WET FLATWOODS RESTORATION AFTER DECADES OF FIRE SUPPRESION

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULLFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTERS OF SCIENCE

UNIVERSITY OF FLORIDA

2011

ACKNOWLEDGEMENTS

I would like to thank my advisor, Carl Fitz for his assistance and support throughout the course of my studies. I would also like to thank my committee members Mack Thetford and Debbie Miller for years of academic support and mentorship. This project could not have been completed without the help of Penelope Bishop, for her always patient assistance in many long field days, Tim Baxely for assistance in the greenhouse, and David Clayton and the Northwest Florida Water Management District.

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December 2011

Chair: H. Carl Fitz
Major: Soil and Water Science

Fire suppression leads to encroachment of woody vegetation into herbaceous ecosystems worldwide. Without fire, wet flatwoods of the southeastern United States have transformed from open grass dominated communities to shrub thickets. To examine the potential for restoration of wet flatwoods converted to shrub thickets by fire suppression we quantified the seed banks, using the seedling emergence technique, and the responses of total vegetation cover to the following multi-plot, multi-site treatments: 1) Thicket - shrub thickets with no modification; 2) Cleared - above-ground woody vegetation removal via GyroTrac + prescribed fire + herbicide applied to woody resprouts; and 3) Disked - same as Cleared, but followed by soil disking.

The Disked treatment significantly reduced woody ground- and canopy- cover, and showed little resprouting and increased herbaceous cover, while the Cleared treatment did not reduce the resprouting of woody species and reduced herbaceous cover. Ten months after treatment, four species (*Rhexia sp., Drosera capillaris, Xyris brevifolia, and Hypericum sp*.) common to fire maintained wet flatwoods were found in vegetation surveys and seed banks of the Disked treatments. These four species were

found in seed banks of the Thicket and Cleared treatments, but not found in the associated vegetation surveys. Thus, soil disking may have helped express the seed bank and reduce woody cover. However, in systems that have been fire suppressed for decades, the vegetation and seed bank analyses indicated that the seed bank will be insufficient to restore the understory community composition without additional management activities such as direct seeding or planting.

CHAPTER 1
INTRODUCTION

Overview

Wet flatwoods are low flat pinelands that span across the southeastern Coastal Plain of the United States. They are an important ecological community because they provide many unique ecosystem services including ground-water recharge, water quality improvement, wildlife habitat, biomass production, carbon sequestration, and energy redistribution (Clark et al. 1999, 2004). Wet flatwoods across the Southeast United States have been drastically altered by the influences of agriculture, silviculture, and development. These practices have led to a fire excluded system which has rapidly changed the structure and species composition of the plant communities. Created by years of fire suppression, this new degraded system no longer supports the rich diversity of flora and fauna that was typical of pre-settlement wet flatwoods communities. By 1900, 50% of natural fire-maintained wet flatwoods had been severely altered and by 1990 almost all of the remaining wet flatwoods had been altered (Ware et al. 1993). In recent years land managers throughout the Coastal Plain have encountered many obstacles in their attempts to successfully restore wet flatwoods.

Intact fire maintained wet flatwoods are dominated by an overstory of longleaf pine (*Pinus palustris* Mill.*)* and an herbaceous dominated understory. In the absence of fire, wet flatwoods become degraded and are dominated by shrubs and hardwood trees (Ainslie 2002). This degraded condition is common throughout the southeastern Coastal Plain and has become a focus for restoration projects in the Florida panhandle. The Northwest Florida Water Management District has initiated over 400 acres of wet flatwoods restoration and has plans for additional restoration sites for the future

(NWFWMD 2010). Numerous studies (Coffey and Kirkman 2004, Cox et al. 2004, and Welch et al. 2004) have led to very good insights into techniques to restore upland groundcover, however, there is comparatively limited understanding of groundcover restoration processes in fire suppressed wet flatwoods. The broad goal of the study is to investigate methods of restoring wet flatwoods groundcover.

Vegetation

Pristine wet flatwoods are pine forests with sparse to no midstory and dense groundcover of hydrophytic grasses, herbs, and low shrubs. The pine canopy typically consists of one pine species or a combination of longleaf pine (*Pinus palustris*) and slash pine (*Pinus elliottii* Engelm.)(FNAI 2010). Compared to longleaf pine dominated wet flatwoods, it is thought that those dominated by slash pine with more shrub cover may have had longer fire intervals of 5-7 years, or a few periods of such longer intervals (Landers 1991).The understory in wet flatwoods is composed of some of the most species rich communities in the western hemisphere and contains some of the highest concentrations of threatened and endangered plant species in the Southeast (Walker and Peet 1983, Peet & Allard 1995).

The Florida panhandle has many threatened, endangered, and/or endemic plant species that are found in fire maintained grassy wet flatwoods. Some of these species include pine-woods bluestem (*Andropogon arctatus*), southern milkweed (*Asclepias viridula*), Curtiss' sandgrass (*Calamovilfa curtissii*), wiregrass gentian (*Gentiana pennelliana*), Panhandle spiderlily (*Hymenocallis henryae*), white birds-in-a-nest (*Macbridea alba*), bog tupelo (*Nyssa ursina*), Apalachicola dragon-head (*Physostegia godfreyi*), pinewoods wild petunia (*Ruellia pedunculata* ssp. *pinetorum*), and Florida skullcap (*Scutellaria floridana*)(FNAI 2010). The high species richness and diversity of these sites make them a priority for conservation and restoration efforts.

Table 1-1 represents commonly found species from nine high quality wet flatwoods sites in the Florida panhandle with supporting data from other sites throughout the panhandle (Kindell 1997, FNAI 2010). High quality fire maintained wet flatwoods have been altered in a variety of ways over the past century, resulting in many of the original flatwoods to become dominated by less desirable woody shrubs and trees, as discussed in the sections below.

Hydrology

At one time wet flatwoods were an abundant community type throughout the coastal plain of the Southeast. Due to the colonization and management by Europeans less than two percent of fire-maintained wet flatwoods remain (Ainslie 2002). Wet flatwoods are easily susceptible to degradation by changes in hydrology and fire regime. Proper hydrology is vital to the success of any wetland restoration effort.

The hydrology of wet flatwoods is maintained by shallow ground water tables, poor drainage, and flat landscapes with low hydraulic gradients (<0.5 percent slope). Soils in wet flatwoods often have an argillic (clay) horizon, which slow drainage. They rarely flood deeper than 10-15 cm yet the water table can drop to 1 m or more below ground when evapotranspiration (ET) is high and rainfall is low (Rheindhart et al. 2002). A disturbance such as ditching would have a dramatic affect on the hydrology of wet flatwoods by slowly draining the system causing a shift in flora and fauna. However, it has been found that hydrologic responses to silviculture are typically short-term increases in the water table due to a reduction in ET (Lockaby et al. 1997a). Tree removal also has been found to have minimal impacts on the hydrology due to soil moisture and heat conditions that prompt vegetation recovery and allowing the disturbed hydrology to recover quickly (Sun et al. 2002). Recent models have suggested that future forest removal and climate change would have pronounced impact in the ground-table during dry periods but limited impacts under wet conditions (Lu et al. 2009). The hydrologic impacts of disturbances, such as ditching, silviculture, and road building, are well documented, as stated above, however the effects of woody invasion on the hydrology of wet flatwoods communities is not well documented.

Disturbance

Wet flatwoods are fire dependant systems and much of their composition, structure and functions depend on natural fire regimes. Nutrient recycling occurs in pulses following fires resulting in a rapid turnover of nutrients that enable wet pine flats to quickly recover their characteristic biomass and structure after fires (Rheinhardt et al. 2002). The historic presettlement fire interval for all types of pinelands across the Southeast is estimated to have been 1-3 years (Frost 1998). This fire interval is sufficient to control the invasion of shrubs and maintain an open herbaceous understory (Drewa et al. 2002). Fire not only keeps wet flatwoods open for herbaceous cover, it also plays a vital role in the reproductive strategies of many species. Some plant species can not only tolerate fire but require fire to promote flowering. Fire is the flowering stimulus for wiregrass (*Aristida stricta* Michx.), a consistently dominant understory plant in longleaf savannas (Platt et al.1988). For those reasons, species composition and structure often reflects the underlying fire regimes of the habitats.

Folkerts (1982) noted that 20 years of fire suppression resulted in the elimination of herbaceous pine flatwoods in some areas of the Gulf Coast of the southeastern US. Loss of the herbaceous understory component is attributed to the reduction in light and competition created by the production of shrubs and trees and from the elimination of germination sites due to litter layer buildup (Maliakal et al 2000). The encroachment of trees such as black titi (*Cliftonia monophylla* L.*)* and titi (*Cyrilla racemiflora* Brit.*)* can happen rapidly and permanently alter the site. In the Apalachicola National Forest over 14% (80,000 acres) of the landscape, was degraded due to titi invasion over the past several decades. It was also determined that fire intervals exceeding 3 years were not adequate to control titi invasion (Hess and Laniray 2008). After several years without fire, woody species may encroach to a point where the reintroduction of prescribed fire will not effectively eliminate the shrubs and trees, and consequently mechanical removal may be necessary (Drewa et al. 2002)**.** Titi can be eliminated by extremely hot fire but that typically results in dangerous crown fires that have the potential to spot and lead to the mortality of pines (Ferguson 1998). Long-term shifts in fire regimes may produce changes to plant communities that are irreversible. (Drewa et al. 2002) showed that the short term (<10 yr) introduction of prescribed fire will not reverse the shift in plant communities.

Frequent fire used as the only restoration tool has not been successful in achieving diverse plant communities in some ecosystems (Heslinga and Grese 2010). In Florida dry prairies, mechanical removal of woody material prior to the reintroduction of fire has been found to be more effective than prescribed burning alone (Watts and Tanner 2006). Fire suppression can also result in the accumulation of organic litter and eventually lead to the formation of an organic layer that is not normally seen in wet flatwood systems. In summary, fire suppression has caused a major shift in plant community dynamics in all fire dependant systems in the Southeast, resulting in the loss or degradation of the majority of wet flatwoods throughout this region (Ware et al. 1993).

When a disturbance regime such as fire has been altered it is possible for the ecosystem to reach an alternate stable state. Alternate states are combinations of ecosystem states and environmental conditions that may persist at a particular spatial and temporal scale (Gunderson 2000). In the case of some wet flatwoods, the alternate state can become a hardwood dominated wet flat. If so, this suggests that those wet flatwoods have shifted to a new state that cannot be restored to the previous condition solely by re-establishing historical disturbance regimes (sensu Suding et al. 2004). Thus, restoration efforts may need to manipulate more than the single factor that led to the degradation (Beisner et al. 2003). Management decisions need to acknowledge that restoring a degraded system can be a complex effort, as the degraded system may represent a stable state resilient to change.

