VEGETATIVE DEVELOPMENT AND DEER BROWSING PATTERNS FOLLOWING BOTTOMLAND AFFORESTATION

By

Kenneth J Ruzicka Jr

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Abstract

Interest in restoring marginal agricultural lands back into natural ecosystems through afforestation has been increasing since the early 1990s. The Cache River watershed has been designated a "wetland of international importance" and many state and national conservation agencies have made afforestation and wetland restoration a priority in this area. Grassy Slough, a formerly row-cropped, 526 ha afforested bottomland in southern Illinois is the centerpiece of the Nature Conservancy's efforts at restoration in the Cache. In 1999 the site was planted at a 3.66 m by 3.66 m spacing with primarily bottomland oak species with the management objective of restoring pre-agricultural vegetation. Sampling occurred during the summer of 2004 and then again the summer of 2006. The intensity and distribution of deer browsing on planted and volunteer seedlings were examined. Also, data was collected on the primary components of the herbaceous layer.

The majority of stems counted were light-seeded volunteer tree species. The influx of these species led to a higher density of stems closest to existing forest cover that decreased with distance away from the potential seed source. Planted oaks constituted seven percent of trees observed on site. Deer herbivory influenced early tree growth and disproportionately impacted seedlings of *Quercus palustris* Muenchh. and *Celtis occidentalis* L. The role that this intense browing pressure will have in shaping the future stand is still undetermined. Other factors such as distance from forest edge are more likely an indicator of the future success of the restoration efforts at Grassy Slough.

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Literature Review

Bottomland Afforestation

Until recently most of the research on bottomland afforestation has been conducted in the lower Mississippi Alluvial Valley (LMAV). This area includes the Delta region; portions of Mississippi, Louisiana and Arkansas within the Mississippi embayment. This research has been conducted in response to a sharp increase in the interest for bottomland hardwood restoration since the early 1990s (King and Keeland 1999; Groninger 2005). This enhanced interest is caused by the fact that these lands are marginal for agriculture due to their frequent flooding. Some of the benefits of bottomland afforestation include wildlife forage, habitat for migratory songbirds and decreased erosion (Twedt 2006; Twedt at al 2004; Kruse and Groninger 2003). Many of these benefits are the direct effect of removing the land from agricultural production (Groninger 2005). An added ecosystem benefit for the reforestation of the LMAV is decreased siltation and increased nutrient uptake, which have implications for the entire Mississippi river as well as for fisheries in the Gulf of Mexico (King and Keeland 1999).

Receiving the benefits associated with large-scale afforestation may be delayed by several major challenges. The first is that the amount of land deforested every year ni the LMAV exceeds the land returned to forest production (King and Keeland 1999). Challenges directly related to afforestation projects include mismatches of species to site, flooding, herbaceous competition, and herbivory (Kruse and Groninger 2003; Schoenholtz et al 2005). Agriculture has also changed desired afforestation sites by altering soil physical and chemical properties, and removing microsite heterogeneity through land leveling (Groninger 2005). These challenges have contributed to the failure of 14 percent of afforestation efforts in the LMAV requiring subsequent replanting. (King and Keeland 1999).

Planting techniques

Bottomland afforestation techniques usually involve planting heavy seeded oak species including pin oak (*Quercus palustris* Muench.), swamp white oak (*Quercus bicolor* Willd.) willow oak (*Quercus phellos* L.), Shumard oak (*Quercus shumardii* Buckl.) and bur oak (*Quercus macrocarpa* Michx.). Oaks are commonly planted in an attempt to recreate pre-agricultural conditions but also because they are appealing to landowners for their wildlife and potential timber values (Groninger 2005; Twedt 2004). Oak aforestation requires planting because oaks have inadequate natural dispersal (Allen 1997). Most programs have a survival goal of 309 trees/ha after three growing seasons (Schoenholtz et al 2005). The most common sources of planting stock are one-year-old bare-root seedlings, direct seeding of acorns and containerized seedlings. Bare-root seedlings are most popular for private reforestation efforts while direct seeding is more commonly used for large public projects. (Allen et al 2004; Schoenholtz et al 2005; King and Keeland 1999). Typically, survivability is higher for planted seedlings than for direct seeding. Krinard and Kennedy (1987) found 80 percent of Nuttall (*Quercus texana* Buckl.) oaks surviving after 4 years while Schweitzer and Stanturf (1999) observed 64 percent Nuttall oak survival after 3 years. Direct seeded acorns have a lower chance of survival. Rates as low as 35 percent survival have been noted but survival has been as high as 65 percent after 5 years for Shumard and cherrybark oak (Kruse 2000; Schweitzer and Stanturf 1999). Small mammal predation and flood conditions are problems for both regeneration methods. A higher eventual stocking rate is expected when using bare root seedlings than when using direct seeding (Kruse 2000; Schweitzer and Stanturf 1999; Allen et al 2004; Schoenholtz et al 2005). Despite this, direct seeding is recommended for efforts where wildlife habitat is the management objective mainly due to its lower cost (Twedt and Wilson 2002). Containerized seedlings are more vulnerable to herbivory but can be planted later in the growing season than bare-root seedlings. More research is needed on the survivability of containerized seedlings compared to bare-root seedlings (Stanturf et al 1998).

Afforestation efforts also rely on seed dispersal from surrounding forests to attain desired densities. Light-seeded species such as green ash (*Fraxinus pennsylvanica* Marsh.), box-elder (*Acer negundo* L.) and silver maple (*Acer saccharinum* L.) are wind dispersed and are usually found close to existing forest cover. Other species such as sweetgum (*Liquidambar styraciflua* L.), and sycamore (*Platanus occidentalis* L.*)* are more commonly flood dispersed and are common on bottomland afforestation efforts (King and Keeland 1999; Groninger 2005; Kruse and Groninger 2003). There has been some concern with the effectiveness of natural seed rain to attain a desired level of diversity on reforested sites (Allen 1997).

Southern Illinois Specifics

A recent study done by Kruse and Groninger (2003) is the most easily comparable project to this proposed research. Their study was also completed in the Cache River watershed and the results should provide an excellent comparison with the proposed study. The sites were five to seven years old afforestation efforts that had been planted with several species of bottomland oak. Kruse and Groninger recorded the vegetation characteristics for several sites taking data on the tree species and height, herbaceous cover and distance from a potential seed source. The data showed that the site was dominated by green ash, boxelder, and sweetgum. The planted oaks comprised of less than five percent of the total stems.

The tree composition of that site was comparable to a study done by Hosner and Minckler (1963). Their study surveyed the tree component of different forest types and areas in southern Illinois. In old fields and bottomland forests, boxelder, sycamore, elms and ashes were the dominant species. As succession progressed the elms and cypress became the dominant species on some of the wettest sites. The importance of oaks was limited to areas where disturbances such as cutting had been large enough to provide openings for regeneration. Even then, oaks were not a dominant species except on more upland and mesic sites rather than bottomland areas (Hosner and Minckler 1963). A study by Bazzaz (1968) demonstrated the natural rate of invasion and succession from one to 40 years in the Shawnee Hills. On naturally invaded sites, *Solidago* and *Andropogon* were the most dominant genus of herbaceous plants throughout the fields for the earlier sere. Light seeded tree species were the first to invade while hard mast species were not prevalent except in the 40 year old fields. The natural dispersal of hard mast species depends upon rodents and their establishment will be delayed until appropriate cover is developed (Bazzaz 1968). The species composition of the herbaceous component also appeared to have an influence on the density of tree stems in the Kruse study. Goldenrod (*Solidago gigantea*) was negatively correlated with oak stem density and height while slender rush (*Juncus dudleyi*) and sedge (*Carex lupulina*) were positively correlated with stem height and oak density respectively. Another study done on old-field succession in southern Illinois focused on the diversity of the herbaceous layer (Bazzaz 1975). He found goldenrod to be a dominant species on the site early in old-field succession that decreased in importance as the site matured and diversity increased. Bazzaz also suggested that species that exude allelopathic chemicals may alter successional pathways. It has been demonstrated that some old field species including *Solidago*, *Andropogon virginicus* and *Sorghum halepense* produce allelopathic chemicals that affect species diversity (Ito et al 1998; Rice 1972; Abdul-Wahab and Rice 1967). Competition for light, nutrients and allelopathy by the herbaceous layer can inhibit bottomland restoration (Twedt 2004). However, competition and depredation have been demonstrated to have a greater effect on woody species seedling survival than allelopathy (Bramble et al 1996).

Deer Browse

Heavy browsing of young trees by white-tailed deer (*Odocoileus virginianus*) is sometimes an important factor limiting afforestation success in this region (Zaczek et al 1997; Russell et al 2001). White-tailed deer is an edge species that prefers to feed in disturbed or early successional communities (Russell et al 2001). Populations of white-tailed deer have increased dramatically since the early 1900s and are currently at population densities higher than historic levels. Deer have been broadly implicated in limiting tree regeneration (Tilghman 1989; Marquis 1974) and reducing forest diversity (Rooney and Waller 2003; Russell et al 2001). Moreover, deer browsing affects individual seedlings by altering stem morphology and reducing stem height, thereby decreasing survivability (Russell et al 2001). When the terminal leader of a sapling is no longer vulnerable to predation by white-tailed deer, at approximately 1.37 m in height (Zaczek et al 1997), these stems have an increased likelihood to be long-term components of the stand. In some areas, white-tailed deer now have sufficiently strong impacts on the ecosystems they inhabit to be considered a keystone species (Rooney and Waller 2003). Deer density is one of the most important factors when considering sites for bottomland afforeststion (Allen 1994) and it is considered to be the greatest factor in determining seedling survival in some areas (Boerner and Brinkman 1996). Deer herbivory primarily influences afforestation by reducing species diversity through browse of preferred species and limiting invasion into old fields (Inouye et al 1994). Browsing of preferred species has the potential to alter successional pathways (Cote et al 2004). In the Allegheny National Forest, boulders inaccessible to deer had a higher species diversity especially in the tree component than areas accessible to deer (Carson et al 2005). Other studies in Pennsylvania have demonstrated that deer prefer cherry (*Prunus* spp.), oak, hackberry (*Celtis occidentalis* L.) and others and will significantly reduce seedling and sapling density in unprotected areas (Tilghman 1989; Marquis 1974; McCormick et al 1993; Castleberry et al 1999). Deer will concentrate and browse more heavily in areas where preferred species are located (Morellet and Guibert 1999).

