Analysis and Quantification of Forest Health using Understory Composition and Establishment of Deer Exclosures

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Abstract

From 2005 to 2006, 93 permanent plots were established across the Central Long Island Pine Barrens to monitor forest health in the unique pine barrens ecosystem, and it was hypothesized then that changes could be detected within 10 years. In the summer of 2011, the plots on the Brookhaven National Laboratory (BNL) property were reanalyzed to determine if changes could be seen earlier, over a 5 to 6 year period. Also, new plots were established where deer exclosures will be erected in order to quantify the effects of deer browsing. For the pre-existing plots, 16- by 25-meter tapes were laid out with 10 twenty-five meter transects within each. For the new plots, the plot corners were randomly chosen and a 16- by 25-meter plot was permanently established along with the 10 transects. For new and pre-existing plots, a 2-meter pole was placed at 20 randomly generated points along each transect and the understory species touching it were recorded. The plots were then categorized as pine- or oak-dominated, based on their overstory composition. The Shannon-Weiner biodiversity index for the pine-dominated plots was 1.439 in 2005/6 and 1.428 in 2011, and for the oak-dominated plots was 1.569 in 2005/6 and 1.497 in 2011. This shows that the understory composition has remained similar for pine-dominated areas, but a slight decline in biodiversity was seen in oak dominated areas. Also, the pine-dominated areas had significantly more understory species than the oak, with 27.6 vs. 22.0 hits per transect on average (t-test, $p=.0067$, $\alpha=.05$). This shows that the oak-dominated areas are experiencing a decline in understory species which could potentially be due to deer browsing. The deer exclosure plots had similar understory species as the control plots, but the percent composition of some species varied and this will be taken into account when future studies are carried out to control for variables other than deer browsing. Future studies will allow management plans to be tailored to the needs of the forest to ensure the survival of this rare ecosystem and the species interactions that exist within it.

Introduction

The Long Island Central Pine Barrens (CPB) region represents an ecosystem dominated by pitch pine (*Pinus rigida*) and oaks (*Quercus spp.*), with acidic, nutrient poor soil that contributes to the specific forest composition (1). The understory is comprised mainly of short shrubs that grow well in acidic soils such as scrub oak (*Quercus ilicifolia*), black huckleberry (*Gaylussacia baccata*) and various blueberry species (*Vaccinium spp*.). This region is unique because many different successional forest types are represented within it which include pine- and oak- dominated areas with different species compositions (2). These different successional stages exist because fire has been present over time and promotes the growth of species such as *P. rigida* and *Q. ilicifolia* (1). A feedback loop exists in the CPB where fire-tolerant understory species have flammable leaves which promote periodic fire that burns the litter allowing pine seedlings to grow thus promoting early successional stage survival (2).

Increased industrialization combined with the creation of railroads in the area, initially promoted the incidence of fire in the CBP region, allowing this area to maintain its existence (3). Over time, increased development led to the alteration and clearing of this important environment. Preservation plans were put into place to prevent the demise of this ecosystem but have led to the quick suppression of natural and accidental fires in these preserved areas (3). This lack of fire is leading to a more oak-dominated, uniform ecosystem, since pine communities need periodic burning to remain in their early successional state, promote the growth of *P. rigida* and *Q. ilicifolia*, and keep the soils relatively acidic and nutrient poor (1).

Another threat to the composition of CPB forests is the high deer population seen in this area. On Long Island, deer have no natural predators and while hunting is allowed it has done very little to curb the population growth of this species. Deer are known to browse on common CBP understory shrubs like the various blueberry species and scrub oak and also enjoy oak tree seedlings and saplings (4). Large mammals such as deer also trample new shoots as they move through the forest which can further damage understory species. Increased deer browsing and trampling have altered the forest floor and left it bare or comprised of huckleberry, ferns and sedges which deer do not commonly eat until there is a food shortage (4).

