Effects of Changes in Canopy Cover on Understory Vegetation in the Long Island Pine Barrens

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Table of Contents

ABSTRACT

Effects of Changes in Canopy Composition on Understory Vegetation in the Long Island Pine Barrens. ANDREW SIEFERT (The Pennsylvania State University, University Park, PA 16802) TIMOTHY GREEN (Brookhaven National Laboratory, Upton, NY 11973).

Pine barrens are rare and important ecosystems found on coarse, droughty, nutrient-poor soils in the northeastern United States. The Central Pine Barrens, located on Long Island in Suffolk County, New York, are a mosaic of communities representing different stages of forest succession, from open canopy pitch pine (*Pinus rigida*) and scrub oak (*Quercus ilicifolia*) barrens to closed canopy pitch pine and finally coastal oak forests. Although the succession of overstory vegetation has been modeled, the effects of changes in overstory composition and increased canopy cover on understory vegetation are not understood. To explore this, overstory and understory cover data were sampled in study plots in the Central Pine Barrens. Understory cover and species richness were analyzed as a function of overall canopy cover and relative pitch pine and hardwood cover. Shrub cover decreased as total canopy cover and relative hardwood cover increased. Dominant understory species were similar in most areas, though *Quercus ilicifolia* abundance declined with increased canopy cover. Species richness was greatest in mixed pine-oak communities. This research contributes to our understanding of understory vegetation- its composition, dynamics, and relationship with the overstory- in the Central Pine Barrens, and provides information that will assist in the management of this important natural resource.

Introduction

The Central Pine Barrens (CPB) is a protected 41,480 ha pine barrens ecosystem on Long Island, New York. Pine barrens are rare and threatened ecosystems found on coarse, nutrient-poor, droughty soils in the northeastern United States [1]. Rare birds, moths, butterflies, and other organisms depend on the unique plant assemblages found in the pine barrens [2-4]. In addition, the CPB overlies the only aquifer on Long Island, making it an important human resource. The Central Pine Barrens Monitoring Program was begun in the summer of 2005 in order to provide a baseline of the ecological health of the CPB and assist in developing management goals and programs [5].

Pine barrens ecosystems are dynamic mosaics of shrubland, woodland, and forest communities. Fire plays a dominant role, creating and maintaining open-canopy pitch pine and scrub oak shrublands. In the absence of fire or other disturbances, these communities undergo facultative succession, changing from open-canopy shrublands to closed-canopy pitch pine forests [1]. The climax community is coastal oak, which is established when tree oaks invade and replace pitch pine as the dominant canopy species. Studies have shown that canopy structure is an important factor in determining the composition of understory plant communities [6,7], but little research has been done on the relationship between overstory and understory composition in the Pine Barrens.

The goal of this study was to determine whether and how differences in tree canopy cover affect the composition and species richness of understory plant communities in the Long Island Pine Barrens. As part of the CPB Monitoring Program, we collected data on canopy and understory cover in study plots throughout the Central Pine Barrens. The focus for the first year of the program was closed-canopy, late-successional communities, so sampling took place primarily in pitch pine, oak-pine, and coastal oak forest. We predicted that total canopy cover and relative abundance of pitch pine and hardwoods in the canopy would lead to significant differences in understory composition. We expected to find a negative relationship between total canopy cover and understory species richness and cover, and species richness was expected to be greatest in areas with a mixed pitch pine and hardwood canopy.

Methods

The field data collection methods were taken from the Monitoring Protocols for Central Pine Barrens Field Plots [5]. The study area is located in the 22,275 ha Core Preservation Area of the Central Pine Barrens on Long Island, New York. Study plots were located within the Forests, Woodlands, and Shrubland target area defined by [8]. This target area was divided into subtarget communities (Table 1) as defined by [9].

Using GIS, 16 x 25 meter ($400m^2$) field plots were selected randomly within the subtargets, no closer than 50 meters to edges of human-dominated land use areas and wetlands, and no closer than 25 meters to boundaries of subtargets.

Canopy and understory cover were sampled systematically in each plot along ten line transects. Line transects were set up at 1.5 m increments, parallel to the 25 m plot boundary, with the first transect located at a random point between 0.5 and 2.0 meters along the 16 m plot boundary. Each line transect contained twenty sampling points at 1 meter increments, with the first point on each transect located randomly between 0.5 and 4.5 meters along the transect for a total of 200 points per plot.

