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Shawnee National Forest Vegetation Plot Analysis

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Final Report

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Executive Summary

Prescribed burns were conducted in 2675 acres (12 individual burn units) in the Hidden Springs and Vienna Ranger District of the Shawnee National Forest in southern Illinois. The prescribed burning program was conducted with the goal of improving wildlife habitat and timber stand condition. Stand condition was monitored from 2004 through 2009 (2013 in two sites) to assess the success in reducing the abundance of undesirable shade tolerant mesic species and increase regeneration of desirable shade intolerant taxa. The results of analyzing data from the monitoring program are reported here from 13 of 23 permanent monitoring plots. Over the first five years of this program the stands are generally increasing in basal area and decreasing in tree density as expected through normal stand maturation. There are indications that the prescribed burning program has been successful in some sites through a reduction in maples and an increase in oaks and hickories, an increase in the herb and shrub layer species richness, and a decrease in the exotic Japanese honeysuckle. The success of prescribed burning as a management tool is site-specific, varying across the landscape, and likely reflecting historical contingency. Continued monitoring of these sites is necessary; analysis of data from additional permanent plots is recommended as is improved intensity of the prescribed burns to enhance efficacy of the management treatment.

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a) to avoid overlap. Arrows show direction of vectors (Table 3, $P<0.1$) fitted to the ordination solution (Table 4).

Introduction

Prescribed burning is widely accepted as a desirable management tool to promote the regeneration of hardwood forest in the eastern deciduous forest. However, site level assessment of pre- and post-burn forest conditions is currently lacking for much of the Shawnee National Forest, IL. Between 2004 and 2013 staff at the Shawnee National Forest, Illinois conducted a number of controlled, prescribed burns in 2675 acres (12 individual burn units) in the Hidden Springs and Vienna Ranger District of the Shawnee National Forest in southern Illinois. The prescribed burning program was conducted with the goal of improving wildlife habitat and timber stand condition through reduction of the understory component of shade tolerant trees (maple, elm), and to increase regeneration of shade intolerant species (oaks, hickories) (Seefeldt 2004, 2006).

A permanent monitoring plot was established at each of 23 sites to represent a variety of habitat types in pine forest and oak-hickory forest. Prescribed burning occurred from September 30 – April 1. A visual assessment of the percent of the plot burned during a prescribed burn was recorded by an observer. Pre-burn and post-burn data on the tree and herbaceous layers were collected to document and monitor changes in response to the burning regime. Analyses of the data from 13 of these plots are summarized in this report. With the analysis of these data, and with future data taken from these plots, the Shawnee National Forest can better decide if the management implemented is attaining the desired project goals. Interpretations drawn from this analysis can help in the establishment of land management strategies.

Methods

Summary data for each of 13 sampled plots from Teal Pond (6 plots), Ramsey (2 plots), Bear Branch (2 plots), Big Boaz, Ashby Pine, and Cedar Grove are presented in Table 1. In each plot, woody plant density including live and dead tree basal area were recorded in a 0.025 ha circular quadrat. Trees were defined as woody individuals with a ≥ 2.5 cm basal area at breast height (~1.3 m). Saplings were defined as woody individuals with basal area < 2.5 cm. The herbaceous layer was monitored by recording the number of stems of shrubs, vines, forbs, ferns, and graminoids in each plot. Nomenclature is according to USDA (2014). Data were collected most, but not all years, from 2004 through 2013.

Data are summarized graphically per plot in terms of performance metrics of tree basal area, and stem density and species richness per strata (tree layer and herbaceous layer) per sample date. The change in relative density per plot of the three most abundant (dominant) taxa is also summarized.

A chi-square analysis was conducted to quantify whether or not performance metrics increased, decreased, or did not change comparing paired pre- and post-burn surveys. Prescribed burns where less than 50% of the plot was burned (Table 1) were excluded from this analysis. Chi-square analyses assumed that the expected frequency of an increase, decrease, or no-change was equal (i.e., 33.3 %). Where there were zero no-change observations for a metric, then the expected frequency of an increase or decrease was 50%.

A landscape perspective of variation in species composition among the 13 plots was conducted using Non-Metric Dimensional Scaling (NMDS) ordination analysis using the vegan package in R (Version 2.0-10: Oksanen et al 2013). This analysis focused upon the density of sapling species in each plot for each year of monitoring (n = 71 plot records) as this strata represents the 'future' composition of the overstory. Seven of the 52 sapling taxa occurred only once and were excluded from the analysis (i.e., *Eleagnus umbellata*, *Fagus grandifolia, Gleditsia triacanthos, Quercus* X *bushi, Quercus* sp., and an unidentified sapling species). NMDS was run on Bray-Curtis dissimilarities following recommendations in Minchin (1987) to ensure a global rather than a local solution. The relationship of species to the resulting ordination solution was determined by computing species weighted averages. The relationship of independent variables to the ordination solution that was retained for interpretation was investigated by fitting vectors of correlation (function envfit in vegan). Fitted variables were the percentage of a plot burned in the prescribed burn immediately preceding an observation (Table 1), the year of sampling, tree, sapling and shrub and herb species richness and density in a plot, tree basal area per plot. Analysis of similarities (ANOSIM: Clarke 1993) was used to test for significant differences among groups of plots characterized by plot number (1 to 13), topographic position (upland, midslope, or floodplain), or dominant tree type (Pines or mixed hardwood). Function anosim in vegan was used running 99,999 permutations to test the significance of the resulting ANOSIM test statistic.

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Table 1. Summary of plots.

Name	Plot Number	Topographic map location	GPS coordinates	Aspect	Burn date / extent (%)	Dominant tree taxa in 2004
Teal Pond Pine Upland	1	Stonefort, SW 1/4 SW 1/4 Sec 15 T11S R5E	N4158022.738 E354085.221	-	Jan 19, 2005 / 100%, Nov 27, 2006 / 100%, and Mar 17, 2009 / 100%	*Pinus echinata, Quercus coccinea/rubra*
Teal Pond Upland	2	Stonefort, SW 1/4 SW 1/4 Sec 15 T11S R5E	N4157785.04 E354048.15	SSE	Mar 19, 2005 / 95%, Nov 27, 2006 / 75%, Mar 17, 2009 / 100%	*Carya glabra/ovata, Quercus stellata.*

Teal Pond Hardwood Floodplain	3	Stonefort, NW 1/4 Sec 22 T11S R5E	N4157376.41 E354085.55	Slight south to flat	Mar 19, 2005 / 70%, Nov 27, 2006 / 100%, Mar 17, 2009 / 100%	*Acer saccharum*
Teal Pond Hardwood Midslope	4	Stonefort, NW 1/4 NW 1/4 Sec 22 T11S R5E	N4157648.85 E354087.55	East	Mar 19, 2005 / 100%, Nov 27, 2006 / 100%, Mar 17, 2009 / 100%	*Carya glabra/ ovata, Quercus alba*
Teal Pond Pine Floodplain	5	Stonefort, NW 1/4 SW 1/4 Sec 22 T11S R5E	N4157648.85 E354087.55	Flat to slight South	Nov 27, 2006 / 10%, Mar 17, 2009 / 50%	*Pinus echinata, Ostrya virginiana, Acer saccharum*

Teal Pond Pine Midslope	6	Stonefort, NE 1/4 NE 1/4 Sec 21 T11S R5E	N4157637.32 E353815.23	West-Southwest		*Pinus echinata, Carya glabra/ovata, Prunus serotina*
Ramsey Pine Upland	7	Eddyville, NE 1/4 SW 1/4 Sec 5 T12S R6E	N4151615.02 E360873.01	Flat	Nov 8, 2004 / 100%, Feb 26, 2006 / 100%, prior to Sept. 2007 / ?, prior to Aug 2009 / ?, prior to Sept. 2013 / ?	*Pinus echinata, Liriodendron tulipifera, Ulmus sp.*

Ramsey Hardwood Upland	8	Waltersburg, SE 1/4 SW 1/4 Sec 5 T12S R6E	N4151364.47 E361052.31	Flat to slightly south	Nov 8, 2004 / 0%, Feb 27, 2006 / 0%, Apr 13, 2006 / 25%, prior to Sept. 2009	*Ulmus alata*, *Nyssa sylvatica*, *Carya ovata*
Bear Branch Pine	9	Eddyville, SE ¼ NE ¼ Sec 31T11S R6E	N4153908.77 E360194.63	Slope – west	March 6, 2007 / 40%	*Pinus echinata*, *Cornus florida*, *Quercus velutina*
Bear Branch Hardwood	10	Eddyville, SE 1/4 NE 1/4 Sec 31 T11S R6E	N4153790.28 E360333.15	Northwest	March 6, 2007 / 5%	*Carya ovata/glabra*, *Cornus florida*, *Quercus velutina*

Big Boaz Hardwood Upland	11	Glendale, SE1/4 NW1/4 Sec 27 T12S R5E	N4145816.71 E354335.85	-	March 12, 2007 / 100%	*Acer saccharum, Carya glabra/ovata, Quercus alba*
Ashby Pine Upland	12	Waltersburg, W1/2 NW1/4 Sec 36 T12S R5E	N4144309.53 E357036.81	-	April 5, 2006 / 80%	*Pinus echinata, Fraxinus americana, Liquidambar styraciflua*
Cedar Grove Pine Upland	13	Glendale, NW1/4 NE1/4 Sec 16 T12S R5E	N 43 28' 44.9" W 088 39' 44.7"	Slight south	March 9, 2007 / 80%	*Pinus echinata, Cornus florida*

Results

Teal Pond Plot 1

Richness in the tree layer decreased along with density while total basal area increased from 2004 – 2009 consistent with stand filling (Fig. 1). Shortleaf pine (*Pinus echinata*) was the dominant tree with basal area increasing. Subdominant winged elm (*Ulmus alata*) and dogwood (*Cornus florida*) showed no change in basal area (Fig. 1d). While there was an overall decrease in stand tree density, the steepest declines in density occurred following prescribed burns (Fig. 1b). There were steep increases in total basal area following the first two of the three prescribed burns (Fig. 1c).

Following burns, shrub and herbaceous layer richness and density did not follow clear increasing or decreasing trends. In 2009, following a burn, relative density of *Sassafras albidum* saplings drastically decreased, while relative density of *Ulmus alata* saplings increased (Fig 2c)

Figure 1. Summary statistics for trees at Teal Pond Plot 1, a) richness, b) density, c) basal area, and d) basal area of the most abundant dominant tree species. Vertical dotted lines indicate prescribed burns.

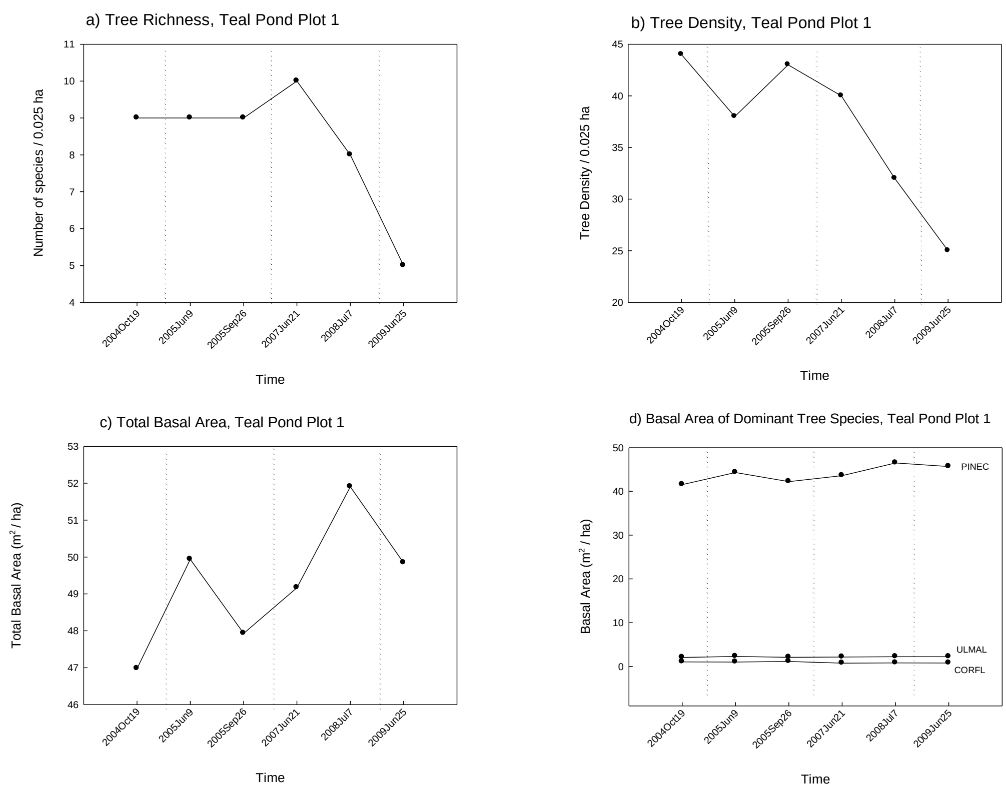
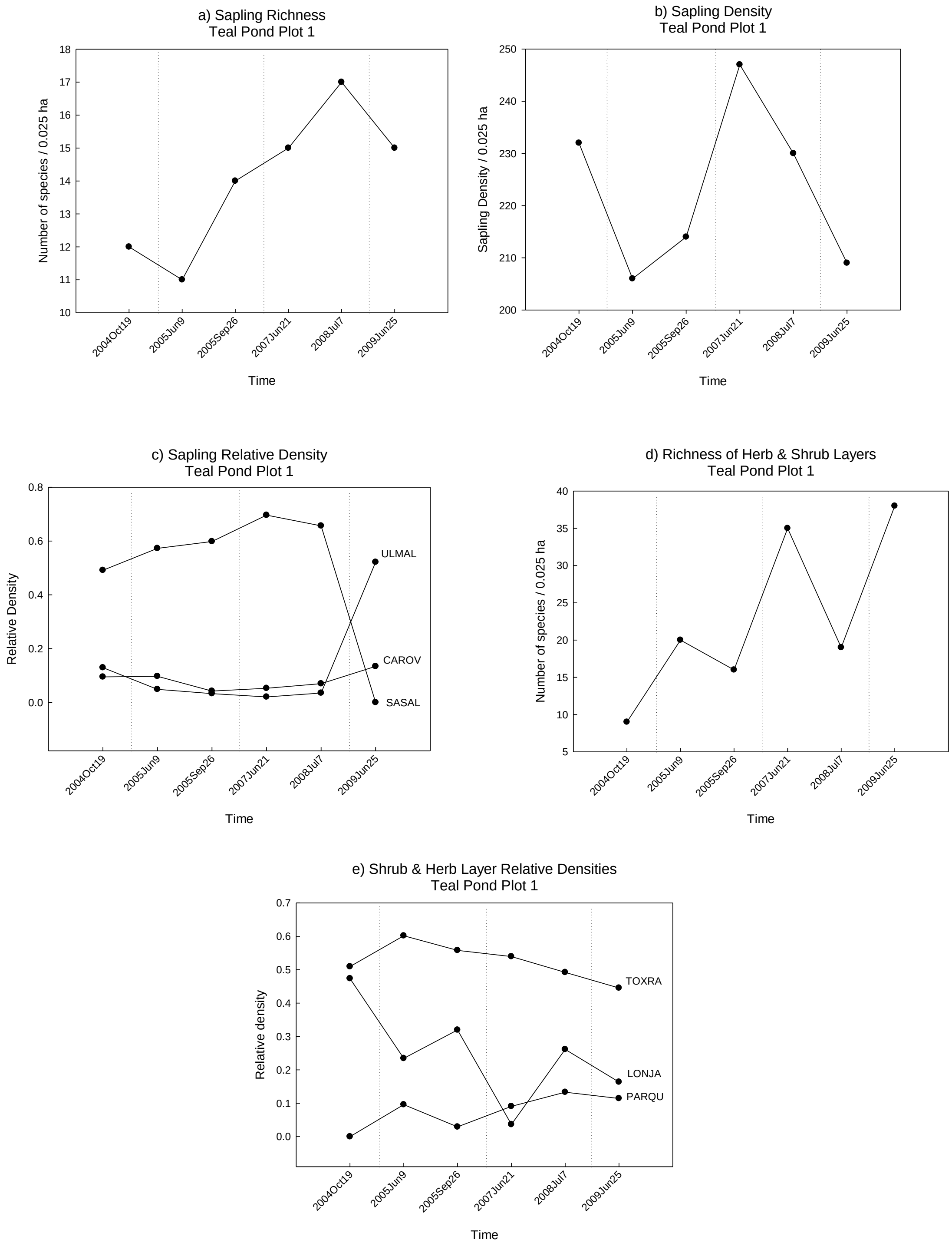


Figure 2. Summary statistics for the sapling and herbaceous layer at Teal Pond, plot 1. a) sapling richness, b) sapling density, c) relative density of three most abundant sapling species, d) herb and shrub layer richness, and e) relative density of the three most abundant herb and shrub layer species.



Teal Pond Plot 2

Tree richness and tree density declined through time while total basal area per hectare increased, especially after burns. Basal area of dominant tree species *Q. stellata* increased through time, the basal area of the dominant species *J. virginiana* remained constant, while the basal area of *C. ovata* initially decreased after 2004, but then began increasing in 2007 (Fig. 3).

Sapling density increased after burns, as did the richness of the shrub and herbaceous layers (Fig. 4a & b). Relative density of dominant sapling species fluctuated through time with no clear patterns (Fig. 4c). The richness of shrub and herbaceous layers increased most steeply in years following a burn (Fig. 4d). Relative density of dominant shrub/herbaceous species *Dichanthelium dichotomum* and *Carex* sp. increased through time, while the relative density of other dominant herbaceous species, *Danthonia spicata* and *Cunila origanoides* initially decreased, but began to increase in later years (Fig. 4e).

Figure 3. Summary statistics for trees at Teal Pond Plot 2, a) richness, b) density, c) basal area, and d) basal area of the most abundant dominant tree species. Vertical dotted lines indicate prescribed burns.