Active Management

Removal of invaded woody species can be the most arduous task of the restoration process. Typically, the clearing of trees and shrubs results in the subsequent resprouting of those plants from their underground biomass. Titi and black titi are aggressive resprouters after removal of aboveground biomass by clearing methods, such as the use of Gyro-trac machines. Gyro-trac machines are all-terrain mulching machines that have shown to be effective at removing and mulching understory and mid-story vegetation, including small-to-medium trees, while causing little physical disturbance to the soils (Mitchell 2005). Control of resprouting has been attempted through fire. More resprouting is found to occur following burns in the dormant season than during the growing season, regardless of habitat or region. However, repeated growing season burns have not resulted in reduced densities of established trees and shrubs in pine savannahs (Drewa et al. 2002). Fire can help control resprouting of woody species by the use of growing season burns, but prescribed fire primarily disrupts the above ground biomass of the plant. When extensive resprouting is a problem, it may be necessary to attempt methods that will have a greater impact on the below ground biomass.

Disking is one such method that impacts the below ground biomass, leading to diminished resprouting of shrubs and trees. The resprouting capability of woody vegetation depends on both above- and below-ground plant reserves, and on the possibility of making or maintaining the necessary storage organs during intervals between disturbances (Bellingham 2000). Disking, to overturn the soil with an implement such as a harrow or plow, has a massive impact on the reduction of above ground and below ground biomass, whereas prescribed fire generally only impacts the above ground biomass. Fritzsch (2004) revealed that disking greatly diminished resprouting vigor in temperate grasslands. The potential for disking to assist in controlling resprouting needs to be examined in wet flatwoods, where resilient woody vegetation species have encroached. Furthermore, disking may have a positive effect on the expression of a seed bank that has been in submission in the soil for years. Thus, it should be important to consider the affects of disking on the seed bank, soil, and vegetative community in wet flatwoods that are targeted for restoration.

Seed Bank

Viable seed banks are imperative to the success of many restoration efforts. Planting vegetation in absences of a viable seed bank can be very expensive and often times the proper native species are not available. In degraded wet flatwoods, woody overgrowth can result in the accumulation of an organic layer that impedes the emergence of the historic seed bank. It is possible that a disking treatment could bring the buried seed bank to the surface and intermix the organic layer with lower mineral soil layers. In a study of shallow marshlands, disking increased vegetation diversity and taxon richness, and increased abundance of annual species but decreased that of perennials (Polesk et al.1995) . Species richness was increased in a study of Carolina bays in the season following disking (Kirkman and Shiritz 1994). However, in order to know what affects disking may have on emergence of seedlings from a seed bank, it is first necessary to know whether or not there is a viable seed bank present.

The presence and composition of a seed bank should be studied before a restoration plan that utilizes the seed bank is attempted (van der Valk & Pederson 1989). When the natural understory vegetation has been eliminated, as in the case of many decades of woody encroachment, reestablishment through a seed bank presents a valuable restoration potential (Simpson et al. 1989). However, reliance on seed banks to revegetate degraded systems has been a widely studied and debated topic in restoration ecology (Aronson et al. 2008, Middelton 1999, 2003, Smith et al. 2002, Wetzal et al. 2001).

While many wetland restoration projects rely on the seed bank for revegetation, many researchers have suggested that the use of a seed bank will never lead to historical diversity. For example, the seed banks of restored wetlands were found to contain fewer species and fewer seeds than those of natural wetlands (Galatowitsh and van der Valk 2006, Aronson et al. 2008). In a review of global seed banks studies (Hopfensperger 2007), species richness was not related to seed banks and the similarity between seed banks and extant vegetation was low in all ecosystems. In fire-suppressed flatwoods there is a potential to lose species which recover vegetatively after fires, but which are not present in the seed bank (Mailakal 2000). For several important species in longleaf pine ecosystems, there is lack of evidence of a persistent seed bank, and reintroduction of seed would likely be necessary for successful complete restoration of groundcover species in these ecosystems (Coffey and Kirkman 2006). However, some target species such as white topped picture plant (*Sarracenia leucophylla* Raf.*)* are very long lived, and are capable of remaining dormant for decades in the seed bank, emerging only after the reintroduction of fire and elimination of woody vegetation (Folkerts 1990). It is apparent that it can be difficult to generalize about the presence and composition of seed banks across habitats and regions. Contrary to Coffey and Kirkman's (2006) studied system, diverse and viable seed banks were found in severely disturbed longleaf pine ecosystems of the North Carolina coastal plain (Cohen et al. 2004).

Study Objectives

Restoration of highly degraded ecosystems can be an ominous task for any restoration ecologist. Degraded wet flatwoods present numerous challenges given that the system has often shifted to an alternate resilient ecosystem. The absence of a natural fire regime creates the shift from an open herbaceous dominated flatwoods system to a tree- and shrub- dominated thicket. The failure of land managers to transform dense woody wetlands into open herbaceous dominated wet flatwoods has increased the necessity to better understand the factors influencing successful restoration. The overall goal of this study is to examine the restoration potential of wet flatwoods sites in Florida, assessing current restoration practices and determining the viability of new combinations of restoration treatments.

Investigating several degraded wet flatwood sites in north Florida, the specific objectives of this study are to: 1) evaluate the vegetation response to a combination of restoration treatments; 2) determine the viability and species composition of the existing seed bank; and 3) following previous restoration treatments, determine if soil disturbance via disking will a) reduce resprouting of undesirable woody species and b) aid in seedling emergence from existing seed banks.

Table 1-1- Common vegetation species found in high quality wet flatwoods of the Florida panhandle (FNAI 2010)

Common Wet Flatwood Species		
Aletris lutea	*Hypericum brachyphyll.*	*Polygala cymosa*
Andropogon arctatus	*Hypericum fasciculatum*	*Polygala ramose*
Aristida beyrichiana	*Ilex coriacea*	*Rhexia alifanus*
Balduina uniflora	*Ilex myrtifolia*	*Rhexia lutea*
Bigelowia nudata	*Lachnanthes caroliniana*	*Rhynchospora chapmanii*
Carphephorus pseudolia.	*Liatris spicata*	*Rhynchospora ciliaris*
Chaptalia tomentosa	*Lilium catesbaei*	*Rhynchospora oligantha*
Coreopsis floridana	*Lophiola Americana*	*Rhynchospora plumose*
Ctenium aromaticum	*Lycopodium spp.*	*Sabatia bartramii*
Dichromena latifolia	*Muhlenbergia expansa*	*Sabatia macrophylla*
Drosera capillaris	*Myrica heterophylla*	*Sarracenia flava*
Drosera tracyi	*Oxypolis filiformis*	*Sarracenia psittacina*
Eriocaulon compressum	*Panicum spretum*	*Scleria baldw inii*
Eriocaulon decangulare	*Pinguicula lutea*	*Scleria triglomerata*
Euphorbia inundata	*Platanthera nivea*	*Taxodium ascendens*
Helenium vernale	*Pleea tenuifolia*	*Tofieldia racemosa*
Helianthus heterophyllus	*Pogonia ophioglossoides*	*Xyris ambigua*
Helianthus radula	*Polygala cruciata*	*Xyris baldwiniana*

CHAPTER 2
METHODS

Site Management History

After sixty years of fire suppression on former wet flatwoods in the Florida panhandle, the overgrowth of shrubs and trees resulted in communities drastically altered from their former states. These areas were overgrown with undesirable vegetation, primarily *Cliftonia monophylla* and *Cyrilla racemiflora* that formed a dense thicket. The thicket had trees that reached 25-30 cm diameter breast height (dbh), stood 5-10 meters tall, and made a solid wall across the landscape (Clayton 2010). A number of former wet flatwoods locations are currently being restored by the Northwest Florida Water Management District (NWFWMD), to mitigate for wetland losses due to activities by the Florida Department of Transportation.

In 2004 the NWFWMD purchased 2,155 acres of land known as the Carter Tract, and established the Sand Hill Lakes Mitigation Bank (SHLMB). Prior to the purchase, the property was used since the early 1950s as a fish camp, with active fire suppression. One of the primary goals of the SHLMB project was to restore wet flatwoods and savannah habitats in the region. The NWFWMD is also performing mitigation activities on state- owned lands that are not official mitigation banks. Ward Creek West (WCW), a 719 acre parcel, was chosen for 145 acres of wet flatwoods restoration. WCW is a coastal landscape comprised of wet flatwoods and savannah with pockets of gum and cypress swamps. Most of this land was converted to slash pine plantation in the early 1960s and fire suppressed. Figures 2-1 and 2-2 show aerial photographs of the SHLMB and WCW landscapes in 1949 and 1953, respectively, that show a mosaic of ecosystems with open pinelands mixed throughout. The landscapes have degraded since that time, and prior to the recent restoration activities (below), generally all of the SHLMB and WCW landscapes were densely forested with undesirable titi and other woody vegetation.

In 2007, the NWFWMD started a five year effort to restore the wet flatwoods under specific mitigation requirements. These requirements constitute the overall restoration goals: 1) Titi and other woody species should be no taller than the coppice sprouts that may have risen from the most recent fire; 2) fire-adapted, native, wet flatwoods herbaceous species shall average at least 55% cover; 3) the average cover of graminiods should be 60% or greater of the total herbaceous groundcover; 4) the collective cover of pioneer species, such as *Andropogon spp.*, should not exceed 25% of those graminoids; and 5) long leaf pine should average between 100-200 trees per acre (FDEP 2005).

The primary management actions that were used to meet the restoration goals were vegetation removal, followed by a single prescribed fire and multiple herbicide applications to control resprouting of woody species (instituted at later times, as described below). In 2007 and 2008, 165 acres of degraded wet flatwoods located at SLMB were cleared by NWFWMD using a Gyro Trac™ machine which cut and mulched all trees and shrubs at each mitigation location (Figure 2-3). In 2008, 145 acres were cleared at WCW using the same method (Figure 2-4). Figure 2-5 shows an example of the site conditions before and after clearing. A single prescribed fire was then conducted at each location during the following winter season. Table 2-1 shows the schedule of restoration activities for all sites. Wiregrass, *Aristida stricta,* and toothache grass, *Ctenium aromaticum* Walter*,* plugs were planted in subsequent years by the

NWFWMD. By 2009, a total of 800,000 wiregrass plugs were planted at SHLMB (with plugs separated by roughly 1 m in many areas), and 2010 survival monitoring data showed mixed results with some areas having high survival, while other areas revealed survival as low as 50% (NWFMD 2010). Our study areas were planted with wiregrass and toothache grass, however neither were found in our study's random vegetation sampling (see Results section).

Several years after the wet flatwoods locations were cleared and burned, there was very little progress towards general restoration goals (personal observation). Ground cover recovery was sparse, which suggested one, or a combination, of the following: lack of bud bank, lack of seed bank of desirable species, unsuccessful seed expression (germination), and/or a lack of recruitment from seeds dispersed by seed rain onto the sites. The resprouting of branches of *Cliftonia monophylla* and *Cyrilla racemiflora* from old stumps and from roots also occurred rapidly following clearing and/or fire (Figure 2-5). Although the clearing operations mulched the trees to the ground level, operations did not disrupt the root systems sufficiently to prevent resprouting of woody species from the roots. In response, the NWFWMD established an herbicide program that sprayed the resprouting trees and shrubs, according to a regular schedule (Table 2-1). The herbicide applications were aimed to control resprouting of all woody species. Herbicide applications, at a minimum, were applied in the spring after first vegetative flush and in the fall after the conclusion of the growing season. The herbicide Triclopyr at 10% concentration was used during all applications. General observations indicated that the herbicide was not effective in preventing resprouting. Moreover, decades of dense titi (and other woody vegetation) growth led to the accumulation of a thick organic soil surface layer, ranging from 5-15 cm. Such a significant organic layer is uncommon in pristine wet flatwoods, which are usually classified as having mineral soils (Rheindhart 2002).