Percent cover values of understory plant species <2 m tall were determined by vertically dropping a narrow, 2-meter pole at each sampling point and recording each species touching the pole. Understory species richness for each plot was the total number of vascular plant species sampled in the plot. Nonvascular plants were not identified at the species level, so they were not included when calculating species richness. Understory vascular plants were classified by growth-form as shrubs (woody plants <5 m tall), herbaceous plants (little or no woody tissue), or trees (woody plant species with height at maturity >5 m). Percent cover values for growth-forms were determined by summing the percent cover of individual species in each plot.

Percent total canopy cover of trees >2 m tall for each plot was determined by taking densitometer readings at sampling points. Relative cover was used to represent the proportional content of pitch pine and hardwood within the total canopy cover of each plot. The community type of each plot was determined by comparing the total canopy cover and relative pitch pine/hardwood cover values calculated from densitometer readings with those established [9] for each community type.

Understory characteristics were analyzed as a function of total percent canopy cover and relative pitch pine/hardwood cover. Linear regression was used to model relationships between independent and dependent variables unless a nonlinear model explained at least an additional 10% of variance (r^2 or R^2). Correlation (r or R = correlation coefficient) was used to measure the strength of the relationships [6].

Results

In all, overstory and understory data were collected in 42 plots: 1 pitch pine-scrub oak shrubland, 5 pitch pine, 5 pine-oak, 15 oak-pine, and 16 coastal oak (Table 2). Five of the coastal oak plots had been severely defoliated by gypsy moth caterpillars, so canopy data from these plots were not included in analysis.

The total understory vascular plant species richness of all plots was 35, and the average species richness of plots was 5.95 (Table 2). Of the 35 species sampled, 15 were unique to one community type, with coastal oak forest containing 12 (Table 2).

Shrub species were dominant in all plots, especially *Gaylussacia baccata* and *Vaccinium pallidum*, which were found in every plot (Table 3). Other common species were *Quercus ilicifolia*, *Vaccinium angustifolium*, *Gaylussacia frondosa*, and *Gaultheria procumbens*. The most common herbaceous species were the fern *Pteridium aquilinum* and the sedge *Carex pensylvanica.* Tree seedlings and saplings found in the understory included *Quercus alba*, *Quercus coccinea*, and *Quercus velutina* (Table 3).

Understory species richness was not related ($p = 0.20$) to total percent canopy cover (Figure 1). Percent of total canopy made up of hardwood (relative % hardwood) explained 15% of variation in understory species richness. Species richness was highest when ratio of pitch pine:hardwood in the canopy was approximately 40:60 (Figure 2)

Total understory cover decreased significantly as percent overstory cover ($p = 0.022$) and hardwood cover ($p < 0.001$) increased, with amount of hardwood cover explaining 29.4% of variation (Figures 3 and 4). Shrub cover was also negatively related to total canopy cover and relative hardwood cover (Figures 5 and 6). Percent canopy cover and relative percent hardwood cover explained 25.6% and 55.2% of variation in shrub cover, respectively. (Figures 5 and 6). There was no significant relationship between canopy cover and herbaceous plant understory cover (Figures 7 and 8). There was a strong negative relationship ($p < 0.001$; $R = 0.82$) between relative percent hardwood cover and *Quercus ilicifolia* cover in the understory (Figure 9).

Discussion

Canopy cover affected understory composition in several ways in our study area. As we predicted, understory species richness was greatest when the canopy contained roughly equal abundances of hardwood and pine (Figure 2). This can be explained in terms of forest succession. The overstory composition of Pine Barrens communities transitions from pine to oak as succession occurs, so the relative proportions of hardwood and pine in the canopy reflect the successional status of a given community. Mixed pine-hardwood communities, which had the greatest understory species richness in our study, represent an intermediate stage in forest succession. There are many hypotheses that describe the relationship between successional stage and plant diversity, but a consensus has yet to emerge. Our findings agree with the intermediate-disturbance hypothesis, which states that diversity will be greatest at intermediate stages of succession [7,10].