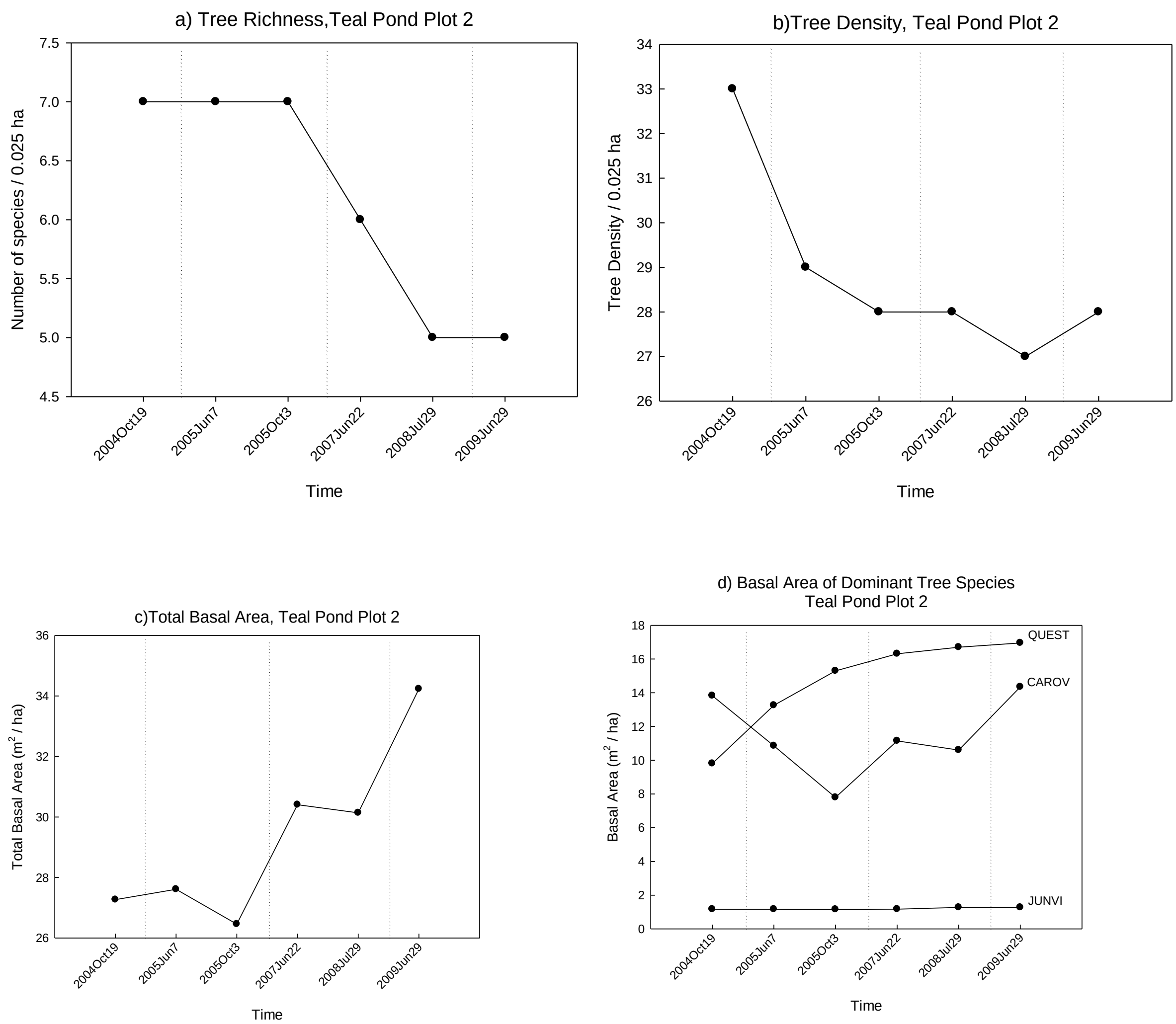
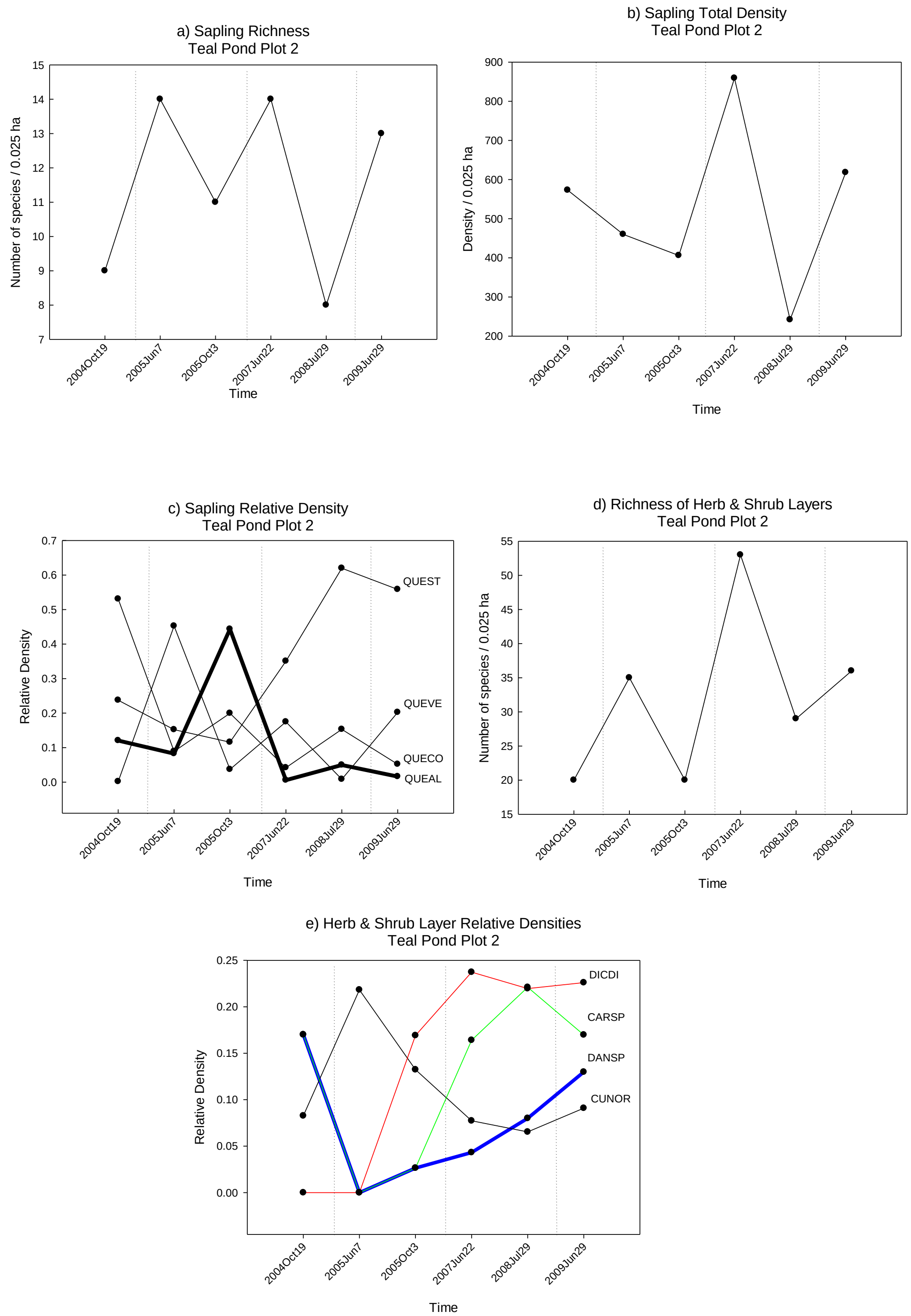


Figure 4. Summary statistics for the sapling and herbaceous layer at Teal Pond, plot 2. a) sapling richness, b) sapling density, c) relative density of three most abundant sapling species, d) herb and shrub layer richness, and e) relative density of the three most abundant herb and shrub layer species.



Teal Pond Plot 3

Tree richness remained constant through time (Fig. 5a), while tree density decreased steeply after a burn in 2005, but increased steeply again by 2008 (Fig. 5b). Total basal area and basal area of the dominant tree species (*Acer saccharum*) increased to 2005 and decreased to 2009 (Fig. 5c & d).

Both sapling richness and sapling density tended to increase after burns (Fig. 6a & b). Relative density of *Carya ovata* saplings decreased over time and especially in burn years. Relative density of *Quercus alba* saplings tended to increase after burns, while the relative density of *Ulmus rubra* remained mostly constant (Fig. 6c). Shrub and herb layer richness also increased after burns (Fig. 6d).

Figure 5. Summary statistics for trees at Teal Pond Plot 3, a) richness, b) density, c) basal area, and d) basal area of the most abundant dominant tree species. Vertical dotted lines indicate prescribed burns.

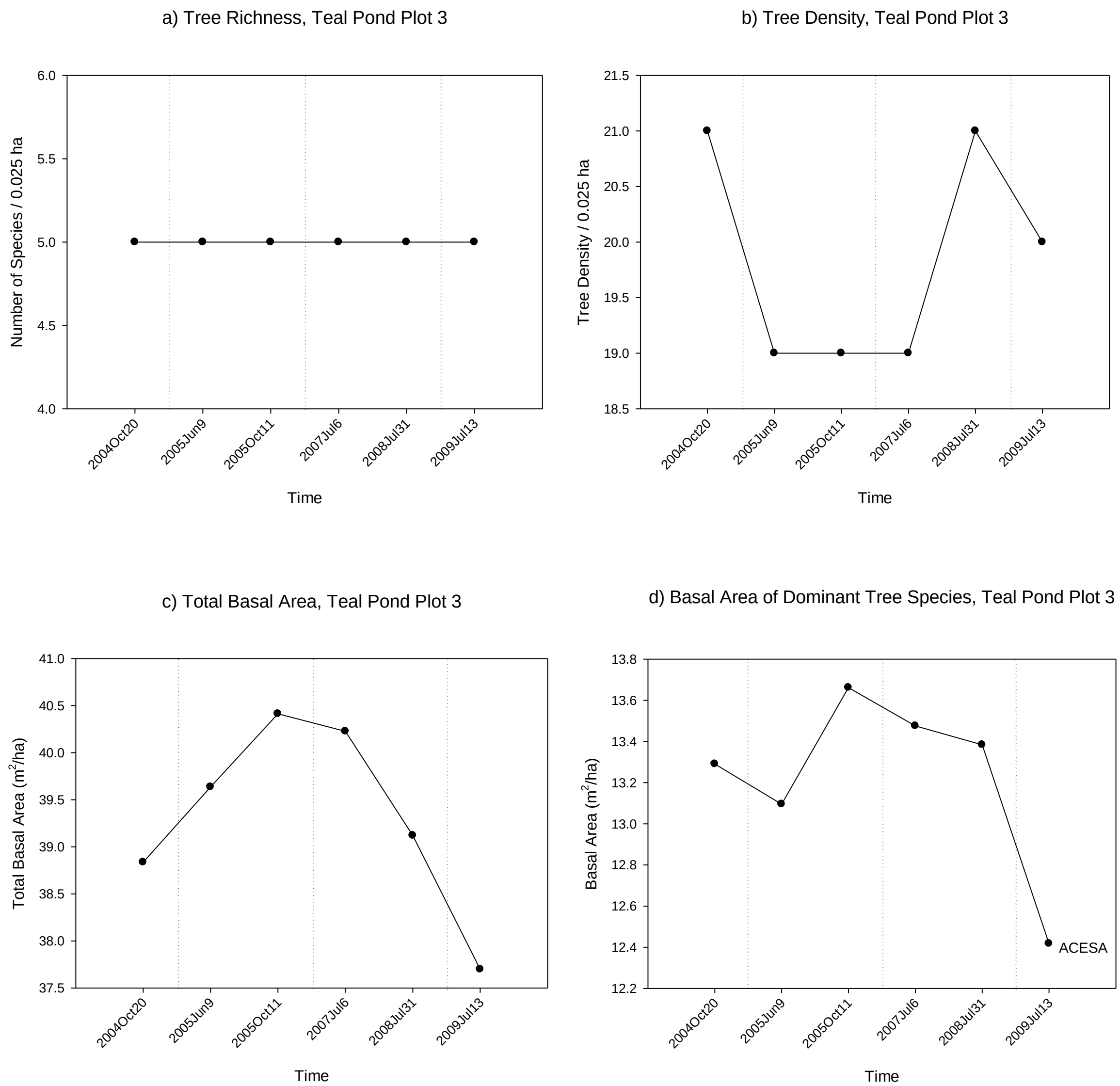
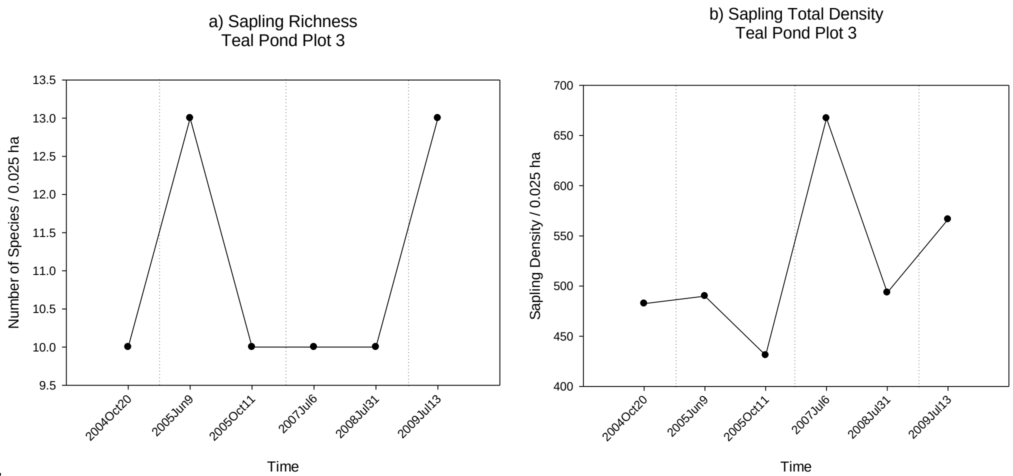
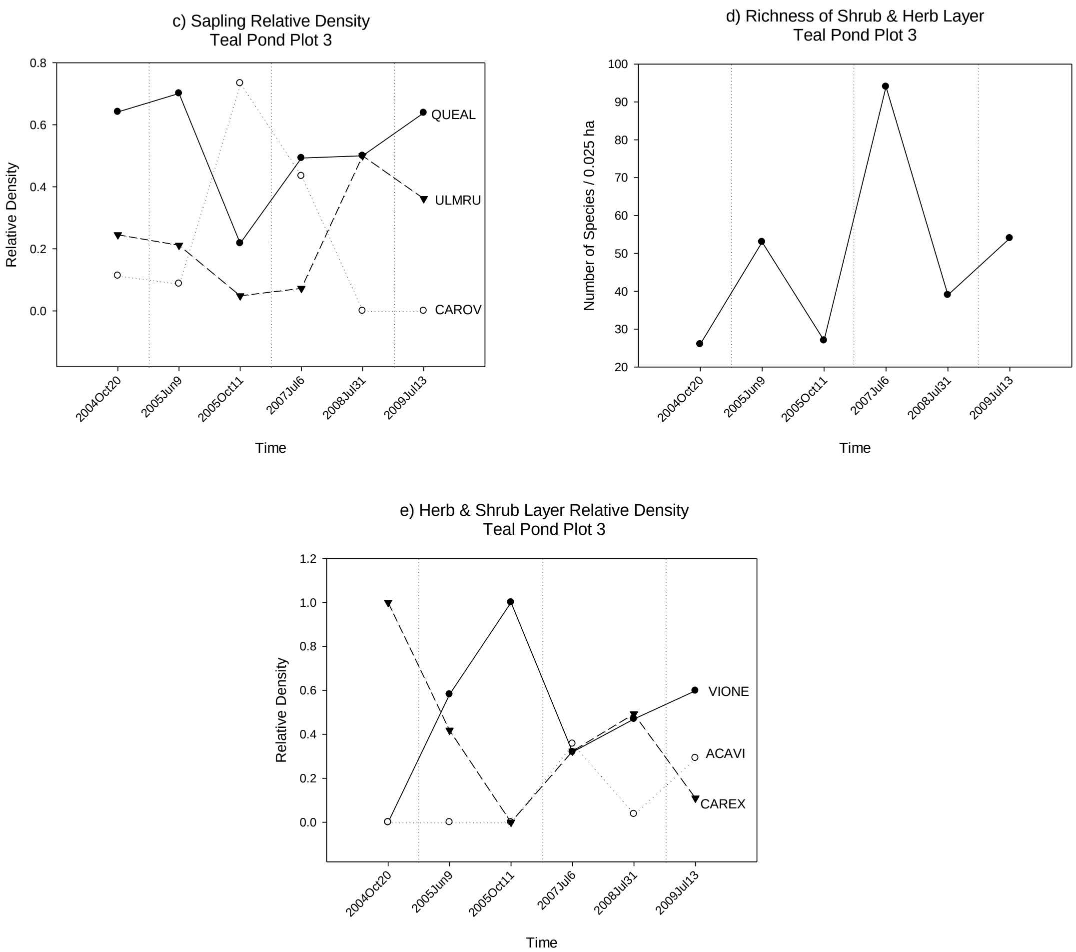


Figure 6: Summary statistics for the sapling and herbaceous layer at Teal Pond, plot 3. a) sapling richness, b) sapling density, c) relative density of three most abundant sapling species, d) herb and shrub layer richness, and e) relative density of the three most abundant herb and shrub layer.



species.



Teal Pond Plot 4

Tree richness and tree density generally decreased through time, except in 2007, when they increased after burning (Fig. 7a & b). Total basal area of all tree species decreased after the first burn in 2005, but increased in all years after. Basal area of dominant tree species (*Quercus alba*, *Carya* spp.) remained constant through time (Fig. 7).

