Vegetation Response to Restoration Treatments in a Former Pine Plantation in North Florida

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VEGETATION RESPONSE TO RESTORATION TREATMENTS IN A FORMER PINE PLANTATION IN NORTH FLORIDA

by

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# Table of Contents

Approving Signatures ........................................ Pg ii
Acknowledgments ............................................... Pg iii
Table of Contents ............................................... Pg iv
List of Tables .................................................. Pg v
List of Figures .................................................. Pg vi
Abstract ........................................................ Pg vii
Introduction .................................................... Pg 1
Community Impacts ............................................ Pg 5
Study System .................................................... Pg 7
Study Method .................................................... Pg 10
Hypotheses Tested ............................................. Pg 11
Analysis ........................................................ Pg 12
Results .......................................................... Pg 15
Discussion ....................................................... Pg 18
Tables ............................................................ Pg 23
Figures .......................................................... Pg 30
Literature Cited ................................................ Pg 57
Appendices ....................................................... Pg 67
List of Tables

Table 1. Richness, abundance & diversity results summary  Pg 23
Table 2. ANOVA results for diversity indices summary  Pg 24
Table 3. ANOVA results for tree canopy  Pg 25
Table 4. ANOVA results for change in tree diameter  Pg 26
Table 5. Mean guild proportional abundance  Pg 27
Table 6. G-test of independence for mean guild abundance  Pg 28
List of Figures

Figure 1. Location of research sites Jacksonville, Florida, USA Pg 29
Figure 2. McGirts Creek Plot Locations & GPS Values Pg 30
Figure 3. Tigers Point Plot Locations & GPS Values Pg 31
Figure 4. Study plot and transect design Pg 32
Figure 5. Mean richness at both study sites (A & B) Pg 33
Figure 6. Mean abundance at both study sites (A & B) Pg 34
Figure 7. Tigers Point Diversity Indices (graphs A – D) Pg 35 - 36
Figure 8. McGirts Creek Diversity Indices (graphs A – D) Pg 37 – 38
Figure 9. Mean change in canopy cover at both sites Pg 39
Figure 10. Mean change in tree diameter (DBH) at both sites Pg 40
Figure 11. Mean guild relative abundance for both sites (A & B) Pg 41
Figure 12. McGirts guild relative abundance (graphs A – C) Pg 42
Figure 13. Tigers guild relative abundance (graphs A – C) Pg 43
Figure 14. Tigers Forbs Species Abundance (graphs A & B) Pg 44
Figure 15. Tigers Graminoid Species Abundance (graphs A & B) Pg 45
Figure 16. Tigers Sub-Shrub Species Abundance (graphs A & B) Pg 46
Figure 17. Tigers Shrub Species Abundance (graphs A & B) Pg 47
Figure 18. Tigers Tree Species Abundance (graphs A & B) Pg 48
Figure 19. Tigers Vine Species Abundance (graphs A & B) Pg 49
Figure 20. McGirts Forb Species Abundance (graphs A & B) Pg 50
Figure 21. McGirts Graminoid Species Abundance (graphs A & B) Pg 51
Figure 22. McGirts Sub-Shrub Species Abundance (graphs A & B) Pg 52
Figure 23. McGirts Shrub Species Abundance (graphs A & B) Pg 53
Figure 24. McGirts Tree Species Abundance (graphs A & B) Pg 54
Figure 25. McGirts Vine Species Abundance (graphs A & B) Pg 55
Abstract

As the human population in Florida continues to expand, development follows, and tree farms give way to homes and businesses. As parks are established, restoration of these semi-natural plantations may provide critical habitat for species conservation. This study evaluates vegetation response to restoration treatments at two study sites, formerly tree farms, now preserves in NE Florida. Treatments included thinning, clearing, or control (no treatment) within 10m² plots. Thinning reduced tree canopy to 20% (2-3 pines / plot) and removed all other vegetation; clearing treatments removed all biomass to bare soil; no herbicides were used. Within these plots richness and abundance was assessed by establishing two parallel transects and counting ramets on a bi-annual basis. Tree diameter at breast height (dbh) was also measured (cm). It was hypothesized that release of resources (thinning and clearing) would increase overall diversity (more so in graminoids and forbs), and encourage more robust tree growth versus control groups. Diversity ANOVA (Simpsons & Shannon indices) showed significant differences due to survey date (p<0.05) at the McGirts Creek site and a significant (p=0.056) effect for the interaction term at the Tigers Point site. Tree dbh also increased at a significantly greater rate in thinned, versus control groups at the Tigers Point site (p=0.03) perhaps due to higher initial tree density, but not at the McGirts Creek site (p=0.85). Placing species into guilds revealed both sites reflected high levels of graminoids in cleared plots, which is consistent with early successional species (pioneer plants). McGirts followed hypothesis as forbs and graminoids were dominant in both thinned and cleared plots and the Tigers Point site had higher levels of vines and shrubs than expected. Restoration goals of increasing vegetative diversity, especially in r-selected species, and robust growth can be met by techniques used in this study.
Introduction:

Restoring land near urban and suburban areas may provide diverse habitat for wildlife and afford beneficial services to people. From 2000 to 2006, the population of Florida increased an estimated 13.2% from 15.9 to over 18 million (US Census Bureau 2006). This rapid growth has greatly accelerated the demand for homes, services and retail centers. As expansion reaches more remote areas, tree plantations are frequently converted into suburban development. As conservation is considered in these areas, tree plantations are also frequently the restoration project of choice due to their ubiquitous nature and semi-natural state. The benefits of water management and critical ecosystem services make conservation an important part of city planning. Green spaces keep cities cooler and offer inexpensive storm water control while trees reduce air pollution and encourage physical activity (Beckett et al. 1997, Chang et al. 2006, San-Salazar & Rausell-Koster 2007). Physical activity has been shown to improve human health by reducing the risk for a host of diseases (Bedimo-Rung et al. 2005). Urban forests, parks and green ways provide social and psychological benefits to people and evidence shows reduced stress, less aggression and an increased quality of life for citizens who utilize green spaces (Chiesura 2003).