Contrary to our expectations, understory species richness was not closely related to total canopy cover (Figure 1). Limited light availability as the result of increasing canopy cover is often associated with a decrease in understory species richness [7]. This relationship did not hold in our study, suggesting that other factors, such as soil characteristics, topography, and water availability may explain the small differences in species richness we observed. Although species diversity and richness are important characteristics, these values alone do not adequately describe the differences between communities [7]. Species richness did not vary greatly between plots with different overstory characteristics in our study, but we observed significant differences in understory composition.

A well-documented pattern in overstory and understory interactions is the negative relationship between canopy shading and understory cover [6,11]. This relationship held in our study, although canopy cover explained only 14% of the variation in overall understory cover and 25.6% of the variation in shrub cover (Figures 3 and 5).

Understory cover responded even more strongly to the relative proportions of pitch pine and hardwood in the canopy (Figures 4, 6 and 9). An existing conceptual model of vegetation dynamics for the Pine Barrens shows the abundance of shrubs in the understory decreasing as the abundance of tree oaks in the canopy increases (Jordan). We found this model to be accurate in our study, with relative hardwood cover explaining 29.4% of the variation in understory cover (Figure 4). Particularly, abundance of *Quercus ilicifolia*, the dominant shrub species in many early-successional Pine Barrens communities, declined significantly as hardwood cover increased (Figure 9). Studies have shown that this species is the host plant for rare moths and butterflies in the Pine Barrens [3]. Preserving early-successional, open- and pine-canopy communities is therefore necessary for preserving these species.

The importance of preserving open-canopy Pine Barrens communities has been a common theme in recent ecological studies of the Pine Barrens [1,3,12]. The value of these communities as habitat for rare birds, insects, and plants is well documented. Empirical data on the composition and diversity of the understory is lacking, though, and this study focused almost exclusively on late-successional communities. In order to have a complete picture of understory dynamics in the Pine Barrens, this research should be continued in the future and expanded to include open-canopy, early-successional communities.

The maintenance of open-canopy Pine Barrens communities has been a special area of concern in Long Island, but we conclude that to best preserve the ecological health of the Pine Barrens, forest managers should seek to maintain a variety of shrubland, woodland, and forest communities. Open-canopy communities Pine Barrens communities, which are globally rare and threatened by fire suppression and development, need to be actively created and maintained through prescribed fires [1]. Closed canopy forest communities may not require active management to maintain, but they are equally valuable. Coastal oak forests contained the most unique understory species of any community in this study (Table 2), and are therefore an important reservoir of plant diversity in the Pine Barrens. Mixed pine-oak forest communities contained relatively high levels of species richness, and although they contained few unique species (Table 2), may serve as corridors or transitional areas between early-and late successional communities [7].

Understanding the interactions between overstory and understory will allow us to predict changes in understory diversity and composition as a result of successional change and forest management in the Pine Barrens. The Central Pine Barrens Monitoring Program's ongoing research will document these changes and provide information that will aid in the management and preservation of the pine barrens of Long Island.

Acknowledgements

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Tables

Community Type	Characteristics
Coastal Oak Forest (CO)	Total canopy cover >60%; oak cover >90% of total tree cover
Oak-Pine Forest (OP)	Total canopy cover >60%; oak cover = 51-90% of total tree cover
Pine-Oak Forest (PO)	Total canopy cover >60%; pine cover = 51-90% of total tree cover
Pitch Pine Forest (PP)	Total canopy cover >60%; pine cover >90% of total tree cover
Pitch Pine-Oak Woodland/Shrubland (PPSO)	Total canopy cover <60%, primarily pitch pine and tree oaks
Dwarf Pine Plains (DPP)	Shrubland dominated by dwarf pitch pine; dense canopy 1-3 m tall

Table 1. Descriptions of Pine Barrens subtarget communities [9].

Community	n	Total sp. richness	Avg. species richness	Unique species
All	42	35	5.95	-
Pitch Pine-Scrub Oak	1	7	7	0
Pitch Pine	5	13	6	2
Pine-Oak	5	14	5.8	0
Oak-Pine	15	18	6.47	1
Coastal Oak	16	31	5.44	12

Table 2. Species richness in Pine Barrens communities.