Sapling richness followed no clear patterns after burns, while sapling density tended to increase after burns. Following the initial burn, there was decreased dominance of *Quercus coccinea* saplings and increased dominance of *Sassafras albidum* saplings. In the shrub and herbaceous layers, richness increased after burns. Density of *Toxicodendron radicans* generally decreased following burns (Fig. 8).

Figure 7. Summary statistics for trees at Teal Pond Plot 4, a) richness, b) density, c) basal area, and d) basal area of the most abundant dominant tree species. Vertical dotted lines indicate prescribed burns.

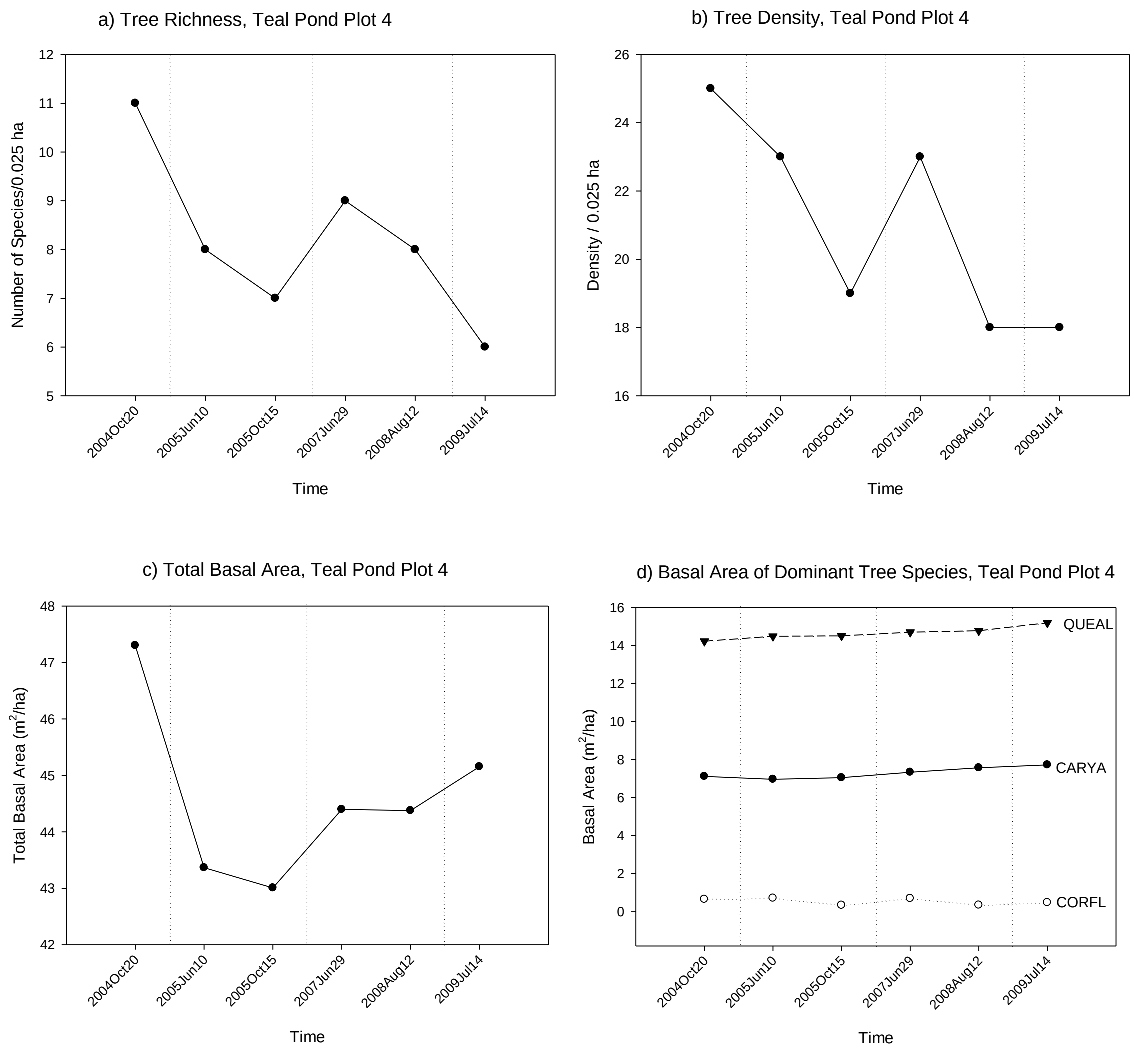
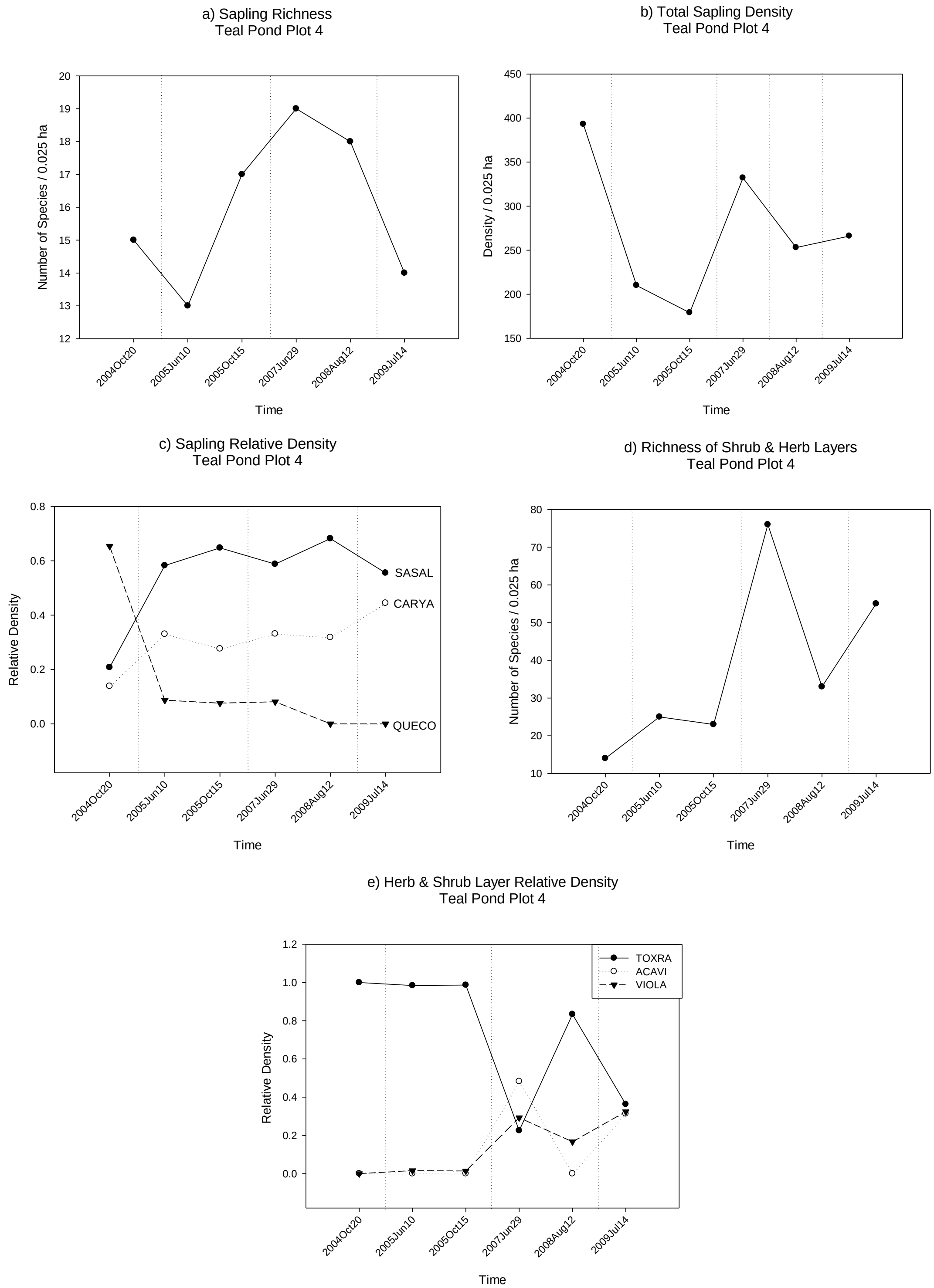


Figure 8: Summary statistics for the sapling and herbaceous layer at Teal Pond, plot 4. a) sapling richness, b) sapling density, c) relative density of three most abundant sapling species, d) herb and shrub layer richness, and e) relative density of the three most abundant herb and shrub layer species.



Teal Pond Plot 5

Tree richness increased through time while tree density decreased through time (Fig. 9a & b). Total basal area increased, especially after the first burn (2006) (Fig. 9c), while basal area of dominant tree species (*Pinus echinata*, *Acer saccharum*, and *Ostrya virginiana*) remained mostly constant through time (Fig. 9d).

Sapling richness and density were both highest in 2007 after a burn, but generally showed no other patterns. Shrub and herbaceous layer richness also increased in 2007 and again in 2009 after burns. Relative density of a dominant invasive shrub, *Lonicera japonica,* decreased over time (Fig. 10).

Figure 9. Summary statistics for trees at Teal Pond Plot 5, a) richness, b) density, c) basal area, and d) basal area of the most abundant dominant tree species. Vertical dotted lines indicate prescribed burns.

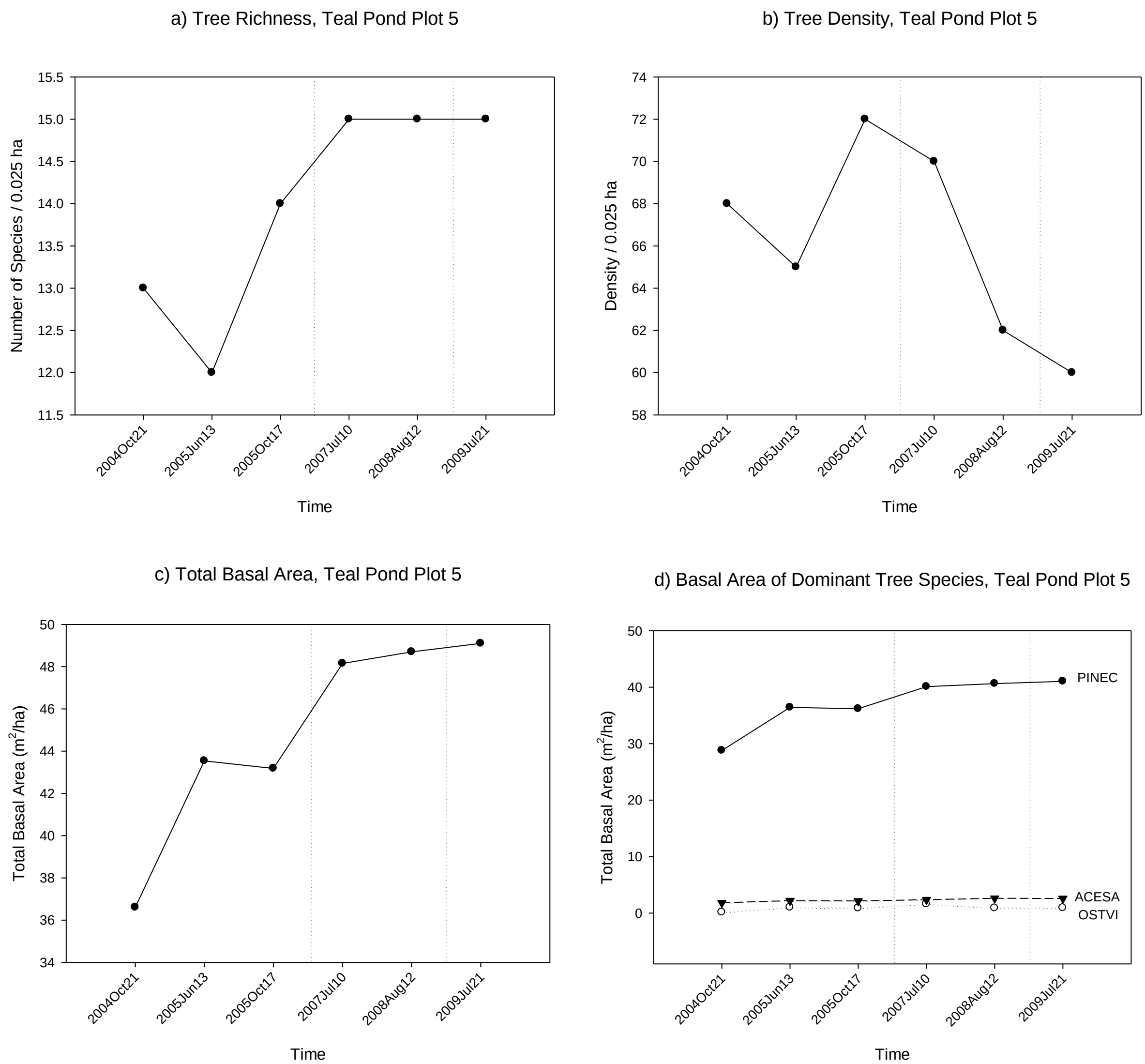
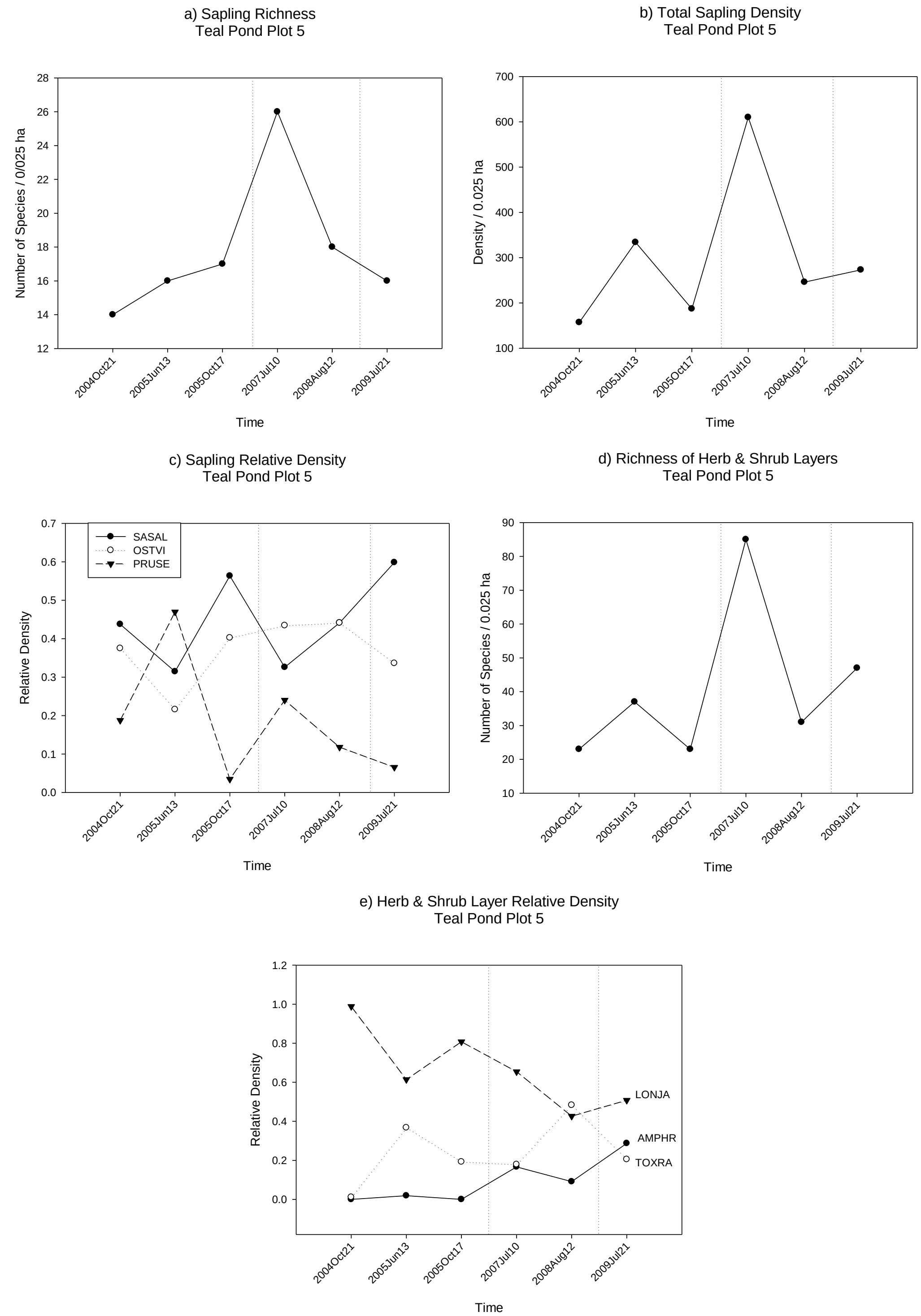


Figure 10. Summary statistics for the sapling and herbaceous layer at Teal Pond, plot 5. a) sapling richness, b) sapling density, c) relative density of three most abundant sapling species, d) herb and shrub layer richness, and e) relative density of the three most abundant herb and shrub layer species.



Teal Pond Plot 6

There was no overall change in tree richness from 2004 to 2009 (Fig 11a). Tree density declined sharply, however, from 2004 to 2009; the largest decrease in tree density occurred between 2007 and 2008 (Fig. 11b). Total basal area generally increased from 2007 to 2009, with a slight decline in 2005 (Fig. 11c). Basal area of the dominant species, *Pinus echinata*, increased slightly from 2004 to 2009, but the basal area of the other two dominant species, *Carya* sp. and *Prunus serotina*, remained constant (Fig. 11d).

Sapling richness sharply increased from 2005 to 2006, but began to decline again from 2008 to 2009 (Fig. 12a). Sapling density also drastically increased during this period (Fig. 12b). After the first burn in 2005, *Fraxinus virginiana* sapling density increased, while abundance of the other two dominant sapling species, *Ulmus sp.* and *Carya* sp., decreased. *Ulmus* sp. sapling density did however increase from 2008 to 2009 (Fig. 12c). Richness of the shrub and herb layers does not appear to follow any clear trend following a burn. It both increased and decreased from 2004 to 2009 (Fig. 12d). Relative density of the three dominant herb/shrub species, *Lonicera japonica*, *Smilax glauca*, and *Parthenocissus quinquefolia*, remained generally constant through the years, although it does appear that the first burn slightly reduced abundance of *L. japonica* (Fig. 12e).