Many different techniques are used to put a dollar amount on the various benefits of green space. One measure includes membership fees and donations to organizations that promote conservation or preservation. For example in 2007 the Sierra Club held assets of over $91 million while direct donations exceeded $11 million (Sierra Club Financial Statement 2007). In addition The Nature Conservancy held a total assets of over one million dollars while donations exceeded $100,000 in 2007 (Nature
Conservancy Financial Statement 2007). Demand for nature-based recreation in the Florida Apalachicola River Basin revealed each person paid on average $74.18 per day resulting in over $484 million annually for the local area (Shrestha et al. 2007). In the Contingent Valuation Method (Stevens et al. 1991) wildlife is valued in two ways; 1) use values (hunting, fishing, viewing, recreation) and 2) non-use values or existence values (the idea wildlife has an innate right to exist). Others have used a multi-tier approach: 1) the resources themselves (bottled water, forest products), 2) the value of resources to people (hunting fishing, recreation), 3) the value of ecological systems for communities (storm water, shading, flood control), and 4) the value of intact ecosystems (predictable climate, soil stability) (Burger et al. 2007). These varied techniques can lead to a site-specific cost for preservation. Ecosystem services may be enhanced by increased vegetative diversity as shown in field and laboratory studies (Naeem et al. 1994).

It has been suggested that urban shade trees may provide up to $200 in annual services. Trees in an urban area sequester carbon, as well as reduce cooling and heating costs, and ultimately reduce power plant emissions (Akbari 2002). In Venezuela the cost-benefit model of carbon sequestration estimated a 6-12 % return on the investment of green space in the long term, 20+ years (Gutman 2002). Yet Zhu (2007) found that demand for urban trees and forest is positively correlated with income levels and so citizen demand may fluctuate with larger economic trends (Adams et al. 2007).

Because local government or non-profit organizations are frequently given the task of managing public lands, developing feasible guidelines for tree farm restoration in North Florida may propel rejuvenation of native habitat more quickly in these areas. Florida tree farms may offer relative ease in restoration because the farmed tree species
(*Pinus elliotii* or *P. palustris*) are native and herbaceous seed banks may be intact depending on silviculture practices (herbicides, prescribed fire).

Plant life provides not only the basis for the food web but a structural and time context for other trophic levels. Naturally occurring plant communities are effected by soils, climate and the hydrological regime (Hartley 2002, Laughlin et al. 2007). Habitat restoration is generally the process of re-establishing these plant communities in a given area (adapted from Miller 2007). Plants are easy to manipulate relative to other organisms that may re-colonize by natural dispersal and it is well established that vegetation composition will directly or indirectly influence all other organisms utilizing an area (Panzer & Schwartz 1998, Provencher et al. 2003, Chen et al. 2006). Some considerations for restoration include removal of non-native vegetation, condition of the seed bank, nearby recruitment sources, soil status and intact historical cycles (tides, avg. temps). The presence of non-native invasive species (including seeds) has been shown to compromise survival of desired seedlings and therefore the success of the treatment (Williams 2002).

Many times in the southeast U.S. the historic cycle of fires can be reinstated as a restoration tool. However fire is not always realistic depending on forest conditions, climate and proximity to homes or property. Thinning vegetation provides an alternative treatment that mimics some of the effects of fire. Thinning is a disturbance that partially removes the dominant plant species, what Levine and Paine (1974) called a *short circuit*, which renews limited resources and allows non-dominant species to colonize. This disturbance creates a continuum of species which are characteristic of relatively early succession stages. Although fire is the historic cyclical disturbance in Florida, thinning is also useful to achieve restoration goals while minimizing risk. These disturbed patches
are re-colonized by random processes (dispersal mechanisms, seed banks) and in natural systems new patches are constantly created by disturbance (Wiens 1976). Richness was found to increase as leaf litter was removed and many recommend a mosaic pattern of vegetation with temporal, spatial and structural heterogeneity (Sullivan et al. 2002, Provencher et al. 2003, Homyack et al. 2004, Chen et al. 2006).

Setting goals for any restoration project requires a unique approach; however a general set of questions may be followed (Miller 2007). Some restoration goals are dictated by threatened or endangered species with clear benchmarks. Other habitat restoration projects may have many stakeholders and therefore multiple priorities. For this reason many restoration projects focus initially on increasing overall vegetative diversity.

Vegetative heterogeneity may help to stabilize populations of fringe or rare species. In a stochastic event some community members may become locally extinct however a heterogeneous distribution on a diverse landscape increases the likelihood of survivors in refugia. This is the idea of a Minimum Dynamic Area or the smallest area which takes into account natural disturbances and has the potential to re-colonize and therefore minimizes extinction (Pickett & Thompson 1978).