Objectives

The aims of this study were to assess the restoration effort of Grassy Slough by examining several interrelated factors. (1) What affect, if any, does distance from existing forest cover have on stem density, browse pressure and herbaceous competition? (2)

What affect, if any, will deer browse have on species composition and spatial arrangement of the tree component? (3) How will the tree and herbaceous components interact and change over time?

Methods

Study Area

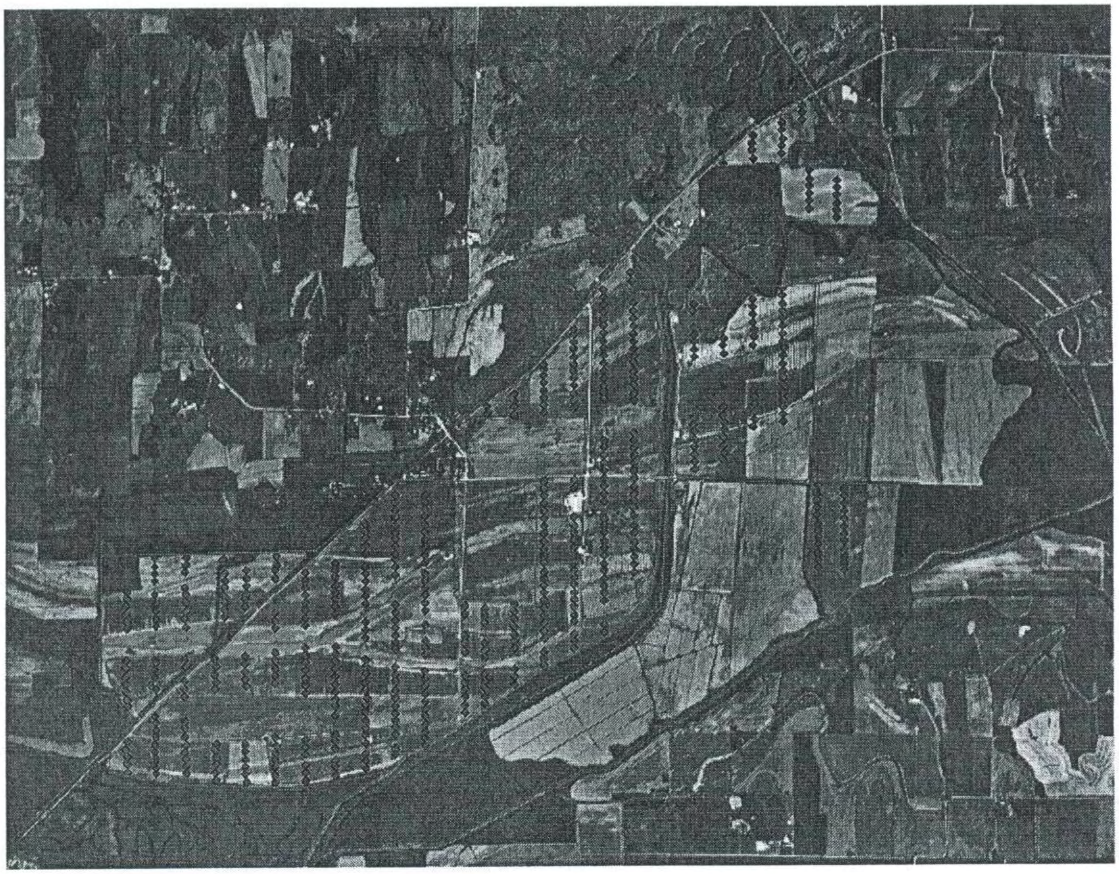
Grassy Slough is a 526 ha old-field restoration project located owned and managed by The Nature Conservancy in the Lower Cache River Watershed near Belknap, Illinois (Figure 1). The Cache River Watershed has been declared a Wetland of International Importance by the Ramsar convention on wetlands and Grassy Slough is an important part of restoring this vital ecosystem. A significant portion of adjacent land supports mature forest cover and is publicly owned. Most of this is to the west and farther north. Lands directly to the west, south and north east are privately owned and used for agriculture. The area is characterized by relatively flat topography with lower lying areas forming permanent wetlands or seasonally flooded sloughs. Karnak (Fine, montmorillinitic, nonacid, mesic, Aquic Haplaquepts) and Weinbach (Fine-silty, mixed, mesic, Aeric Fragiaqualfs) soil series predominate which are classified as poorly drained and are associated with bottomland forest cover (USDA 1959). The site was in agricultural production, primarily soybean row cropping, until the growing season immediately prior to tree planting in the fall of 1999. Tree seedlings were grown for one growing season at the Nature Conservancy nursery at Grassy Slough. The planting was done on a 3.66 m by 3.66 m spacing (1075 trees per hectare) for a total of 360,000 trees. Most seedlings planted initially were pin oak (*Quercus palustris.*) but swamp white oak (*Quercus bicolor* Willd.) and bald cypress (*Taxodium distichum* (L.) Rich. *var. distichum*) were also used. The cypress was planted in constructed wetlands throughout the site. Subsequent plantings in 2000 and 2001 included willow oak (*Quercus phellos*), shumard oak (*Quercus shumardii.*) and bur oak (*Quercus macrocarpa* Michx.).

Figure 1. Grassy Slough, near Belknap, Johnson County, Illniois.

Sampling Methods

Vegetation sampling occurred during summers of 2004 and 2006. The sampling was designed to provide uniform coverage of the site which was roughly a rectangle measuring 1.4 km long (NW to SE) and 4.6 km wide (SW to NE) (Figure 1). Sampling transects were positioned 200m apart across the entire site. Circular plots 5.51 m^2 were placed 50 m apart along these transects after the first plot was placed a random distance away from each transect terminus. The plot size was used to measure stocking as 5.51 m^2 is the space required for an oak stem to grow to the age of 20 years (Kruse and Groninger 2003).

Figure 2. Grassy Slough near Belknap, Illinois. Map shows all plots from 2006.



In each plot, stems of tree species greater than 50 cm tall were tallied. Height was measured and incidence of deer browse was recorded for each tallied stem. Only trees with cut terminal leaders were considered to be broswed by deer. Browse on leaves was not recorded. A plot was considered to be stocked if at least one stem was above 1.37 m making it less vulnerable to deer predation and likely to become a long term component of the stand (Kruse and Groninger 2003; Zaczek et al 1997). Percentage cover for herbaceous species equal to or greater than 5 percent cover was recorded for each plot. For some genre of herbaceous plants, identification separate species not possible because of a lack of reproductive structures or identifying characteristics and only the generic is used to identify these species. The generic name is also used for three genus of tree species that were indistinguishable, (some *Quercus* spp. *Crataegus* spp. and *Celtis* spp.) The locations of the plots were recorded using a GPS unit and then entered into ArcGIS (Environmental Systems Research Institute, Redlands CA). Plot distance to the nearest forest edge was then calculated by using a USGS digital orthoquad aerial photograph in ArcGIS.

Data Analysis

Data from both 2004 and 2006 were analyzed separately for each of these tests unless noted in the procedure. All statistical tests were run using SAS 9.1.2 statistical software (SAS institute Inc. 2004). A t-test was used to determine if a significant difference existed between the heights of browsed and unbrowsed stems. This was done by the comparing the average tree height of browsed and unbrowsed stems for each species in 2004 and 2006 and then within species in 2006. Significance was determined at an alpha of 0.05.

The plots were grouped into 50 m intervals and stem density (number of stems per hectare) was calculated for each interval. The relationship between distance from the nearest forest edge versus total tree density and total oak density were examined using linear regression for all individuals measured and for individuals taller than 1.37 m. Stem density was then transformed using the inverse log to normalize the data. Density of all trees and all oaks were analyzed in this way. Using this method the density of all trees taller than 1.37 m per hectare and all oaks taller than 1.37 m were also similarly grouped.

Linear regression was also used to determine the existence of a relationship between the incidence of deer browse and distance. In each plot the number of stems browsed was divided by the total number of stems in the plot to determine the percentage browsed in each plot. These plots were then grouped by the same 50 m intervals in the prior regressions. The incidence of browse was then transformed using the inverse log to ensure normality.

To determine the stocking status of the site linear regression was also used to establish the locations that stocked plots were occurring. The plots were grouped by the same 50m intervals as in the other regressions. The number of stocked plots was analyzed as a function of distance as well as the number of plots stocked with at least one tree. The percentage of plots stocked and the percentage of plots stocked with at least one tree were also calculated for each interval. Individual regressions were used to find the relationship between these variables and distance from forest edge. The distances were then transformed using the square root transformation to ensure normality.

The relations between the herbaceous component and the tree component tests were tested using Pearson Correlation Coeffecients. Correlations were examined in each plot for the number of trees, the aggregate height of those trees, the percentage browse and the percent cover of the herbaceous species. The aggregate height is cumulative height of all stems in a plot. Using aggregate height as a variable to incorporate the height and number of trees into a single variable has been devised to describe the relative prevalence of a species and its likelihood to continue within the stand (Fei et al 2006). A linear Pearson correlation was generated for each pairwise combination. To ensure statistical robustness and to investigate the relationships most likely to affect the efficacy of the restoration effort only herbaceous species found on at least 25 plots were analyzed. In 2006, plots that were located on a constructed dam where planted tall fescue is the dominant herbaceous species were also not included. These plots were not used in order to remove an artificial significance of fescue across the site as it is only prominent on a dam to hold in flood waters for constructed wetlands. A total of 10 plots were removed from this area.

T-tests were used to evaluate the relationship between stocking and the herbaceous component. For each of the major herbaceous species ($n \geq 25$) a t-test was run to test if there was a difference between the average percent cover of the herbaceous species for stocked and unstocked plots.