The NWFMWD conducts annual vegetative sampling, at the conclusion of each growing seaon, at all wet flatwoods restoration sites. The percent vegetative cover is monitored at set transect locations throughout the wet flatwoods restoration areas. The results are published in annual reports (NWFWMD 2010). The results of the vegetative sampling conducted by the NWFWMD may not be consistant with the results of our study due to different sampling techniques and primarily due to the continued use of herbicide applications in the areas sampled by NWFWMD, wheras our study areas discontinued the use of herbicide application at the start of our study.

Study Sites

Six field study sites were chosen within the broader locations of SHLMB and WCW described above. General visual surveys determined all potential sites within these locations. Sites were sought that resembled each other with respect to elevation and hydrologic regimes, which was generally assumed to be reflected by the surrounding vegetation types.

The landscape at SHLMB is a mix of sandhills, wet flatwoods, wet prairies, cypress domes and lakes. SHLMB was historically comprised of wet flatwoods or wet savannahs that transitioned to wet prairies before entering the cypress edges. Study sites 1-4 are located at SHLMB, between the sandhills and edges of the cypress lakes (Figure 2-3). Sites 1, 2, and 3 are dominated by occasionally ponded Clara and Plummer soils, while site 4 is dominated by ponded Pantego and Clara soils (USDA

2010). Clara, Plummer, and Pantego soils are very deep, very poorly drained, moderately to rapidly permeable soils that formed in thick loamy sediments on the Coastal Plain (USDA 1999,2004).

The landscape at Ward Creek West is typical of the outer Coastal Plain of the Florida panhandle. It is a mosaic of pine flatwoods communities mixed with depressional wetlands. Ward Creek West contains research sites 5 and 6 (Figure 2-4). WCW contains soils from the Rutledge series with Rutledge sands consisting of very deep and poorly drained soils with rapid permeability formed on sandy Coastal Plain sediments (USDA 1995).

Sampling Plots

At each of the six study sites, three 15 m X 15 m plots were established: two plots (Cleared and Disked) were within the area previously cleared of vegetation, and one plot (Thicket) was within the closest available woody thicket outside of the cleared area. The Cleared and Disked plots were chosen such that they generally appeared to have consistent vegetative and/or soil conditions within each site, and their borders were within at least 2-10 m of each other. The Thicket plot for each site was in an area that was estimated to represent the pre-cleared condition, based on proximity and relative elevation. The NWFWMD had previously selected the locations for vegetation removal, and those locations were not always in close proximity to titi thicket habitats. Thus, the Thicket plot associated with each study site was not always in the immediate vicinity of Cleared and Disked plots. Rather than being considered experimental control treatments, the primary purpose of the Thicket plots was to determine if the clearing method itself had an impact on the seed bank and to examine species composition of the titi thicket.

Seed Bank

The seedling emergence method was considered to be the most suitable method for assessing aspects of the existing seed bank in the study sites. Rather than observing successful emergence of seedlings, the alternative of extracting individual seeds from soils can lead to difficulties in seed identification, and to unknown viability of the extracted seeds. Poiani and Johnson (1988) found that while emerged seedlings were well (93%) correlated with the seeds found in the soil samples, some plant species may require specific conditions (e.g., drought, cold, or stratification) to germinate. Such conditions may not be provided by the seedling emergence method (Galinato and van der Valk 1986). Nevertheless, the seedling emergence method provides useful indications of the presence of many (but not all) of the viable seeds within a location, which is the simple objective of this part of the study.

Seedling emergence was observed in the lab, using soil core samples collected from each site. Because of the existence of large woody debris, not all soil locations within a plot were available for sampling. Within each plot, all possible sample locations were identified and separated into two microrelief categories, either high or low. The elevation difference from low to high locations was estimated to be approximately 30-50 cm, and was generally associated with long-term vegetation growth prior to clearing the plot. Five high locations and five low locations were randomly chosen within each plot. Random selection was achieved by locating all available core sample locations, flagging and numbering them, and then randomly selecting until five high and five low locations were chosen. In May-June 2010, a three inch diameter coring device was used to sample all locations, for a total of 180 samples. The coring device contained a stainless steel sharpened head attached to a 60 cm clear acrylic tube. Every core was taken to the depth to include 10 cm of mineral soil. This was accomplished by taking deep cores, removing and measuring the organic layer and then placing the first 10 cm of mineral soil in a tube and cutting it away from the remaining core sample. An organic layer is not typical in wet flatwoods (Rheindhart 2002). Therefore, it was imperative to set a standard depth of mineral soil and allow the organic layer to fluctuate per sample. Taking a core to a standard depth of 10 cm total would have produced many samples that were only organic material.

All soil cores were transported to the University of Florida greenhouse in Milton, Florida for the seedling emergence experiment. Once the core samples air-dried for at least 10 days, it was evident that many of the samples contained a mixed organic/mineral zone between the normally-distinct organic and mineral layers, with the mixed layer indistinguishable in the field. Therefore, the cores were then divided into three subsamples, organic, mixed and mineral. The mineral fraction remained as the lower 10 cm of the core. The samples were then sifted through a 2 mm sieve to remove any roots or large organic materials. The volume and mass of the subsamples from each core was recorded.

In July 2010, a 30 mL sample was taken from each subsample and spread evenly across 12 inch round pots that contained 300 ml of farfard media mix. The pots were then labeled and placed randomly on greenhouse benches with an automatic irrigation system that supplied a fine mist of water via an intermittent mist system. The irrigation was controlled by automated timer (QCom Environmental Control System) that provided a minimum of five seconds of misting every 30 seconds from dawn to dusk. The greenhouse was enclosed and climate controlled, allowing for germination conditions that approximated summer months to continue through the fall and winter. Once a month during the duration of the experiment, all emerged species were identified and counted individually, then removed from the pots. Plants that could not be indentified were removed from the twelve inch round pot and potted into a separate pot until species identification could be determined. After approximately seven months of observation, germination became limited, and the seedling emergence experiment was terminated.

Vegetation Sampling

Existing vegetation was sampled in the Cleared and Disked plots at each site in June 2010, and then repeated in November 2010 and May 2011. The Thicket plot at each site was sampled in November 2010 and again in May of 2011. It was not sampled in June of 2010 because those plots primarily contained dense woody species, and seasonal variability in species composition had been previously observed to be minimal. Vegetation was surveyed in the Cleared and the Disked plots multiple times to ensure that most seasonal species were recorded, and to provide some indication of short-term trends in vegetation structure and species composition. The vegetation was sampled at the same (randomized) core sampling locations. A 1 x 1 m quadrat was placed directly over each core sample location, and the percent cover of each species was estimated visually within each of 20 sub-quadrats within a grid of the 1 m^2 quadrat. For each tree species that provided overhead canopy cover, the relative cover of each was estimated by standing inside the quadrat and visually assessing the percent cover.

Soil Disturbance

After the initial vegetation surveys and soil sampling the Disked plot at each site was disked in July of 2010 using a 24” disk harrow. The entire 15 m X 15 m plot was disked, affectively removing and breaking up woody roots, and also bringing mineral soil to the surface. The disking disturbed the top 20-30 cm of soil (Figure 2-6).

Data Analysis

The Sorenson’s similarity index (S) was used to compare relationships between the seed banks and the extant vegetation among all treatments, dates, and elevations. It was also utilized to compare the relationships among extant vegetation of all treatments.

$$S = \frac{2W}{a + b}$$

where a = # of species in sample a

b = # of species in sample b

W = # of species shared by the two samples

Data were organized using a combination of ordination techniques. Ordination aims at arranging species and treatments in a low dimensional space such that similar entities are in close proximity and dissimilar entities are more distant. Ordination was used to show patterns of similarity between the seed bank and extant vegetation using relative cover of the extant vegetation and relative abundance of the seed bank applying nonmetric multidimensional scaling (NMS), with Sorenson's distance matrix. NMS was also utilized to show similarity in vegetation between treatments. NMS analyses were completed in PC-ORD 6 (McCune and Medford 2006), based on guidelines by Peck (2010) using the autopilot function and setting the distance measure to Sorenson (Bray-Curtis). Based on the stress calculations (difference in rank order distances of data and ordination), PC-ORD recommended two dimensions for the final run. Principal components analysis (PCA) was an additional ordination tool used (in PC-ORD 6) to display the relationship between treatments as well as the relationship of certain species to the various treatments.

The effects of treatment, date, and elevation were analyzed for the following variables; herbaceous cover, woody groundcover, woody canopy cover, total woody cover, bare ground, *Cliftonia monophylla, Rhexia spp., Hypericum sp., and Xyris brevifolia* using repeated measure ANOVA (PROC MIXED in SAS 9.2) with Bonferroni corrections to separate means. Herbaceous groundcover was the total combined percent cover of all herbaceous species found in extant vegetation surveys. Woody groundcover was the combined percent cover of all woody species found in extant surveys. Woody canopy was the total combined percent cover of woody canopy species in extant vegetation surveys. Total woody equaled the combination of woody groundcover and woody canopy cover. Bare ground included all areas where vegetation was absent. The variables above were chosen to determine the impacts of restoration activities on the broad goals of removing woody vegetation and increasing herbaceous vegetation. *Cliftonia monophylla* was chosen because it is the primary woody species of concern. *Rhexia spp*., *Xyris brevifolia* Michx., and *Hypericum sp*. were chosen because they are all species indicative of pristine wet flatwoods. Results higher than $p > 0.05$ were not considered significantly different. Tests for normality were run in (SAS 9.2) and it was determined that the data met the assumptions of normality and did not need transformation.