Both short and long-term monitoring are needed. Some have found highest vegetative diversity in mid-successional stages (Ferris et al. 2000), perhaps as early as 2 - 3 years post-treatment (Converse et al. 2006). Others found legumes and forbs showed a large biomass increase five years after thinning and burning treatments (Moore et al. 2005). Others found the 11th - 12th years after restoration treatments show the highest species richness in coniferous forests (Laughlin et al. 2007). Although not all studies
show significant increases species composition was affected in some way (Lindgren & Sullivan 2001). Therefore recommendations for maintaining biodiversity include multiple successional stages and structural heterogeneity (Homyack et al. 2004).

Trees also respond positively restoration treatments as thinning in loblolly pine (Pinus taeda) plantation operations was found to increase tree diameter, foliar output and biomass in general (Bladwin et al. 2000, Arevalo and Fernandez-Palacios 2005). Even old growth, like ponderosa pine (Pinus ponderosa Dougl. Ex Laws) have been shown to benefit from restoration treatments with increases in leaf nitrogen, carbon, water potential and insect resistance (leaf toughness) (Wallin et al. 2004, Stone et al. 1999). Former land use practices will obstruct or facilitate restoration success.

**Community Impacts**

The abundance and diversity of terrestrial primary consumers (herbivores) are species specific, and highly linked to vegetative and habitat diversity (Murdoch et al. 1972, Michel et al. 2007, Moro & Gadal 2007). Thinning in conifer stands has been shown to change plant composition and significantly alter animal use patterns (Homyack et al. 2004). In northwest Florida there is evidence for leaf litter thresholds to maintain small mammal abundance (Litt et al. 2001, Converse et al. 2006). The diversity of small mammals can be manipulated by purposeful thinning at various densities (Sullivan et al. 2005). It has also been found that small mammals are most abundant and diverse over mixed successional stages (French et al. 1976, Churchfield 1987).

In one study tree thinning increased abundance of some rodent species but not others (Fox et al. 2003). However vegetation alone may not explain all patterns as Merritt et al. in 2001 found that inter- and intraspecific competition may be responsible for
population dynamics of six small mammal species in Pennsylvania as opposed to the general explanation of seasonality or resource based schemes. Not all small mammals are limited by structural requirements as some species are limited by food availability (Smith 2007). Further, large herbivores affect small mammals directly and indirectly by altering structural habitat and competing for understory browse (Smit et al. 2001).

Insects constitute another large group of primary consumers, albeit in limited host ranges, whose diversity is often correlated with plant diversity (Murdoch et al. 1972, Panzer & Schwartz 1982). Monoculture forests can have higher levels of herbivory than mixed stands (Jactel et al. 2006, Jactel & Brockerhoff 2007), and in one pine plantation a buffer of broadleaf forest reduced infestation of the pine stem borer (Dioryctria sylvestrella) (Jactel et al. 2002). In other studies vertical plant structure appears to influence syrphid hoverflies and carabid ground beetles (Humphrey et al. 1999). Tree canopy may be an important population factor for coleopterans (Jukes et al. 2002) depending on scale of study. In Arizona, a ponderosa pine (Pinus ponderosa Dougl. Ex Laws) restoration site, species richness was found to be highest where forest canopy was reduced (Laughlin et al. 2007). Generally insect species richness was the best correlate of bird species richness for Provencher et al. in 2003.

Because plant diversity is so important to nearby taxa, the purpose of this initial study was to assess the change in relative vegetative composition across three treatment regimes occurring in former pine plantations that are now preservation land, in Northeast Florida.
Study System:

Two study sites are located in Jacksonville Duval County, Florida (Figures 1, 2 & 3). Both sites were purchased by the City of Jacksonville (COJ) and designated for preservation in perpetuity for local residents as part of the Preservation Project Jacksonville (PPJ) initiated in 1999. Both study sites are former pine plantations, heavily planted with slash pine (*Pinus elliottii*) with densities varying from approximately 20 to 50 trees per 10m² plot and both sites lack robust herbaceous growth due to the heavy leaf litter.

The Betz / Tigers Point site (Tigers) (Figures 1 & 3) is located northeast of the city center and is surrounded by salt marsh vegetation which drains into the Trout River watershed by way of Edwards Creek first and, eventually, the Atlantic Ocean. This site is part of the Pumpkin Hill Buffer State Park, the greater Timucuan Ecological and Historic Preserve (Appendix 1) and the Project Preservation Jacksonville Plan. Remnants stands contain dense mature pines (*P. elliottii*) approximately 50-60 trees per 10 m², a thick undergrowth of saw palmetto (*Serenoa repens*) and gallberry (*Ilex glabra*). Herbaceous growth includes Elliott’s milkpea (*Galactia elliottii*), the bunch grass *Dicanthelium sp.* and the chalky bluestem broomsedge (*Andropogon virginicus var. glaucus*). This site is on a small point sticking north into Edwards Creek and surrounded for many kilometers to the southeast, south and southwest by former tree farms and natural land and to the west, north and east by the waterway. This tends to make this site very sunny and dry with few public visitors.

The McGirts Creek site (McGirts) (Figures 2 & 3), is located slightly closer to the city center in the southwest portion of Jacksonville. Unlike Tigers, McGirts site is part of
the St. Johns River freshwater watershed and drains initially into the Ortega River and, eventually, to the Atlantic Ocean. Initial visual inspection gave the impression of less herbaceous layer, slightly more leaf litter and about 18-20 trees per 10 m². This site is surrounded to the northeast, east and southeast by former tree farm and wetlands towards McGirts. It is surrounded to the south, west and north by suburban development with a relatively contiguous urban forest connected to the site. This site generally has more standing water present and two drainage ditches, one meter in depth run along approximately 20 meters along the entrance road. Some study plots are within 20 meters of these ditches (Fig. 2, parallel lines). Canopy vegetation at McGirts is similar to Betz / Tigers Point with slash pine (P. elliottii) dominating but also includes the water oak (Quercus nigra) and hog plum (Prunus umbellata), but lacks saw palmetto (S. repens) and gallberry (I. glabra) densities. Prominent herbaceous vegetation includes yellow jessamine (Gelsemium sempervirens), huckleberry (Gaylussacia frondosa var. tomentosa) and some plots contain large stands of Carolina redroot (Lachnanthes caroliana) an obligate wetland species. This site seems to be more humid and shaded than Tigers and with more visitors.