Results

Tree Composition 2004

A total of 1878 trees of 26 species encompassing 15 genera were observed within 537 sample plots in 2004 (Table 1). The major constituents, green ash, boxelder, sweetgum, and sycamore accounted for 66 percent of all stems and over 90 percent of all stems above the browse line. No individuals of these four species were planted and are considered light-seeded invader species. Planted oaks represented five percent of all stems, and three percent of the stems greater than 1.37 m. Only 23 percent of plots attained stocked status with stems greater than 1.37 m. Thirteen percent of these stocked plots (three percent of all plots) contained at least one oak stem, while nine percent were stocked with only oak. Across the entire site, 32.4 percent of all plots contained no stems.

Tree Composition 2006

A total of 1941 trees of 27 species of 16 genera were observed in 539 sample plots in 2006 (Table 2). The major components were green ash, boxelder, hackberry and sweetgum. These species accounted for over 67 percent of total stems and for 68 percent of stems greater than 1.37 m. Sycamore was a more important component of trees above 1.37 m than hackberry. Green ash, boxelder, sweetgum and sycamore account for 83 percent of stems above 1.37 m. Planted oaks accounted for seven percent of all stems and 6 percent of all stems greater than 1.37 m. Thirty seven percent of the plots in 2006 reached stocked status with at least one stem greater than 1.37 m. Twenty six percent of these stocked plots contained at least one oak stem above 1.37m (10 percent of total plots) while 15 percent contained only oak. In 2006, 21 percent of all plots lacked any stems greater than 0.5m.

Table 1. The percent of total tree stem composition, percent of stems larger than 1.37m and the percent browsed for each individual species at Grassy Slough in 2004.

Species	Percent of total tree stem composition ≥ .5m n= 1878	Percent stem ht. ≥ 1.37m n= 418	Percent Browsed
Fraxinus pennsylvanica	34.8	25.4	28.1
Acer negundo	17.7	21.9	30.7
Liquidambar styraciflua	14.1	27.8	0.4
Platanus occidentalis	9.1	16.2	2.6
Celtis occidentalis, laevigata	8.9	0.4	96.1
Quercus palustris	5.1	3.4	94.3
Ulmus americana	2.2	0.2	73.0
Acer rubrum	1.8	0.0	9.7
Populus deltoides	1.1	0.8	5.6
Acer saccharinum	0.9	0.4	25.0
Taxodium distichum	0.9	2.0	6.7
Ulmus rubra	0.9	0.0	93.3
Quercus macrocarpa	0.6	0.0	90.0
Quercus spp.	0.4	0.2	100.0
Quercus michauxii	0.3	0.0	100.0
Salix nigra	0.2	0.4	0.0
Quercus bicolor	0.2	0.4	75.0
Quercus rubra	0.2	0.0	100.0
Quercus velutina	0.2	0.2	100.0
*Nyssa sylvatica**	0.1	0.0	0.0
*Acer saccharum**	0.1	0.0	100.0
*Catalpa speciosa**	0.1	0.0	0.0
*Crataegus spp.**	0.1	0.0	0.0
*Juniperus virginiana**	0.1	0.0	0.0
*Quercus stellata**	0.1	0.2	100.0
*Quercus falcata**	0.1	0.0	100.0

* Only one individual observed

Table 2. The percent of total tree stem composition, percent of stems larger than 1.37m and the percent browsed for each individual species at Grassy Slough in 2006.

Species	Percent of total tree stem composition ≥ .5m n=1941	Percent stem ht. ≥ 1.37m n= 696	Percent Browsed
Fraxinus pennsylvanica	22.5	36.5	36.2
Acer negundo	16.3	13.5	31.0
Celtis occidentalis, laevigata	15.0	2.3	86.6
Liquidambar styraciflua	13.7	15.7	10.5
Platanus occidentalis	10.1	17.1	3.6
Quercus palustris	7.0	5.7	72.6
Ulmus rubra	5.2	0.4	88.1
Acer saccharinum	2.4	4.3	6.5
Acer saccharum	2.3	0.5	26.7
Populus deltoides	1.3	0.8	56.0
Acer rubrum	1.0	0.2	36.8
Taxodium distichum	0.6	1.2	8.3
Juniperus virginiana	0.6	0.5	0.0
Quercus macrocarpa	0.4	0.4	100.0
Liriadendron tulipifera	0.3	0.1	20.0
Ulmus americana	0.3	0.0	80.0
Nyssa sylvatica	0.2	0.1	0.0
Quercus bicolor	0.2	0.0	100.0
Quercus michauxii	0.2	0.1	33.3
Salix nigra	0.2	0.4	0.0
Gledistsia triacanthos	0.1	0.0	0.0
Quercus spp.	0.1	0.0	100.0
Quercus velutina	0.1	0.0	0.0
*Catalpa speciosa**	0.1	0.0	100.0
*Cercis canadensis**	0.1	0.1	0.0
*Quercus phellos**	0.1	0.1	0.0
*Ulmus alata**	0.1	0.0	100.0

* Only one individual observed

Among the major constituents of the site, the differences between 2004 and 2006 are presented in Table 3. The most notable is the increased presence of hackberry in the

Table 11. Pearson correlation coefficients for the percent cover in a plot of major herbaceous species and the number of tree stems, aggregate height of those stems, incidence of browse and distance from forest edge. Data are from Grassy Slough in 2004.

Species	Statistic	Number of trees	Aggregate height	Browse	Distance to edge
Amaranthus spp.	Coefficient	-0.36245	-0.32916	0.03207	0.28838
	P - value	0.1394	0.1823	0.8995	0.2458
Andropogon virginicus	Coefficient	-0.11797	-0.09967	-0.0114	0.08281
	P - value	0.2154	0.2957	0.9080	0.3853
Aster spp.	Coefficient	0.00218	0.31725	0.16423	**-0.45985**
	P - value	0.9927	0.1729	0.4890	**0.0414**
Bromus spp.	Coefficient	-0.21071	-0.21071	**0.30588**	**0.32752**
	P - value	0.1225	0.1225	**0.0231**	**0.0147**
Campsis radicans	Coefficient	0.09391	-0.01368	-0.0559	0.19076
	P - value	0.4641	0.9153	0.6636	0.1342
Conyza canadensis	Coefficient	0.25617	-.027157	0.30522	0.15257
	P - value	0.2756	0.2469	0.1907	0.5208
Epilobium ciliatum	Coefficient	-0.00801	0.03105	0.13679	0.21304
	P - value	0.9619	0.8532	0.4128	0.1991
Erigeron annuus	Coefficient	-0.15531	-0.23803	0.18456	**0.36852**
	P - value	0.3658	0.1621	0.2812	**0.0270**
Juncus tenuis	Coefficient	-0.03079	0.09146	-0.0831	0.15815
	P - value	0.8201	0.4987	0.5391	0.2400
Juncus spp.	Coefficient	-0.24111	-0.19303	0.27088	0.27581
	P - value	0.3200	0.4285	0.2620	0.2531
Setaria spp.	Coefficient	-0.06194	0.07082	-0.0696	-0.09385
	P - value	0.7637	0.7310	0.7355	0.6484
Solidago spp.	Coefficient	0.03221	0.01202	-0.0674	-0.08791
	P - value	0.6217	0.8540	0.3013	0.1774
Sorghum spp.	Coefficient	-0.15569	0.15225	-0.0264	0.08939
	P - value	0.3793	0.3900	0.8820	0.6152
Valerianella radiata	Coefficient	-0.21849	-0.21291	0.08729	-0.32892
	P - value	0.3547	0.3674	0.7144	0.1568

*Significant values in bold

stand. The increase of hackberry from 8.9 percent to 15 percent of the total number of stems was not reflected in the percentage of hackberry that are above the browse line. The percentage of stems above the browse line were dominated by the same four species in 2004 and 2006: green ash, boxelder, sycamore, and sweetgum. Green ash became even more important as it increased 11.1 percent from 25.4 percent of stems above the browse line in 2004 to 36 percent in 2006.

Table 3. Compositional changes in the importance of major species at Grassy Slough between 2004 and 2006.

Species	Change in the percent of total tree stem composition	Change in the percent of stems above the browse line
Fraxinus pennsylvanica	- 12.3	+ 11.1
Acer negundo	- 1.4	- 8.4
Celtis occidentalis, laevigata	+ 6.1	+ 1.9
Liquidambar styraciflua	- 0.4	- 12.1
Platanus occidentalis	+ 1.0	+ 0.9
Quercus palustris	+ 1.9	+ 2.3
Ulmus rubra	+ 4.3	+ 0.4
Acer saccharinum	+ 1.5	+ 3.9
Acer saccharum	+ 2.2	+ 0.5
Populus deltoides	+ 0.2	0.0
Acer rubrum	- 0.8	+0.2

Browse

Incidence of browsing for each species in 2004 and 2006 are in Tables 1 and 2 respectively. Among the major constituents of the stand, hackberries, elms and planted oaks are the most heavily browsed species in both 2004 and 2006. The graphs in figures 2 and 3 show the percentage browse for each species with greater than 15 stems found across the site.

Figure 3. Percent browsed stems for tree species with greater than 15 stems at Grassy Slough in 2004.