Species	Life Form	Frequency	Communities
Gaylussacia baccata	shrub	1.00	all
Vaccinium pallidum	shrub	1.00	all
Quercus ilicifolia	shrub	0.71	all
Vaccinium angustifolium	shrub	0.60	all
Carex pensylvanica	sedge	0.52	PPSO, PO, OP, CO
Pteridium aquilinum	fern	0.43	all
Quercus alba	tree	0.24	PP, PO, OP, CO
Quercus velutina	tree	0.21	PP, PO, OP, CO
Quercus coccinea	tree	0.19	PP, PO, OP, CO
Gaylussacia frondosa	shrub	0.17	PO, OP, CO
Gaultheria procumbens	shrub	0.17	PP, PO, OP, CO

Table 3. Common Pine Barrens understory plant species.

Figures

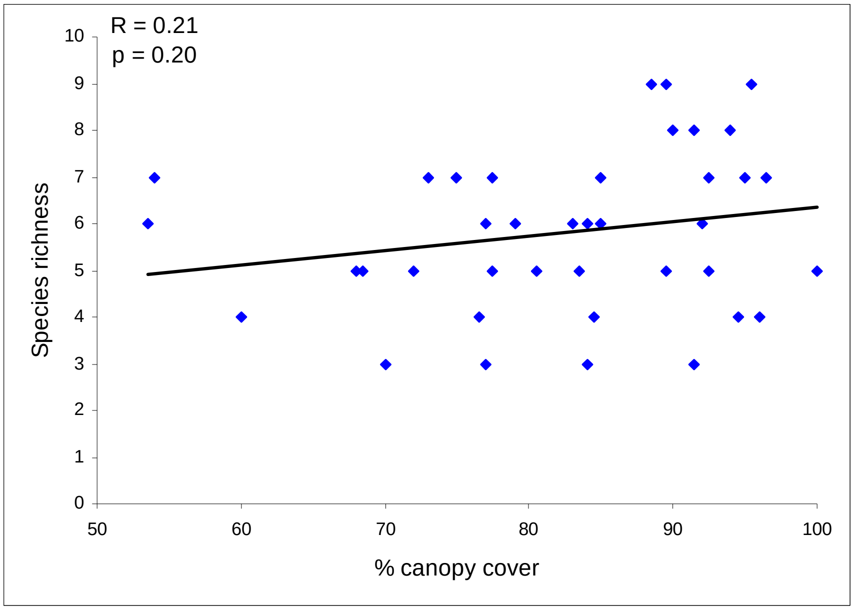

Figure 1. Relationship between total percent canopy cover and understory species richness, with linear regression.

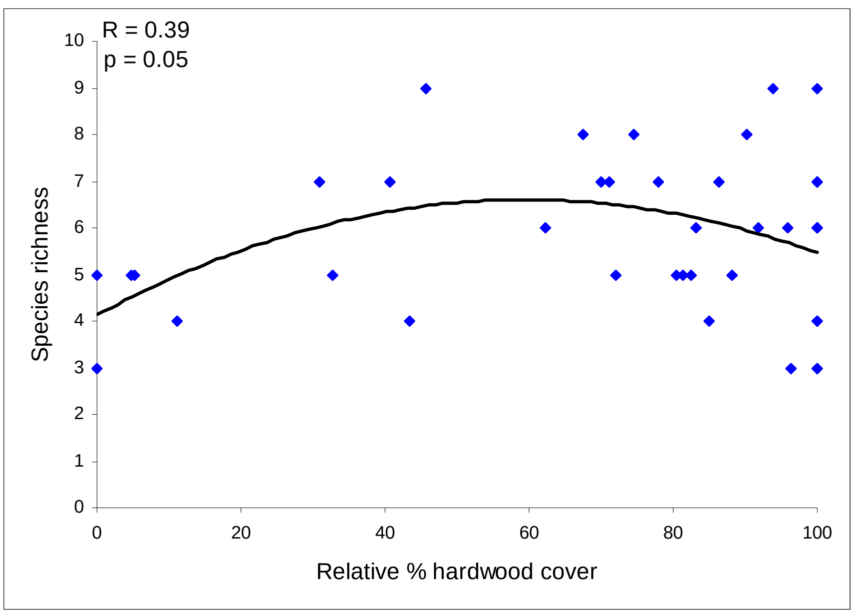

Figure 2. Relationship between relative percentage of hardwood cover in canopy and understory species richness, with polynomial regression.