Based on the Department of Transportation Florida Land Use, Cover and Forms Classification System (FLUCCS) the vegetation at Tigers indicates a possible historic condition of the upland coniferous forest type Pine Flatwoods (FLUCCS 411). Tree canopy is dominated by slash (P. elliottii), and longleaf pine (P. palustris), while the mid-story is heavily occupied by saw palmetto (S. repens), gallberry (I. glabra) and the understory by various herbaceous species and grasses. There is a possibility of the site grading into a temperate hardwood (FLUCCS 425) along the shoreline dominated by a
variety of slightly more mesic dwelling species including oaks (Quercus spp.), cabbage palm (Sabal palmetto), bays (Persia borbonia, Gordonia lasianthus, Magnolia virginiana), wax myrtle (Myrica cerifera) and sweet gum (Liquidambar styraciflua).

McGirts Creek is classified as a wetland coniferous forest type stream and lake swamps (Bottomland FLUCCS 615). This community has a mix of possible creek and stream bank dwellers including water oak (Q. nigra), red maple (Acer rubrum), sweetgum (L. styraciflua), tupelos (Nyssa spp.) along with cypress (Taxodium spp.) and slash or loblolly pine (P. elliottii or P. taeda). Various moisture dwelling herbaceous species were also present.

These communities can serve as a reference point, but initially an overall increase in treatment plots in vegetative diversity was hypothesized. Seed banks and natural dispersal mechanisms along with limiting factors will contribute to re-colonization. The differences between the two sites make them individual with distinctive characteristics and therefore will have unique responses to any treatments. However initial plant life is expected to favor r-selected species such as graminoids and forbs, typically annuals which produce many small seeds and colonize quickly. More k-selected species like trees, shrubs, and woody vines are expected to encroach after the first growing season. These species put more energy toward root development and produce seeds later in life. Further pioneer species like grasses and sedges may create microclimates for seedlings of other species to germinate as well as restore soil ecology and nutrient cycling. Therefore it may be useful to analyze vegetation with respect to plant guild relative abundance.
Study Method:

Study plots were randomly selected at each research site to receive one of three treatments; control, thinned, or cleared. Fifteen (N = 15) study plots were established at the McGirts Creek site (n = 5 per treatment) and nine study plots (N = 9) at the Betz/Tigers Point site (n = 3 per treatment). Plots were randomly assigned to treatments using a twenty-sided die. Independent sampling was established by locating all plots a minimum of 10 meters (m) from each other. The study plots were 10 X 10m which has been proposed as an effective size for study, using multiple plots to gather a representative sample unit (Peet et al. 1998). Control plots received no treatment. In thinned plots two or three randomly selected living pine trees (P. elliottii) were left to achieve 20% canopy cover, all other vegetation was cleared. Cleared plots were razed to bare soil and raked, shrub and tree stumps were left in the ground. Clearing and thinning was accomplished by chainsaw and hand tools, no herbicides were used. Debris from thinning and clearing was left in piles within a few meters of each plot. These treatments were applied at McGirts Creek in March of 2006 and at Betz/Tigers Point in October of 2006.

Plots were marked by stakes and survey flagging low to the ground so as not to impede animal traffic. In each plot, two permanent vegetation transects were randomly selected to occur at 2.5, 5.0 or 7.5 meters; no two transects overlapped. The orientation of these parallel transects was also randomized by die roll (Fig. 4). Plant transects were assessed two times per year, mid-growing season June to August and during dormant season November to January. This sampling schedule minimized impact to herbaceous species while maintaining a consistent plant characterization from year to year. Further sampling during the dormant season emphasized the presence of evergreen species and
annual fluctuation of cover. Sampling began in the dormant season of 2006 and was considered in this study until the growing season of 2008. The transect belt was a one half meter zone on either side of the transect line and every individual plant or ramet rooted within the belt was counted. During dormant season vegetation was not counted if they lacked photosynthesizing tissues or green leaves. Individuals not rooted in the belt were not counted.

Tree characteristics including canopy cover and trunk diameter at breast height (dbh) were also measured. Canopy density readings were compared as percent cover using a field densitometer (R. E. Lemmon, spherical densiometer model-e, Forestry Suppliers). Canopy readings were taken at a height of approximately 1.5 meters in the center point of each plot facing each cardinal direction. Readings were averaged for each plot and compared to initial percent canopy cover from 2006. Finally tree diameter was assessed by dbh (cm) during 2006 and again in 2008. Only thinned and control plots were assessed in this manner because cleared plots had no canopy cover during the period of the study.