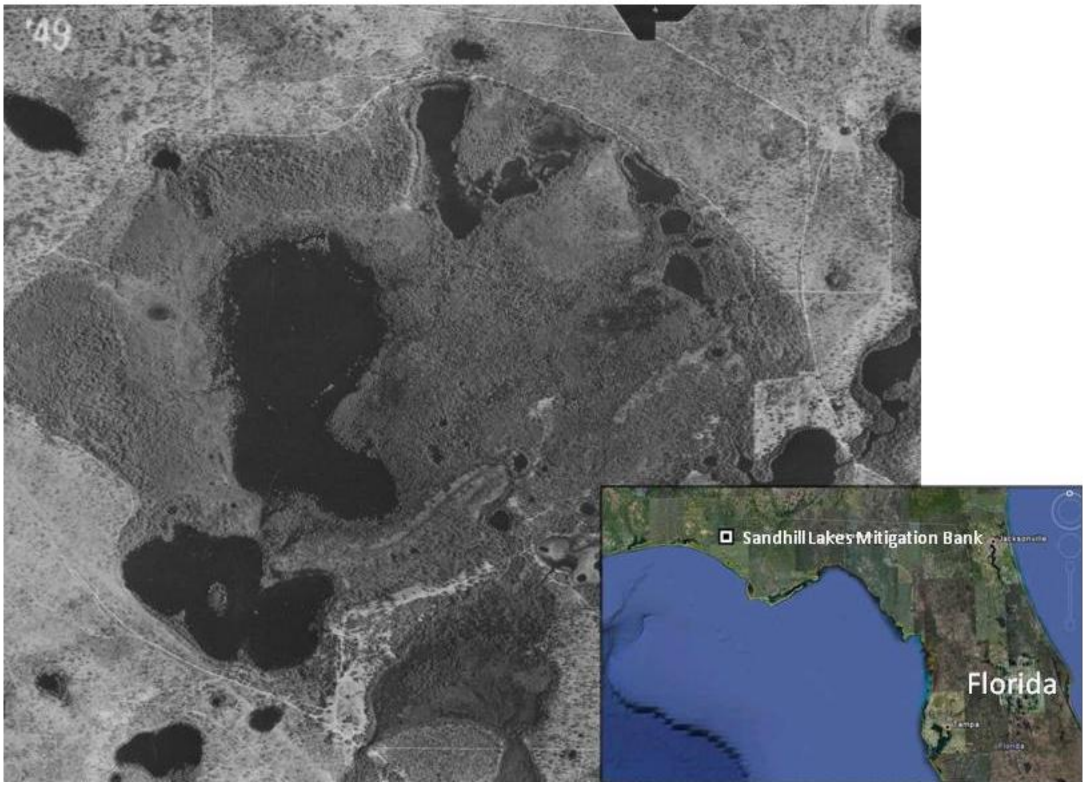

Figure 2-1.Sandhill Lakes Mitigation Bank (SHLMB) in 1949, showing the overall heterogeneity of the habitats. (USDA 1949)

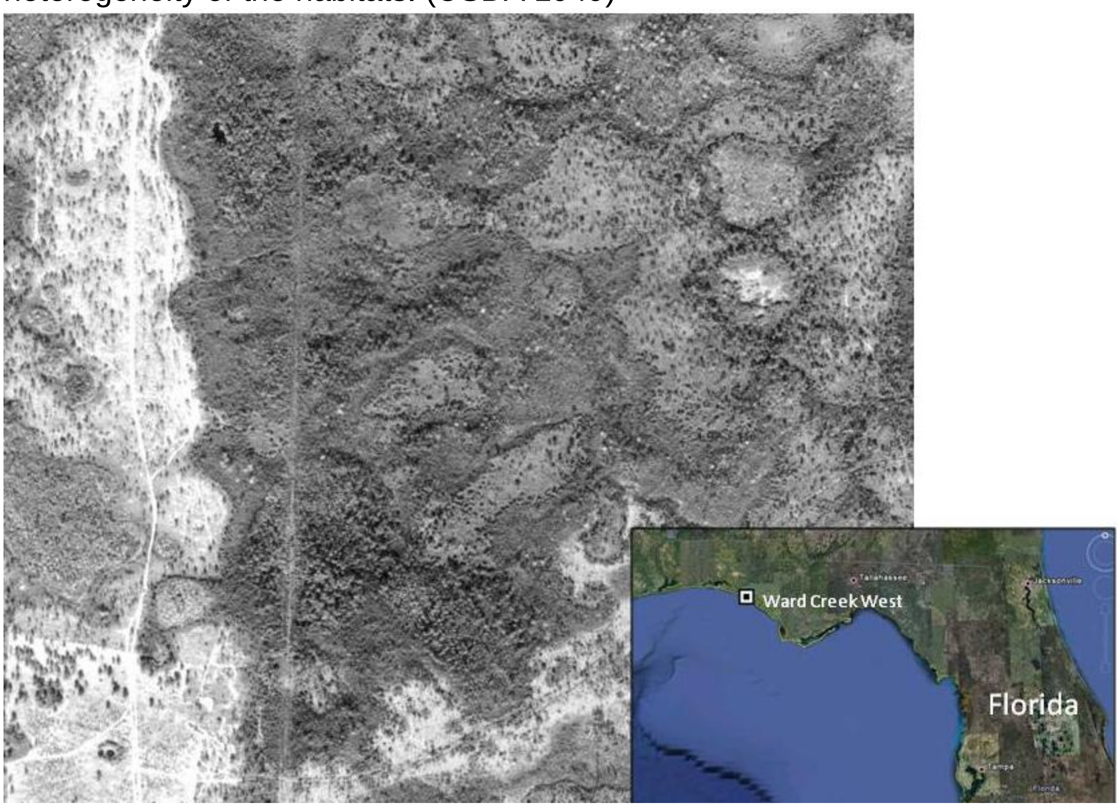

Figure 2-2. Ward Creek West (WCW) in 1953, showing the overall heterogeneity of the habitats. (USDA 1953)

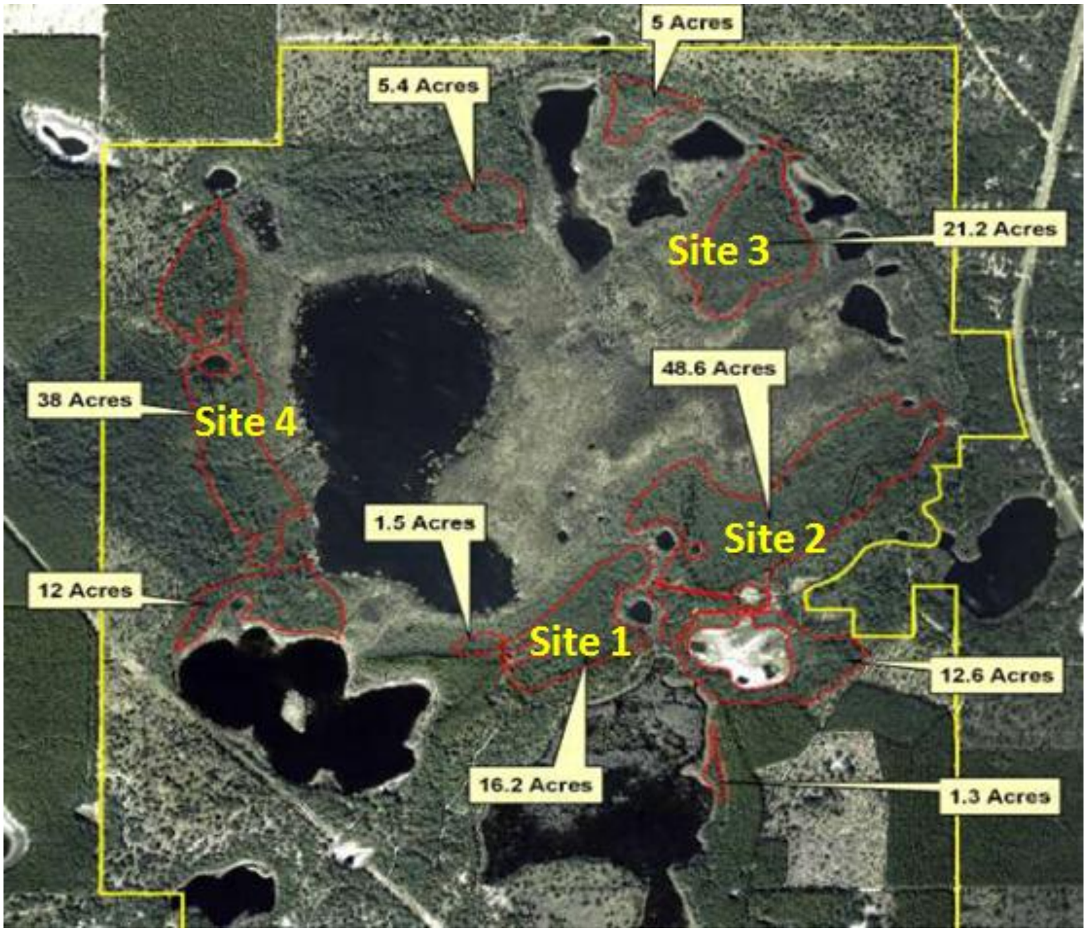

Figure 2-3. Sandhill Lakes Mitigation Bank (2007), showing the outlines of locations that were subsequently cleared of vegetation and site locations 1-4. (Photo courtesy of NWFWMD).

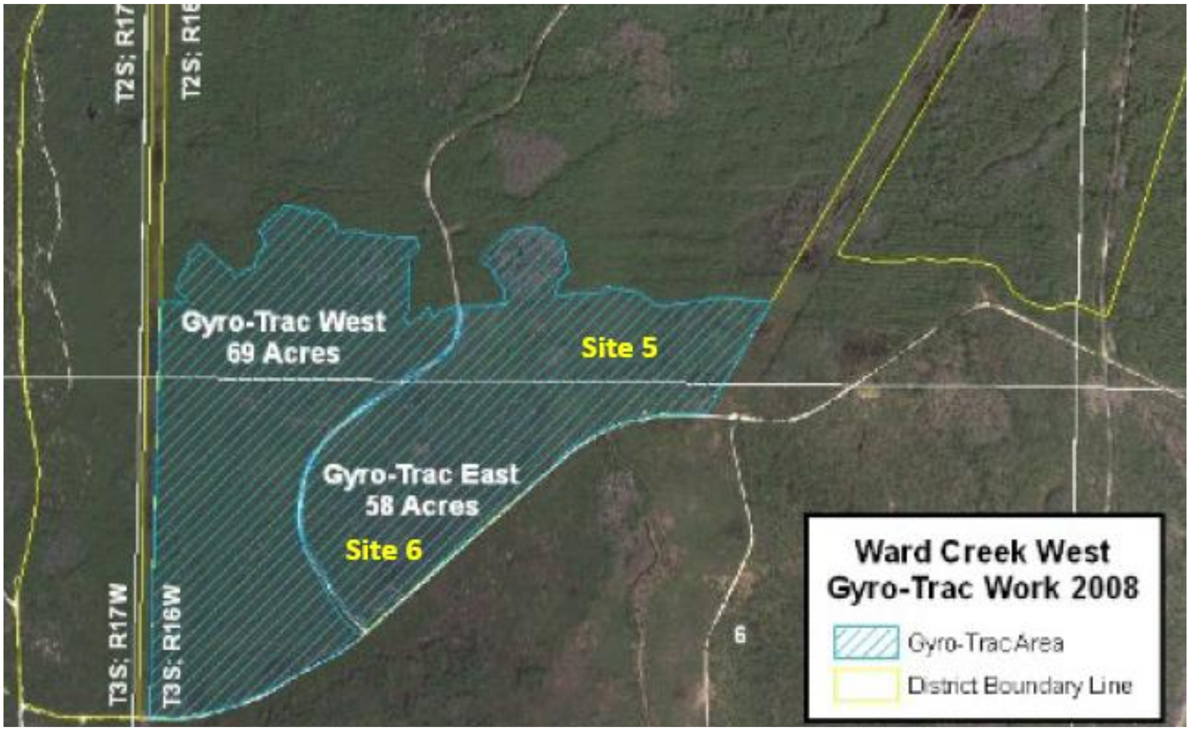

Figure 2-4.Ward Creek West (2008), showing the outlines of locations that were subsequently cleared of vegetation and site locations 5-6. (Photo courtesy of NWFWMD).