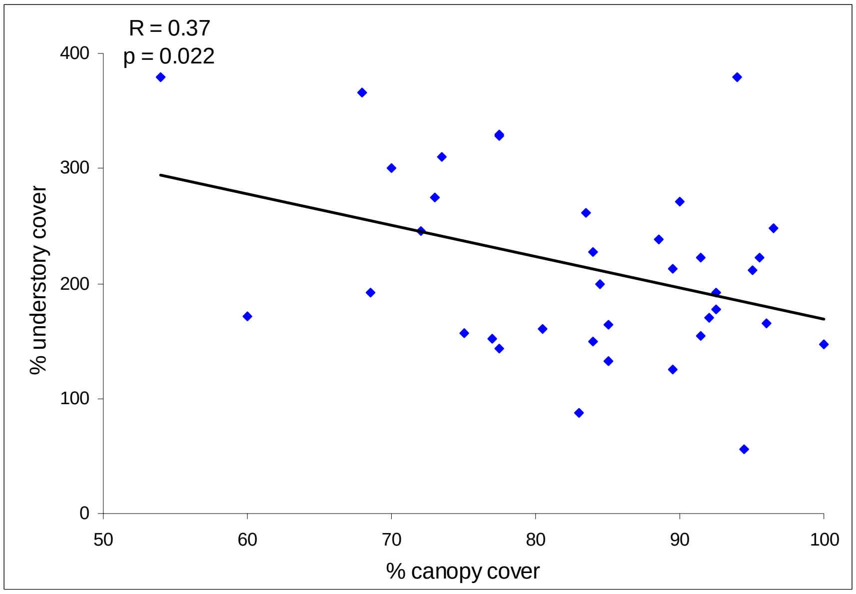

Figure 3. Relationship between total percent canopy cover and percent understory cover, with linear regression.

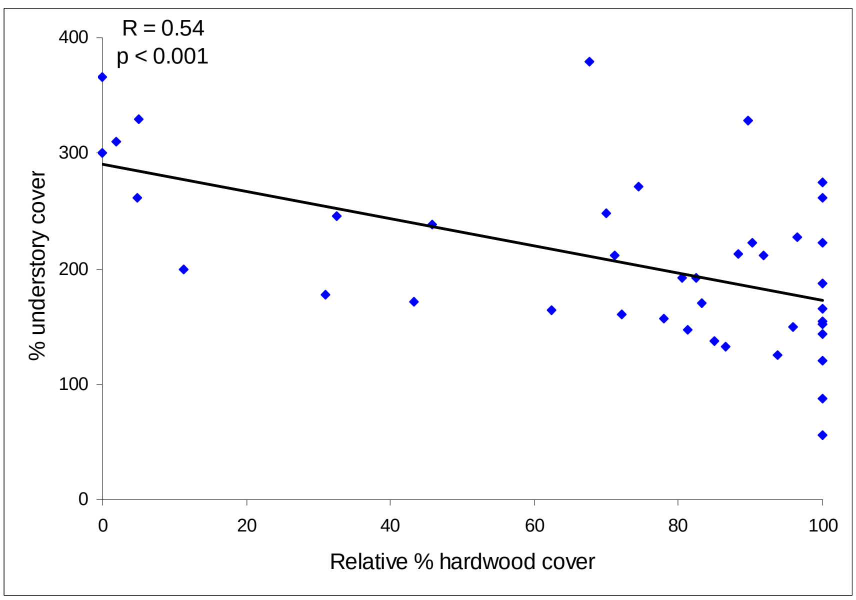

Figure 4. Relationship between relative percentage of hardwood cover in the canopy and understory percent cover, with linear regression.