Figure 11: Summary statistics for trees at Teal Pond Plot 6, a) richness, b) density, c) basal area, and d) basal area of the most abundant dominant tree species. Vertical dotted lines indicate prescribed burns.

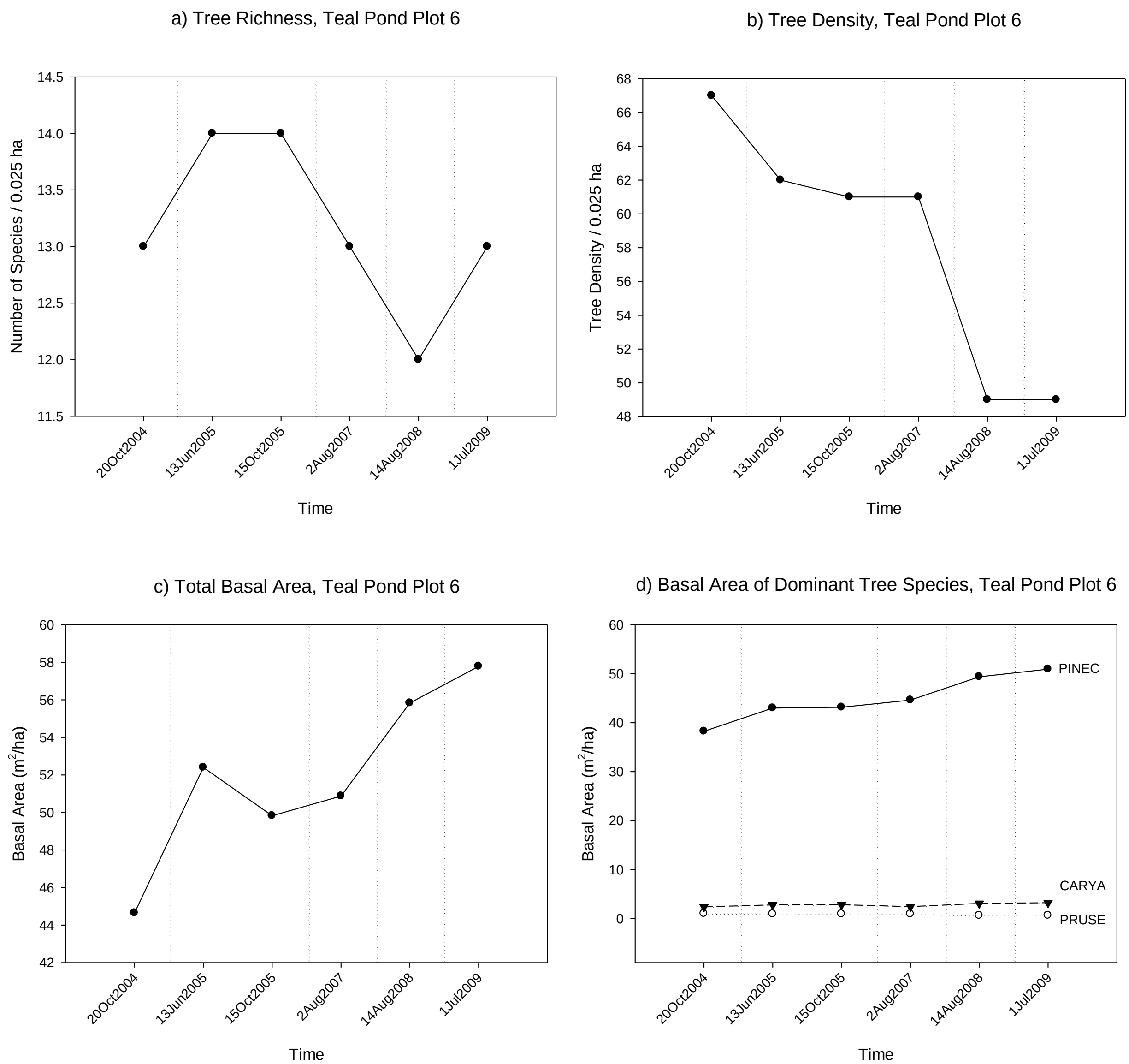
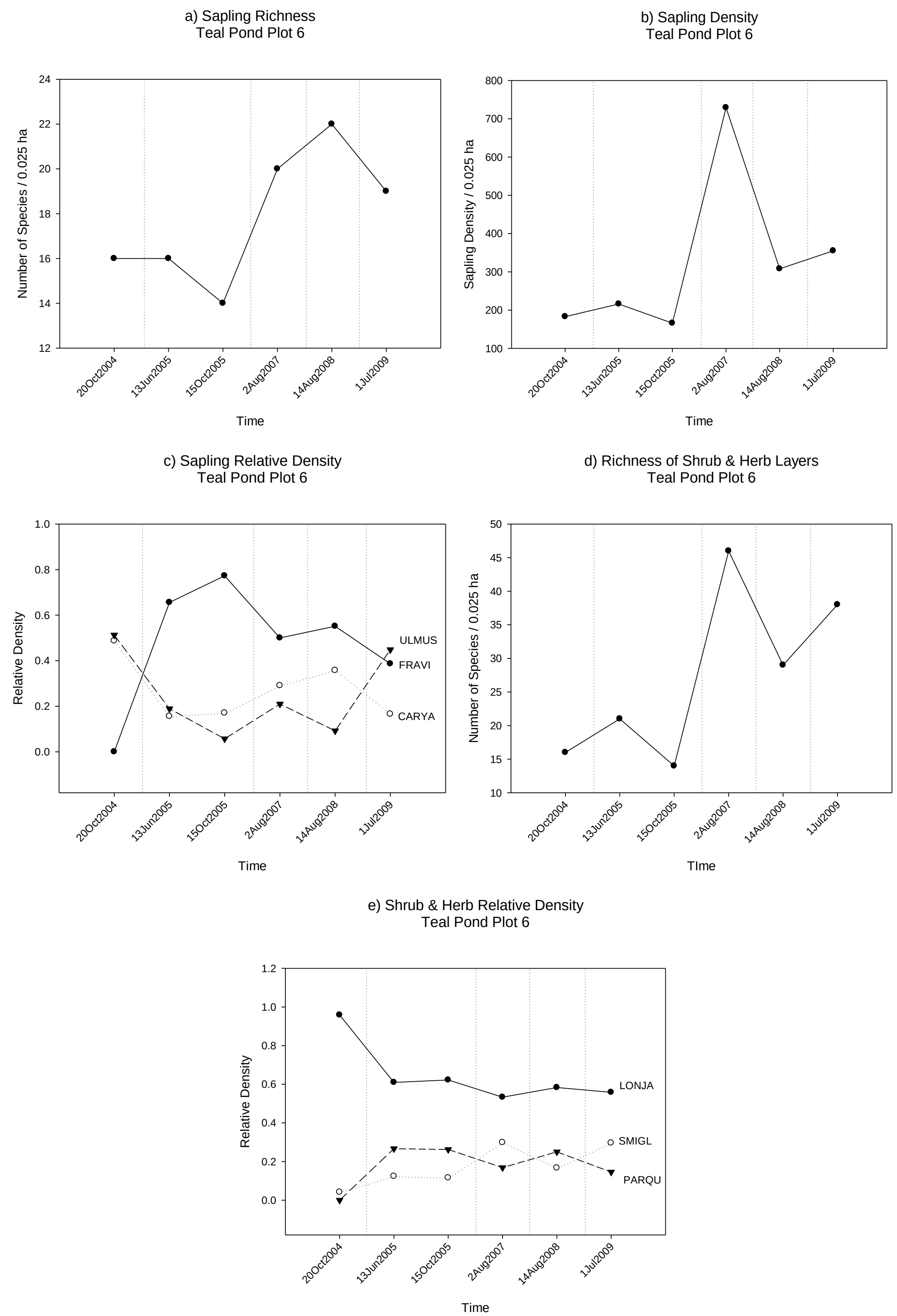


Figure 12: Summary statistics for the sapling and herbaceous layer at Teal Pond, plot 6. a) sapling richness, b) sapling density, c) relative density of three most abundant sapling species, d) herb and shrub layer richness, and e) relative density of the three most abundant herb and shrub layer species.



Ramsey Pine Plot 7

Tree richness and tree density generally declined from 2004 to 2013 (Fig. 13a & b). However, total basal area increased in all years from 2004 to 2014 (Fig. 13c). Basal area of dominant species *Liriodendron tulipifera* and *Ulmus* sp. generally remained constant, although basal area of *Pinus echinata* increased slightly each year (Fig. 13d).

Sapling richness varied drastically among the collection years with no discernible typical response to burning. Sapling richness was highest in 2005 and lowest in 2013 (Fig. 14a). Sapling density drastically increased from 2005 to 2006, but in 2007 it returned to the 2005 level (Fig. 14b). The relative density of the three dominant sapling species (*Fraxinus americana*, *L. tulipifera* and *P. echinata*) did show any particular response to fire, but when density of *F. americana* saplings was lowest (2006), density of the other two dominant species increased sharply (Fig. 14c). Richness of the shrub and herbaceous layers generally increased through time, with small decreases in some years (Fig. 14d). Relative density of dominant herbaceous and shrub species shows no patterns through time (Fig. 14e).

Figure 13: Summary statistics for trees at Ramsey Plot 7, a) richness, b) density, c) basal area, and d) basal area of the most abundant dominant tree species. Vertical dotted lines indicate prescribed burns.

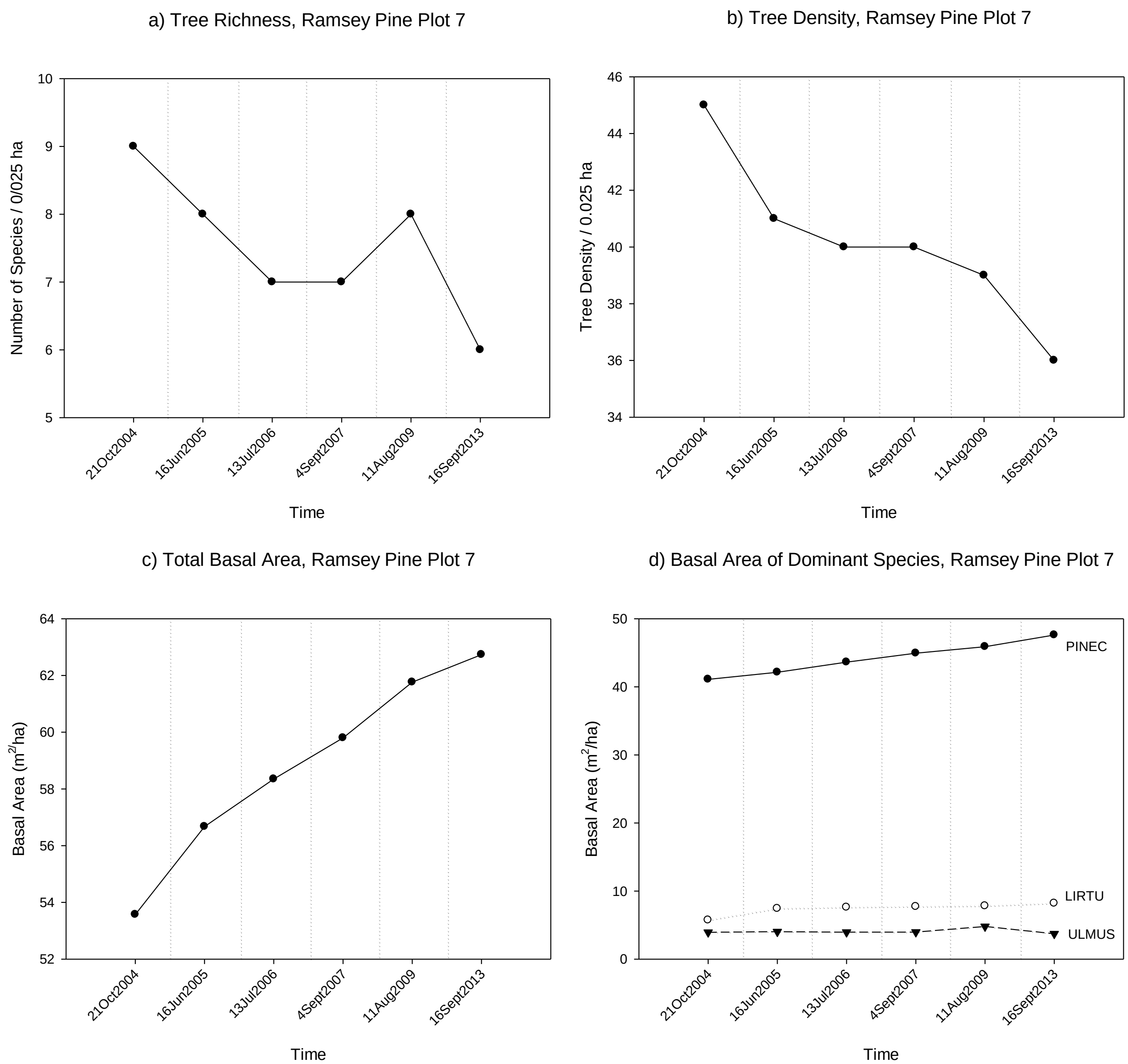
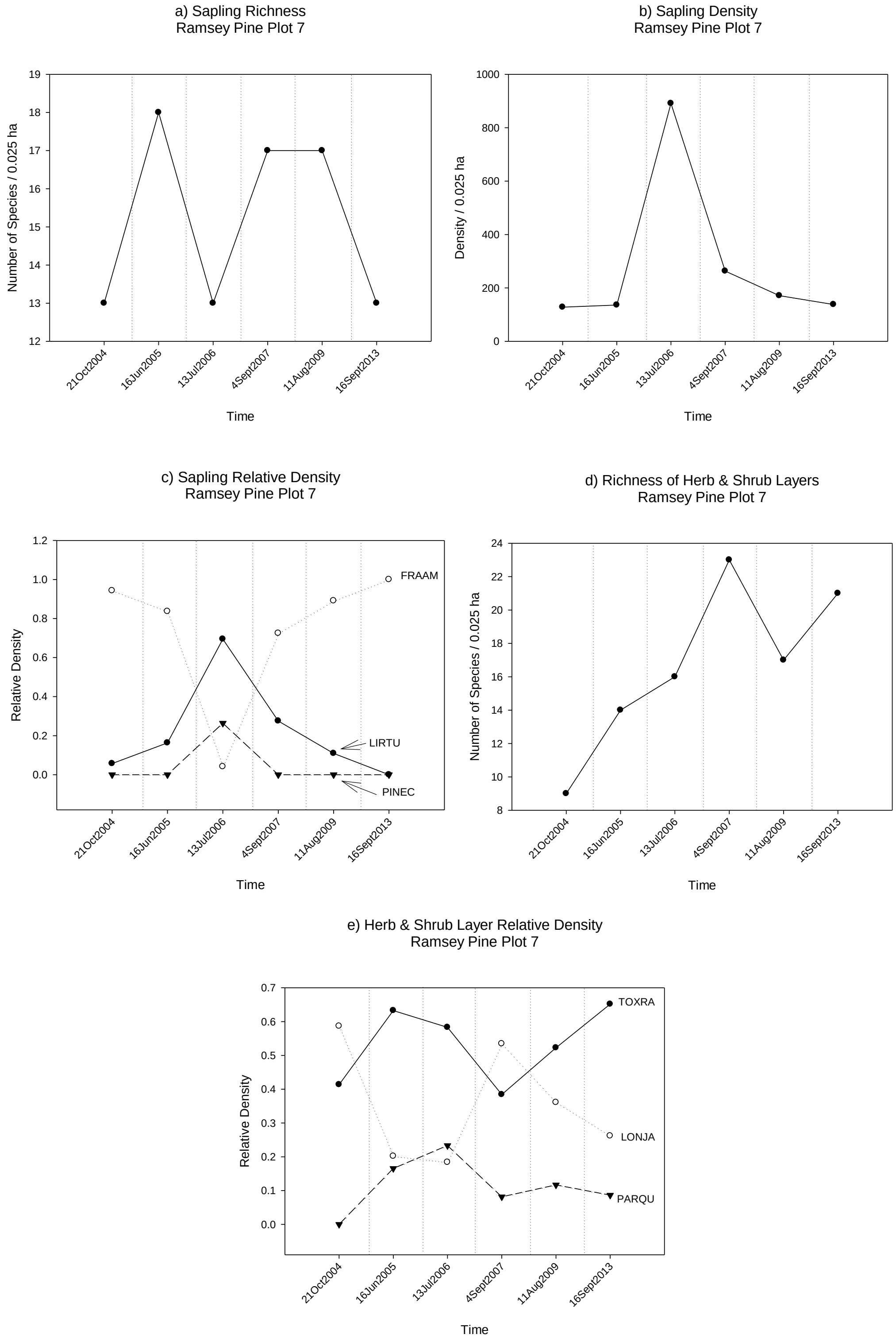


Figure 14: Summary statistics for the sapling and herbaceous layer at Ramsey, Plot 7. a) sapling richness, b) sapling density, c) relative density of three most abundant sapling species, d) herb and shrub layer richness, and e) relative density of the three most abundant herb and shrub layer species.



Ramsey Plot 8

Tree richness declined after the first burn but increased slightly from 2007 to 2009 (Fig. 15a). Tree density declined overall from 2005 to 2009, with a sharp decrease following the second burn (Fig. 15b). Total basal area was constant except for a sharp decrease in 2007; it increased to prior levels again in 2009 (Fig. 15c). Basal area of dominant species *Carya* sp. and *Ulmus alata* remained constant through time, but basal area of *Nyssa sylvatica* decreased slightly though time (Fig. 15d).