Since the alteration of the CPB ecosystem has long been apparent, it was considered necessary to put in place a monitoring system to help determine the health of the forest and track changes in its make-up. For this reason, The Foundation for Ecological Research in the Northeast (FERN) made studying the health of the CPB region one of its goals and began monitoring the area (5). From 2005 to 2006, 93 permanent forest health monitoring (FHM) plots were established across Long Island to study many parameters that affect forest health such as soil depth and pH, overstory and understory composition and numbers of trees and seedlings, and noted damage to plants from mammals, insects and birds. At the start of this study it was predicted that a 10% change in forest health could be detected after 10 years, which would allow researchers to assess the direction in which forest growth is heading after the same data were collected again (5).

In 2011, it was decided that the FHM plots located on the Brookhaven National Laboratory (BNL) property would be analyzed again to see if any changes in the state of the forest could be seen in less than 10 years, which would allow management plans to be tailored to the needs of the forest. Seven of these plots were revisited on the BNL site and the same data collected to continue the efforts to study the changes in forest state. Also, three experimental plots were established to be fenced in and used as deer exclosures to help quantify the effects of deer browsing and trampling in the area. Various factors such as height, density, percent make-up and biodiversity were studied for understory species to see how its composition has changed since the establishment of FHM plots. The FHM plots will serve as controls for the deer exclosures where the same understory analysis will be performed. Since deer are only able to browse on plants up to 2 meters in height, changes in understory provide a good model for changes in deer browsing and the effects it has on forest health.

Materials and Methods

In order to locate the FHM plots to repeat data collection in 2011, maps were produced with coordinates of the plots and these were entered into a handheld Global Positioning System (GPS). When the original plots were established, the four corners, two midpoints and the center were permanently marked with rebar and a metal cap. A witness tree was also marked near the plot and a 4-foot t-post was put in the ground near this tree (5). These permanent markings allowed the FHM plots to be spotted once the general area was located, since the GPS cannot track many satellites in the forest, thus decreasing its accuracy.

Once the FHM plots were located, four 50-meter tapes were used to set up the plot with two 16- and two 25-meter sides, seen in Figure 1 (5). Once the 16-by 25-meter plot was laid out, the center cap was located and a tripod set up at the center of the plot. Pictures were taken from the center to each corner, using the compass direction indicated on the original data sheet, to photographically record changes over time in the plot. The height of the different forest layers was also estimated to produce a more quantitative measure of height change over time (5).

In order to analyze the understory composition of the plot, ten 25-meter randomized line transects were established across the plot, also shown in Figure 1. First, a random number was chosen between 50 and 200 and this represented the starting point along the 16-meter edge from .5 to 2.0 meters. A line transect was set up at this starting point and then every 1.5 meters until 10 transects were established. Another random number was then chosen between 50 and 450 as the starting point along the 25-meter edge from .5 to 4.5 meters. For each of the 10 line transects, a random number between 1 and 10 was chosen and added to the start point on the 25-meter edge, and this marked the first point along the transect (5). At this point, a narrow 2 meter collapsible pole was placed in the ground, and each species that touched the pole was recorded. The percent tree cover over the point was estimated using a densitometer (5). This process was then carried out until data was collected at a total of 20 points along the transect.

For 3 of the 7 FHM plots that were analyzed, a comparable plot was set up nearby to establish a deer exclosure. The locations of these new plots were chosen based on proximity to the previously established plot and similarity of forest composition so that the FHM plots could act as control areas for the deer exclosures. Locations of all plots used in this study can be seen in Figure 2. For these new plots, the M1 corner was randomly chosen and 16-by 25-meter plot was established. The same data were collected in these deer exclosure plots as in the FHM ones, and in the future fencing will be put up to ensure deer browsing is removed from the area.