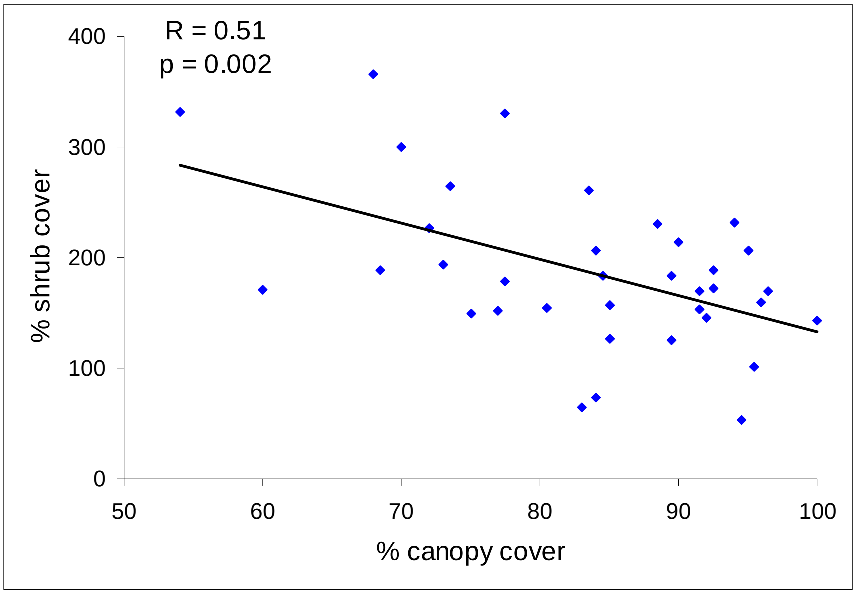

Figure 5. Relationship between total percent canopy cover and percent shrub cover, with linear regression.

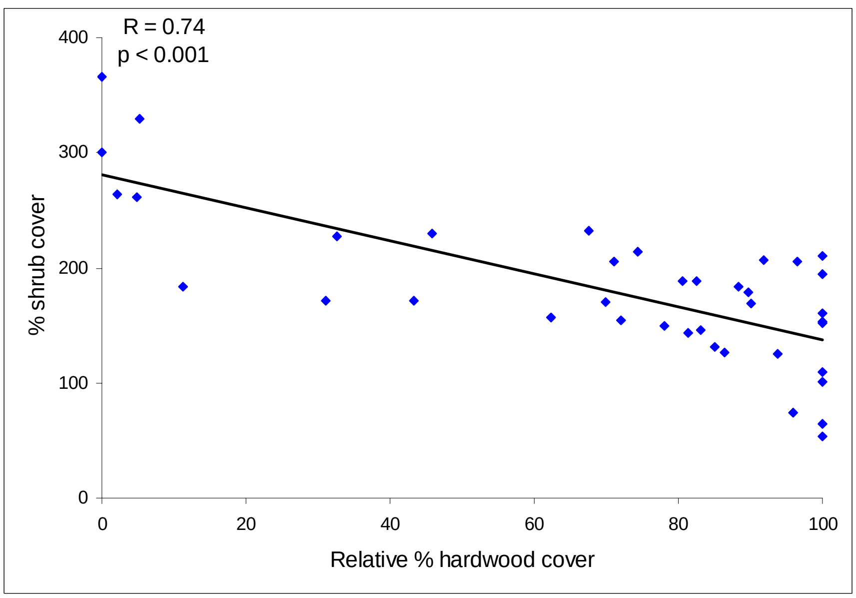

Figure 6. Relationship between relative percentage of hardwood cover in the canopy and percent shrub cover, with linear regression.

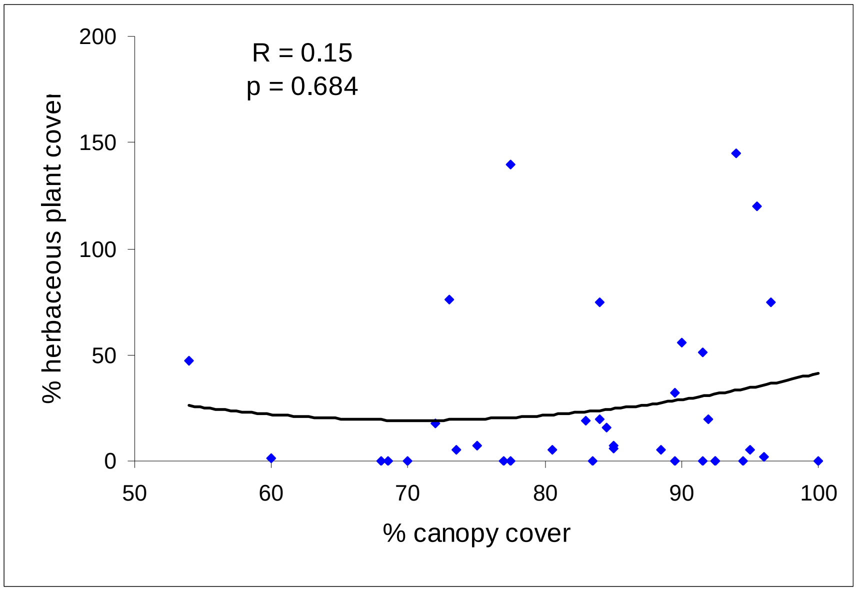

Figure 7. Relationship between percent canopy cover and percent herbaceous plant cover, with polynomial regression.