Sapling richness decreased after the first burn in 2005, but began increasing again in 2007 and 2009 (Fig. 16a). Sapling density increased from 2004 to 2006, decreased in 2007, and increased again in 2009 (Fig. 16b). Relative density of dominant sapling species showed no net change from 2004 to 2009, however, in 2006, when *Liriodendron tulipifera* density increased drastically, density of the other two dominant species, *Carya* sp. and *N. sylvatica*, decreased (Fig. 16c). Richness of the herbaceous and shrub layers increased steadily through time (Fig. 16d). There was generally no change in the dominant shrub/herbaceous species, but *L. japonica* did decrease slightly in abundance from 2004 to 2009 (Fig. 16e).

Figure 15: Summary statistics for trees at Ramsey Plot 8, a) richness, b) density, c) basal area, and d) basal area of the most abundant dominant tree species. Vertical dotted lines indicate prescribed burns.

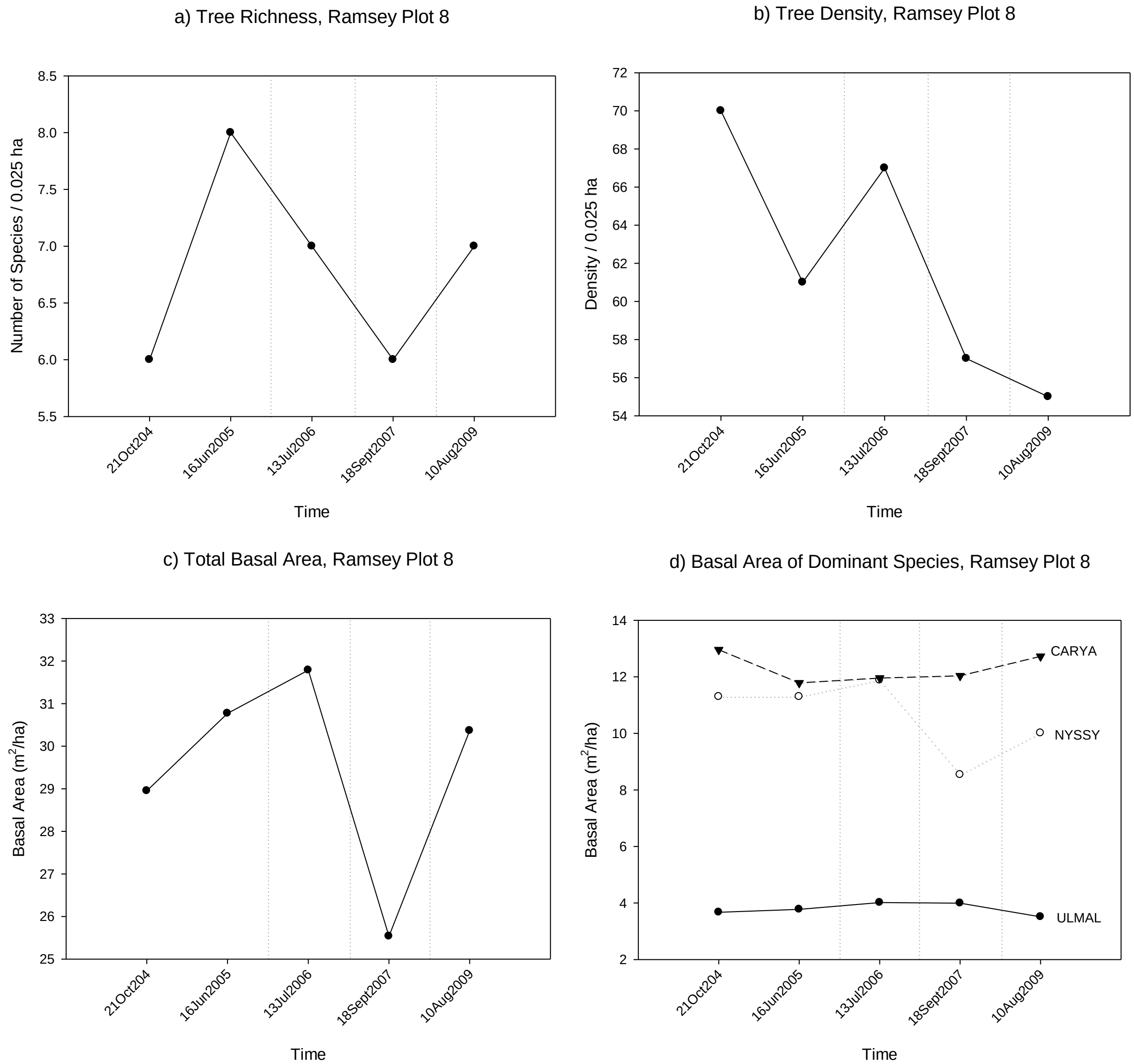
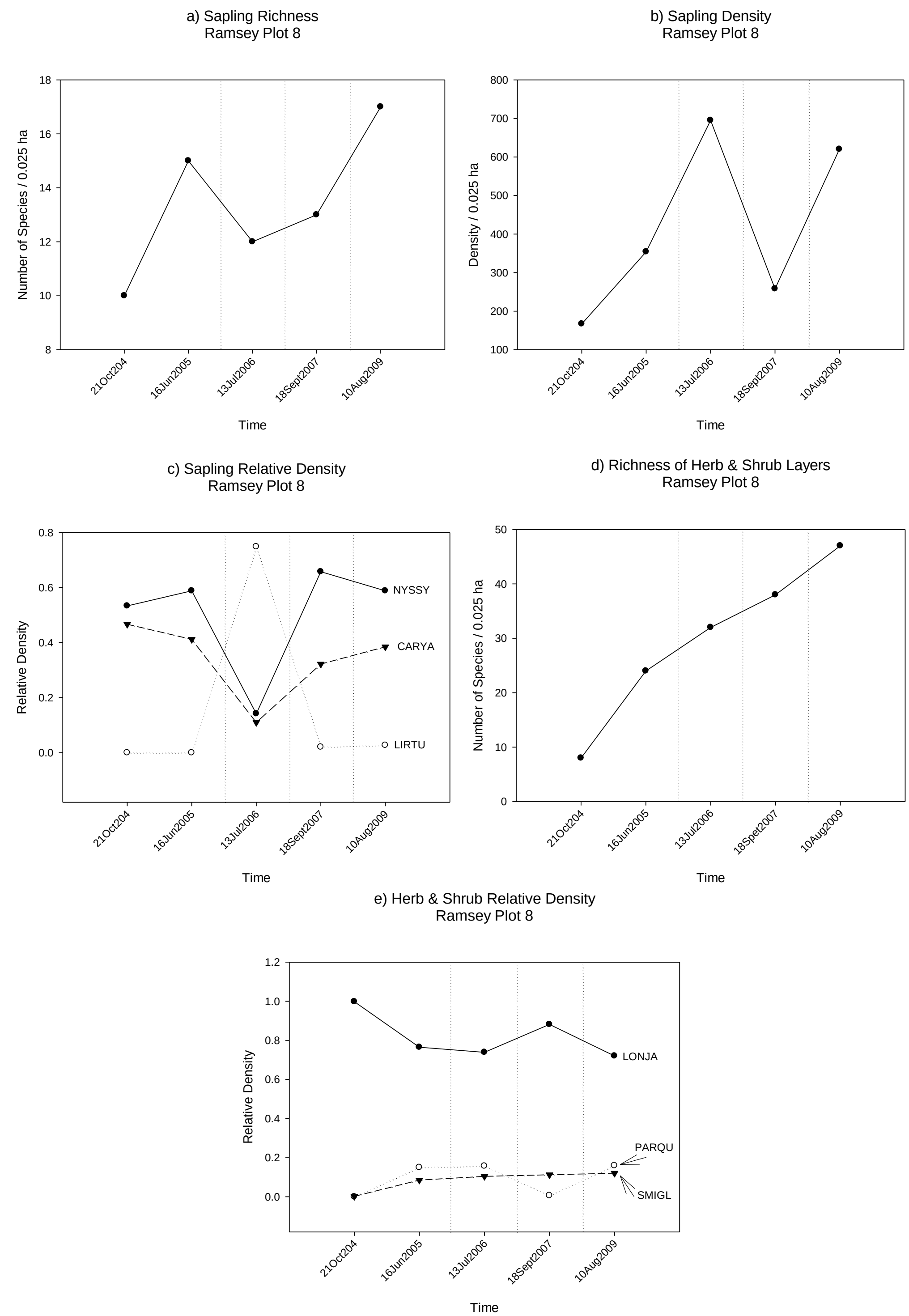


Figure 16: Summary statistics for the sapling and herbaceous layer at Ramsey Plot 8. a) sapling richness, b) sapling density, c) relative density of three most abundant sapling species, d) herb and shrub layer richness, and e) relative density of the three most abundant herb and shrub layer species.



Bear Branch Pine plot 9

Tree richness and density increased slightly following the early 2007 burn, but there after declined by 2009 to levels lower than the initial levels in 2004 (Fig 17a,b). Basal area decreased slightly following the burn as did basal area of the dominant species, *Pinus echinata* (Fig 17c,d). By 2008, basal area of the trees had increased sharply. Basal area of the other dominant trees, *Cornus florida,* and *Quercus velutina* remained relatively level from 2004 – 2009. Sapling richness, sapling density, and richness in the shrub and herb layer increased following the prescribed burn although the sapling richness and density decreased again thereafter (Fig 18a,b,d). The relative density of *Pinus echinata* saplings increased following the burn decreasing again later, while *Carya* spp. and *Quercus stellata* saplings decreased following the burn but increased again in later years seemingly at the expense of *Pinus echinata* saplings (Fig 18c). The relative density of the dominant forbs, *Lonicera japonica*, *Toxicodendron radicans* and *Smilax glauca* showed no apparent response to the prescribed burn (Fig 18e).

Figure 17: Summary statistics for trees at Bear Branch Pine plot 9, a) richness, b) density, c) basal area, and d) basal area of the most abundant dominant tree species. Vertical dotted lines indicate prescribed burns.

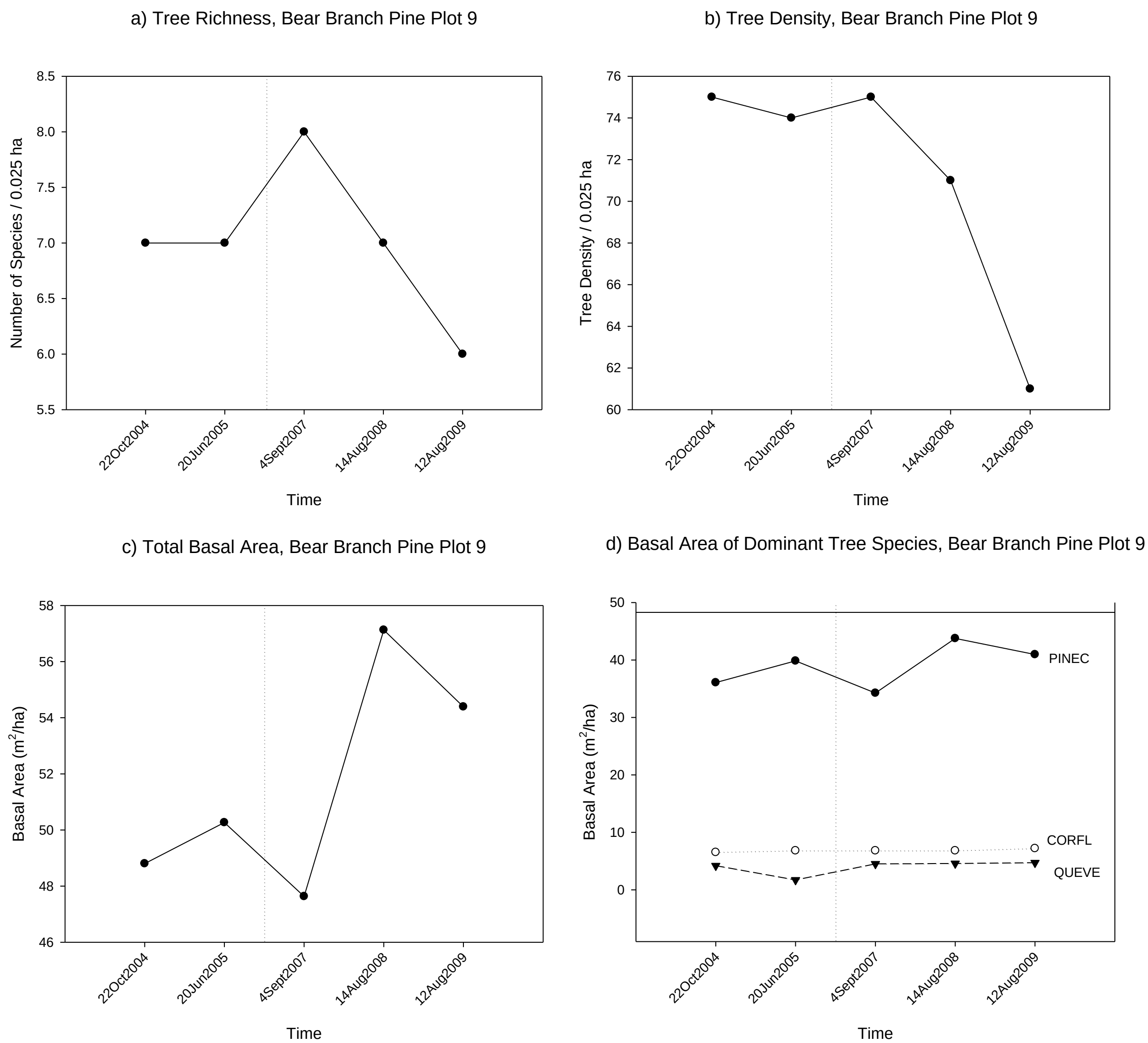
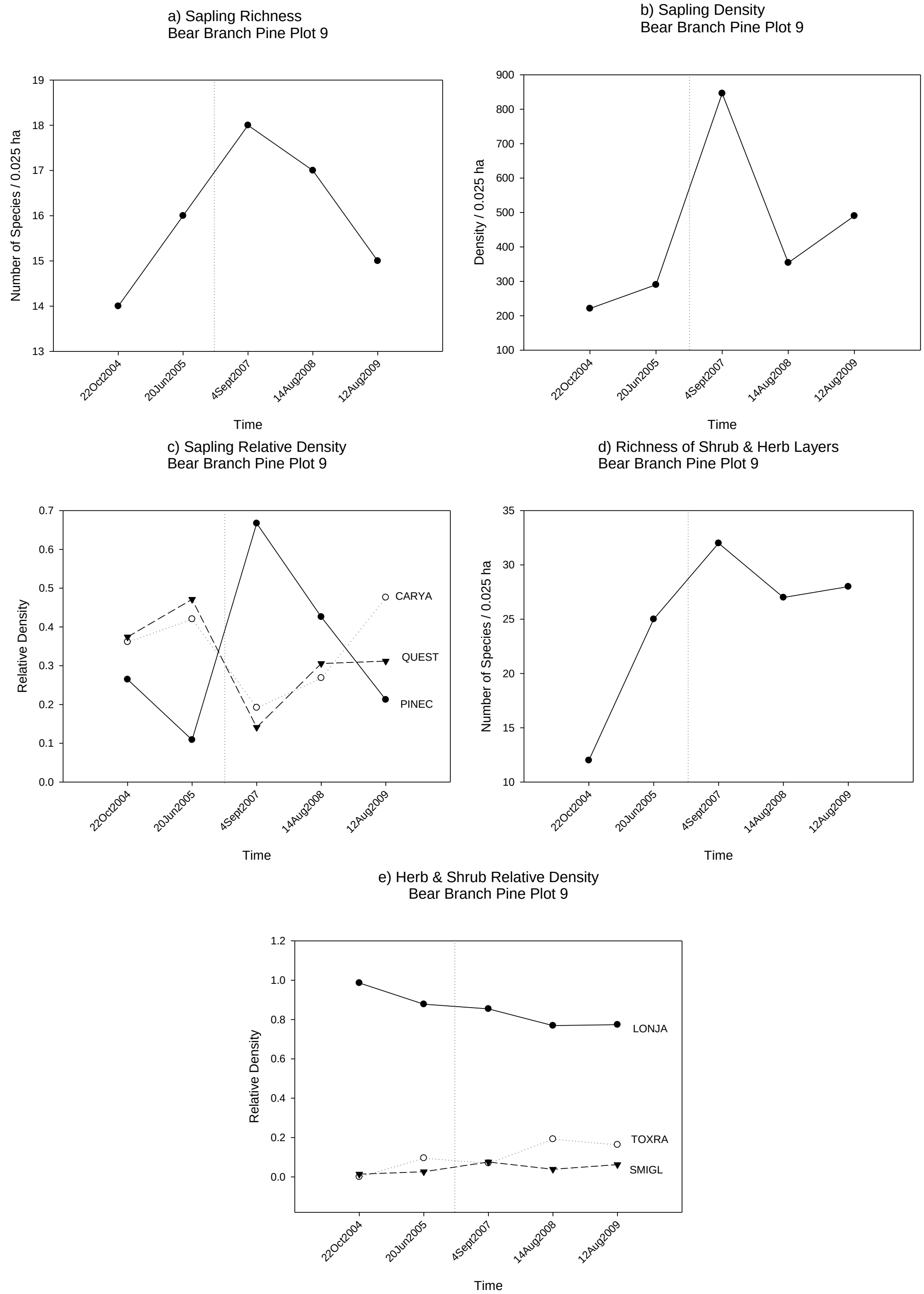


Figure 18: Summary statistics for the sapling and herbaceous layer at Bear Branch Pine plot 9. a) sapling richness, b) sapling density, c) relative density of three most abundant sapling species, d) herb and shrub layer richness, and e) relative density of the three most abundant herb and shrub layer species.