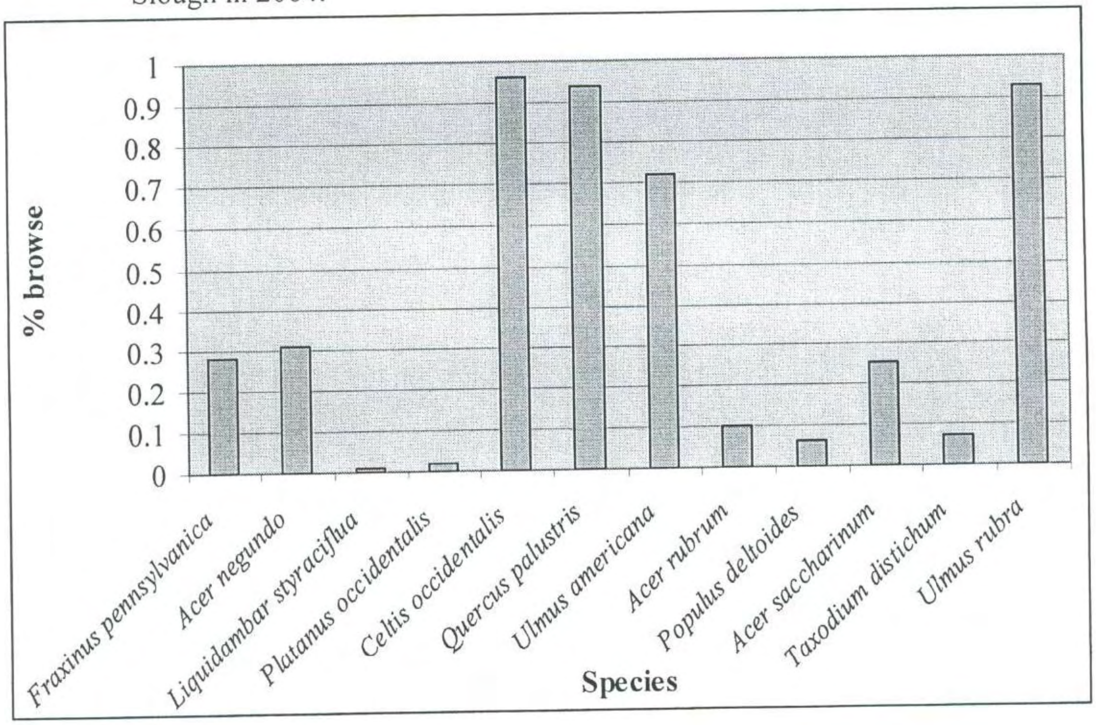
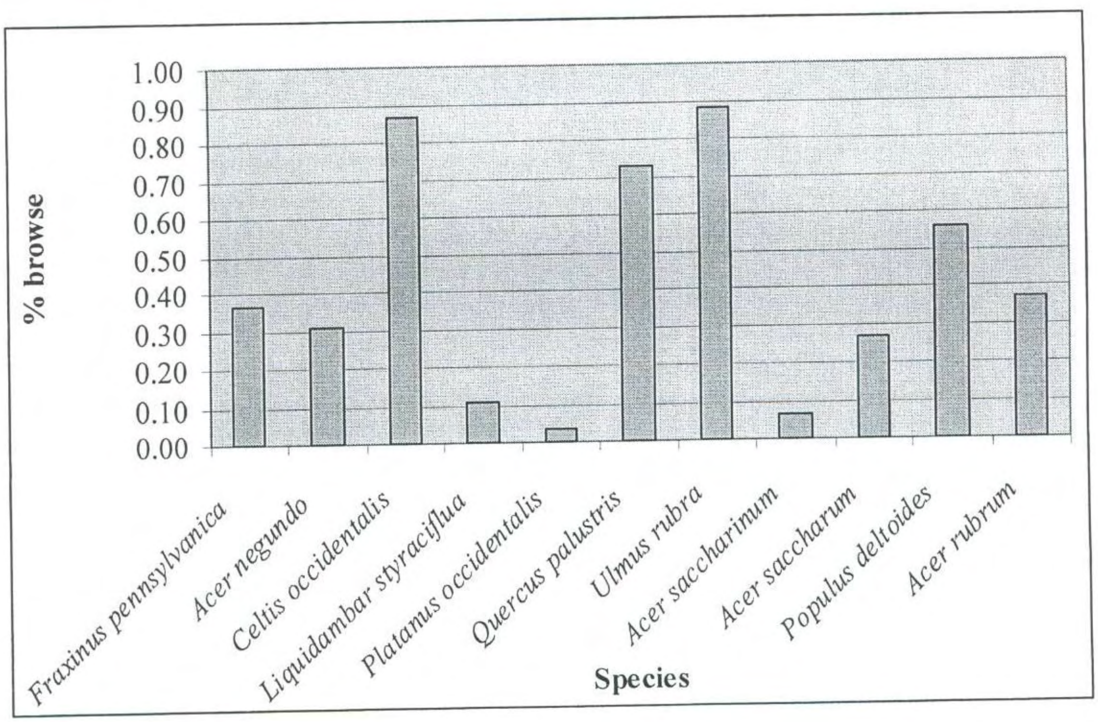


Figure 4. Percent browsed stems for tree species with greater than 15 stems at Grassy Slough in 2006.



T-tests run on the heights of browsed and unbrowsed trees show that incidence of browsing was associated with smaller height. (Table 4).

Table 4. T-test for average height for each species with < 15 stems to test for differences between browsed and unbrowsed height

	Browse	N	Mean	Std Error	Variance	DF	t value	Prob>t
2004	Browsed	12	81.467	36.195	Equal	22	3.43	0.0024
	Unbrowsed	12	116.69	52.87				
2006	Browsed	11	88.981	27.728	Equal	20	2.94	0.0082
	Unbrowsed	11	145.71	22.261				

Browsed stems had a 30 percent decrease in average stem height in 2004 and a 39 percent decrease in 2006 compared with unbrowsed stems. Figures 5 and 6 show the average unbrowsed and browed height for each species with greater than 15 stems in 2004 and 2006.

Figure 5. Average stem height for browsed and unbrowsed stems in 2004.

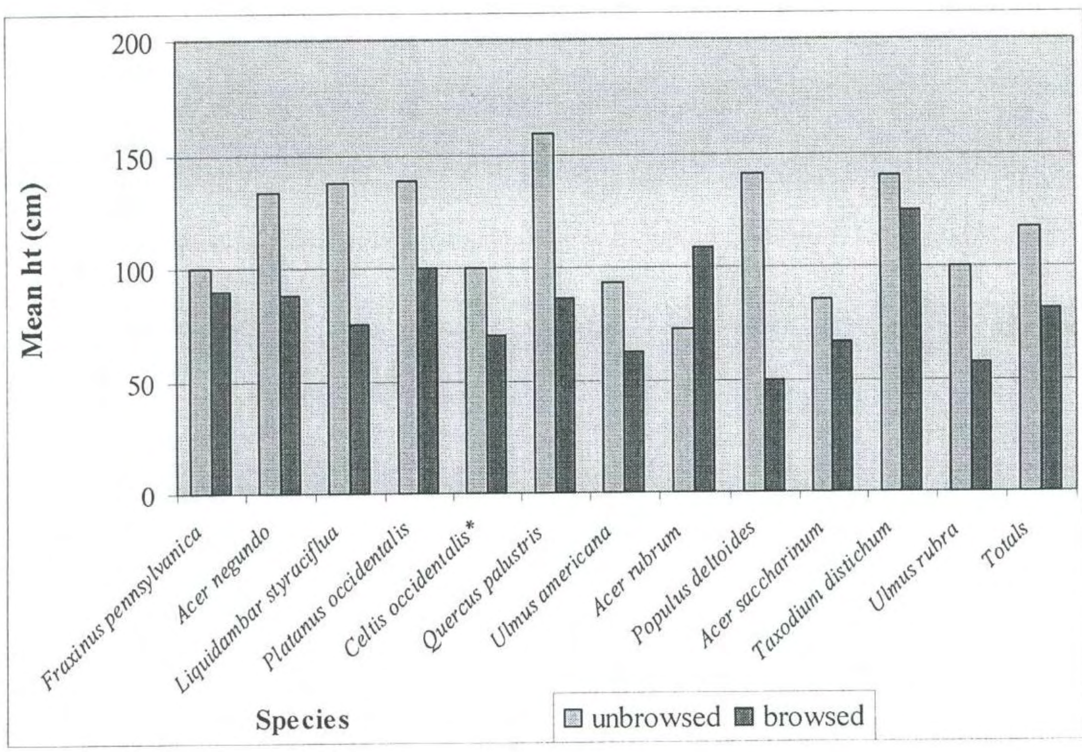
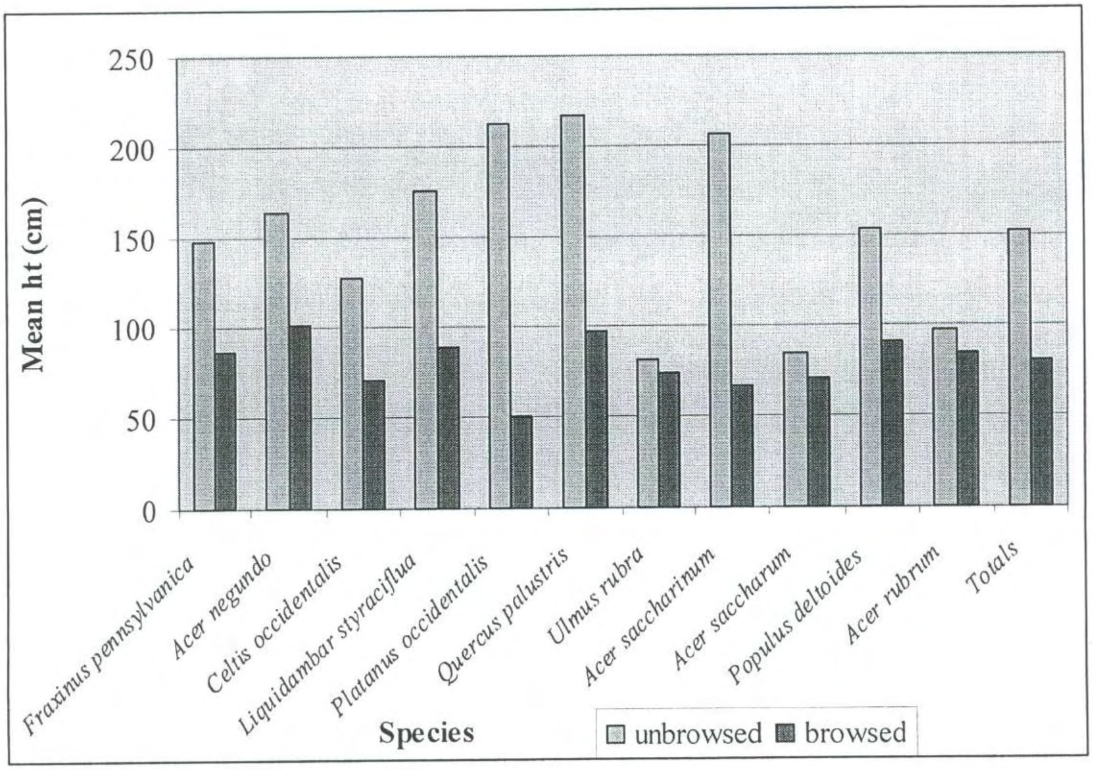


Figure 6. Average stem height for browsed and unbrowsed stems in 2006.



