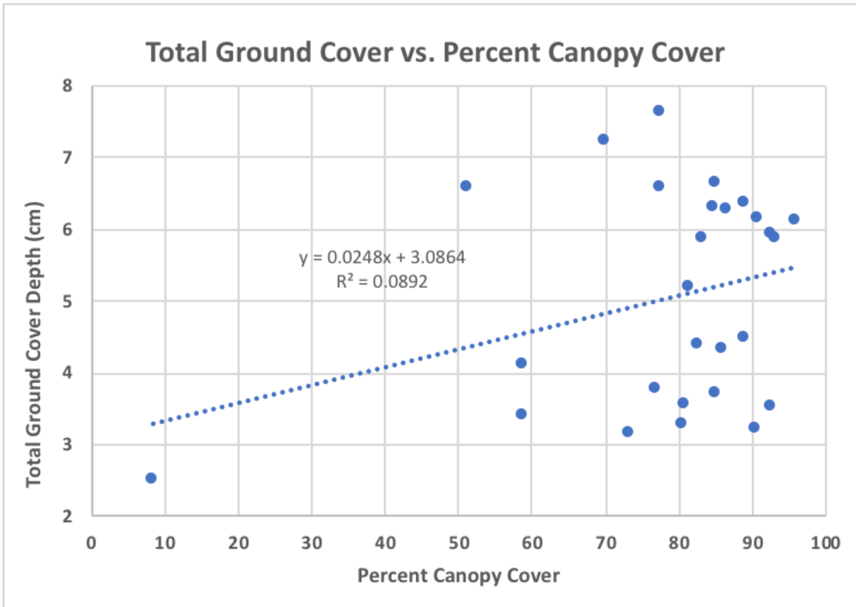

Figure 3: This graph shows the relationship between total ground cover (y-axis) and canopy cover (x-axis). Total ground cover is the plot average of the sum of leaf litter and duff.

The results from canopy cover and duff depth had a r value of 0.271, r-squared value of 0.074, and p value of 0.171. Canopy cover and litter depth had a r value of 0.246, r-squared value of 0.061, and p value of 0.215. Canopy cover and combined ground cover had a r value of 0.299, r-squared value of 0.089, and p value of 0.130. The relationship between litter depth and percent canopy cover was the strongest (p value of 0.215) The data suggests that a relationship might exist since all graphs show a positive relationship, although with such small r values the relationship is very weak. Two other scatter plots were created using exponential and power trendlines between total ground cover and percent canopy cover; this still generated r-squared values that suggests a weak relationship.

The average litter depth varied from 2.68 cm to 2.98 cm depending on oak percentage in the overstory (Table 1) while the average duff depth varied from 2.29 cm to 1.89 cm (Table 2). The average of total ground cover (duff + litter) varied from 4.84 cm to 5.16 cm, across the categories, but not in a clearly increasing or decreasing trend (Table 3). The highest duff depth was found to be in the >75% oak plots, and the lowest duff depth was found in the <25% oak. However, the categories were not statistically different from each other, as shown by the ANOVA test (see p-values below, Tables 4-6).

Leaf Litter Summary				
Groups	*Count*	*Sum*	*Average*	*Variance*
>75% Oak	16	43.67	2.729375	0.49644375
50-75% Oak	3	8.05	2.68333333	1.47255208
25-50% Oak	5	14.9	2.98	0.23567188
<25% Oak	16	47.675	2.9796875	0.66283073

Table 1: The summary of the values for the average of all 40 leaf litter measurements within each plot. The variance is the difference of the average leaf litter measurements between plots within each forest community. The sum and the average are of each plot in each forest community. The count is the number of plots that fit in each forest community.

Duff Summary				
Groups	*Count*	*Sum*	*Average*	*Variance*
>75% Oak	16	36.645	2.2903125	0.45001823
50-75% Oak	3	6.475	2.15833333	0.23583333
25-50% Oak	5	10.6125	2.1225	0.72948438
<25% Oak	16	30.3095	1.89434375	0.71862668

Table 2: The summary of the values for the average of all 40 leaf litter measurements within each plot. The variance is the difference of the average duff measurements between plots within each forest community. The sum and the average are of each plot in each forest community. The count is the number of plots that fit in each forest community.

Total Ground Cover Summary				
Groups	*Count*	*Sum*	*Average*	*Variance*
>75% Oak	16	80.315	5.0196875	1.2223649
50-75% Oak	3	14.525	4.84166667	2.81192708
25-50% Oak	5	25.8125	5.1625	1.37054688
<25% Oak	16	78.1843	4.88651875	2.11001795

Table 3: The summary of the average of all 40 duff and leaf litter measurements (a.k.a total ground cover) added together within each plot. The count, sum, average, and variance are the same as the duff and litter tables.

Bartlett's test was conducted before performing the ANOVA test to ensure that this kind of statistical test is valid. The Bartlett's test is used to assess the significance of the difference in the variation of the groups. This test gave a p-value of 0.9994, null hypothesis that there is not a significant difference in variances between categories could not be rejected. This meant an ANOVA is viable.

The ANOVA analysis tested if the average litter, duff, and combined litter and duff depths varied across forest community types with differing proportions of oak. This ANOVA evaluated the significance of the difference in duff, leaf litter, and combined ground cover between each forest community type. The ANOVAs resulted in p-values of 0.77, 0.54 and 0.97 for duff, leaf litter and combined ground cover respectively (Tables 4-6 in the appendix). Thus, duff, leaf litter, and combined ground cover were not significantly different amongst the forest communities.