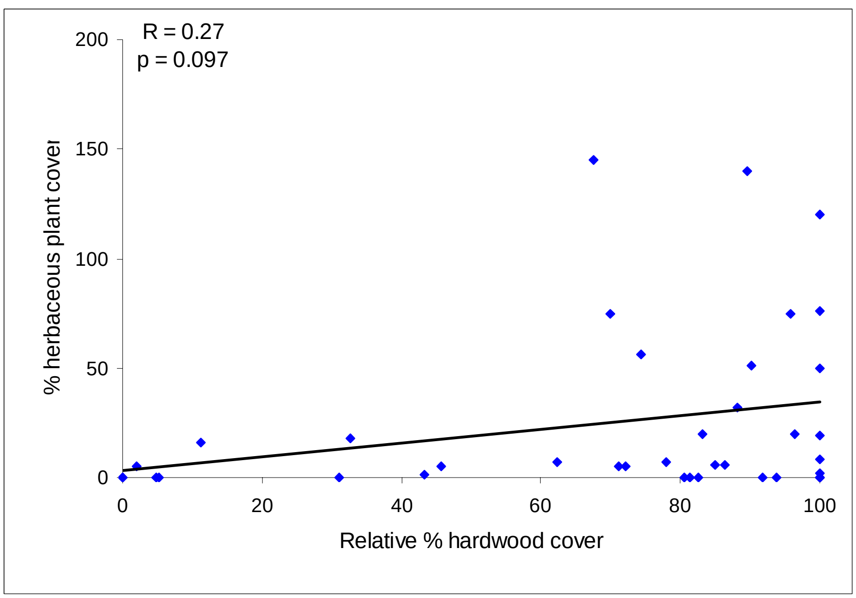

Figure 8. Relationship between relative percentage of hardwood cover in the canopy and percent herbaceous plant cover, with linear regression.

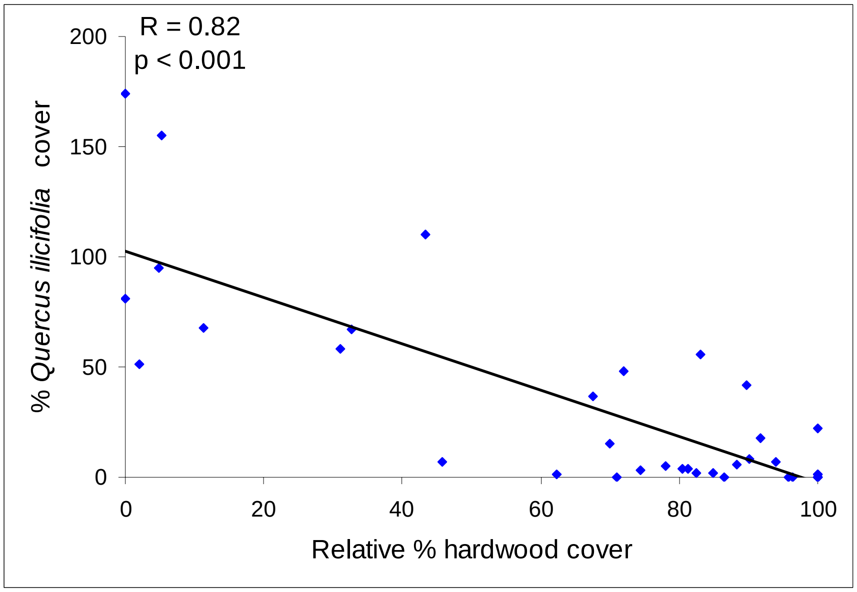

Figure 9. Relationship between relative percentage of hardwood cover in the canopy and percent *Quercus ilicifolia* cover.