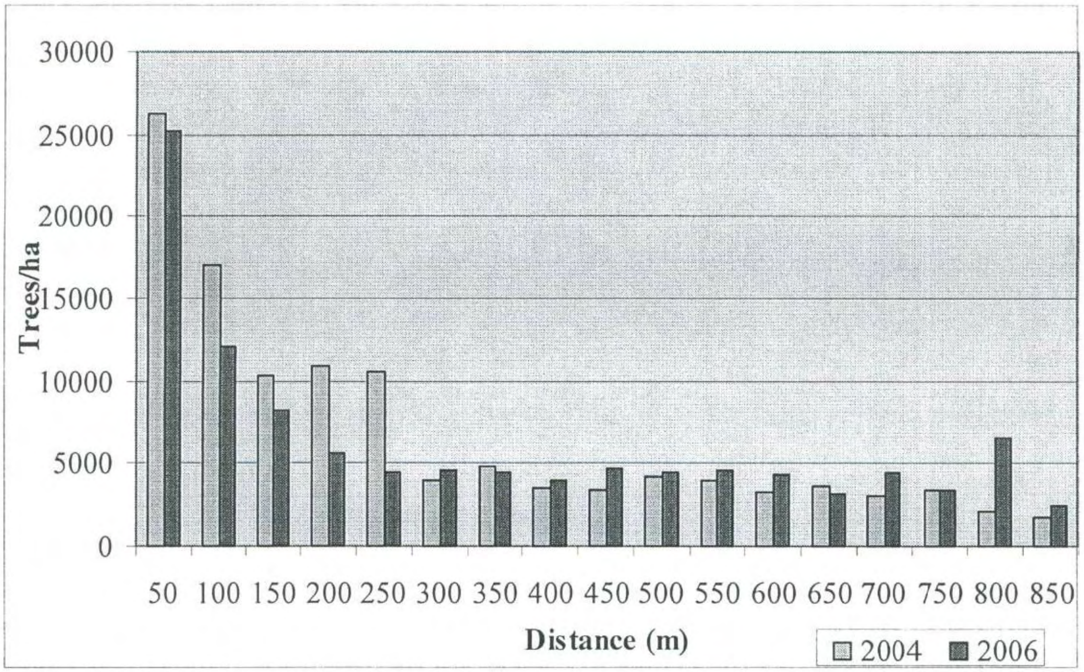
Distance effects

Both stem density measures for all species combined (>0.5 m and >1.37 m) were negatively correlated with distance from the forest edge for both 2004 and 2006 (Table 4). Stem density for stems greater than 1.37 m was also negatively correlated with distance from forest edge (Table 5). All regressions in this section have R^2 values between 0.64 and 0.89 indicating that distance from the forest edge plays a significant role in stem density (Figure 7).

Table 5. Summary table for linear regressions with distance and stem density for 2004 and 2006.

Year	Variable	F Value	D.F.	p > F	R-square	Slope	Y-intercept
2004	stems/ha	117.06	1,15	<.0001	0.886414	-7649.86	51832.24
	stems >1.37m /ha	27.22	1,15	<.0001	0.644708	-1952.51	12934.353
2006	stems/ha	31.64	1,15	<.0001	0.678417	-5552.66	38931.643
	stems >1.37m /ha	30.16	1,15	<.0001	0.667817	-2786.58	18334.97

Figure 7. Stems per hectare and distance at Grassy Slough in 2004 and 2006.



Oak density and distance from forest edge were positively correlated in 2004. The trend was the same but not significant in 2006 (Table 6, Figure 8). Oak stems greater than 1.37 m in height were not significantly correlated with distance from forest edge, although these tests were not statistically robust because of a scant population of oaks taller than 1.37 m (Table 6).

Figure 8. Oak stems per hectare and distance at Grassy Slough in 2004 and 2006.

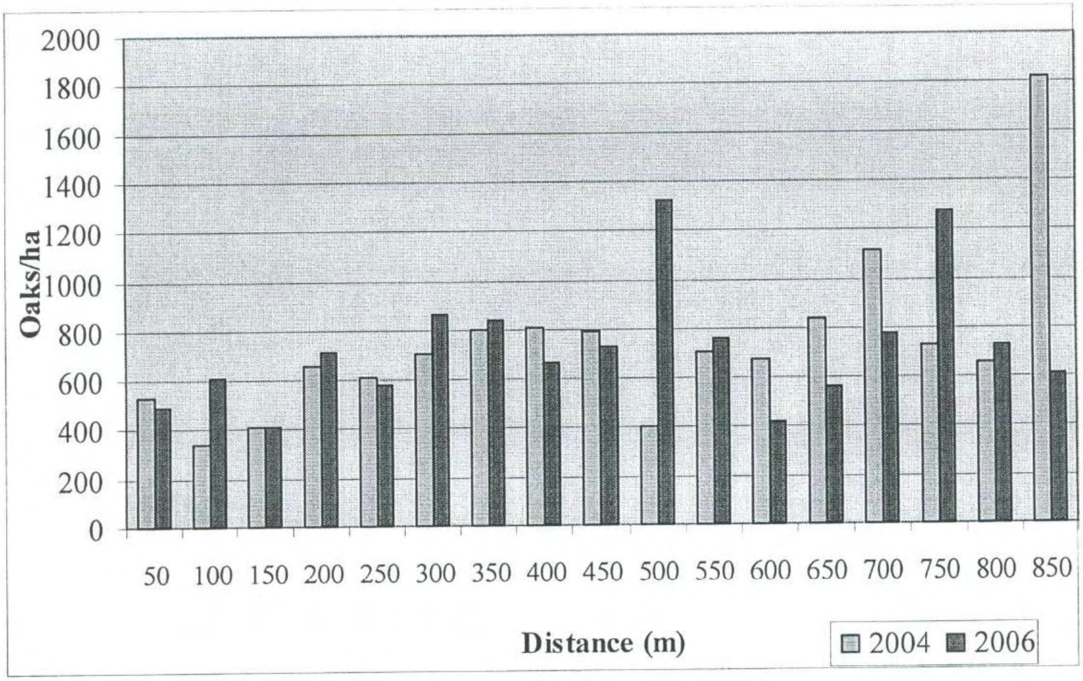


Table 6. Summary table for linear regressions with distance and oak density for 2004 and 2006.

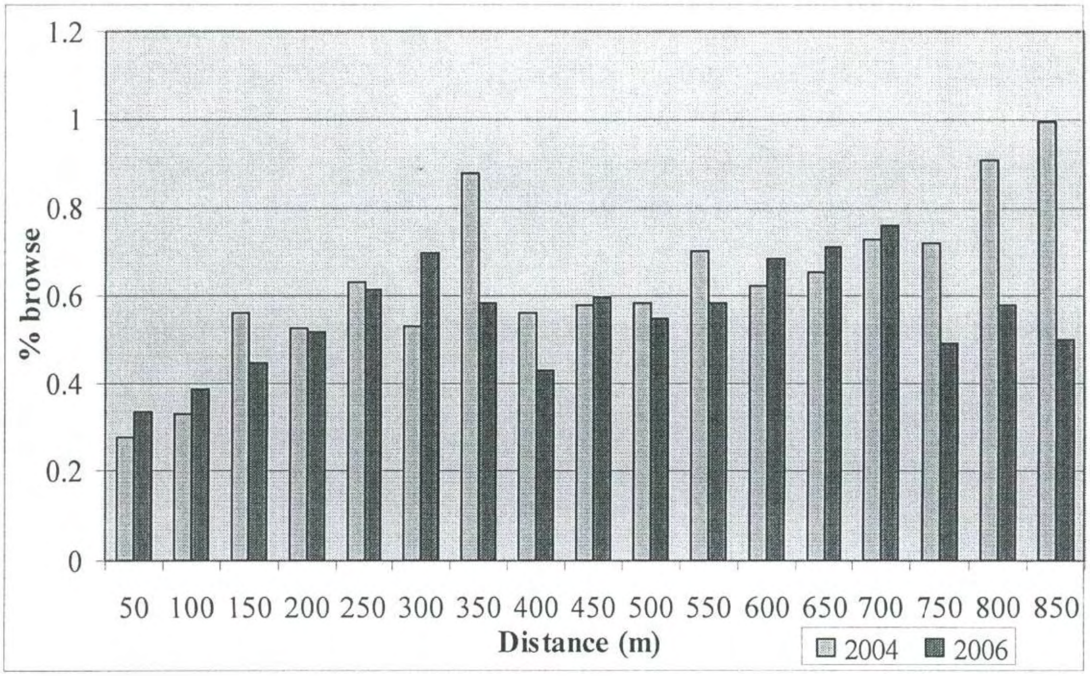
Year	Variable	F Value	D.F.	p > F	R-square	Slope	y-intercept
2004	oak stems/ha	11.50	1,15	0.0040	0.43395	0.001	6.0744
	oak stems >1.37m /ha	0.4	1,15	0.5366	0.02598	-0.499	5.7124
2006	oak stems/ha	1.74	1,15	0.2071	0.10388	0.0004	6.3493
	oak stems >1.37m /ha	1.49	1,15	0.2409	0.09042	72.99	-155.97

Incidence of browse was positively correlated with distance from forest edge for both 2004 and 2006 (Table 7, Figure 9).

Table 7. Summary table for linear regressions with distance and percent browse for 2004 and 2006.

Year	Variable	F Value	D.F.	p > F	R-square	Slope	y-intercept
2004	percent browse	25.68	1,15	0.0001	0.63127	0.0002	-1.17404
2006	percent browse	4.97	1,15	0.0415	0.24882	0.0002	0.67062

Figure 9. Incidence of browse and distance at Grassy Slough in 2004 and 2006



Stocking

The proportion of plots stocked with a tree of any species was not significantly correlated with distance from forest edge during 2004 and 2006. Both showed a negative trend and 2006 was nearly significant. Incidence of oak stocking was not significantly correlated with distance in 2004 or 2006 (Table 8).