For each plot, the pictures taken in 2005/6 and 2011 were compared along with estimated understory height data to study understory height changes. Also, the total number of hits for each understory species in each plot was compared between the 2005/6 and 2011 data to look at how the density of the understory has changed. The changes in diversity of the understory layer were analyzed by calculating the Shannon-Weiner biodiversity index for each plot (6). The plots were also split into two categories based on the overstory composition of the forest, either oak- or pine-dominated, and this is also shown in Figure 2 (7). For each category, the Shannon-Weiner biodiversity index was again calculated. Also, the average number of species hits per transect was calculated and compared between years and between overstory category to look at general trends in the density of the understory

Results

Photographic comparison showed similar density and slightly increased height of the understory layer for the two pine-dominated plots, 52 and 91. Both plots experienced a slight increase in biodiversity and height of understory and a slight decrease in the number of understory species hits per plot, and a summary of these variables for all plots is in Table 1. Plots 93 and 5 had slightly decreased and increased biodiversity indices, respectively, but both had more species hits per plot and increased height and photographic comparison showed evidence of increased understory density and height. The understory layer of plots 81 and 29 looked very similar in photographs from 2005/6 and 2011 and also had the same estimated understory height. Plot 81 had increased biodiversity and less species hits per plot while 29 had similar biodiversity and fewer species hits per plot. Plot 30 experienced a slight increase in biodiversity and height of the understory and a slight decrease in understory density compared to 2005.

Picture comparison of plot 93 and its corresponding deer exclosure showed that both had very dense understory layers but the height of vegetation in the deer exclosure was lower. Quantitative analysis showed the deer exclosure had higher biodiversity and hits per plot but lower understory height compared to FHM plot 93 which will serve as its control, again shown in Table 1. Deer exclosures 5 and 91 appeared less dense because more forest floor was seen in the pictures and they had higher vegetation compared to their corresponding FHM plots. It was determined that deer exclosures 5 and 91 had lower biodiversity and higher estimated understory heights compared to their controls. Deer exclosure 5 had more hits per plot while deer exclosure 91 had fewer hits per plot.

The Shannon-Weiner biodiversity index was calculated when the plots were combined by overstory type. It was 1.439 in 2005/6 and 1.428 in 2011 for the pine-dominated plots and 1.569 in 2005/6 and 1.497 in 2011 for the oak-dominated plots. The pine-dominated plots had slightly fewer hits compared to 2011 while the oak plots had more, but neither was statistically significant. In 2005/6 pine-dominated plots had more hits per transect than oak-dominated, with 26.9 and 20.0, respectively (t-test, p=.0002, α=.05). In 2011, pine-dominated areas also had more understory species hits than the oak, with 27.6 vs. 22.0 hits per transect on average (t-test, p=.0067, α=.05).

Understory composition was analyzed for the two overstory categories, and pie charts of species distributions can be seen in Figure 3. For the pine-dominated areas, statistically less *G. baccata* (t-test, p=0.0006, α=.05), *Pteridium aquilinum* (t-test, p=0.0266, α=.05) and *Q. ilicifolia* (t-test, p=.0020, α=.05) were hit in 2011 compared to 2005/6, summarized in Table 2. Slightly more *Vaccinium pallidum* and *Vaccinium angustifolium* were hit but neither was statistically significant, again seen in Table 2.

For the oak- dominated areas, statistically less *P. aquilinum* (t-test, p=0.0118, α=.05) and *Q. ilicifolia* (t-test, p=0.0239, α=.05) were hit in 2011 compared to 2005/6, summarized in Table 3. Similar numbers of *V. angustifolium* were hit and slightly higher numbers of *G. baccata*, *V. pallidum* and *Carex pensylvanica* were hit but none were significant, again seen in Table 3.

It was determined that deer exclosure 93 had more *Quercus alba* (t-test, p=0.0361, α=.05) and *C. pensylvanica* (t-test, p=0.0005, α=.05) hits and less *G. baccata* (t-test, p=0.0015, α=.05) hits. It also had *V. angustifolium* present which was not seen in the control FHM plot. Deer exclosure 5 had more *C. pensylvanica* (t-test, p=0.0378, α=.05) and *G. baccata* (t-test, p=0.0000, α=.05) hits and less *V. angustifolium* (t-test, p=0.0422, α=.05) and hits than FHM plot 5. Deer exclosure 91 had less *V. pallidum* (t-test, p=0.0014, α=.05) and *Q. ilicifolia* (t-test, p=0.0083, α=.05).