Table 2-1. Schedule of management activities

Location	Veg. Clearing	Fire	Herbicide
Site 1- Sandhill Lakes	April 2007	December 2007	Sept. 08,May, July, Oct. 09, & May 10
Site 2- Sandhill Lakes	March 2007	December 2007	May, July, & Sept. 09, & May 10
Site 3- Sandhill Lakes	May 2007	December 2007	May, July, & Sept. 09, & May 10
Site 4- Sandhill Lakes	July 2008	December 2008	May, July, & Sept. 09, & May 10
Site 5-Ward Creek West	August 2008	December 2008	May, July, & Sept. 09, & May 10
Site 6-Ward Creek West	August 2008	December 2008	May, July, & Sept. 09, & May 10

Schedule of vegetation management activities conducted by NWFWMD at the six site locations used in this study. Veg. Clearing is vegetation removal with Gyro-Trac; Fire is prescribed burning; Herbicide is herbicide application. The herbicide Triclopyr at 10% concentration was used for all applications and all woody species were targeted.

A

B

Figure 2-5. An example of the thorough vegetation removal at a Ward Creek West mitigation location. A) The foreground shows the remaining vegetative debris, and the background shows the dense thickets of *Cliftonia monophylla* and associated vegetation. The photograph was taken in August 2008, immediately after Gyro-Trac vegetation removal. B) Same site 2 months later. (Photos courtesy of NWFWMD).

Figure 2-6. WCW July 2010. Immediately following disking treatment. Mineral soils are observed mixed on surface with organics. Beyond the disked plot there is visible *Cliftonia monophylla* resprout cover throughout the Cleared plot. (Photo courtesy of author).

CHAPTER 3
RESULTS

Herbaceous Cover and Composition

The influence of the restoration treatments on herbaceous cover was considerable, yet variable among treatment and through time. The Thicket plots had little to no herbaceous cover during any sampling date. Total herbaceous cover was significantly affected by treatment ($p= <0.001$, $F= 33.29$, $df= 2,10$) , date ($p=0.0003$, $F=20.40$, $df= 2,10$), microrelief ($p=0.0096$, $F=16.63$, $df=1,5$), and there was a significant interaction of date with treatment ($p=<0.0001$, $F= 20.40$, $df=4,20$). Mean herbaceous cover for the untreated Thicket plots did not significantly vary through time and had significantly less herbaceous cover than the Cleared and Disked treatments. Prior to disking, herbaceous cover of the Cleared plots and the plots to be disked (June 2010) did not differ significantly (Table 3-1). By November (4 months after disking) herbaceous cover was significantly greater in Cleared plots compared to Disked or Thicket plots. Herbaceous cover in the Cleared plots increased significantly from June to November, but decreased by the May sampling date. Disked plots increased in herbaceous cover from June to November, however, not significantly. Eleven months after disking, the greatest mean herbaceous cover, 27.2%, occurred in Disked plots and differed significantly from all other treatments and dates.

Microrelief significantly affected the cover of herbaceous species ($p= 0.0096$, $F= 16.63$, $df =1, 5$). Microrelief by treatment was found close to significant ($p= 0.056$, $F= 3.89$, $df =2, 10$). Mean cover was higher in the lower elevation locations, increasing from 10% to 16%, and from 6% to 15%, for Disked and Cleared treatments, respectively. Eleven months after disking (May 2011), mean cover was 7% and 14% in the high and low sites (respectively) in Cleared plots and 21% and 33% in high and low sites in Disked plots. *Lachnanthes caroliana* Lam. and *Rhynchospora sp.* were the two species that showed the greatest percent increase from high to low elevations (Appendix-B).

There were 14 herbaceous species found in the plots during the course of the study. The most common species were *Rhynchospora sp., Dicanthelium spp., Andropogon spp.,* and *Lachnanthes caroliana* (Appendix-A). Five of the 14 documented species were listed on the (FNAI 2010) list of common wet flatwoods species of high quality panhandle sites (Table 1-1). One of those species was located in Thicket plots, two of those species were located in the Cleared treatment plots, and all five in the Disked treatment plots. The interaction of date and treatment was significant for *Rhexia spp.* (P=0.0037, F=5.51, df=4,20). *Rhexia spp*. were located in Disked plots four months after disking (November) but none were found in the Cleared plots (Table 3-2). *Rhexia spp.* cover increased significantly from the November to May in the Disked plots. The interaction of date and treatment was significant for cover of *Xyris brevifolia* (P=0.0093, F=4.5, df= 4,20). *X. brevifolia* was found solely in the Disked plots in May 2011 and was not found in any treatment at any other date. *Drosera capillaris* Poir.*, Bidens mitis* Michx., *Hedyotis sp.*, and *Syngonanthus flavidulus* Michx. were also only found in Disked plots in May 2011 (Appendix-A). In May 2011, there were no herbaceous species documented in the Thicket plots, six herbaceous species in the Cleared plots, and 11 herbaceous species in the Disked plots. *Rhynchospora sp., L. caroliana,* and multiple *Dicanthelium* species had the greatest increase in percent cover in the disked plots following disking.

Woody Cover and Composition

Woody species cover and composition were significantly altered by the restoration treatments. The effect of treatment ($P=<0.0001$, $F= 54.65$, $df=2,10$), microrelief ($P=0.0066$, $F=19.95$, $df=1,5$) , and the interaction of date and treatment were significant ($P=0.0007$, $F= 7.58$, $df= 4,20$) (Table 3-1). Thicket plots showed little to no variation in woody groundcover throughout the three sampling dates. The Cleared plots showed a trend of increasing woody groundcover over time. Woody cover increased from 17% in June to 27% in November 2010, and 40% in May 2011. The woody groundcover in the Cleared plots did not differ significantly from the Thicket plots.

Contrary to the increases in woody cover in the Cleared plots, the Disked treatment showed a trend of decreased woody groundcover. Prior to disking, the mean cover was 14% in June of 2010, decreased to 2% in November 2010, and 3% in May 2011. After disking, the mean woody groundcover of the Disked plots was significantly lower than the means of the Thicket and Cleared plots (Table 3-1), with the trends evident in Figure 3-1.

Woody groundcover was combined with woody canopy cover (which was measured independently from groundcover) to quantify the affects of the treatments on total woody material that covers and shades the plots. The interaction of date and treatment was significant for woody cover ($P=0.0007$, $F=7.58$, $df=4,20$). Mean woody cover was greater than 124% for Thicket plots on all dates and was significantly greater than that found in Cleared and Disked plots for all dates (Table 3-1). There was no woody canopy cover in the Cleared or Disked plots.

Microrelief significantly affected total woody cover (ground cover + canopy cover) (P=0.0066,F=19.95,df=1,5). Woody ground cover of Thicket plots was 37% for high sites and 24% for low sites and total woody cover was 132% for high and 119% for low sites in the Thicket plots. Total woody cover for Cleared plots was 33% on high sites and 23% on low sites. Woody cover of Disked plots was 9% on high sites and 4% on low sites.

There were a total of 19 woody species found within all the plots. The most common species were *Cliftonia monophylla, Lyonia lucida* Lam., and *Cyrilla racemiflora. Cliftonia monophylla* was the dominant woody species at all sites and treatments. Treatment and the interaction of date with treatment were significant for the cover of *Cliftonia monophylla* (P= <0.0001, f= 30.89, df= 2,10 and P= 0.0034, F= 5.62, df= 4,20), but microrelief was not a significant factor. The mean cover values of this species in the Cleared plots in November 2010 and May 2011 were significantly higher than the mean percent cover in all other dates and treatments (Table 3-2), reaching a maximum of 27% in May of 2011. A contrary trend was seen in the Disked plots, in which the mean cover of *Cliftonia monophylla* decreased significantly from 9% in June 2010 to 1% in November 2010 and May of 2011.

Lyonia lucida was the second most dominant species by cover at all treatment sites, and increased proportionally in percent cover more than any species (Appendix-A). *L. Lucida* had the lowest decrease in mean cover of all woody species in the Disked plots. *Hypericum sp.* were documented in November 2010 and May 2011 solely in the Disked treatment plots. Treatment and the interaction of date with treatment were significant (P= 0.0004, F= 8.30, df= 4,20). In November, the mean cover of *Hypericum* *sp*. was 0.03% and significantly increased to 0.73% in May of 2011. *Pinus elliottii* was only documented in May 2011. The emergence of the above two new species, common species of maintained wet flatwoods, contributed 1.15% of the total 3.4% total woody mean cover for the Disked treatment plots in May of 2011. While, these changes may seem insignificant, they show a trend in a shifting plant community.

Seed Bank Composition

During the course of the seven month seedling emergence study, a total of 1,600 seedlings emerged. Among these 1,075 seedlings of 13 different species were considered weedy/pioneer species, 39 seedlings of one invasive species (*Lygodium japonicum* Thunb.) were found, and the remaining seedlings represented 12 different species that were considered common to maintained wet flatwoods (Table 3-3). Five of the 12 common wet flatwoods species were listed in the (FNAI 2010) list of common species of high quality wet flatwoods of the Florida panhandle (Table 1-1). Thirty- five taxa germinated from the seed bank of which 18 were indentified to the species level, 11 to genera, and a group of ferns to order. Many species were difficult to indentify to the species level, due to the timeframes of the experiment and lack of flowering. Four of the species that were identified to genera in Table 3-3 contained more than one species, as presented below.

The genus *Xyris* was represented by *Xyris brevifolia* and *Xyris baldwiniana* Schult., with *Xyris brevifolia* being the majority of seedlings that emerged. The *Cyperus* genus was represented by at least two species, *Cyperus erythrorhizon* Muhl. and *Cyperus* sp. *Rhexia spp.* was predominately *Rhexia virginica* L., but also contained *Rhexia mariana* L., and *Rhexia alifanus* Walter. *Dicanthelium spp*. represented at least three different species. Pteridophyta, ferns, were represented by several different species. The most common of all species were *Hedyotis sp*. (829) seedlings*, Xyris spp*.(188) seedlings, *Hypericum sp*. with (98) seedlings, and *Erigeron sp*. with (83) seedlings.

The largest number (740) of seedlings occurred in the mineral soil layer, with 442 found in the mixed soil horizon, and 417 in the organic layer. This numeric predominance in the mineral layer was strongly influenced by the presence of *Hedyotis sp*., representing three-fourths of the emerged seedlings of the mineral layer. If the pioneer/weedy species *Hedyotis sp.* were not considered in the totals, the distribution of seedling by soil layer switched to dominance by the organic horizon (with 160 in the mineral layer, 255 in the mixed horizon, and 355 in the organic layer).

Lygodium japonicum, an exotic invasive species, had 39 seedlings emerge. While there is a possibility the spores were introduced in the greenhouse, it is unlikely due to the fact that the seedlings were only found in mixed and organic soil samples and they were not found in the control pots that were intermixed in the seed bank study. There were no occurrences of *L. japonicum* in any of the extant vegetation surveys.

The distribution of seedling by treatments was 499 in the Cleared plots and 1,100 in the thicket. In this case, "cleared" includes both the Disked and Cleared plots combined (because the soils were not disked until after the soil cores were taken). Again, the presence of *Hedyotis sp.* had a significant influence on the distribution of seedlings, with 789 occurring in the Thicket plots. If *Hedyotis sp*. is ignored, the totals are 459 seedlings in Cleared plots and 311 in Thicket plots. Microrelief did not have a strong influence on the distribution of seedlings, with 772 in high locations and 827 in low locations (Table 3-3).