Table 8. Summary table for linear regressions with distance and the proportion of stocked plots in 2004 and 2006.

Year	Variable	F Value	D.F.	p > F	R-square	Slope	y-intercept
2004	stocked	0.51	1,15	0.4863	0.03285	-0.047	0.62906
	oak stocked	0.32	1,15	0.5817	0.02070	0.0108	-0.0228
2006	stocked	3.77	1,15	0.0714	0.20066	-0.059	0.713901
	oak stocked	1.10	1,15	0.3099	0.06858	0.0292	-0.04225

Herbaceous and Vine Composition 2004

A total of 69 different species were identified at Grassy Slough from May-June 2004 (Table 8). Seventeen groups were only identified to the genus level and recorded as major species groupings. *Aster spp., Solidago spp. and Carex spp.* are examples of groups that were only identified to the genus level (Table 8). *Solidago spp., Andropogon virginicus, Campsis Radicans* and *Juncus tenuis* were the most common species found at Grassy Slough. which comprised 64.8, 32.8, 19.9 and 15.6 percent of total plots respectively. *Soligago* and *Andropogon virginicus* also had a high mean percent cover at 64.8 and 32.8 when compared to other more common species at Grassy Slough (Table 9).

Table 9. Herbaceous and vine species composition at Grassy Slough in 2004.

Species	Number of plots where present	Percent of total plots n=537	Mean percent cover when present
Abutilon theophrasti	1	0.2	10.0
Ambrosia aremisiifolia	16	3.0	15.6
Amaranthus spp.	28	5.2	17.0
Ambrosia trifida	3	0.6	10.0
Andropogon virginicus	176	32.8	26.2
Apocynum cannabinum	6	1.1	18.3
Asclepias syriaca	3	0.6	15.0
Aster spp.	29	5.4	38.6
Bidens frondosa	4	0.7	28.8
Bromus spp.	71	13.2	35.1
Carex annectens	24	4.5	20.8
Campsis radicans	107	19.9	24.1
Carduus nutans	1	0.2	20.0
Chenopodium album	5	0.9	10.0
Cirsium vulgare	15	2.8	15.7
Commelina communis	1	0.2	10.0
Conyza canadensis	40	7.4	18.4

Cyperus esculentus	1	0.2	20.0
Cynodon dactylon	2	0.4	67.5
Cynodon spp.	21	3.9	21.7
Daucus carota	3	0.6	30.0
Digitaria spp.	8	1.5	33.1
Epilobium ciliatum	58	10.8	18.8
Erigeron annuus	62	11.5	17.9
Erigeron philadelphicus	4	0.7	10.0
Erigeron stigosis	1	0.2	10.0
Festuca arundinacea	9	1.7	22.8
Galium aparine	6	1.1	18.3
Galinsoga ciliata	12	2.2	28.3
Geranium carolinianum	10	1.9	13.5
Gnaphalium obtusifolium	1	0.2	20.0
Hordeum pusillum	23	4.3	28.7
Ipomoea lacunosa	2	0.4	30.0
Juncus spp.	29	5.4	24.7
Juncus tenuis	83	15.5	36.0
Lactuca scariola	1	0.2	25.0
Lespedeza cuneata	1	0.2	20.0
Lepidium virginicum	2	0.4	10.0
Lonicera japonica	16	3.0	32.2
Lolium spp.	6	1.1	24.2
Lycopus Americanus	1	0.2	35.0
Medicago lupulina	14	2.6	27.1
Myosotis spp.	6	1.1	14.2
Myosotis spp.	3	0.6	18.3
Parthenocissus quinquefolia	5	0.9	13.0
Phytolaccaamericana	2	0.4	12.5
Phragmites australis	3	0.6	31.7
Physalis subglabrata	1	0.2	10.0
Plantago purshii	3	0.6	26.7
Plantago spp.	2	0.4	22.5
Polygonum spp.	11	2.0	25.5
Pycnanthemum tenuifolium	1	0.2	10.0
Rubus allegheniensis	7	1.3	22.1
Rubus occidentalis	3	0.6	20.0
Ruellia strepens	2	0.4	20.0
Senecio aureus	1	0.2	10.0
Senecio spp.	1	0.2	10.0
Setaria spp.	39	7.3	37.6

Solanum carolinense	5	0.9	17.0
Solidago spp.	348	64.8	43.0
Sorghum spp.	54	10.1	29.5
Stellaria alsine	3	0.6	43.3
Stellaria graminea	1	0.2	10.0
Torilis japonica	4	0.7	32.5
Toxicodendron radicans	11	2.0	20.5
Trifolium aureum	4	0.7	17.5
Trifolium pratense	3	0.6	25.0
Trifolium spp.	1	0.2	15.0
Valerianella radiata	26	4.8	17.9
Unknown	13	2.4	29.8

Herbaceous and Vine Composition 2006

A total of 76 different species were identified at Grassy Slough from May-June 2006 (Table 10). Seventeen groups were only identified to the genus level and recorded as major species groupings. *Aster* spp., *Solidago* spp. *and Carex* spp. are examples of groups that were only identified to the genus level (Table 10). *Solidago* spp., *Andropogon virginicus*, *Juncus tenuis* and *Campsis radicans* were the most common species found at Grassy Slough, which comprised 82.4, 62.6, 20.6 and 20.4 percent of total plots respectively. *Soligago* and *Andropogon virginicus* also had a high mean percent cover at 41.3 and 29.1 when compared to other more common species at Grassy Slough (Table 10). These two species were also the most likely to form pure stands or to dominate the most plots.

Table 10. Herbaceous and vine species composition at Grassy Slough in 2006.

Species	Number of plots where present	Percent of total plots (n=529)	Mean percent cover when present
Abutilon theophrasti	1	0.2	5.0
Agrimonia parviflora	1	0.2	20.0
Agropyron repens	1	0.2	10.0
Ambrosia aremisiifolia	9	1.7	7.2
Amaranthus spp.	29	5.5	9.3
Andropogon virginicus	331	62.6	29.1
Apocynum cannabinum	33	6.2	7.1
Arundinaria gigantea	1	0.2	45.0
Aster spp.	64	12.1	43.2
Asclepias syriaca	12	2.3	12.5
Bidens frondosa	3	0.6	8.3
Bromus spp.	55	10.4	23.0
Carex annectens	91	17.2	22.4
Carduus nutans	4	0.8	8.8
Campsis radicans	108	20.4	16.3
Carex spp.	16	3.0	17.8
Chenopodium album	4	0.8	12.5
Cirsium vulgare	3	0.6	6.7
Conyza canadensis	31	5.9	14.0
Cynodon dactylon	2	0.4	7.5
Cynodon spp.	24	4.5	20.2
Daucus carota	2	0.4	5.0
Digitaria spp.	2	0.4	7.5
Epilobium ciliatum	30	5.7	11.5
Erigeron annuus	77	14.6	7.4
Erysimum cheiranthoides	1	0.2	10.0
Erigeron philadelphicus	5	0.9	6.0
Erigeron stigosis	1	0.2	5.0
Festuca arundinacea	12	2.3	34.7
Gaillardia aestivalis	1	0.2	5.0
Galium aparine	8	1.5	6.3
Galinsoga ciliata	9	1.7	12.2
Geranium carolinianum	35	6.6	7.3
Gnaphalium obtusifolium	1	0.2	5.0

Hordeum pusillum	15	2.8	18.7
Ipomoea lacunosa	1	0.2	5.0
Juncus effusus	3	0.6	10.0
Juncus spp.	6	1.1	18.3
Juncus tenuis	109	20.6	26.2
Lactuca scariola	3	0.6	5.0
Lespedeza cuneata	15	2.8	24.0
Lepidium virginicum	2	0.4	12.5
Lonicera japonica	77	14.6	27.2
Lolium spp.	3	0.6	13.3
Lycopus americanus	1	0.2	5.0
Medicago lupulina	32	6.0	17.3
Myosotis spp.	2	0.4	5.0
Oenothera laciniata	1	0.2	10.0
Oxalis stricta	2	0.4	7.5
Parthenocissus quinquefolia	19	3.6	13.2
Phragmites australis	8	1.5	38.1
Physalis subglabrata	2	0.4	5.0
Plantago purshii	2	0.4	10.0
Plantago spp.	1	0.2	15.0
Polygonum spp.	4	0.8	12.5
Poe trivialis	1	0.2	5.0
Rosa multiflora	1	0.2	10.0
Rubus allegheniensis	21	4.0	18.8
Rubus occidentalis	1	0.2	15.0
Ruellia strepens	1	0.2	5.0
Senecio aureus	2	0.4	12.5
Senecio spp.	4	0.8	10.0
Setaria spp.	53	10.0	18.4
Solidago spp.	436	82.4	41.3
Sorghum spp.	42	7.9	23.8
Solanum carolinense	2	0.4	10.0
Stellaria alsine	2	0.4	5.0
Stellaria graminea	2	0.4	10.0
Torilis japonica	2	0.4	10.0
Toxicodendron radicans	30	5.7	16.8
Trifolium aureum	18	3.4	19.7
Trifolium pratense	7	1.3	22.9
Trifolium spp.	3	0.6	15.0
Valerianella radiata	72	13.6	13.4
Vitis spp.	8	1.5	8.1

Unknown	5	0.9	20.2

Herbaceous Correlation Analysis 2004

In 2004, there were no significant correlations between the herbaceous percent cover and the tree component (Table 11). The only significant correlations were for distance and one correlation with browse. Incidence of *Aster* spp. was negatively correlated with distance from the forest edge (r = -0.45985) while *Bromus* spp. (r = 0.32752) and *Erigeron annuus* (r = 0.36852) were positively correlated with distance from the forest edge. *Bromus* spp. was also positively correlated with the incidence of browse (r = 0.30588).