Bear Branch Hardwood plot 10

The March 6, 2007 prescribed burn affected only 5% of the area of this plot (Table 1) and so had questionable effect on the vegetation in this plot. Tree richness did not change from 2004 – 2009 (Fig 19a) while tree density was steadily declining as total basal area increased (Fig 19b, c). The relative abundance of the three dominant trees, *Carya glabra/ovata*, *Nyssa sylvatica*, and *Cornus florida* exhibited little change over this time period (Fig 19d). Sapling richness, sapling density, and richness of the herb and shrub layers increased following the burn, but, at least for the two richness metrics, this followed a preexisting trend (Fig 20a, b, d). Relative density of dominant species in the sapling and in the herb and shrub layer were relatively steady from 2004 – 2009 without any clear response to the prescribed burn (Fig 20c, e).

Figure 19: Summary statistics for trees at Bear Branch Hardwood plot 10, a) richness, b) density, c) basal area, and d) basal area of the most abundant dominant tree species. Vertical dotted lines indicate prescribed burns.

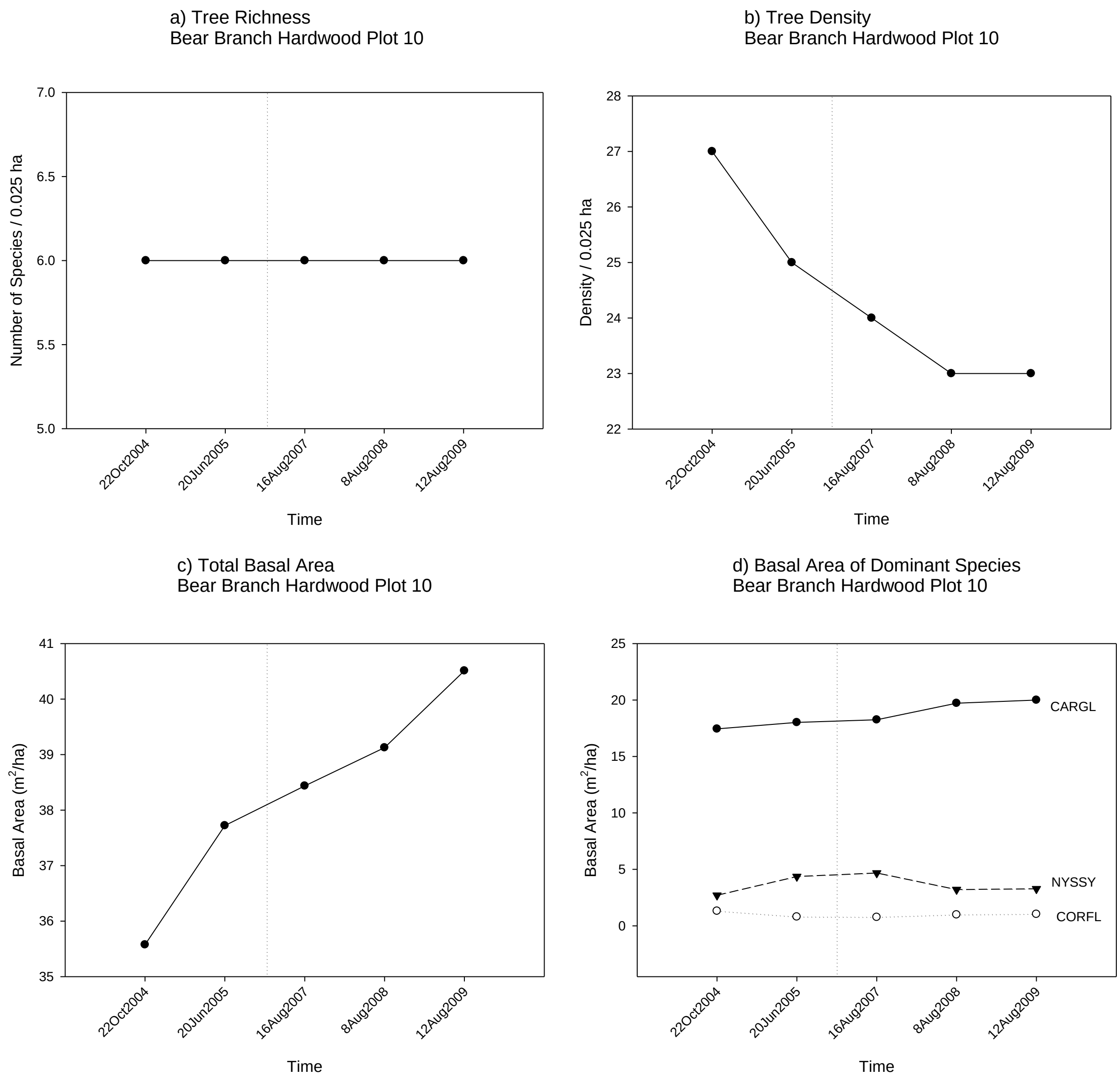
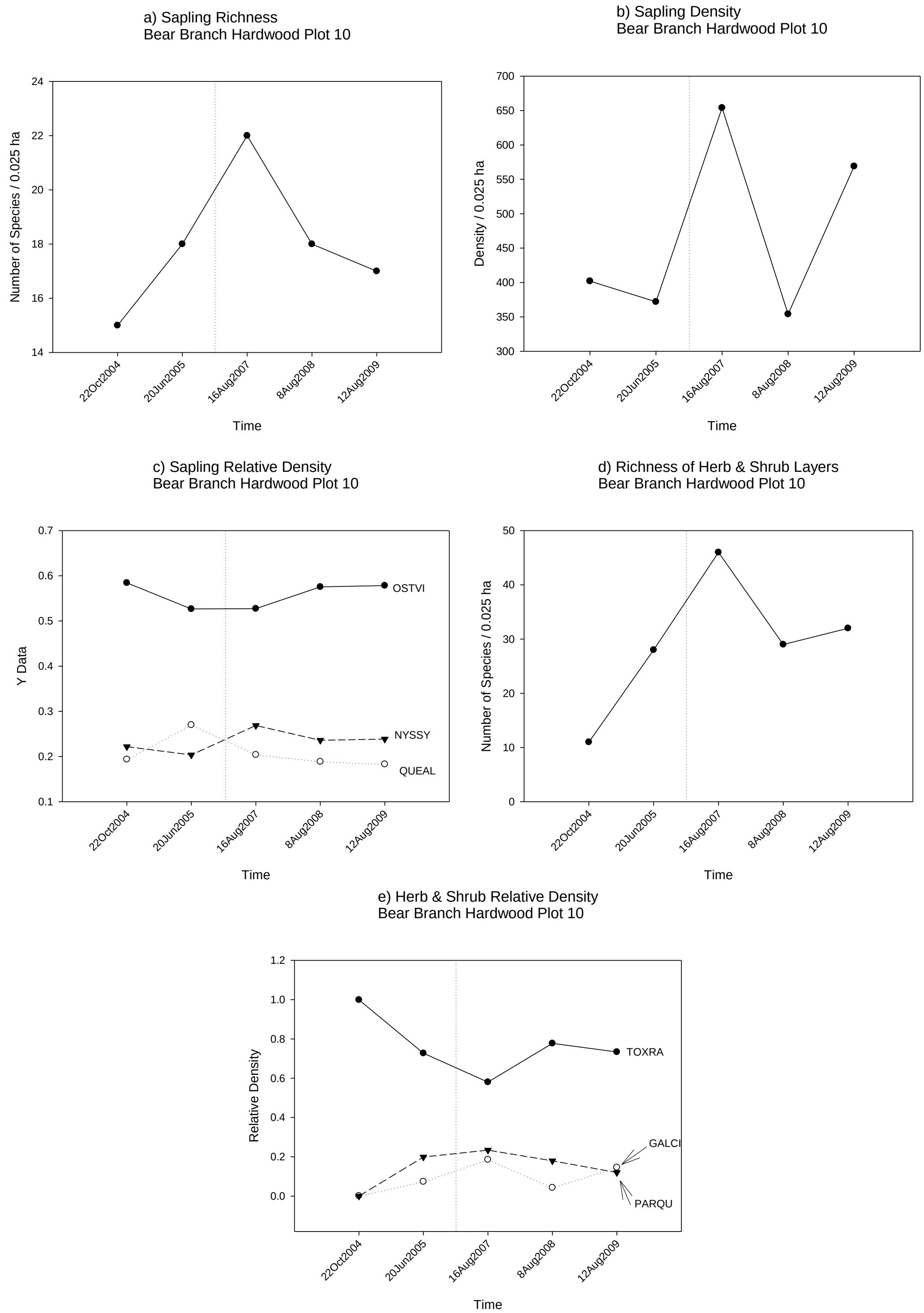


Figure 20: Summary statistics for the sapling and herbaceous layer at Bear Branch Hardwood plot 10. a) sapling richness, b) sapling density, c) relative density of three most abundant sapling species, d) herb and shrub layer richness, and e) relative density of the three most abundant herb and shrub layer species.



Big Boaz Hardwood Upland plot 11

Richness in the tree layer remained constant over time, however, tree density and total basal area both increased following the prescribed burn on March 21, 2007 (Fig 21a, b, c). Overall, the trend was a decrease in tree density accompanied by an increase in total basal area over time. Basal area of the dominant *Quercus alba* steadily increased from 2004 – 2009 while basal area of *Carya glabra/ovata* and *Acer saccharum* showed little change (Fig 21d). Sapling richness and density, and herb and shrub layer richness all increased following the prescribed burn, although the values of these metrics decreased again later (Fig 22a, b, d). There was no clear response of relative density of the dominant sapling species to the prescribed burn (Fig 22c). Relative density of *Vitis vulpina* increased sharply following the burn, while *Phytolacca americana* showed a short-lived increase and *Podophyllum peltatum* declined substantially (Fig 22e).

Figure 21: Summary statistics for trees at Big Boaz Hardwood Upland plot 11, a) richness, b) density, c) basal area, and d) basal area of the most abundant dominant tree species. Vertical dotted lines indicate prescribed burns.

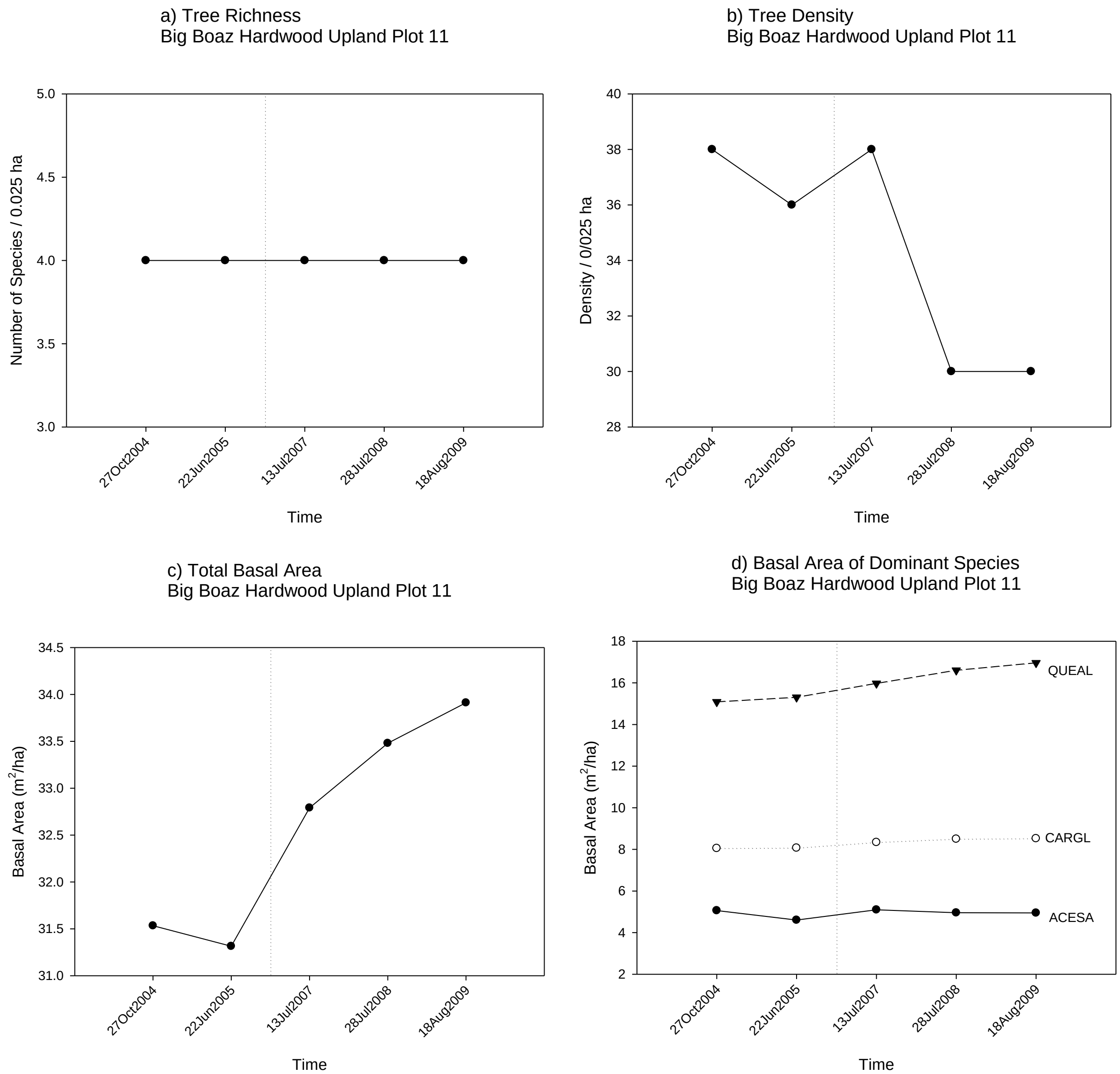
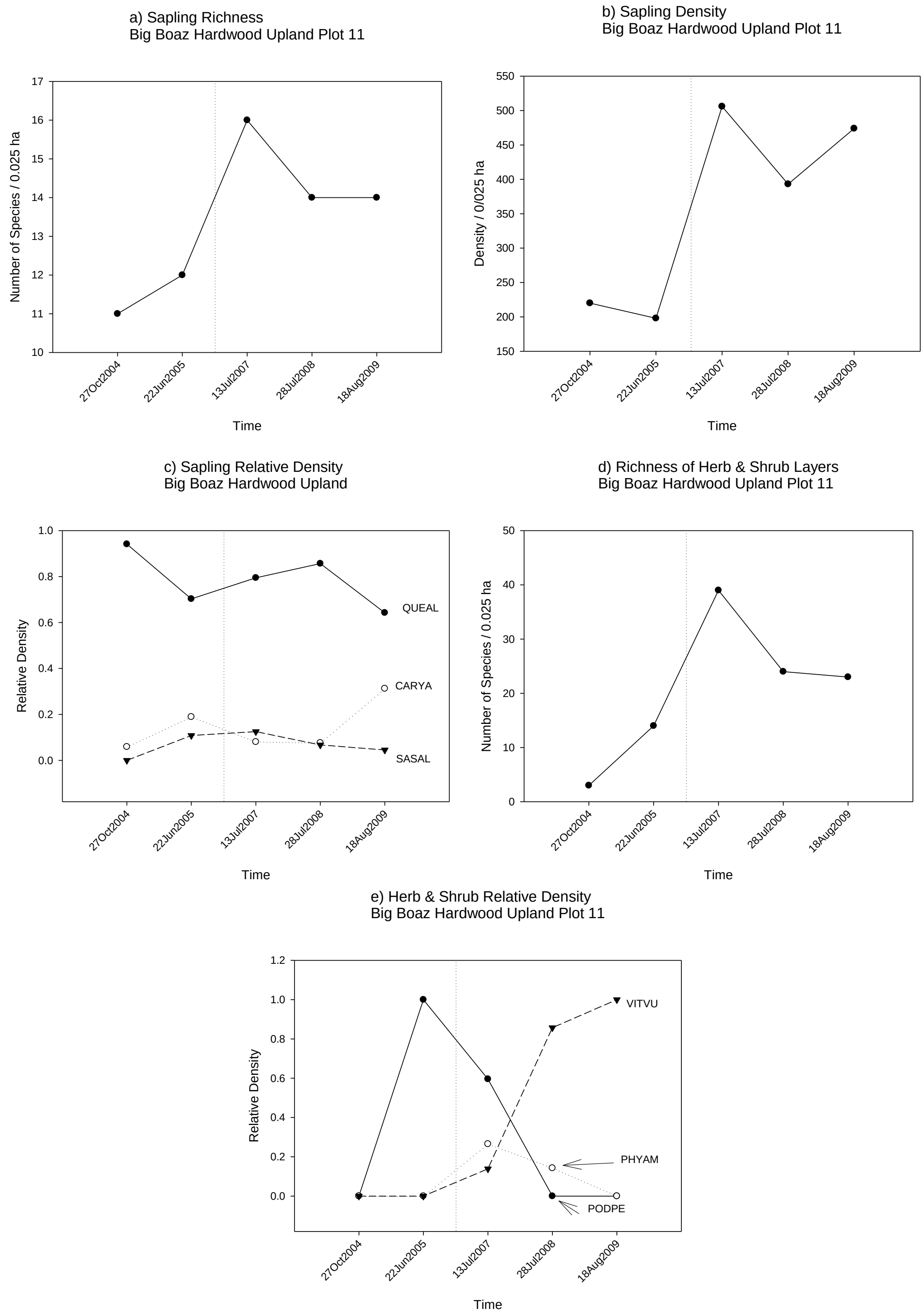


Figure 22: Summary statistics for the sapling and herbaceous layer at Big Boaz Hardwood Upland plot 11. a) sapling richness, b) sapling density, c) relative density of three most abundant sapling species, d) herb and shrub layer richness, and e) relative density of the three most abundant herb and shrub layer species.



Ashby Pine Upland plot 12

Following the April 5, 2006 prescribed burn of this plot, there was a decrease in tree richness and density, and an increase in total basal area (Fig 23a, b, c). The decline in density and increase in total basal area continued thereafter and was associated with a steady increase in basal area of the dominant *Pinus echinata* (Fig 23d). Although sapling richness declined following the prescribed burn (Fig 24a), it is unclear if this was in response to the burn or not. Similarly, there was no clear response in the sapling, shrub, or herb layers to the prescribed burn (Fig 24).