Hypotheses Tested:

Hypothesis 1: A significant increase in vegetative diversity especially in pioneer species was expected in thinned and/or cleared plots versus control plots. No significant differences in vegetative diversity between thinned and cleared plots were expected within the time frame of the study. Hypothesis 2: Canopy cover was expected to increase significantly in thinned or cleared plots compared to control plots. Although no trees remain in cleared plots, trees surrounding plots will increase canopy due to reduced competition for resources. Hypothesis 3: An increase in mean tree diameter was expected
(dbh) in thinned versus control plots because of increased availability of light and soil nutrients in thinned plots.
Analysis:

Analysis of plant community responses relied on a few assumptions about the underlying populations at each site. Assumptions include; 1) species are distributed normally or along a Gaussian probability distribution, 2) our treatment method was applied in a random fashion, 3) Variance ($S^2$) between samples is equal, 4) samples are independent from each other. In this analysis the independent variables are sampling event (survey) and treatment type (treatment) while dependent variables include species richness ($s$), abundance ($N$) various diversity measures and guild abundance. Each site was analyzed separately as differing sample sizes and environmental conditions preclude direct statistical comparison. SPSS version 15.0.0 for Windows licensed to University of North Florida) was used for data analysis. Microsoft Excel was also used for some calculations and analysis of variance (ANOVA).

Initially richness ($s$) and abundance ($N$) were summarized and examined. Two-way ANOVA was then used to examine the source of variation between groups. Diversity indices that take both $s$ and $N$ into account were also calculated. For instance the Simpson’s Diversity Index uses the proportion of the total number ($N$) a species ($n_i$) occupies. Simpson’s Index also called dominance ($l$) is the probability of two individuals taken at random are the same species (intraspecific encounter).

\[ l = \Sigma_{i=1}^{n_i} n_i(n_i - 1) \div N(N - 1) \]

Where $l =$ Simpson’s diversity index

$n_i =$ each species in a series beginning at species $n_1$

$N =$ total number of individuals in each plot
The difference from 1.0 expresses the diversity index $D_s$, or the probability two individuals selected at random belong to different species (interspecific encounter).

$$D_s = 1.0 - \ell$$

The inverse of $\ell$ yields another useful estimation of diversity ($d_s$) which conveys the number of random attempts to retrieve two individuals of the same species.

$$d_s = 1.0 / \ell$$

Overall Simpson indices tend to under represent infrequent species by subtracting one from abundance and then multiplying by itself ($n*(n-1)$). Therefore if only a single individual is present ($n = 1$) the model drives species contribution to zero.

On the other hand, the Shannon Index ($H'$) provides a measure of diversity based on the proportional abundance of each species present in the sample. This index also assumes a representative sample is taken randomly from a larger community or sub-community. $H'$ provides better representation for uncommon or rare species.

$$H' = -\sum_{i=1}^{n} \left( p_i \right) \times \left( \log_{10} p_i \right)$$

Where

- $H'$ = diversity index
- $p_i$ = proportion of the total species the $i^{th}$ species occupies ($n_i / N$)

Next, a two-way ANOVA was used to assess variation in diversity between plots for was investigated at each site using an ANOVA. The assumption of equal variances was tested by an F-test.

Where

- Independent (fixed) Factors: Treatment and Survey
- Dependent Variable: Diversity Indices Values
- Significance: $\alpha = 0.05$
In an effort to review broader scale patterns, species were grouped into functional
groups or guild categories including: forb, graminoid, sub-shrub, shrub, vine and tree
(USDA, NRCS. 2009). The change in relative abundance in guilds from 2006 to 2008
was assessed using a two-way ANOVA with site and survey date as fixed effects. Again
the assumption of equal variances was evaluated by F-test.

Where Independent (fixed) Factors: Treatment and Survey Date

Dependent Variable: Diversity Indices Values

Significance: $\alpha = 0.05$

Additionally a likelihood ratio test was used to assess variation from expected
random distribution. The replicated G-test of independence is preferred to chi-square
because it can examine two or more categorical variables with two or more possible
values. Observed values in this study are theoretical and derived from existing
proportions.

**Generally** \( G = 2 \cdot \Sigma ( \text{Obs} \cdot \ln (\text{Obs} / \text{Exp}) ) \)

Where \( G = \) test statistic

\( \text{Obs} = \) observed values

\( \text{Exp} = \) expected values based on null hypothesis

Next changes in tree diameter (dbh) were assessed in thinned and control plots
only, from 2006 to 2008. A t-test was used to compare the effects of thinning versus
control on pine tree dbh.

\[ t = \frac{(X_1 - X_2)}{S_{x_1,x_2} \sqrt{1/n_1 + 1/n_2}} \]

Where \( t = \) test statistic
\[ \bar{X}_i = \text{mean of the } i^{th} \text{ group} \]

\[ n_i = \text{sample size of the } i^{th} \text{ group} \]

\[ S_{X_iX_2} = \sqrt{\frac{(n_1 - 1)S_{X_1}^2 + (n - 1)S_{X_2}^2}{n_1 + n_2 - 2}} \]

And\[ S^2_{X_i} = \text{Variance of the } X_i^{th} \text{ group} \]

Finally changes in tree canopy were examined from November 2006 to November 2008 and ANOVA will be used to test for significant differences between groups.

Where Factors: Treatment and Survey

Dependent Variable: Mean % Cover

Significance: \( \alpha = 0.05 \)
Results

Mean richness and abundance provided some general trends viewed over time but no significant results. Tigers showed lower richness in control plots compared with thinned or cleared plots. McGirts pattern of richness shows thinned plots with the lowest mean richness followed by control and then cleared plots (Fig. 5). This also indicates fundamental differences in how each site responded to treatments. Abundance, however, showed a more similar pattern between sites and was highest in cleared plots (Tigers N= 659.4, McGirts N= 596.4) followed by thinned (Tigers N= 273.2, McGirts N= 314.2) and control plots (Tigers N= 185.3, McGirts N= 288.9) (Fig. 6).