Herbaceous Correlation Analysis 2006

In 2006, there were no significant correlations between the herbaceous percent cover and the tree component (Table 12). The only significant correlations were for distance and two correlation with browse. *Asclepias syriaca* (r = 0.59293) and *Campsis radicans* (r = 0.24695) were positively correlated with distance from the forest edge. *Medicago lupulina* was negatively correlated with distance from forest edge (r = -0.3527). *Amaranthus* spp. (r = 0.36777) and *Valerianella radiata* (r = 0.32381) and positively correlated with incidence of browse.

Table 11. Pearson correlation coefficients for the percent cover in a plot of major herbaceous species and the number of tree stems, aggregate height of those stems, incidence of browse and distance from forest edge. Data are from Grassy Slough in 2004.

Species	Statistic	Number of trees	Aggregate height	Browse	Distance to edge
Amaranthus spp.	Coefficient	-0.36245	-0.32916	0.03207	0.28838
	P - value	0.1394	0.1823	0.8995	0.2458
Andropogon virginicus	Coefficient	-0.11797	-0.09967	-0.0114	0.08281
	P - value	0.2154	0.2957	0.9080	0.3853
Aster spp.	Coefficient	0.00218	0.31725	0.16423	**-0.45985**
	P - value	0.9927	0.1729	0.4890	**0.0414**
Bromus spp.	Coefficient	-0.21071	-0.21071	**0.30588**	**0.32752**
	P - value	0.1225	0.1225	**0.0231**	**0.0147**
Campsis radicans	Coefficient	0.09391	-0.01368	-0.0559	0.19076
	P - value	0.4641	0.9153	0.6636	0.1342
Conyza canadensis	Coefficient	0.25617	-.027157	0.30522	0.15257
	P - valuc	0.2756	0.2469	0.1907	0.5208
Epilobium ciliatum	Coefficient	-0.00801	0.03105	0.13679	0.21304
	P - value	0.9619	0.8532	0.4128	0.1991
Erigeron annuus	Coefficient	-0.15531	-0.23803	0.18456	**0.36852**
	P - value	0.3658	0.1621	0.2812	**0.0270**
Juncus tenuis	Coefficient	-0.03079	0.09146	-0.0831	0.15815
	P - value	0.8201	0.4987	0.5391	0.2400
Juncus spp.	Coefficient	-0.24111	-0.19303	0.27088	0.27581
	P - value	0.3200	0.4285	0.2620	0.2531
Setaria spp.	Coefficient	-0.06194	0.07082	-0.0696	-0.09385
	P - value	0.7637	0.7310	0.7355	0.6484
Solidago spp.	Coefficient	0.03221	0.01202	-0.0674	-0.08791
	P - value	0.6217	0.8540	0.3013	0.1774
Sorghum spp.	Coefficient	-0.15569	0.15225	-0.0264	0.08939
	P - value	0.3793	0.3900	0.8820	0.6152
Valerianella radiata	Coefficient	-0.21849	-0.21291	0.08729	-0.32892
	P - value	0.3547	0.3674	0.7144	0.1568

*Significant values in bold

Table 12. Pearson correlation coefficients for the percent cover in a plot of major herbaceous species and the number of tree stems, aggregate height of those stems, incidence of browse and distance from forest edge. Data are from Grassy Slough in 2006.

Species	Statistic	Number of trees	Aggregate height	Browse	Distance to edge
Amaranthus spp.	Coefficient	0.12641	-0.05053	**0.36777**	-0.1452
	P - value	0.5135	0.7946	**0.0497**	0.4524
Asclepias syriaca	Coefficient	-0.30266	-0.29412	-0.2500	**0.59293**
	P - value	0.3390	0.3534	0.4332	**.0422**
Campsis radicans	Coefficient	0.00594	-0.07262	-0.1296	**0.24695**
	P - value	0.9514	0.4551	0.1813	**0.0100**
Medicago lupulina	Coefficient	-0.06162	0.01734	0.02696	**-0.3527**
	P - value	0.7376	0.09250	0.8835	**0.0477**
Valerianella radiata	Coefficient	-0.02631	-0.11593	**0.32381**	0.03882
	P - value	0.8276	0.3357	**0.0059**	0.7479

*Significant values in bold

Herbaceous cover and stocking

Among the major herbaceous species only one had a significant difference among the mean percent cover for stocked and unstocked plots. The mean percent cover of *Valerianella radiata* in stocked plots was 10 while in unstocked plots it was 14.5 (Table 13).

Table 13. T-tests for the mean percent cover between stocked and unstocked plots at Grassy Slough 2006.

Species	Stocking	N	Mean	Std Error	Variance	DF	t value	Prob>t
Valerianella radiata	Stocked	17	10	6.124	Unequal	52.2	-2.06	0.0440
	Unstocked	55	14.455	11.61				

Discussion

Tree Composition

The composition of the tree component in this study is similar to other studies done in bottomland forests in southern Illinois. Grassy Slough was dominated by light-seeded species of green ash, boxelder, sycamore and hackberry. This was expected though all of these species are volunteers that were not planted at the site. (Kruse and Groninger 2003; Hosner and Minckler 1963; Bazzaz 1968 1975; Hodges 1997). Natural regeneration of oaks was rare and was found only near abundant seed sources. Mature oaks were observed close to the edges of Grassy Slough but natural reproduction of oaks had a minimal impact on the afforestation effort (Table 1, Table 2). The presence of fast-growing volunteers may develop into favorable microsites for oaks that will lead to eventual oak dominance (Kruse and Groninger, 2003; Shear et al, 1996).

Changes in the tree composition between 2004 and 2006 were mostly notable for the changes in the percent of hackberries that were observed and the percent of green ash above the browse line in 2006. Hackberry was found mostly in the smaller size classes suggesting that a recent bumper seed crop or an influx of avian seed dispersal contributed to its rise in the smaller size classes (Allen, 1997). It is also possible that in 2004 many of these trees were smaller than 50 cm and not tallied. Also notable is the decline in dominance of sweetgum in 2006. It is possible that the early prevalence of sweetgum was due to its ability to sprout from suppressed root buds. Roots from trees in the surrounding forest may have sprouted and given sweetgum regeneration a head-start. Later competition has reduced the ability of sweetgum to recruit into the stand reducing its percentage of stems.

In 2004 and 2006 green ash had the greatest percentage of stems but that percentage declined. However, this species increased dramatically in percent of trees above the browse line. This coupled with the decrease in percentage of the boxelder and sweetgum above the browse line suggests that green ash is moving into taller size classes more quickly than the other major species (Table 3). Other research supports green ash's ability to grow quickly on similar sites (Kruse and Groninger 2003). On several plots green ash is growing in very dense clumps as an even aged cohort. The density of these plots is likely to decline as competition will select for a few stems to become dominant.

A potential problem with the reliance of ash for the afforestation effort is likely infestation by the emerald ash borer (*Agrilus planipennis)*. Although this exotic pest has only been confirmed in two northern Illinois counties it has the potential to cause extensive damage as 22 percent of the trees at Grassy Slough are potentially vulnerable. This has potential repercussions for the viability of the stand as 25 plots or 12.5 percent of all stocked plots are stocked with only green ash. The borer attacks trees as small as four to five centimeters in diameter at breast height putting some of the larger ashes at Grassy Slough at risk if an outbreak is discovered in southern Illinois (Hack et al 2002).

Distance and Tree Density

The bulk of species found at Grassy Slough were light seeded invader species disseminated by wind, so it was not surprising that distance from forest edge played a large role in both stocking and stem density. Total stem density declines rapidly from zero until about 250 m away from the forest edge then remains steady. These results support other studies which suggest that wind dispersed seeds are most dense from 0 to 90 (Allen 1997) or 200 m (Twedt 2004) from forest edge. In a similar area in southern

Illinois volunteer stem density was sufficient up to 160 m from the forest edge without supplemental plantings (Kruse and Groninger 2003). Seed dispersal is variable with wind patterns, flooding conditions and seed production but it seems likely that areas within 250 meters of a forest edge will have adequate stem density. Seedling establishment and survival is also dependent on microsite conditions that can affect the likelihood of particular species' ability to colonize farther into an old field (Meiners et al 2002). The distance effect is most likely exacerbated with stand age. Twedt (2004) reported that distance from forest edge was more effective in predicting stem density in stands 11-20 years old than stands 2-10 years old. Older stems at Grassy Slough that have made it above 1.37 m and are more likely to become a long term component of the stand have a similar relationship with distance.

When light seeded species were excluded from the analysis and only the planted oaks were used, the slopes differed. The density of oaks increased away from the forest edge. The relationship was only significant in 2004 but the trend was similar and nearly significant in 2006. This discrepancy may be due to higher depredation of oaks closer to the forest edge or competition with the higher stem densities of light seeded species. Density of oaks taller than 1.37 m had no significant relationships with distance as there were not enough for a statistically valid test. Considering the age of the stand the lack of oaks growing above 1.37 m is potentially worrisome for the goal of a hard mast producing forest at Grassy Slough.

Stocking is used to measure the potential of a young stand to become a closed canopy forest. The results of stocking and distance are similar to that of the relationship with stem density and distance. Most of the stocked plots are close to the forest edge suggesting that the farther away from the forest edge the less likely a contiguous closed canopy forest will develop. Oak stocking was inconclusive, showing no significant correlation with the proportion of stocked plots and distance from the forest edge. This is similar from previous research in southern Illinois which showed no significant relationship with oak stocking and distance. The spatial evenness of the planted oaks was believed to be the reason for this (Kruse and Groninger 2003). A similar pattern for oak stocking at Grassy Slough is not surprising.