Vegetation and Treatments

The NMS ordination of extant vegetation cover of all treatments from May 2011 revealed an obvious separation between treatments (stress= 13.79, P=0.004) (Figure 3-2). The Disked treatments showed a clear pattern of breaking away from the Cleared treatments and complete separation from the Thicket treatments. The Thicket plots also showed some separation from the central areas that had the most commonality, however most of the thicket points accumulated in the center of the two dimensional space, clumped with Cleared plots. The Cleared treatment plots remained in the central area of the ordination and were intermixed with the thicket plots. These ordination results support the earlier data that suggests the Cleared plots became more similar to the Thickets plots, while the Disked plots increasingly differed from the other two treatments.

The PCA ordination of the final sampling date (Figure 3-3) showed very similar results to the NMS ordination. The species highlighted in Figure 3-3 are considered species of highest concern. The three most common woody species, *Cliftonia monophylla, Lyonia lucida, and Cyrilla racemiflora*, were all associated with the thicket and cleared treatment plots. The species common to "maintained" wet flatwoods, *Rhexia* sp., *Xyris* sp., *Rhynchospora* sp., *Drosera capillaris*, and *Dicanthelium* sp., were all associated with the disked treatment plots. This PCA ordination further supports the above results, all indicating that common wet flatwoods species were most closely associated with Disked treatments, while problematic woody species were most closely associated with the Cleared and Thicket treatments.

Similarity between Vegetation and Seed Bank

Comparisons between the treatment areas revealed little similarity between the seed banks and the extant vegetation, based on Sorenson's similarity indices (Table 3-4). This index ranks similarity on a scale from 0.0 to 1.0, with 1.0 indicating the most similarity. The extant vegetation of the Cleared treatments became less similar to the seed banks from June of 2010 to May 2011, starting at 0.34 and ending at 0.29. However, the extant vegetation of the Disked treatments revealed the opposite, and increased in similarity to the seed bank from June 2010 to May 2011, starting at 0.23 and ending at 0.41. The highest similarity value between extant vegetation and seed banks was 0.48, for the comparison between the seed banks of the Cleared treatments and the extant vegetation of the Disked treatments in May of 2011. The lowest similarity values were 0.06 for the comparison of the seed bank of the Cleared and the extant vegetation of the Thickets in May of 2011.

Sorenson's similarity index was also used to calculate the similarity in species composition between treatments through time. Sorenson's similarity indices showed the composition of both the disked and cleared treatment becoming less similar through time when compared to species composition in June of 2010 (Table 3-4). Species composition remained similar through time for the thicket (0.84).

The second NMS ordination showed a clear distinction between the seed banks and the extant vegetation (Figure 3-4). There were no overlapping points in the two dimensional space, and the separation between the seed bank and extant vegetation was significant (stress= 7.95, $P= 0.004$). These results provided further evidence that the composition of the seed banks was dissimilar from that of the extant vegetation.

Table 3-1. Cover means for treatments by date and variable.

	Date		
Management	June 2010	November 2010	May 2011
		Bare Ground	
Thicket	--	70.1 b	67.4 b
Cleared	73.6 ab	55.9 bc	49.7 c
Disk	80.6 a	88.9 a	67.8 b
		Herbaceous	
Thicket	--	0.5 de	0.3 e
Cleared	5.0 cd	16.6 b	10.7 bc
Disk	3.0 cd	9.5 cd	27.2 a
		Woody Groundcover	
Thicket	--	29.2 abc	32.3 ab
Cleared	17.4 bc	27.2 abc	40.1 a
Disk	13.9 cd	1.7 d	3.4 d
		Woody Groundcover +Canopy	
Thicket	--	124.2 a	127.3 a
Cleared	17.4 c	27.2 bc	40.1 b
Disk	13.9 cd	1.7 d	3.4 d

Mean percent cover of species lumped into cover-type categories for all treatments and dates. The repeated measures ANOVA Bonferroni corrections ($\alpha = 0.05$) separated the means within cover type category, with differences between sample means followed by the same letter not being significantly different. Canopy cover was an independent measure that could have a value of 100%, thus “Woody Groundcover + Canopy” can by >100. The Thicket plots were not sampled in June 2010.

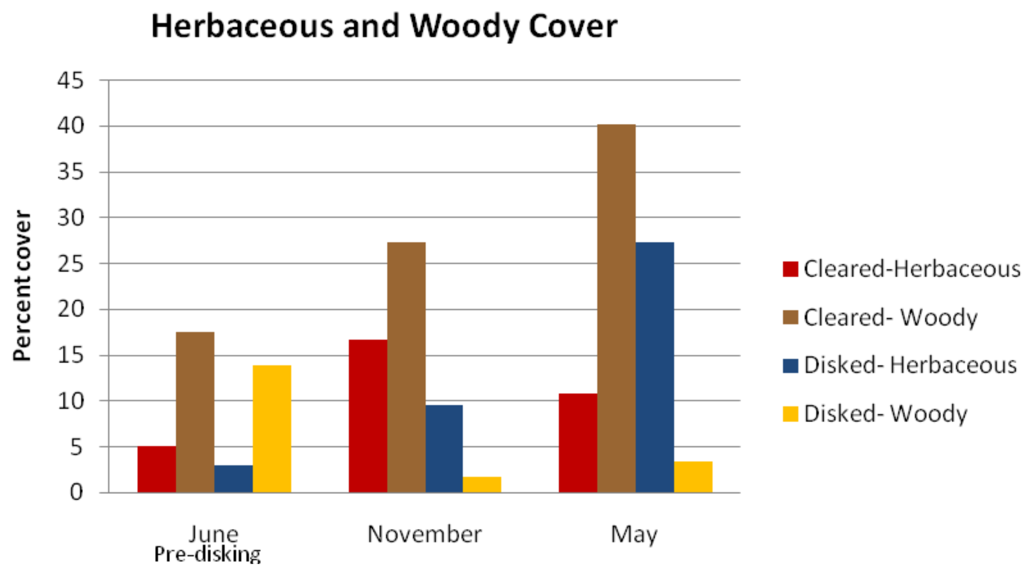

Figure 3-1. Mean percent cover for cleared and disked treatments for June 2010, November 2010, and May 2011. Herbaceous= herbaceous species; Woody= woody groundcover species. Cleared - above-ground woody vegetation removal via GyroTrac + prescribed fire + herbicide Triclopyr applied to woody resprouts; and Disked - same as Cleared, but followed by soil disking.

Table 3-2. Mean percent cover for selected species by treatments and dates.

	Date		
Management	June 2010	November 2010	May 2011
		Cliftonia monophylla	
Thicket	--	5.6 b	6.5 b
Cleared	10.9 b	18.4 a	26.7 a
Disk	8.7 b	0.7 b	1.3 b
		Hypericum sp.	
Thicket	--	0.0 b	0.0 b
Cleared	0.0 b	0.0 b	0.0 b
Disk	0.0 b	0.03 b	0.73 a
		Rhexia sp.	
Thicket	--	0.0 b	0.0 b
Cleared	0.0 b	0.0 b	0.05 b
Disk	0.0 b	0.03 b	0.6 a
		Xyris brevifolia	
Thicket	--	0.0 b	0.0 b
Cleared	0.0 b	0.0 b	0.0 b
Disk	0.0 b	0.0 b	0.8 a

Mean cover (not including canopy) of selected species for all treatments and dates. The repeated measures ANOVA Bonferroni corrections (α= 0.05) separated the means within a species, with differences between sample means followed by the same letter not being significantly different. The Thicket plots were not sampled in June 2010.

Table 3-3. Total Seedling emergence from seed bank

Species	Species description	Total #	Soil Fraction			Treatment		Elevation	
			Mineral	Mixed	Organic	Cleared	Thicket	High	Low
Centella asiatica	HC	2	0	0	2	1	1	1	1
Conzya canadensis	HP	57	14	12	31	40	17	30	27
Cyperus spp.	HC	13	1	4	8	7	6	7	6
Dichanthelium spp.	HC	31	13	6	12	24	7	13	18
Drosera capillaris	HC	17	0	17	0	0	17	1	16
Erechtites hieraciifolia	HP	3	0	2	1	2	1	3	0
Erigeron sp.	HP	83	38	16	29	59	24	49	34
Eupatorium capillaris	HP	23	0	1	22	9	14	11	12
Pteridophyta	HC	24	0	1	23	13	11	10	14
Fimbristylis sp.	HC	2	1	0	1	1	1	0	2
Gnaphalium pensylvanica	HP	2	1	0	1	2	0	2	0
Gnaphalium spicatum	HP	6	0	2	4	3	3	2	4
Hedyotis corymbosa	HP	19	0	3	16	18	1	16	3
Hypericum sp.	WC	98	17	28	53	20	78	36	62
Juncus sp.	HC	8	3	0	5	3	5	2	6
Lachnanthes caroliana	HC	1	0	0	1	1	0	1	19
Ludwigia sp.	HP	4	2	0	2	1	3	2	2
Linaria canadensis	HP	1	0	1	0	1	0	1	0
Lygodium japonicum	HI	39	0	9	30	23	16	20	0
Lyonia lucida	WC	20	3	1	16	8	12	12	8
Oxalis corniculata	HP	52	8	27	17	42	10	21	31
Rhexia spp.	HC	47	2	32	13	40	7	31	16

Table 3-3 Continued.

Species	Species description	Total #	Soil Fraction			Treatment		Elevation	
			Mineral	Mixed	Organic	Cleared	Thicket	High	Low
Rhynchospora spp.	HC	36	3	14	19	25	11	19	17
Hedyotis sp.	HP	829	580	187	62	40	789	449	380
Xyris spp.	HC	188	56	78	54	117	71	36	152
Total Species		25	14	19	21	22	21	23	19
Total Seedlings		1599	740	442	417	499	1100	772	827

Total seedling emergence of individual species from seed bank by Soil Fraction, Treatment, and Microrelief category. Species description; H=herbaceous, W= woody species, C= common wet flatwoods species, P= pioneer/weedy species, and I= invasive exotic species.

Table 3-4. Sorenson's similarity index

Treatment	Cl-June	Cl-Nov	Cl-May	Dk-June	Dk-Nov	DkMay	Th-Nov	Th-May	SdCl	Sd-Dk	Sd-Th
Cl-June	1										
Cl-Nov	0.92	1									
Cl-May	0.79	0.85	1								
Dk-June	0.87	0.79	0.73	1							
Dk-Nov	0.67	0.72	0.81	0.69	1						
Dk-May	0.63	0.69	0.68	0.59	0.71	1					
Th-Nov	0.47	0.44	0.47	0.44	0.48	0.48	1				
Th-May	0.43	0.54	0.43	0.53	0.44	0.34	0.84	1			
Sd-Cl	0.34	0.36	0.29	0.32	0.35	0.48	0.15	0.06	1		
Sd-Dk	0.25	0.27	0.25	0.23	0.32	0.41	0.11	0.06	0.82	1	
Sd-Th	0.29	0.31	0.29	0.27	0.3	0.48	0.15	0.12	0.88	0.84	1

Similarity relationships between extant vegetation of treatments and between seed bank and extant vegetation of treatments, using Sorenson's similarity index (0.0 - 1.0, with 0=least similar, 1= most similar). Cl= Cleared treatments, Dk= Disked treatments, Th- Thicket treatments, and Sd= Seed bank.