Discussion

In all but one of the FHM plots that were revisited in 2011, an increase in biodiversity was seen. This indicates that while there is still a large deer population on BNL grounds, the health of the forest in increasing in general, since biodiversity is a factor used to measure forest health (6). The deer population on the BNL site experienced a population spike in 2003, and it is possible that the increase in browsing associated with this increase affected the numbers of plants that survived to produce seeds that year (8). This in turn would affect the growth of many plants and shrubs in the upcoming growing seasons and could have contributed to the lower biodiversity seen in 2005/6. The deer population then experienced a decline until 2007, and the population still has not reached the level seen in 2003, which would have allowed increased plant survival and contributed to the increase in biodiversity.

The pine-dominated plots have higher understory densities than the oak-dominated ones which could be attributed to the fact that deer enjoy browsing on oak seedlings while they will only turn to pine seedlings in times of food shortage (4). Both pine- and oak-dominated plots saw a decrease in *Q. ilicifolia* since 2005/6 which could also be due to the fact that deer enjoy *Quercus spp* .and have continued to browse on these species since the initial data collection. Both types of plots also had significantly less *P. aquilinum* present which is not associated with deer browsing because they usually do not prefer ferns (4). In many of the plots this species was seen dead or with broken stems so it's possible that even though deer do not eat these large, top heavy ferns, they do crush them while moving through the forest. It is also possible that the surveys done in 2005/6 as well as 2011 harmed these ferns because the transect tapes used got caught on them and also the boots worn by researchers could have added to trampling.

The pine-dominated plots also had a decrease in *G. baccata* over time. Since deer prefer *Vaccinium spp.* and *Quercus spp.* over this shrub, a decrease could be associated with less deer browsing (4). It is possible that other species were able to thrive in these areas since the initial surveys and therefore fewer nutrients were available for *G. baccata*. In general it appears that the oak-dominated plots have experienced more deer browsing over time than the pine-dominated plots. The two plot categories experienced both increases and decreases in understory density and average plant height, showing that deer prefer certain locations on the BNL site and therefore no uniform trends were seen over time in these variables. Since neither oak- nor pine-dominated plots have experienced a significant increase in any species since 2005/6, it shows that deer browsing is still present and suppressing the growth of many understory species' populations.

It appears that deer exclosures 5 and 91 experience more deer browsing currently than their control FHM plots. They both had lower numbers of species that deer are known to browse on, higher numbers of species that are unpalatable to deer and lower biodiversity than the FHM plots (4). Deer exclosure 93 had higher biodiversity and a higher occurrence of plants deer enjoy browsing which means this plot has less deer presence than its compatible FHM plot. While the deer exclosure plots did not have the exact same make-up as the control FHM plots, the differences have been noted and can now be taken into account when future studies are carried out after fencing is installed. For deer exclosure 93 which has little deer browsing currently, the changes in understory composition may not be very significant. For deer exclosures 5 and 91 which have evidence of high deer browsing, it will be important to note the rate at which certain species increase in an area after herbivore removal. It will also be interesting to note the addition of new forest layers in the 1-3 meter range after deer browsing is removed because these layers could provide nesting areas for migratory birds and new habitats for other mammals. Future studies will allow for the continued monitoring of forest health, quantification of deer browsing effects and provide more insight into the species interactions that exist within the Long Island CPB region.

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Figures:

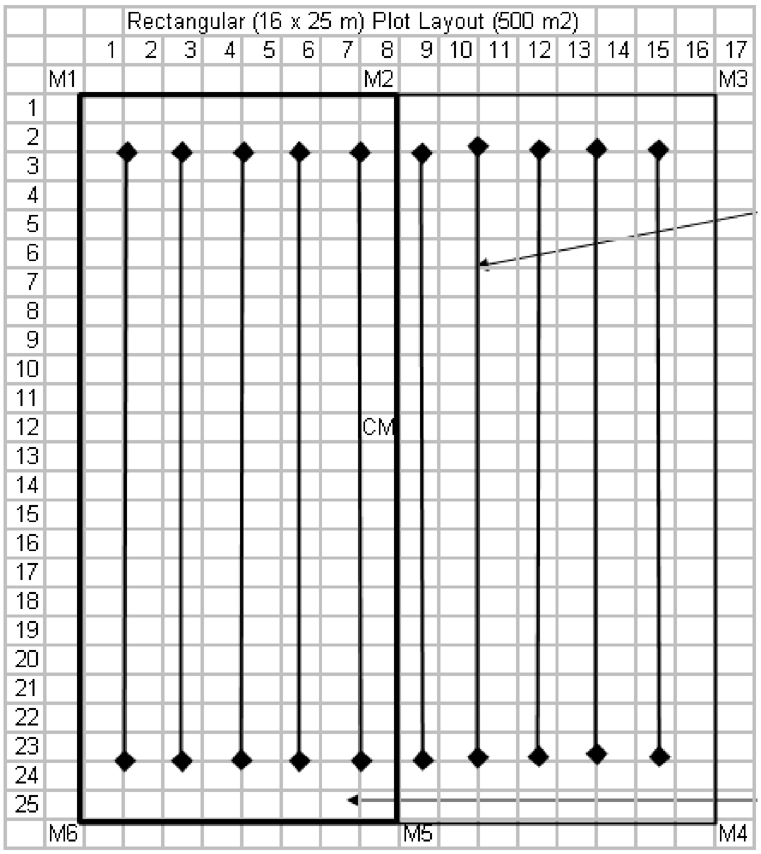

Figure 1: A schematic representation of the plot with side lengths, corner names and example line transect locations (5).