At Tigers Point, significant deviation (total G, p< 0.05) from a random distribution among guilds was found using the G-test. However these deviations could not be attributed directly to treatment effects (Table 6). Species diversity indices revealed that cleared and thinned plots fluctuated with contrary seasonal trends while control plots fluctuated less and seemed to represent a more stable pattern (Fig. 7). In cleared plots at Tigers, relative abundance was clearly shifted by treatments as graminoids revealed higher values over most survey dates. Vines also held higher than expected values especially in summer 2007 (Figs. 11, 13). Solidago was an important member and increased dramatically such as cleared plots at Tigers (Fig. 14, B). Surprisingly thinned plots seemed more similar to control plots as both were dominated by the vines G. elliottii as well as Smilax spp. and shrubs I. glabra and S. repens. At Tigers, ANOVA of guild abundance showed that only the main effect, treatment, is marginally significant (p= 0.056) (Table 6).
At McGirts Creek, a significant G-test value (pooled G, p < 0.05) revealed a significant deviation from a random distribution of guild abundance due to treatment effects (Table 6). Diversity indices at McGirts revealed a similar pattern to Tigers where some treatment plots showed seasonal variation. At McGirts, however, cleared plots were more stable while control and thinned groups fluctuated seasonally. After the first survey control and thinned plots followed a very similar diversity pattern indicating perhaps a similar species composition (Fig. 8). ANOVA of diversity at McGirts revealed survey date as significant (p < 0.05) for l, d, and both main effects, survey and treatment, were significant for $H'$. Tukey's post-hoc test also revealed that cleared plots were significantly different than both thinned (p = 0.01) and control (p < 0.001) groups. The diversity index D did not meet assumption of homoscedasticity for two-way ANOVA but Kruskal-Wallis showed treatment group mean ranks were significantly different than each other (p < 0.05) (Table 2).

At McGirts, all plots are dominated by graminoids and vines. Cleared and control plots are roughly equivalent in graminoid abundance but control maintains higher vine abundance. Thinned plots were also dominated by vines and graminoids but displayed a more even guild distribution, even allowing shrubs to increase abundance (Fig. 11, A). Relative guild abundance at McGirts reinforced how important vines like *G. sempervirens* as well as *Smilax spp* were for all treatment groups (Figs 19, 25). Graminoids like *D. dichotomum, A. virginicus var. glaucus* and mesic dwelling *L. caroliana* showed increasing prominence in cleared plots while vines declined over time (Fig. 12, C). Thinned plots revealed increased values for forbs such as *Solidago spp.* during the first (winter 2006) survey. ANOVA of guild abundance revealed the main
effect, guild and the interaction effect, guild x treatment as significant (p< 0.05) (Table 6). Although different factors were responsible at each site, hypothesis #1 is supported, there are significant differences between cleared and thinned plots compared to control plots at both sites.

Change in tree canopy displayed a unique pattern at each site. Significant changes in tree canopy were found at both sites, McGirts canopy ANOVA showed significant results for both main effects survey and treatment (p< 0.05) and Tukey’s post-hoc supported this further as cleared plots were found to be significantly different than both thinned and control plots (p< 0.001) (Table 3). Tigers ANOVA revealed the main effect treatment as significant in explaining variation and Tukey’s post-hoc showed control plots significantly different (p< 0.05) than thinned and cleared plots (Table 3).

Trees were dominated by *P. elliottii* and the persimmon *Diospyros virginiana* at Tigers (Fig.18) while *Q. nigra* and *A. rubrum* dominate at McGirts (Fig. 24). Only changes in tree canopy at Tigers support hypothesis #2 as cover was expected to increase significantly in thinned or cleared plots versus control.

Tree diameter changed significantly during this study but not as expected (Fig. 10). At both sites control plots changed significantly (p< 0.05) from November 2006 to November 2008 while change in thinned plots from 2006 to 2008 was only marginally significant at Tigers p= 0.057 (Table 4). At Tigers a non-significant increase was expected in cleared or thinned plots compared to controls. However the significant change in control plots from 2006 to 2008 (at both sites) and the significant difference between thinned and control plots at Tigers exceeded expectations.
Discussion

As anticipated, the composition of vegetation was significantly altered by clearing and thinning treatments used in this study. Both sites showed a deviation from a random distribution (G-test) and at McGirts these results are due to treatments. When treatments removed dominant vegetation it made limiting resources (light, moisture, soil and space) more available. This release may have allowed for germination of seeds, encouraged recruitment and re-sprout from underground vegetative sources (Berger et al. 2004). Generally this resulted in increased vegetative abundance and diversity which will likely have direct effects on local primary consumers including birds, rodents and insects (Waltz and Covington 2004).

Interestingly this study showed mean richness was less affected while mean abundance clearly increased in cleared plots at both sites, a trend which may apply to management goals. This response also suggests an intact seed bank, as some seeds can last for decades (Berger et al. 2004), or a source for recruitment of nearby. It is also noteworthy that zero non-native invasive species were recorded at either site, enhancing the restoration potential. Increased abundance trends also revealed that r-selected species that can colonize quickly and competitively exclude neighbors persisted. One trade off for rapid growth was dormancy during the Florida winter. This resulted in seasonally high relative abundance values as populations rose and declined. Many vines showed high abundance across treatment regimes at both sites like *Smilax* spp., *G. sempervirens*, and *G. elliottii*. Diversity indices detected early successional seasonal fluctuations. ANOVA for species diversity showed different results at each site as treatment effects
were more significant at Tigers while time since treatment (and interaction effects) were more significant at McGirts.