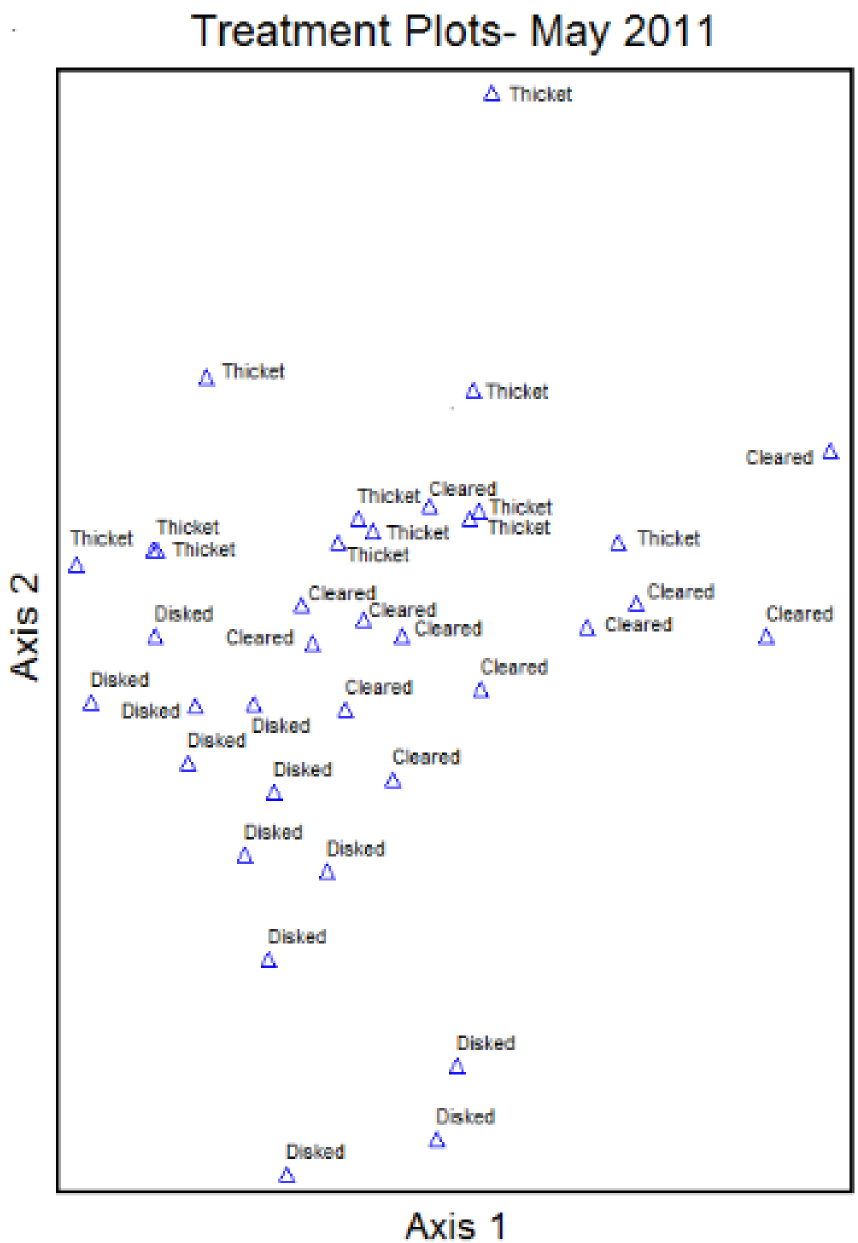

Figure 3-2 . NMS ordination representing similarity between treatments. Mean species cover values from the last sampling date of May 2011 were used for the ordination. Disked plots show the greatest separation from the Thicket plots. Thicket - shrub thickets with no modification; Cleared - above-ground woody vegetation removal via GyroTrac + prescribed fire + herbicide Triclopyr applied to woody resprouts; and Disked - same as Cleared, but followed by soil disking.

Treatment Plots- May 2011

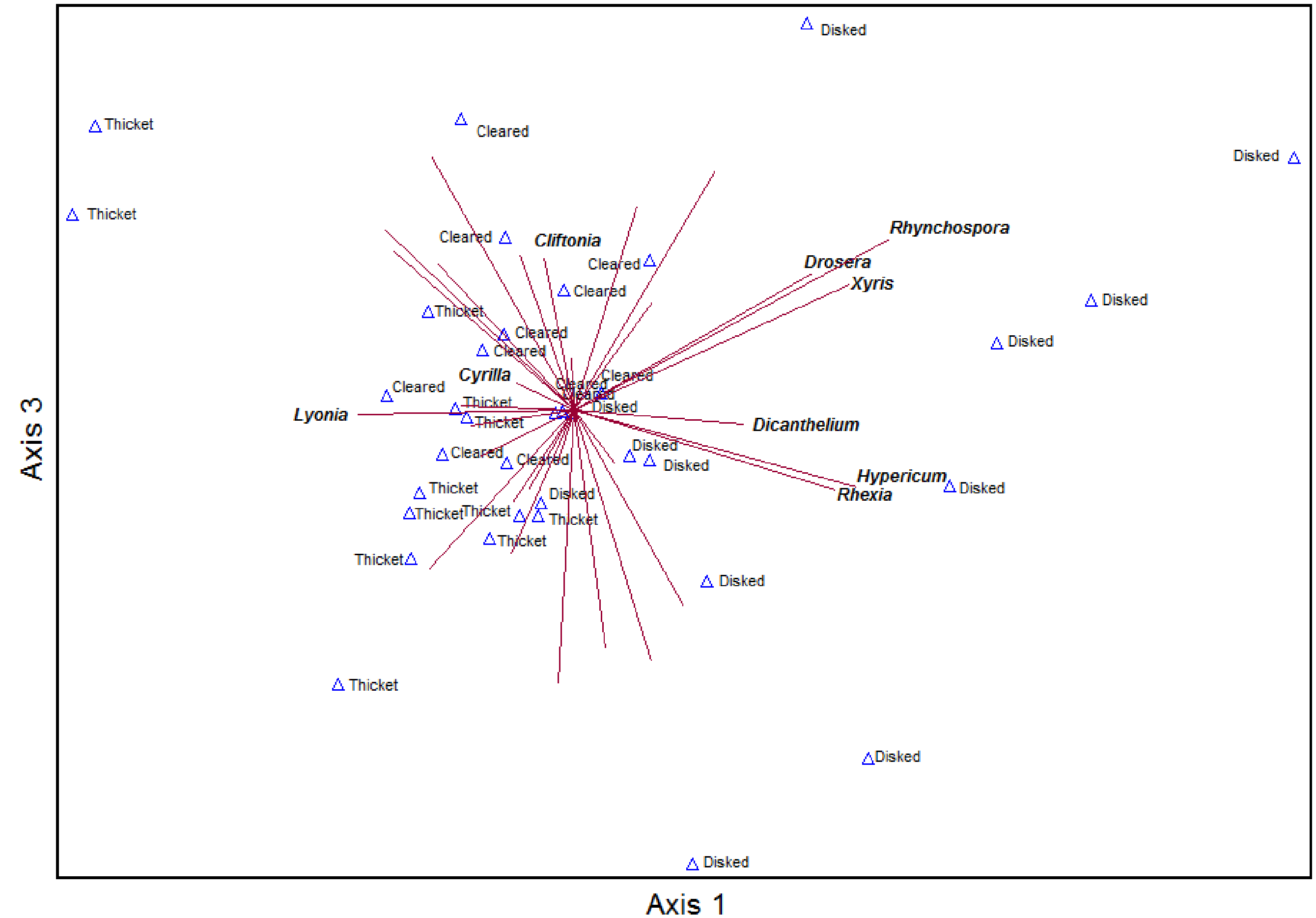

Figure 3-3. PCA ordination representing similarity between treatments. Mean species cover values from the last sampling date of May 2011 were used for the ordination. Woody and herbaceous species of concern were selected to show species associations with treatments. Thicket - shrub thickets with no modification; Cleared - above-ground woody vegetation removal via GyroTrac + prescribed fire + herbicide Triclopyr applied to woody resprouts; and Disked - same as Cleared, but followed by soil disking.

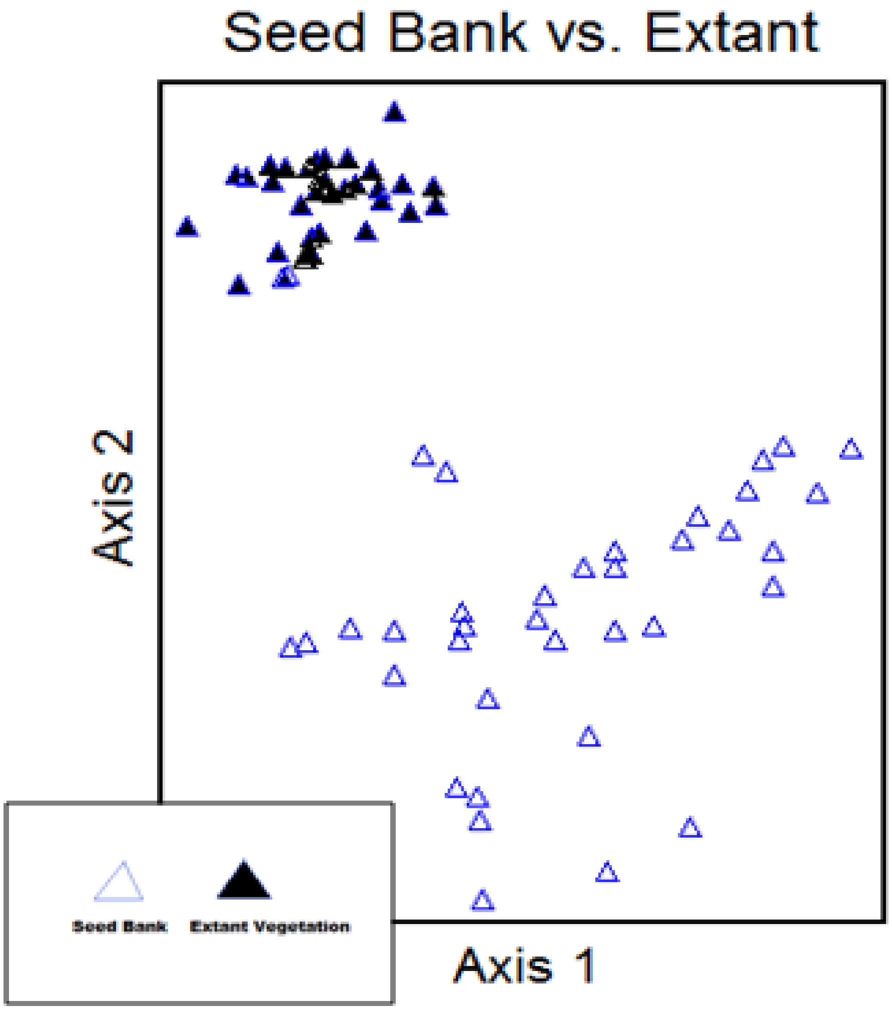

Figure 3-4. NMS ordination of extant vegetation similarity to seed bank. Clear separation between extant vegeation and seed bank is shown above. Seed bank data and the extant vegetation data (May 2011) were derived from total emergence of the combination of the Cleared and Disked treatments.