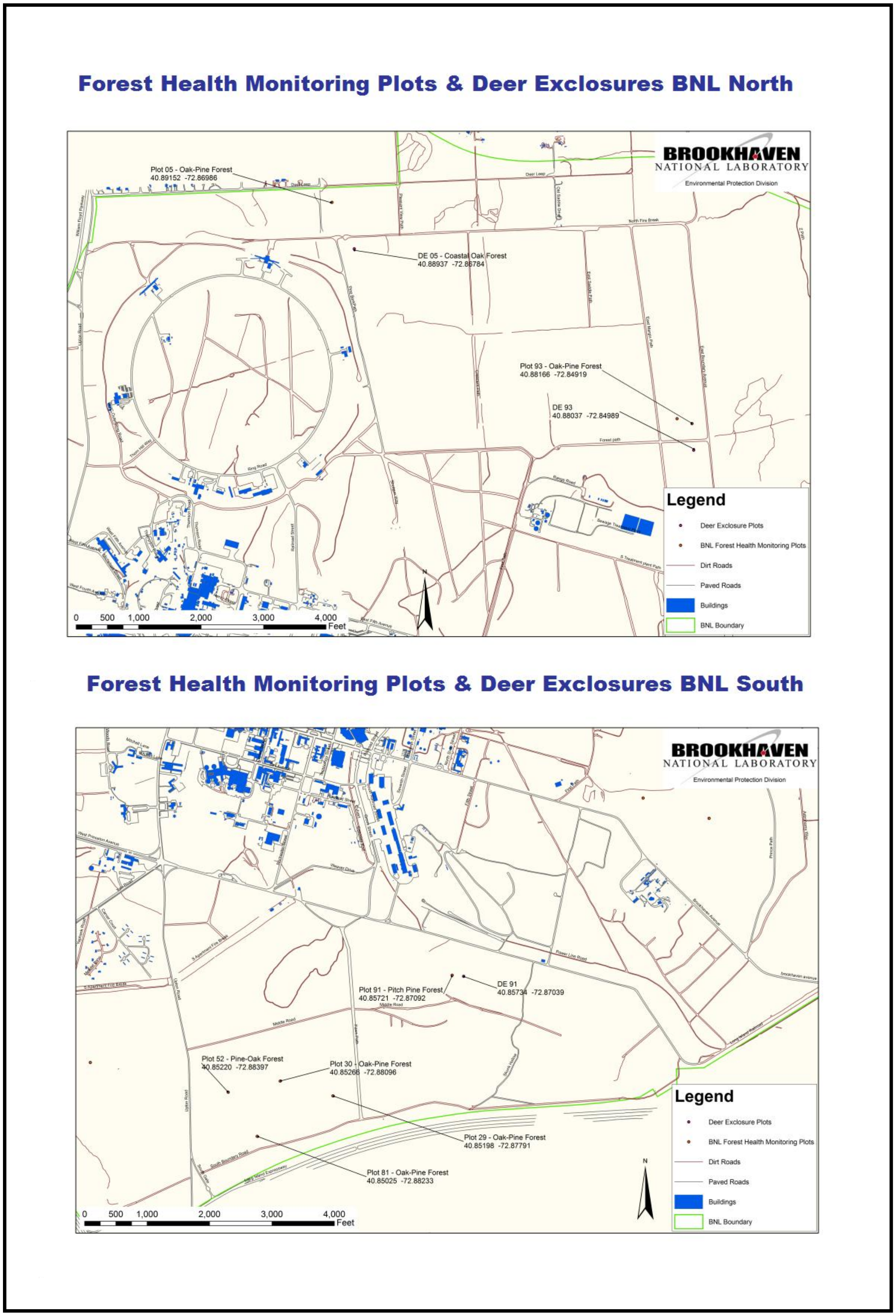

Figure 2: Coordinates and Overstory Classifications of FHM and Deer Exclosure plots

Table 1: Biodiversity, Density and Height data for FHM and Deer Exclosure plots

Plot	**29 (2005)**	**29 (2011)**	**30 (2005)**	**30 (2011)**	**52 (2006)**	**52 (2011)**	**81 (2006)**	**81 (2011)**
Overstory Category	Oak-pine	Oak-pine	Oak-pine	Oak-pine	Pine-oak	Pine-oak	Oak-pine	Oak-pine
Shannon Weiner biodiversity index	1.611	1.684	1.723	1.823	1.142	1.330	0.978	1.506
Total species hits per plot	204	171	245	220	252	233	173	203
Estimated height of understory layer	0.25	0.28	0.1	0.3	0.1	0.6	0.5	0.5

Plot	**5 (2005)**	**05 (2011)**	**DE 05**	**91 (2006)**	**91 (2011)**	**DE 91**	**93 (2006)**	**93 (2011)**	**DE 93**
Overstory Category	Coastal oak	Coastal oak	Coastal oak	Pitch pine	Pitch pine	Pitch pine	Oak-pine	Oak-pine	Oak-pine
Shannon Weiner biodiversity index	1.234	1.261	1.081	1.301	1.593	1.468	1.069	0.948	1.558
Total species hits per plot	134	176	241	300	264	194	257	292	384
Estimated height of understory layer	0.5	0.9	0.52	0.5	0.75	0.6	1.4	1.8	0.6

Table 2: Comparison of pine-dominated understory composition in 2005/6 and 2011

Pine dominated	Total hits (05/06)	Avg. hits/transect	variance 05/06	Total hits (11)	Avg. hits/ transect	variance	P-value	% increase	% decrease
Gaylussacia baccata	232	11.6	6.67	173	8.65	7.5	0.0006		25.4310
Vaccinium pallidum	118	6.21	7.62	120	6	16.63	0.4254	1.6949	
Vaccinium angustifolium	78	7.8	14.4	129	6.45	10.79	0.1758	65.3846	
Pteridium aquilinum	35	2.5	4.73	16	1.23	0.36	0.0266		54.2857
Quercus ilicifolia	88	8	10.8	38	3.8	6.62	0.0020		56.8182

Table 3: Comparison of oak-dominated understory composition in 2005/6 and 2011

Oak dominated	Total hits (05/06)	Avg. hits/ transect	variance 05/06	Total hits (11)	Avg. hits/ transect	variance	P-value	% increase	% decrease
Gaylussacia baccata	300	7.32	30.32	312	7.8	22	0.3493	4.0000	
Vaccinium pallidum	322	7	8.98	334	6.82	10.74	0.3880	3.7267	
Vaccinium angustifolium	141	4.15	6.86	141	4.41	4.77	0.3315	-	-
Carex pensylvanica	132	5.08	8.31	161	4.6	4.66	0.2411	21.9697	
Pteridium aquilinum	63	2.86	2.5	38	1.9	1.04	0.0118		39.6825
Quercus ilicifolia	37	2.18	2.9	19	1.27	0.21	0.0239		48.6486