Control plots at Tigers showed less variation in species diversity from season to season compared thinned and cleared plots, perhaps indicating a stable, successional stage. Thinned and cleared plots tended to vary more from season to season, fluctuating above and below control plot values. Cleared plots exhibited the highest diversity in summer with graminoids and vines while thinned plots had highest diversity values in winter with shrubs and graminoids. This alternating pattern was reflected in all Simpsons and the Shannon diversity indices. Interestingly cleared plots at McGirts displayed the same pattern, less fluctuation in species diversity over time while control and thinned plots varied seasonally. These fluctuations are what we would expect if the successional clock had been set back. Faster growing, quick to reproduce (r-selected) species utilize resources as they are made available. In later years (perhaps decades) more shrub, sub-shrub and trees should increase relative abundance as the slower growing, slower to set seed (k-selected) species return.

Cleared plots at both sites had the highest abundance of graminoids as expected. This again indicates the presence of r-selected species (generally annuals) as relative abundance fluctuates seasonally. Therefore if restoration goals include establishing low browse, clearing may be a treatment to consider. Indeed at Tigers it seemed cleared plots responded with a grassy stable state, persisting at least throughout this study.

Trees responded with robust growth to treatments as expected (Bladwin et al. 2000) and increased dbh faster in thinned plots, significantly so at Tigers. Canopy cover results showed some plots were more unique than others. Canopy cover increased in all
but thinned plots at Tigers. This may be due to sampling canopy in November 2006 erroneously before deciduous trees dropped leaves which can vary in northeast Florida from October to December. Surprisingly tree species at Tigers shifted highest abundance from *P. elliottii* to the persimmon *D. virginiana* in a relatively short time. At McGirts cleared plots also showed highest abundance for *Q. nigra*, another unexpected trend which may imply another restoration step is needed as many times restoration in Florida includes reducing the amount of hardwoods in forests that have invaded because of alterations in the natural fire regime. If hardwood reduction is a management goal, then initial restoration treatments may require follow-up monitoring or action. McGirts Creek showed an intuitive pattern as one might hypothesize a release of resources would increase canopy in those trees closest in proximity first. In this case trees in thinned plots are best suited, trees on the edge of each cleared (or thinned) plot are next best positioned and seedling trees, say in cleared plots, competed marginally in the canopy (recorded at breast height) during this study.

Some species may be considered for use in post-planting. Species like *Solidago spp.* proving capable of large increases of abundance in the short term. Ferns were another important pioneer and most likely emerged from underground sources after treatments. One species that was ubiquitous at both sites was *D. dichotomum* which also proved a fast colonizer along with *A. virginicus var. glaucus* at Tigers and the mesic *Lachnanthes caroliana* at McGirts. At both sites shrubs in high abundance included the ever-present *I. glabra* along with *Hypericum spp.* and at Tigers and *Vaccinium spp.* at McGirts. It has been suggested the most common pioneer species may be suitable for use
in regional restoration of plant communities (Lane & Texler 2009), thereby speeding planning and post-planting species selection.

Thinned plots frequently experienced the benefits of clearing vegetation (increased pioneer plants) while maintaining relatively high abundances of other plant groups. In this way thinned plots were also more even in guild distribution. Thinning may be a more moderate restoration technique, but mixed treatments would most likely lead to the most increase in abundance and diversity.

Former pine plantations in northeast Florida may utilize these restoration techniques with greater confidence as they can meet the general goals of increasing abundance and diversity without the risks of prescribed fire. These results also show that recruitment of specific taxa or functional groups (guilds) may be facilitated by these different treatments as each group response in a unique manner.

Future research should seek to expand sample size at both sites, perhaps increasing sampling to four times per year and randomize transects each time. Insect populations are currently being assessed and mammals should also be monitored for a full picture of restoration. Further long term monitoring should be put in place as this study represents only the first two years after treatments were applied, a relatively short time frame. Finally in the future partnering with the City of Jacksonville to allow landscape scale treatments would enhance results.
<table>
<thead>
<tr>
<th>Site</th>
<th>Treat</th>
<th>Survey **</th>
<th>Richness -ss, s</th>
<th>Abundance, N</th>
<th>Simpson Dominance, ( I )</th>
<th>Simpson Inter- ( D_i )</th>
<th>Simpson Intra- ( d_i )</th>
<th>Shannon, ( H' )</th>
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Table 1. Richness, abundance & diversity results summary *Site 1 = McGirits, 2 = Tigers, **Survey 1 = Winter 2006, 2 = Summer 2007, 3 = Winter 2007, 4 = Summer 2008.
<table>
<thead>
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<th>Descriptive</th>
<th>Site</th>
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<th>Variable(s)</th>
<th>Outcome</th>
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<td>2-Way ANOVA</td>
<td>Independent: 1-Survey, 2-Treatment Dependent: Richness (s)</td>
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</tr>
<tr>
<td></td>
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<td>Survey Treatment</td>
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<td></td>
<td>Treatment</td>
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<td>Treatment</td>
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<td>Treatment</td>
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<td>Treatment</td>
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<td></td>
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<td>Tukey's HSD</td>
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<td>Cleared sig diff than both</td>
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<td>2-Treatment Dependent: Dominance (I)</td>
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<td></td>
<td></td>
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<td>p = 0.276</td>
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<td>Treatment</td>
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<td>Diversity (D,)</td>
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Table 2. ANOVA results for diversity indices summary, Significant and marginal values in bold, * Values ln transformed prior to ANOVA. ** Values sin transformed prior to ANOVA.
<table>
<thead>
<tr>
<th>Site</th>
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<th>Outcome</th>
<th>Tukey's HSD</th>
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<tr>
<td></td>
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<td>Cleared plots sig. diff. than thinned (p=0.000) &amp; control (p=0.000)</td>
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<td>Survey * Treatment</td>
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<td>McGirts</td>
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<td></td>
<td>Survey</td>
<td>p= 0.131</td>
<td>Control plots sig. diff. than thinned (p=0.009) &amp; cleared (p=0.000)</td>
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<td>Survey * Treatment</td>
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Table 3. ANOVA results for tree canopy, Independent variables: treatment & survey, Dependent variable: canopy cover, significant values in bold.
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Table 4. t-test results for change in tree diameter, Δ= difference from 2006 to 2008, significant values in bold.
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<th>Survey</th>
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Table 6. Results of ANOVA and G-test of independence for mean guild relative abundance. Significant values in bold. *= Values SIN transformed to meet assumption of homoscedasticity. **= Values LOG10 transformed to meet assumption of homoscedasticity.
Figure 1. Location of research sites Jacksonville, Florida, USA