Deer Browse

The most noticeable effect of deer browse at Grassy Slough was the reduced height of browsed stems. This can lead to reduced growth rates, stem mortality andpoor growth form. The effect of deer browse is widely documented for both individual plants and ecosystems (Russell et al 2001; Cote et al 2004). Deer at Grassy Slough also have shown a preference for certain species of tree, most notably the planted oaks as well as the volunteer hackberries and elms. Deer preference for oaks and hackberries has been observed in southern Illinois in other studies (Schoenholtz et al 2005). The species that are preferred browse for deer at Grassy Slough also form a small percentage of trees making it above the deer at 1.37 m. Comparing the percent browse moving away from the forest edge shows that the percentage of trees being browsed is higher in areas with lower stem density (greater distances). Oaks are also more likely to be found farther away from the forest edge. This suggests that the deer may be actively seeking to browse in areas where preferred browse species (i.e. planted oaks) are more apparent. Deer have exhibited this behavior in other studies (Morellet and Guibert 1999). This could explain why there are more plots stocked with oaks closer to the forest edge because the oaks are less apparent and the deer move to areas where they are more apparent. Considering the typical small stature of oak stems, it is possible that oak stocking will increase substantially over the next several years (Twedt and Wilson 2002). It seems more likely however that deer browse will have a negative impact on the overall composition of the forest at Grassy Slough by reducing the number of oaks, hackberries and elms that make it into canopy. This has potential to delay eventual crown closure or prevent it in areas where density of non preferred species is low.

Herbaceous Analysis

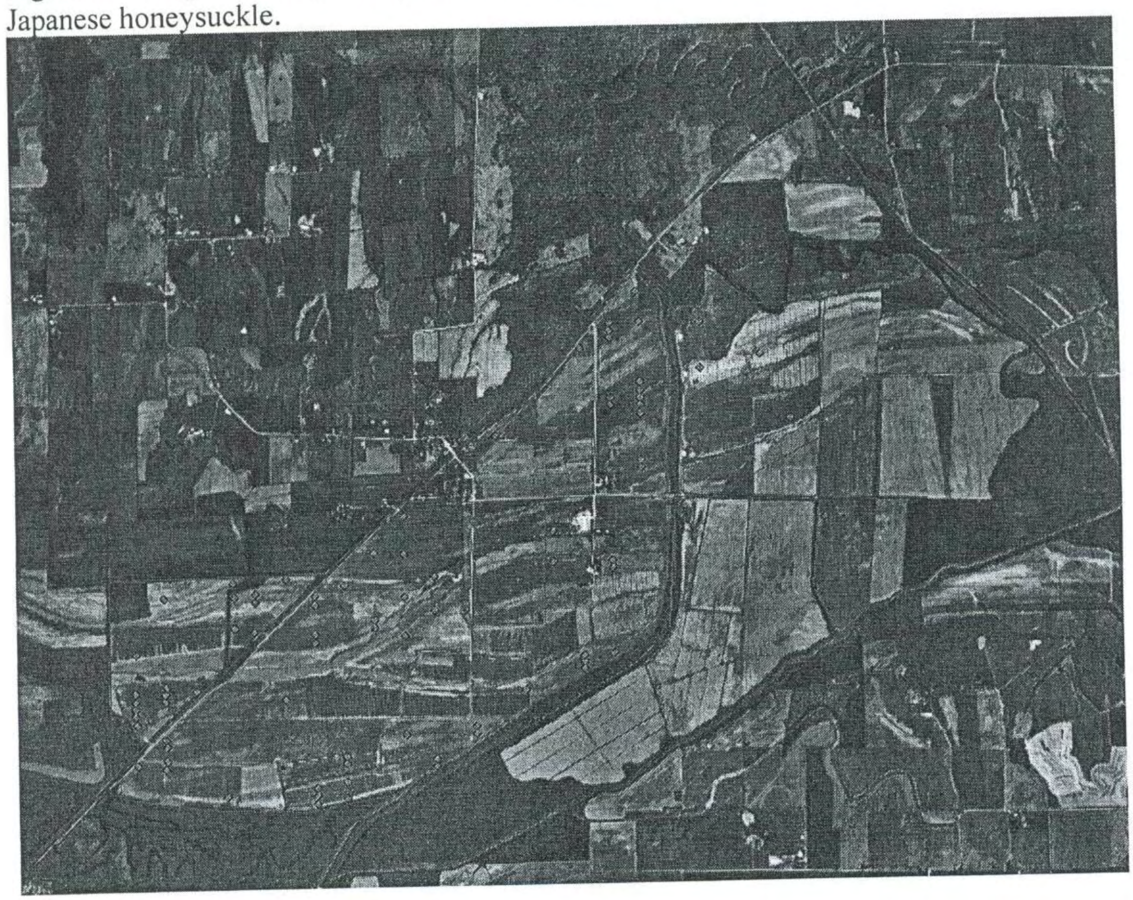
Unlike a previous study in southern Illinois (Kruse and Groninger 2004), there were no significant correlations found between the herbaceous layer at Grassy Slough and either stem density or aggregate height. This does not mean that competition with the herbaceous layer is not important at Grassy Slough. It is possible that other factors such as microhabitat variation, deer browse and distance from the forest edge impact the tree component much more than does the herbaceous component. *Solidago spp.* and *Andropogon virginicus,* the two most abundant species at Grassy Slough, were also the most common species found in other bottomland old field sites in southern Illinois (Kruse and Groninger 2003; Hosner and Minckler 1963; Bazzaz 1968, 1975). They form dense clumps that can be resistant to tree invasion through allelopathy or competition (Bazzaz 1975; Twedt 2004; Bramble et al 1996).

The herbaceous component is was not a static fixture at Grassy Slough. Relative dominance among the species found on the most plots changed between 2004 and 2006. On bottomland sites, elevation and hydrology are the primary drivers of vegetation dynamics (Battaglia et al 2002). Data was not collected on elevation, controlled flooding by berms and dikes or precipitation. Further study would need to be conducted incorporating these variables before conclusive statements can be made on the vegetative dynamics at Grassy Slough.

There were several herbaceous species that were correlated with higher incidence of browse on trees in the same plot. *Amaranthus* spp. and *Bromus* spp. are rated as preferred browse for deer in Texas (Armstrong et al 1991). It is possible that the presence of these herbaceous species enticed the deer to browse longer and more thoroughly in plots where they were located, leading to an increased percentage browse of the tree component. *Valerianella radiate,* the other species that was positively correlated with deer browse also showed a significant difference in its percent cover of stocked plots and unstocked plots. In stocked plots there was less *Valerianella radiata* than in unstocked plots. The correlation with percent browse and percent cover and the tests between stocked and unstocked plots suggest that this species plays some role in deer browse.

Invasion by exotic plants had not been covered extensively in the bottomland afforestation literature but its presence throughout Grassy Slough is a cause for concern. Japanese honeysuckle (*Lonicera japonica)* can form dense mats that out compete native vegetation. It can climb and overtop small trees, alter stem morphology, shade out competing vegetation and eventually form near monospecific stands (Nuzzo 1997). It has the potential to severely degrade areas at Grassy Slough as it is difficult to remove once established. Japanese honeysuckle propagates from avian dispersed seeds and vegetative propagation, thus its potential for rapid invasion is high. It is spreading rapidly at Grassy Slough and presents a problem for future management of the site. In 2004, the species was found in 16 plots and in 2006 it was found in 77 plots or 14.6 percent of plots. It is also not only a problem in existing populations at the edge, it is also rapidly invading the interior of Grassy Slough (Figure 10). Many of these interior populations are forming mature colonies and flowering in the high light conditions presenting an even greater potential for further invasion (personal observation). Heavy deer browse has the potential to exacerbate this situation by potentially stunting tree growth and vigor making it more vulnerable to competition with exotic vines.

Figure 10. Map of Grassy Slough in Southern Illinois in 2006. Marked plots contain Japanese honeysuckle.



Conclusions and Management Recommendations

Grassy Slough is dominated by light-seeded volunteer tree species such as green ash and boxelder. This is not unexpected from previous research in bottomland restoration. Planted oaks comprised a small portion of trees found at the site and an even smaller portion of trees growing to above 1.37 m in height. Distance was found to be an important feature in determining stem density of non-oaks. Stocking and stem density regressions indicate that areas within 200 m of a forest edge are more likely to develop a contiguous closed canopy forest.

Deer browse appears to have a large effect on the tree component especially on preferred browse species: oaks, elms and hackberry. The potential for deer browse to affect the long term viability of the oak component and thus the success of the afforestation effort at Grassy Slough is unclear. A higher percentage of trees being browsed farther away from the forest edge coupled with an increased likelihood of finding an oak in the interior suggests that oaks are more vulnerable to deer predation and thus less likely to survive and become long term components of the stand. This will have implications for the future wildlife carrying capacity or Grassy Slough. Further research needs to be done in order to accurately predict how high deer browsing pressure will affect the future stand.

The effects of competition with the herbaceous component are overshadowed by the effects of distance and deer browse on the tree component at Grassy Slough. It is likely that the herbaceous component plays a role in the efficiency of this afforestation effort though. The competition for light and space as well as alleopathy can affect the tree component. The herbaceous component also has the potential to either hide a tree from predation or attract deer can affect a tree's growth and survival.

At Grassy Slough continued management would need to address the problem with deer herbivory. Continued study into the effectiveness of exclosures or deer repellant is recommended as well as a potential herd cull. Management activities should focus mostly on the areas of Grassy Slough further than 200 m from a forest edge as areas closer are already more likely to develop into a closed canopy forest.

Control and eradication of Japanese honeysuckle should also be a priority for management at Grassy Slough. It will continue to spread, damaging young trees and excluding areas it occupies from supporting trees. If management is delayed, the problem with only get worse. The site also needs to be continuously monitored for the emerald ash borer as an infestation would have a large impact on the afforestation effort. Finally, more research needs to be done to further understand the dynamics of how deer browse will affect the eventual stand.

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VITA

Graduate School
Southern Illinois University

Kenneth J Ruzicka Jr Date of Birth: May 23, 1982

4205 South 24th Street, Quincy, Illinois 62305

6 S 531 Naper Boulevard, Naperville, Illinois 60540

Knox College Galesburg, Il
Bachelor of Science, Biology, Economics, June 2004

Special Honors and Awards:
Xi Sigma Pi, Forestry Honor Society, 2005

Thesis Title:
Deer Browsing and Bottomland Afforestation at Grassy Slough in the Cache River Valley

Major Professor: Dr. John W. Groninger, Department of Forestry

Publications:

Abstract:
Ruzicka K.J. and J.W. Groninger. 2006. Illinois Society of American Foresters Fall 2006 meeting. Reforestation in the Cache River Valley. Ullin, IL September 2006

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