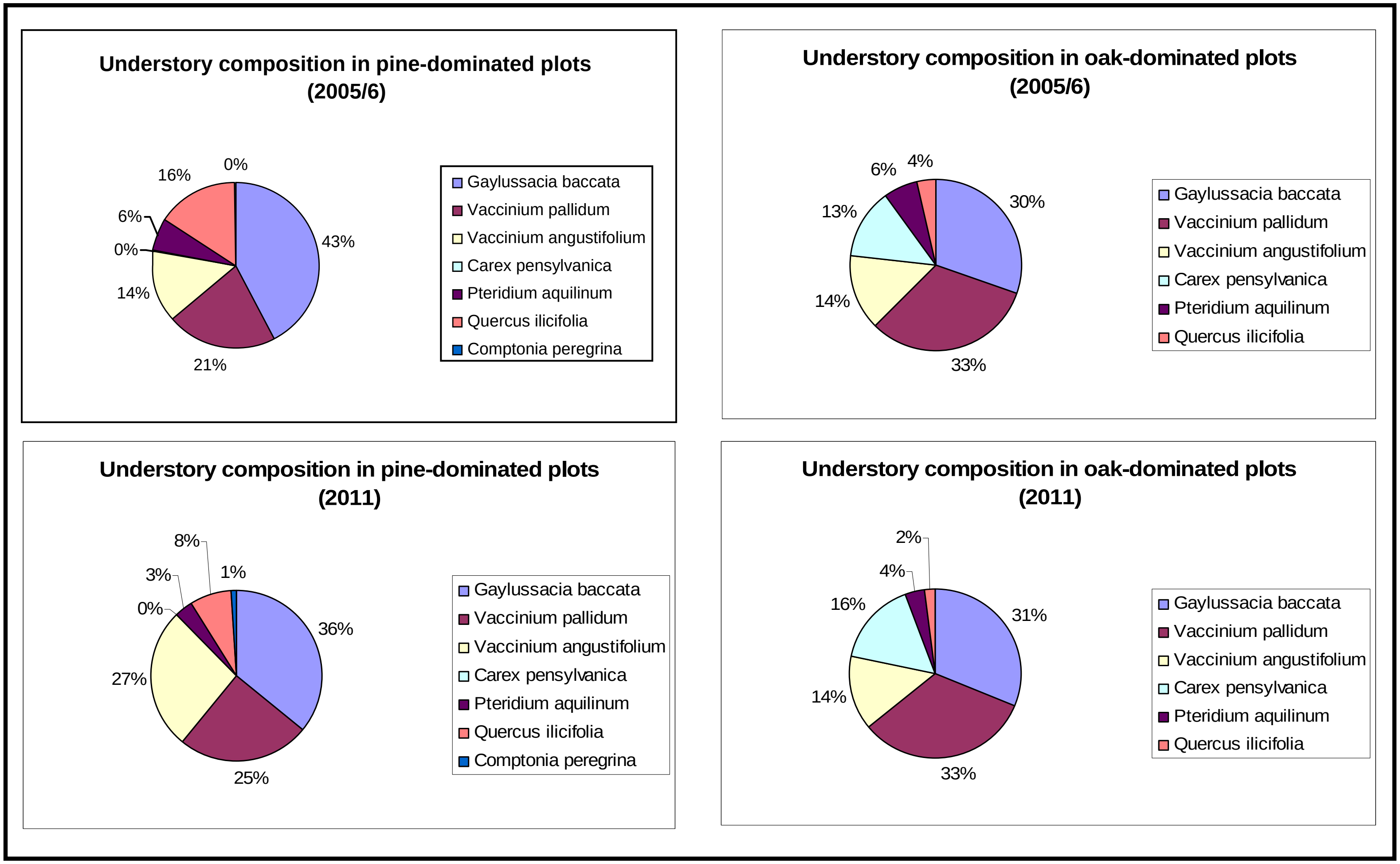

Figure 3: Understory species composition for pine- and oak- dominated plots in 2005/6 and 2011