From City of Jacksonville website: http://www.coj.net/Departments/Recreation+and+Community+Services
Figure 2. McGirts Creek Plot Locations & GPS Coordinates, parallel lines north of plots indicate approximate location of drainage ditches.
Figure 3. Tigers Point Plot Locations & GPS Coordinates
Figure 4. Plot and transect design. Three possible transect locations marked by dotted line (2.5, 5.0 or 7.5m), solid line indicates transect belt, black dots indicate rooting location.
Figure 5. Mean richness at both study sites, graph A= survey, graph B= treatment, error bars indicate standard error of the mean (SEM).
Figure 6. Mean abundance at both study sites, graph A = survey, graph B = treatment type, error bars indicate SEM.
Figure 7, page 1 of 2

A) Tigers Dominance, $I$

B) Tigers Diversity $D$
Figure 7. Tigers Point Diversity Indices, A) $l$ B) $D_s$, C) $d_s$ D) $H'$, error bars indicate SEM.
Figure 8. McGirts Creek Diversity Indices, A) $I$, B) $D_s$, C) $d_s$, D) $H'$, error bars indicate SEM.
Figure 9. Mean change in canopy cover (November 2006 to November 2008) at both sites, error bars indicate SEM.
Figure 10. Mean change in tree diameter (DBH) at both sites; error bars indicate SEM.
Figure 11. Mean guild relative abundance for both study sites, A = McGirts, B = Tigers, error bars indicate SEM.
Figure 12. McGirts Guild Relative Abundance, A= Control, B= Thinned, C= Cleared, error bars indicate SEM.
Figure 13. Tigers Guild Relative Abundance, A= Control, B= Thinned, C= Cleared, error bars indicate SEM.
Figure 14. Tigers Forbs Species Abundance, 1= control, 2= thinned, 3= cleared, error bars indicate SEM.
Figure 15. Tigers Graminoid Species Abundance, 1= control, 2= thinned, 3= cleared, error bars indicate SEM.
Figure 16. Tigers Sub-Shrub Species Abundance, 1 = control, 2 = thinned, 3 = cleared, error bars indicate SEM.
Figure 17. Tigers Shrub Species Abundance, 1= control, 2= thinned, 3= cleared, error bars indicate SEM.
Figure 18. Tigers Tree Species Abundance, 1 = control, 2 = thinned, 3 = cleared, error bars indicate SEM.
Figure 19. Tigers Vine Species Abundance, 1= control, 2= thinned, 3= cleared, error bars indicate SEM.
Figure 20. McGirt's Forb Species Abundance, 1= control, 2= thinned, 3= cleared, error bars indicate SEM.
Figure 21. McGirts Graminoid Species Abundance, 1 = control, 2 = thinned, 3 = cleared, error bars indicate SEM.
Figure 22. McGirts Sub-Shrub Species Abundance, 1 = control, 2 = thinned, 3 = cleared, error bars indicate SEM.
Figure 23. McGirts Shrub Species Abundance, 1= control, 2= thinned, 3= cleared, error bars indicate SEM.
Figure 24. McGirts Tree Species Abundance, 1= control, 2= thinned, 3= cleared, error bars indicate SEM.
Figure 25. McGirts Vine Species Abundance, 1= control, 2= thinned, 3= cleared, error bars indicate SEM.
Literature Cited:


Allison, M., Ausden, M., 2005 Effects of removing the litter and humic layers on heathland establishment following plantation removal. *Biological Conservation* 127:177-182.


Bellocq, M. I., Smith, Sandy M., 1995 Influence of reforestation technique, slash, competing vegetation and duff depth on the overwintering mortality of Pissodes strobi (Coleoptera: Curculionidae), the white pine weevil. Forest Ecology and Management 78:1-10.


Cain, M.D., Shelton, M.G., 2003 Fire effects on germination of seeds from Rhus and Rubus: competitors to pine during natural regeneration. New Forests 26:51-64.


United States Census Bureau, 2006 State and County QuickFacts available online http://quickfacts.census.gov/qfd/states/12000.html
National Plant Data Center, Baton Rouge, LA 70874-4490 USA.


Appendix 1.

Tigers Study Site as part of greater Timucuan Preserve, (small line) and Nassua River aquatic preserves. Courtesy of:

**Nassau River - St. Johns River Marshes Aquatic Preserve**

**Fort Clinch State Park Aquatic Preserve**