Figure 23: Summary statistics for trees at Ashby Pine Upland plot 12, a) richness, b) density, c) basal area, and d) basal area of the most abundant dominant tree species. Vertical dotted lines indicate prescribed burns.

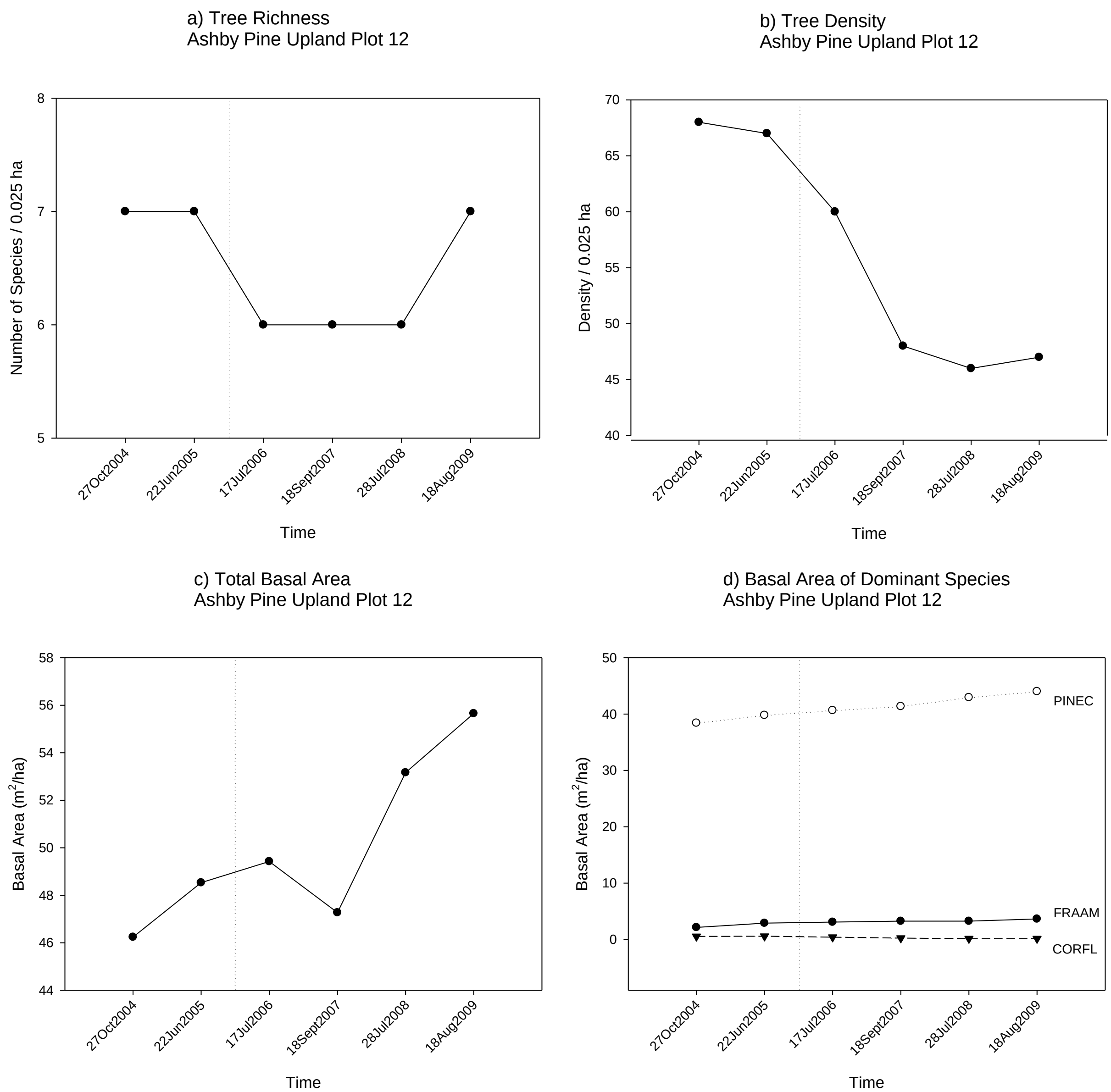
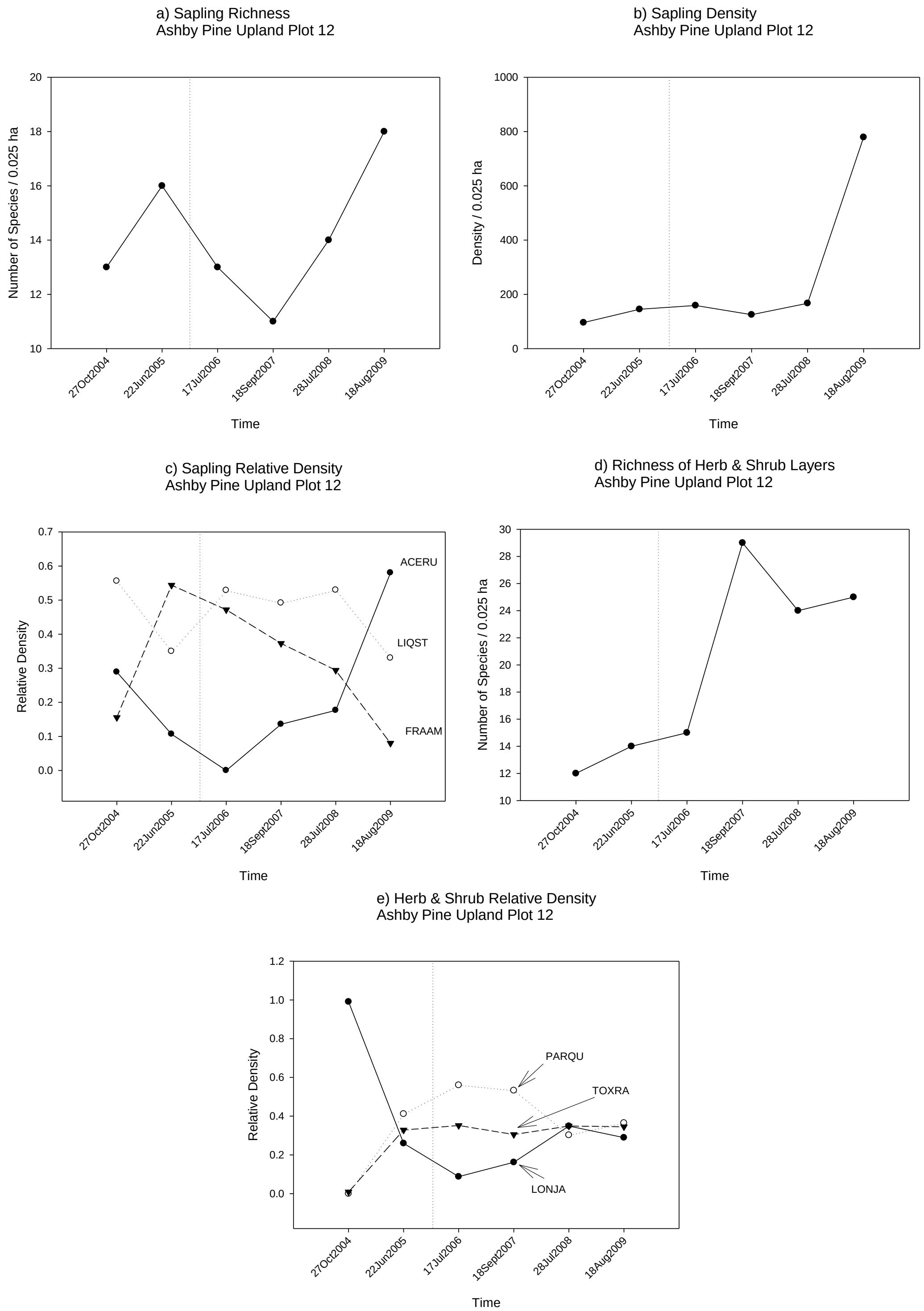


Figure 24: Summary statistics for the sapling and herbaceous layer at Ashby Pine Upland plot 12. a) sapling richness, b) sapling density, c) relative density of three most abundant sapling species, d) herb and shrub layer richness, and e) relative density of the three most abundant herb and shrub layer species.



Cedar Grove Pine plot 13

The March 12, 2007 prescribed burn of this plot corresponded to a continuation of an ongoing decline in tree density (Fig 25b). Total basal area of the trees increased sharply following the burn as did the basal area of the dominant *Pinus echinata* (Fig 25c, d). Tree richness (Fig 25a) and basal area of *Cornus florida* and *Ulmus americana* did not change following the burn. Sapling richness and density both decreased following the burn (Fig 26a, b) which richness of the herb and shrub layer decreased (Fig 26d). Accompanying the changes in the sapling layer was a decrease in the relative density of *Prunus serotina* and a continuation of an increase in *Aralia spinosa* (Fig 26c). In the herb and shrub layer, the relative density of *Lonicera japonica* increased while *Toxicodendron radicans* decreased (Fig 26e).

Figure 25: Summary statistics for trees at Cedar Grove Pine plot 13, a) richness, b) density, c) basal area, and d) basal area of the most abundant dominant tree species. Vertical dotted lines indicate prescribed burns.

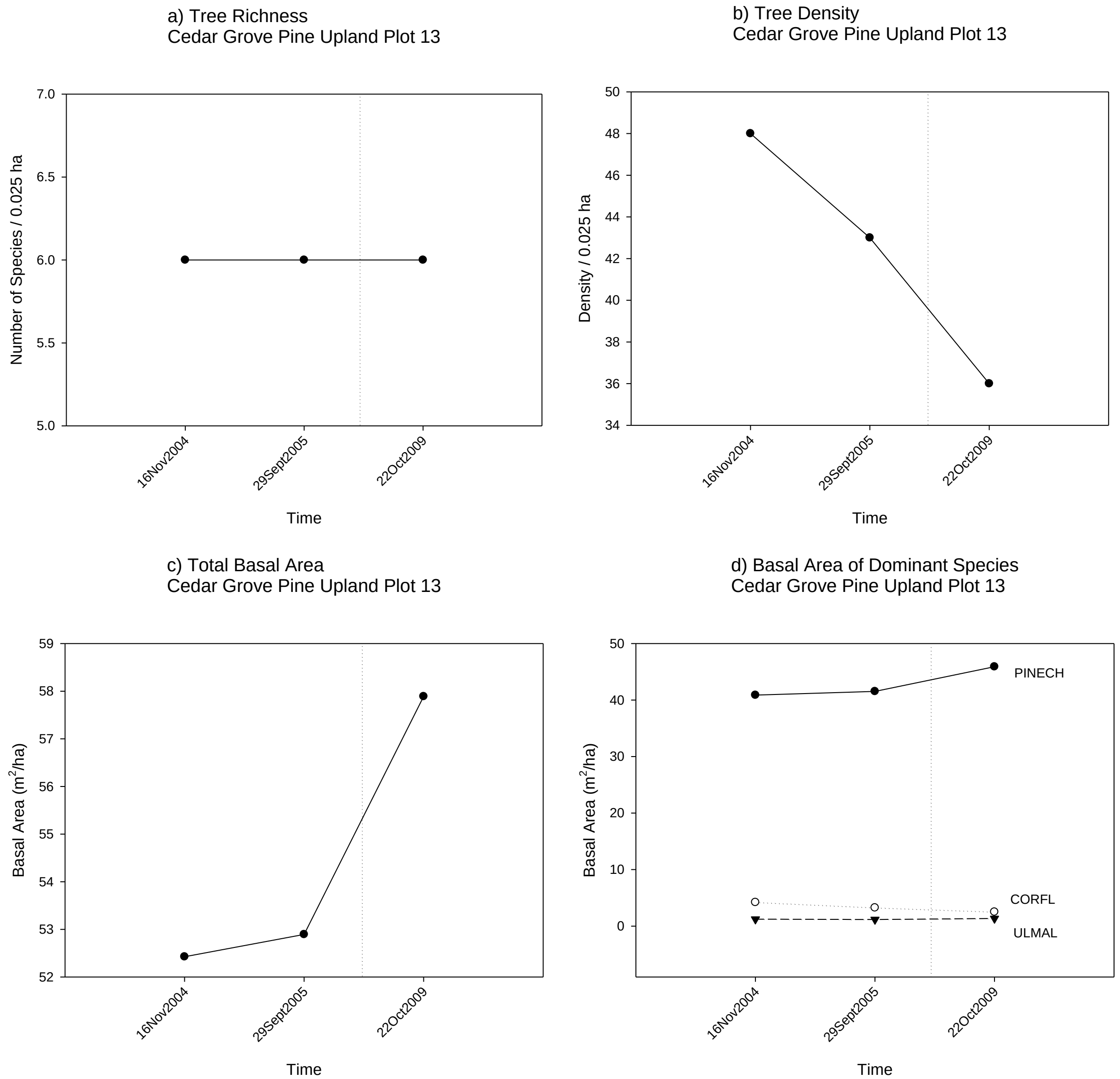
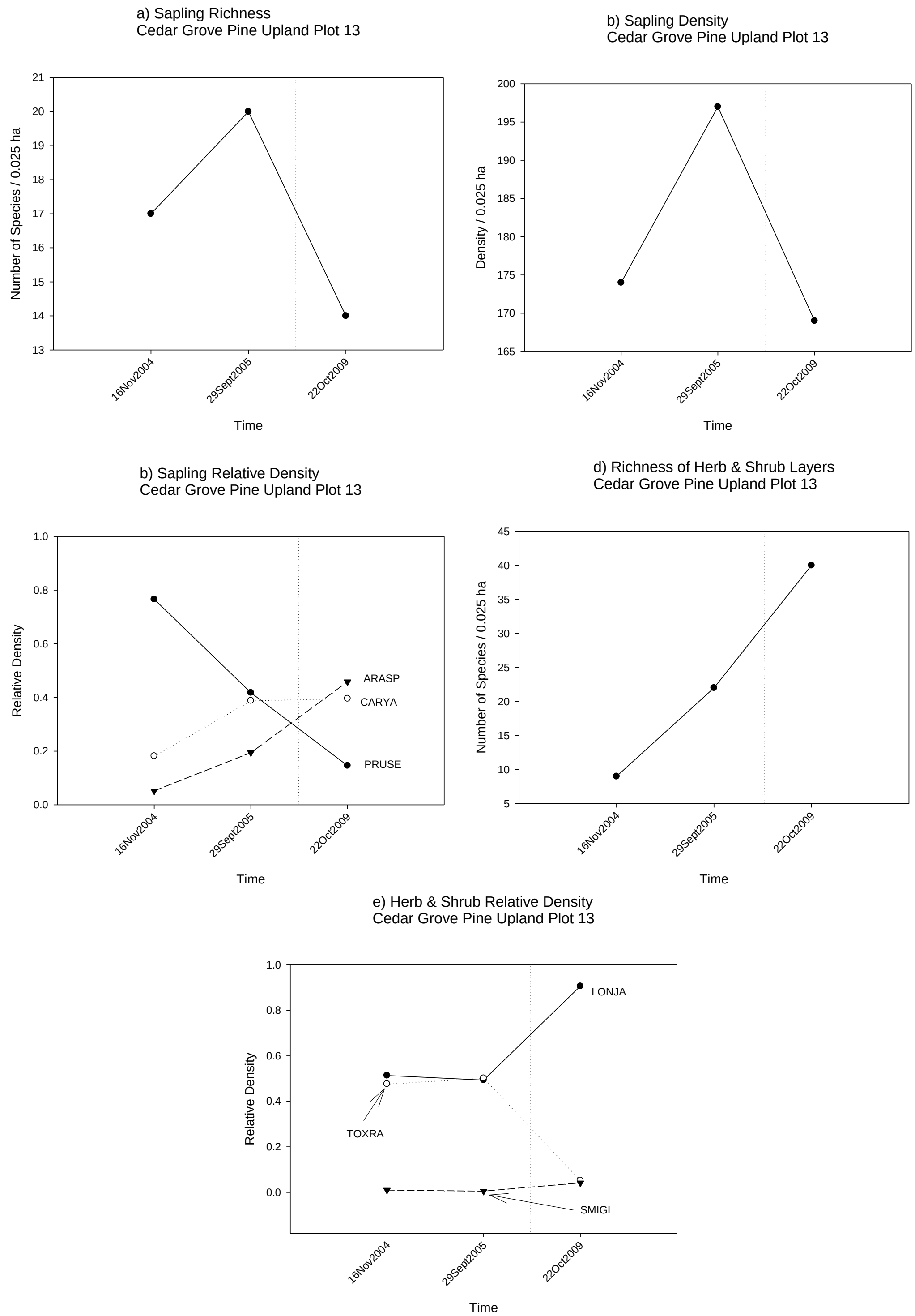


Figure 26: Summary statistics for the sapling and herbaceous layer at Cedar Grove Pine plot 13. a) sapling richness, b) sapling density, c) relative density of three most abundant sapling species, d) herb and shrub layer richness, and e) relative density of the three most abundant herb and shrub layer species.



Analysis of trends

Trend analysis showed that over all plots where there was a prescribed burn that covered ≥50% of the plot, tree total basal area, sapling density, and herb and shrub richness increased while tree density decreased (Table 2, Fig 27). Post-burn increases and decreases of tree layer richness was not significantly different to each other or to cases of no change. Except in one of 19 cases there was either a post-burn increase or decrease in sapling richness but they were equally frequent. Of species that occurred frequently enough for analysis, the sapling density of oaks and hickories (*Quercus* spp. and *Carya* spp.) increased post-burn (11 cases) more often than decreased (8 cases) whereas the density of beech (*Fagus grandifolia*) and maples (*Acer rubrum* and *A. saccharum*) decreased (Fig 28). The basal area of oaks and hickories increased 8 times following a prescribed burn, decreasing only once, however, low statistical power precluded a significant result. Observations of a basal area increase of *Pinus echinata* trees were more frequent post-burn than in the absence of burning. The shade tolerant *Acer saccharum* was a dominant in three plots (Teal Pond plot 3, Teal Pond Pine plot 5, and Big Boaz plot 11), decreasing in basal area following each prescribed burn in Teal Pond plot 3, showing no change at plot 5, and increasing slightly at plot 11 (Figs 5d, 9d, and 11d: too few data for statistical analysis). In the herb and shrub layer, the relative density of *Lonicera japonica* decreased post-burning more often (13 times) than it increased (3 times). Other species in the tree, sapling, and herb/shrub layers were too infrequent as an important relative dominant to allow analysis of trends.