Discussion:

In this study, we tested if ground cover depth was related to total overstory percentage canopy cover or oak overstory percentage cover. The hypothesis was not supported by our analyses; we found no significant correlation between canopy cover and ground cover (litter and duff, combined or separated). Likewise, the secondary hypothesis was rejected based on our findings, thus as the species composition of the forest shifts towards oak-dominance there is not an increase in ground cover (litter and duff, combined or separate). These results could be the consequence of poor or missing data. We related ground cover only to the percentage of oak trees based only on pine and oak dbh's, this means that the data used could be underrepresenting other deciduous trees in the plots, such as *Sassafras albidum*. *Sassafras albidum.* These species' leaf decomposition rate and its effect on decomposition of leaves around it is not well studied. Although these deciduous trees species represent a very low percentage of the species composition within the plots, they may still have the ability to skew the data.

Another stipulation is that there was not much data in the literature on the actual annual build-up or even drop of leaf litter of pines or oaks. An inference was made about the expected leaf litter depth in oak-dominated forests based on the higher leaf drop and decomposition rate of deciduous trees than pine trees. This may have been an oversimplification and the multitude of variables that go into leaf litter build-up and decay may be outweighing the effects of annual drop and decomposition rate. For instance, the soil composition could be highly variable between plots that fall within the same forest community because of the local geology, the hydrology, the thermal regime, and understory composition, among other factors[18]. Part of this variability could come from the abundance of micro fauna in the soil that are decomposers of leaf litter, such as springtails, which respond to environmental or biotic factors[18]. Recent weather events could have aided to the variability of the ground cover depths as well because rain can weigh down the leaves decreasing depth and a particularly dry week can fluff up the leaf litter increasing depth[19].

It was found that our litter sampling methods were closely related to another experiment done in NYC, relating litter depths of oak dominated forests to seedling regeneration. This team sampled randomly along three, 50 meter transects, taking litter measurements every 2 meters. They measured the depth by placing a wooden dowel into the ground until it hit the harder duff layer and taking the height measurement on the dowel- much like we did. However, this team also took samples of the litter mass, providing them with the opportunity to run analysis based off litter depth, mass, and density[19]. Given the opportunity, future pine barren research could include data collection on litter mass and density.

Lastly it is important to consider understory vegetation contribution to the leaf litter because they annually drop their leaves. Huckleberry (*Gaylussia baccata*), blueberry (*Vaccinum pallidum* and *V. angustifolia*) and scrub oak (*Quercus ilicifolia*) are the dominant understory cover in the Long Island Central Pine Barrens; each of these species can produce large amounts of leaf litter annually if they are in high abundance. *Quercus ilicifolia* is a shrub within the oak family and tends to grow in great abundance where is it found, its leaves are thick and can greatly influence the ground cover depth. Due to the shrubby nature of *Quercus ilicifolia* it was not counted in the calculation of oak tree dominance. Nevertheless, the leaf litter of this species could influence the measured litter and duff depth measurements.

Our study opens the doors for future directions and further consideration for a more multivariate approach to the question of what controls ground cover depth in the Long Island pine barrens. However, throughout each plot, there was a significant layer of ground cover. Bare mineral soil was lacking in most of our plots, the lowest average ground cover for a plot was 2.5cm. This may be enough to impede pitch pine germination and recruitment since ideally pitch pines prefer bare mineral substrate to germinate[5–7]. Research should be conducted to see if there is a change of litter depth over time, in order to understand future ground cover regimes. This would aid in predicting pitch pine recruitment in the time to come. Our study only provides a snapshot of the current state of the pine barrens. Future replication can provide data and models that show trends in the pine barrens.

Conclusion:

The importance of understanding the leaf litter and duff depth dynamics of the Long Island Central Pine Barrens cannot be overstated, for this is one of the first obstacles a pine seed must face before and during germination. If the ground cover regime is not optimal the seedling will never gain a competitive edge over the oak's superior growth rate. Pine recruitment is a topic of interest with the recent shift from the historic pine-dominance to now oak-dominance in the Pine Barrens due to fire suppression and other stressors on pine trees. Thus, understanding the viability of pine recruitment in various forest types is important, and one huge factor into this recruitment is litter and duff depth. There was no relationship found between the abundance of oaks and the average ground cover depth, and there was no significant relationship found between canopy cover and ground cover depth. Likely there is a stronger variable influencing the ground cover, or maybe there is a multitude of variables and a multivariate experiment (or models) would help to bring light to this. A future experiment or model of this caliper could give the decision makers and land managers insights into the factors that affect ground cover and the ability link the ground cover to pine establishment in this unique and threatened ecosystem.

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Appendix.

Table 4:

Leaf Litter ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.66756552	3	0.22252184	0.37650141	0.77046946	2.86626555
Within Groups	21.2769089	36	0.59102525			
Total	21.9444744	39				

Table 5:

Duff ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.26890894	3	0.42296965	0.72788876	0.54207062	2.86626555
Within Groups	20.9192778	36	0.58109105			
Total	22.1881868	39				

Table 6:

Total Ground Cover ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.3856632	3	0.1285544	0.07575419	0.97266531	2.86626555
Within Groups	61.0917843	36	1.69699401			
Total	61.4774475	39				