The ranking of the relative dominance of trees was unchanged from one time period (observation) to the next for trees regardless of the occurrence of a prescribed burn (Table 3) with only one exception at Teal Pond 2 following a 2004 prescribed burn when *Quercus stellata* became more dominant than *Carya ovata* (Fig 3). By contrast, there were 7% and 12% more changes in relative dominance following a burn in the sapling and herb and shrub layers, respectively compared with between observations without a prescribed burn (Table 3).

Table 2. Trend analysis showing chi-square (χ^2) analysis comparing numbers of increases, decreases, or no-changes of performance metrics between pre- and post-burn surveys (critical $\alpha = 0.05$). RBA = Relative basal area of dominant trees, RD = Relative density of dominant saplings and herbs.

Performance metric	Number of increases	Number of decreases	Number of no-changes	χ^2	df	*p*
Tree density	4	17	6	10.89	2	<0.005
Tree richness	7	10	10	0.67	2	ns
Tree total Basal Area	22	5	0	29.56	2	<0.005
Sapling density	16	10	1	12.67	2	<0.05
Sapling richness	9	9	1	6.73	2	<0.05
Herb and Shrub richness	25	2	0	42.89	2	<0.005
Tree layer RBA *Quercus* spp. and *Carya* spp.	8	1	-	5.44	1	ns

Tree layer RBA *Pinus echinata*	14	2	-	9.00	1	<0.025
Sapling layer RD *Quercus* spp. and *Carya* spp.	11	8	1	7.9	2	<0.025
Sapling layer density *Fagus* and *Acer* spp.	9	7	1	6.91	2	<0.05
Herb layer RD *Lonicera japonica*	3	13	-	6.25	1	<0.025
Herb layer RD *Toxicodenron radicans*	4	9	1	2.88	2	ns

Table 3. Number and percentage of changes in rank ordering of relative dominance among the top three dominant species from one monitoring period to the next following a prescribed burn (≥ 50% severity Table 1: n = 21) or without or with a low intensity (< 50%) prescribed burn (n = 34 [32 for trees]).

	Following prescribed burn		No prescribed burn	
	Number	% of burns	Number	% of burns
Trees	1	5	0	0
Saplings	12	57	17	50
Shrubs and herbs	10	47	12	35

Figure 27. Density (a, c, e) and richness (b, d, f) for trees (a, b), saplings (c, d), and herbs and shrubs (e, f) before and after prescribed burns. Plots burned multiple times over the monitoring period are represented by more than one point. The line shows the 1:1 relationship. Points on the line are from plots in which the density or richness was the same before and after burning.

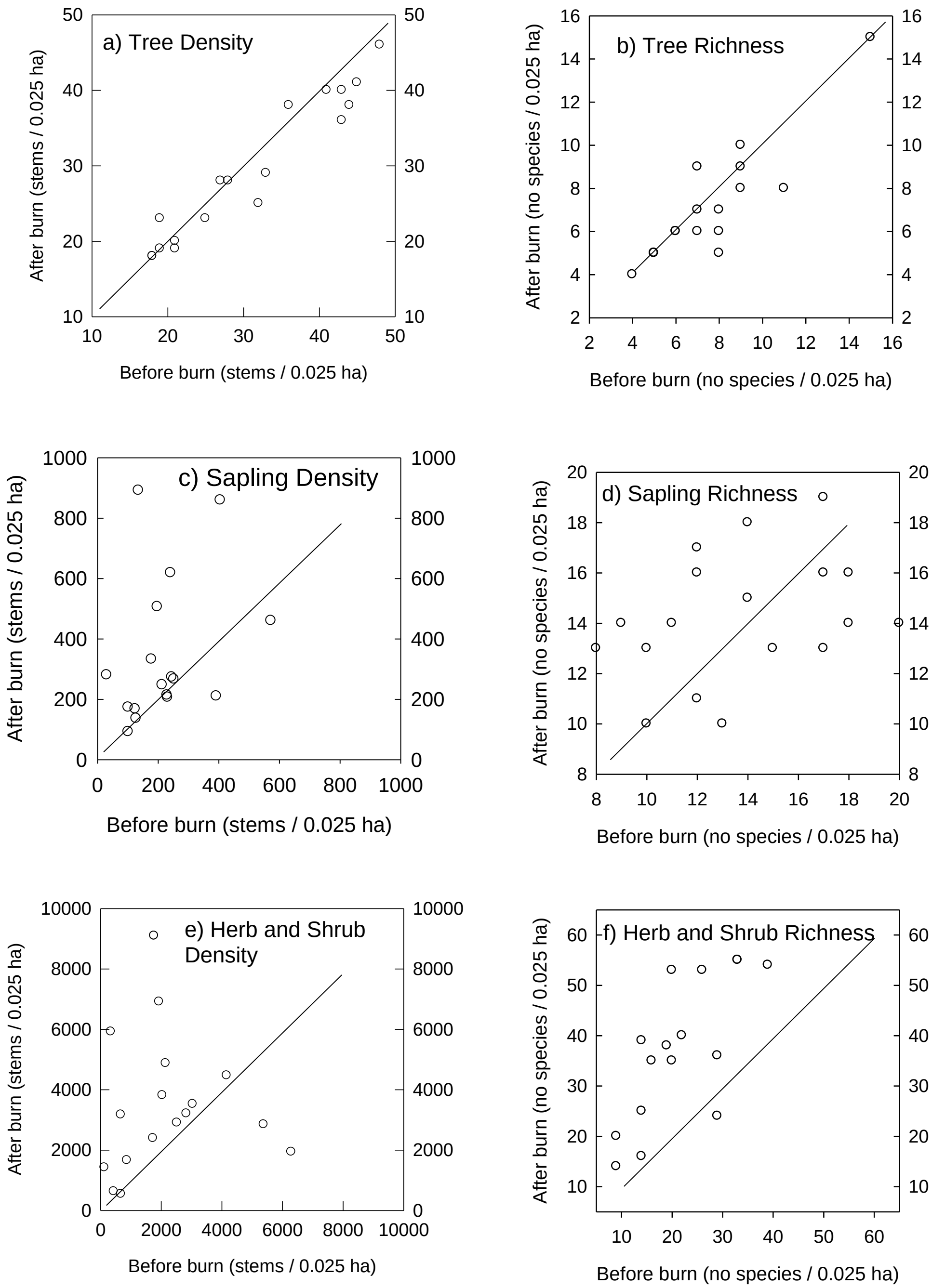
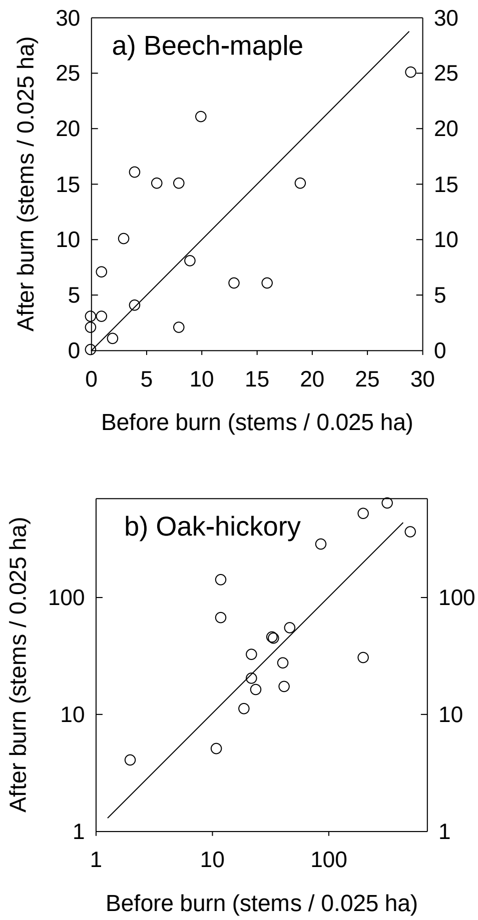


Figure 28. Density of (a) beech and maple and (b) oak and hickory saplings before and after prescribed burns. The line shows the 1:1 relationship. Points on the line are from plots in which the density or richness was the same before and after burning. The densities for oak-hickory saplings are shown on a log scale because of the wide range of values (2 – 629 saplings per 0.025 ha plot).



Landscape analysis of sapling density

Forty-five sapling species contributed to a three-dimensional global MNDS solution (Stress = 0.15) of the sapling density data that was retained for interpretation. Stress of a two-dimensional solution was considered too high at 0.24 to provide a reliable interpretation. The most five abundant sapling species across all plots contributing to the ordination were *Quercus alba* (mean 38.3 ± 7.6 sapling stems per 0.025 ha, n = 67 occurrences, the highest of all sapling species), *Sassafras albidum* (30.1 ± 4.6, n=55), *Quercus stellata* (22.9 ± 7.2, n=24), *Ostrya virginiana* (21.6 ± 5.8, n=37), and *Carya* sp. (21.1 ± 3.6, n = 46).

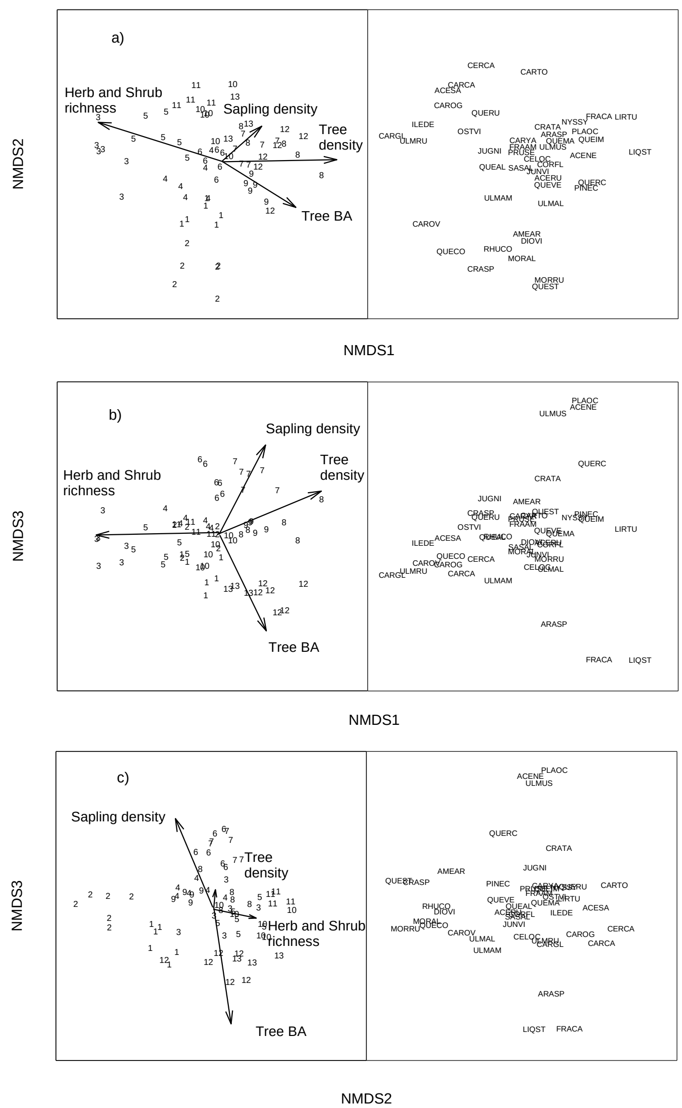
Distribution of plots with respect to the three NMDS axes was related independently to tree and sapling density, tree basal area, and herb and shrub richness (Table 4) indicating gradients in sapling species composition with respect to these variables. The strongest relationship of these variables to the NMDS ordination was that of tree density. Plots associated with the tree density vector were Ramsey Hardwood plot 8 and Ashby Pine plot 12 and included species centroids (i.e., high weighted averages across the ordination space) for saplings of *Liquidambar styraciflua* and *Quercus* sp. Plots associated with the tree basal area vector included species centroids of several sapling species including *Aralia spinosa, Liquidambar styraciflua* and *Frangula caroliniana* (Fig 29). The sapling density vector was associated most closely with Teal Pond Pine plot 6 and Ramsey Pine plot 7 and included species centroids for saplings of *Acer negundo, Platanus occindentalis* and *Ulmus* sp. Plots with the herb and shrub richness vector were Teal Plots 3 and 5 (i.e., low NMDS 1 scores) and were associated with the species centroids of saplings of *Carya glabra* and *Ulmus rubra*. Percentage of a plot that burned prior to sampling, year of sampling, sapling species richness, and tree species richness were unrelated to the dissimilarity among plots summarized by the ordination.

Sapling composition among plots differed significantly among sites (ANOSIM, plot R = 0.85, P = 0.001). Distinct clusters of points from plots sampled multiple times are evident in the ordination plots (Fig 29) reflecting a degree of site specific uniqueness in sapling composition. For example, points representing Teal Pond plot 2 all had low NMDS axis 2 scores compared with the points representing plots from other sites. Similarly, points representing Teal Pond plots 3 and 5 had low NMDS axis 1 scores. In addition, there were significant differences in sapling composition among plots when characterized by topography (upland, midslope, or floodplain, R = 0.12, P = 0.009) and dominant tree (Pine versus mixed hardwood, R = 0.26, P = 0.001).

Table 4. Fit (r^2 and P) of environmental vectors to the 3-dimensional NMDS solution (Fig 27). Direction cosines are shown for each NMDS dimension (NMDS1, NMDS2, NMDS3) which allows the coordinates of the units of vectors with $P < 0.1$ to be plotted (Fig. 27) scaled relative to their correlation (square root of r^2).

Variable	NMDS1	NMDS2	NMDS3	r^2	P
Burn (%)	-0.44	-0.81	0.38	0.06	0.28
Year	0.35	0.02	-0.94	0.01	0.87
Sapling richness	0.29	0.92	0.28	0.09	0.11
Sapling density	0.56	-0.35	0.75	0.112	0.06
Tree richness	-0.69	-0.05	0.75	0.03	0.61
Tree basal area	0.47	0.30	-0.83	0.10	0.09
Tree density	0.98	0.03	0.15	0.53	<0.0001
Herb and Shrub richness	-0.93	0.34	-0.09	0.11	0.07
Herb and Shrub density	0.59	0.22	0.77	0.01	0.84

Figure 29. 3-dimensional Non-metric Dimensional Scaling (NMDS) ordination of sapling density by species in each plot (stress = 0.15). Panels show plots with respect to a) NMDS axes 1 versus 2, b) NMDS axes 1 versus 3, and c) NMDS axes 2 versus 3. Left hand panels show plot numbers, right hand panels show species centroids based on weighted averages (codes are 4-5 letter genus-species abbreviations). Coordinate for some species codes adjusted slightly in panel a) to avoid overlap. Arrows show direction of vectors (Table 3, P<0.1) fitted to the ordination solution (Table 4).



Discussion

The lack of plot replication within a site precluded statistical analysis within sites. However, some general trends are discernible both within and across sites. As expected, through time most plots show an increase in total tree basal area concomitant with a decrease in tree density. These changes reflect succession, stand filling and maturation. Consistent with previous studies on the effects of management in the Shawnee National Forest (Parker and Ruffner 2004), prescribed burning hastens these changes albeit with an accompanying increase in species richness in all strata. In addition, desirable oaks and hickories also increase following prescribed burning but there was little evidence for a decrease in undesirable shade tolerant species such as *Acer saccharum* and mesic species such as *A. rubrum* with the use of prescribed fire. As a sapling *Fagus grandifolia* only occurred once in one plot (Cedar Grove Pine plot 13 in October 2009) and so it's response to fire could not be investigated with these data. Less desirable from a naturalist management perspective was the increase in *Pinus echinata* following burning in those stands where it occurs.

The 2004-2009 five-year time period encompassed by the monitoring in this study (note: Teal Pond plot 3 and Ramsey Pine plot 7 monitoring extended 9 years, and Teal Pond plot 4 10 years), is a relatively short period of time to expect substantial changes in the tree layer in the absence of fire-induced mortality (Chandy et al., 2009). Moreover, although some plots experienced frequent relatively complete prescribed burns affecting over 50% of the plot, some plots were subject to only a few burns that were often incomplete. For example, there were three burns all in excess of 75% cover affecting the three Teal Pond plots. At Teal Pond plot 3 the dominant but undesirable shade tolerant *Acer saccharum* exhibited a decrease in relative basal area following prescribed burning while saplings of desirable shade intolerant *Quercus alba* increased. By contrast, at Bear Branch Hardwood plot 10, there was only one prescribed burn and it had affected only 5% of the plot meaning that the changes that did occur from 2004-2009 could not be related to the effects of the use of prescribed burning as a management tool.

Overall, there were some clear patterns across the landscape that, averaged over all plots, could be related to the use of prescribed burning. Patterns included increases in richness of taxa and an increase in desirable oaks and hickories. These effects were variable among sites suggesting that management must respond to a high degree of among-site historical contingency (Parker & Pickett 1997). The case for the use of fire in the management of southern Illinois forests is clear and has historical precedence (Zaczek et al., 2002, Ozier et al., 2006, Ruffner & Groninger 2006). However, as shown here, the value of prescribed burning as a management tool has to be assessed on a site by site basis accompanied by long term monitoring and careful record keeping of the intensity and cover of each prescribed burn. Where prescribed fires appear ineffective in encouraging the growth of an oak-hickory community, for example in plots dominated by pines (e.g., Teal Pond 1), it has been suggested that other silvicultural practices such as selective cutting may be necessary (Jones & Anderson 2011).

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