CHAPTER 4
DISCUSSION

Herbaceous Cover and Composition

The results suggest very little progress towards restoration of the herbaceous plant community in these north Florida wet flatwoods. FNAI (2009) recommended that wet flatwoods herbaceous cover should exceed 25% with less than 2% cover of bare ground. Furthermore, a reference community for Florida panhandle wet flatwoods had herbaceous cover of 74% and bare ground of less than 2.5% (FNAI 2009). However, the restoration techniques utilized by NWFWMD on our wet flatwoods sites resulted in less than 11% herbaceous cover after four years of implementation. The addition of the soil disturbance via disking resulted in increases in herbaceous cover to 27%, which was still much lower than the reference community but suggests a potential for herbaceous cover restoration. However, the study did not reveal whether that trend towards increased herbaceous cover will continue. To the contrary, the Cleared treatments showed trends of decreasing herbaceous cover suggesting that without further management activities restoration of the herbaceous community is unlikely.

Herbaceous species common to wet flatwoods were found in our study, but major components of the reference plant community were missing. Peet and Walker (1984) documented over 50 herbaceous species in unimpacted wet pinelands of North Carolina (that are similar to Florida wet flatwoods), with *Muhlebergia expansa, Ctenium aromaticum,* and *Aristida stricta* being the dominant grasses. This is consistent with Florida reference communities and the species list of Table 1-1. In a classification of Florida wet pinelands Carr et al. (2010) found that herbaceous species were 95% of indicator species for that community. The herbaceous composition found in our study varied greatly from that of reference wet flatwoods, with the Cleared treatments containing only six herbaceous species. Dominant warm season grasses were not found in either our vegetation surveys or the seed bank emergence. *Sarrecenia* spp., an iconic species of wet flatwoods and prairies of the Florida panhandle, were absent. There were also major families, such as Asteraceae, absent from our surveys.

Site preparation techniques have been previously explored to determine the effects on understory plant communities. A study on coastal plain pine plantations, examined several methods of site preparation including chopping, burning, and disking, finding little change to the herbaceous biomass (Brockway et al. 1998). Our study revealed that chopping, burning, and disking led to an increase in herbaceous cover and species richness. The Disked treatments had eleven herbaceous species, compared to six in the Cleared treatments. The increase in species was likely the result of the disking treatment expressing the seed bank. Three of those species, *Drosera capillaris, Rhexia sp.,* and *Xyris brevifolia* are considered common herbaceous species of reference wet flatwoods and were all found in the seedling emergence study.

Fire suppression results in the proliferation of a midstory component that leads to the accumulation of a litter and root layer that diminishes the herbaceous groundcover (Maliaikal et al. 2000). The organic layer in our study ranged from 0-20 cm in depth (Appendix-C) and had the potential to suppress emergence of seeds and reduce the necessary mineral germination locations. The results suggest that microrelief, elevated microsites, suppressed the emergence of herbaceous species due to a buildup of organic material that remained from remnant titi mounds. The depressed microsites had higher cover and richness of herbaceous species. The increased herbaceous cover and richness that we found in the Disked treatments could be a result of the disking process that breaks down and mixes the inhibitory organic layer or otherwise expose the mineral soils. The disking did not show any immediate negative effects to the herbaceous community, with no reduction in species compared to the pre-disking surveys, and increased percent cover of all species.

There are several factors that could have influenced the herbaceous cover results. During the first 1-2 years after gyro-tracking and burning there remained large deposits of woody debris that could have potentially suppressed germination sites and prevented emergence from the seed bank or from seed rain entering the site. There also have been irregular rain patterns during the study period. In 2010, there was a wet spring followed by a drought in June (personal observation), which could have decimated any seedlings that had emerged in the spring. In 2011, an extreme drought took place throughout the spring and into the summer which could have prevented new emergence of herbaceous species. The brief (1 yr) time period of the study was also a limiting factor. Additional monitoring over the next few years would be beneficial to confirm the trends we saw in our research.

Woody Cover and Composition

After removal of woody vegetation by mechanical means or burns, resprouting of woody species has proven to be one of the most difficult obstacles in the restoration of all types of pinelands. Dormant season burns, as used in our research area, are not effective in controlling woody resprouting and in some cases have led to vigorous resprouting that exceeded the woody biomass prior to the burn (Drewa et al. 2002). Growing season burns were also determined to be ineffective at eliminating resprouting, but the practice did control resprouting more effectively than dormant season burns (Drewa et al. 2002). Our results were consistent with the above findings and confirmed that *Cliftonia monophylla* and *Lyonia lucida* are especially aggressive resprouters. Moreover, significantly higher woody cover was found at the elevated microrelief sample locations, which is likely due to the fact that those sites were generally remnant mounds of *Cliftonia monophylla* which resprouted.

Herbicide application is a common management tool to control resprouting of woody vegetation in pinelands and many other fire dependant herbaceous ecosystems. Selective herbicides have been effective in controlling woody resprouts in many longleaf pine communities (Jack et al. 2005, Brockway et al. 2000). However, these results differed dramatically from our study. Four to five herbicide applications, of Triclopyr at 10% concentration, over the course of three years proved to be ineffective in controlling the resprouting of *Cliftonia monophylla* or *Lyonia lucida*. In the Cleared (but non-disked plots), woody cover increased significantly throughout the study and did not seem inhibited by herbicide. It is likely that without further management actions, the woody groundcover will continue to expand and prevent restoration of the herbaceous groundcover.

The NWFMWD 2010 SHLMB annual report states “results show we're progressing extremely well towards diverse wet flatwoods” with 10% woody cover (NWFWMD 2010). These results differ significantly from the results of our Cleared plots in the same region, which had 27% woody cover in November of 2010. NWFWMD applied one more herbicide application in the fall of 2010, prior to sampling, which could be a reason for their comparatively lower woody cover values. Our study indicates that if herbicide in discontinued in cleared (but undisked) areas, woody species will be able to resprout. The NWFWMD woody cover results may differ if some moderate time is allowed for resprouting after herbicide application. Furthermore, our Cleared plot results did not show a trend towards diverse wet flatwoods, species richness did not increase during our study, and the observed increase in woody cover suppressed the ability for herbaceous cover to increase. However, as noted below, our experimental plots in which the soil was disked had significant decreases in woody cover.

Site preparation treatments for pine plantations have been studied thoroughly, with many of the treatments similar to the restoration treatments of this study. A combination of treatments including disking has been found to be effective at controlling woody sprouts and increasing species richness, evenness, and diversity (Nilsson and Allen, 2003, Fredrickson et al. 1991). In our study, disking treatments appeared to significantly help reduce woody groundcover and prevent resprouting. The disk harrow was able to break and disrupt root systems (personal observation), which prevented most resprouting during the course of this experiment. The primary species of concern, *Cliftonia monophylla*, had significantly decreased cover in the disking treatment. While there was a slight increase in cover from November of 2010 to May of 2011, the resprouts were limited to small areas where the disking was relatively ineffective, and did not sufficiently disrupt the remaining roots. There did not appear to be any new areas resprouting from underground root structures. *Lyonia lucida*, a woody species of less concern, was not suppressed by the disking treatment, but it is unlikely that it will have a significant impact on the overall woody cover in the long term. Two new woody species were found after the disking treatment: *Hypericum fasculatum* and *Pinus elliottii*.

The emergence of *Pinus elliottii* is most likely due to the breakdown of surface organic material, exposing the necessary mineral soils for germination. *Hypericum fasculatum* was also found in the seedling emergence study and was only found in the Disked treatment areas, suggesting that its emergence was a result of the disking treatment.

The ability to control the rapid occurrence of woody resprouting is a key element to successful restoration of these systems. If successful, it opens up or maintains germination locations for new seeds, decreases competition with herbaceous species, and allows for fuel continuity and fire carry. Overall, our results suggest that a disking treatment following clearing and burning could be beneficial for a number of reasons, including the suppression of woody resprouts. However, it is important to acknowledge that disking treatments may not be appropriate in systems that are not as degraded as those in our study sites. Here, fire suppression led to the complete absence of groundcover and the conversion of the habitat to a stable, densely forested system. When restoring sites with remnants of healthy groundcover, disking could be detrimental to any existing, desirable warm season perennial grasses and other native groundcover species.

Seed Bank

Via seed banks and other recruitment processes, natural recolonization of plants has been the primary source for revegetation in many wetland restoration efforts worldwide. While this method of natural recolonization is popular, it has rarely led to plant communities that resemble the original diversity of unimpacted wetlands (Aronson and Galatowitsch 2008, Allen 1997, Middleton 2003, Smith et al. 2002). The results of our study support those findings and suggest that the seed banks of degraded wet flatwoods would not be sufficient in restoring the plant communities to reference conditions. Almost half of the species found in the seed bank were considered weedy species and are not characteristic of reference wet flatwoods communities.

Nevertheless, some species that are common to reference wet flatwoods, such as *Rhynchospora sp., Rhexia sp., Xyris sp.,* and *Dicanthelium spp*., were represented in the seed bank. *Rhynchospora sp.* and *Dicanthelium spp.* were also found in the seedling emergence study, and were two of the common herbaceous species found in the vegetation surveys.

In contrast, *Andropogon spp.* were prevalent in the surveys, yet were not found in seed bank. The seed bank also did not contain any common perennial warm season grasses, asters, or legumes (common to reference wet flatwoods), all of which suggests that sole reliance on the existing seed banks is a poor method for restoration of these habitats.

The seed bank analysis did reveal several species common to wet flatwoods that were not found in the vegetation surveys. Such dissimilarity between seed banks and extant vegetation occurs in many ecosystems worldwide (Thompson and Grime, 1979). Sorenson's similarity index (0-1 range) is a common tool used to analyze the similarity between communities, and index values over 0.50 are rare. Hopsfensperger's (2007) review of seed bank studies concluded that wetland communities had an average value of 0.47 similarity between the seed bank and vegetation. The seed bank similarity to extant vegetation in our study ranged from 0.25 to 0.48. The highest values of similarity were found between the seed banks and vegetation found in our last sampling of May

2011. This suggests that the disk treatment successfully promoted seedling emergence from seed bank.

However, the trend of increasing similarity in this relatively short term study does not necessarily imply that the system is closer to being restored. The extant vegetation in this case is dissimilar from reference wet flatwoods, and therefore the similarity relationships show seed bank expression potential, but not necessarily restoration to intact wet flatwoods communities.

Seedling emergence of woody species was low, considering that the site has been dominated by woody trees and shrubs for the past several decades. There was only one *Cliftonia monophylla* individual, and twenty *Lyonia lucida* individuals, the two dominant woody species at these locations. The absence of a woody seedling presence could be a result of the limitations of the seedling emergence technique (Brown 1992). There also could be a connection with the timing of the soil sampling in summer. Collections made in the late spring would have been affected by a natural cold stratification prior to entering the greenhouse, which could have stimulated germination. In addition, many species did not flower during the experiment, making it difficult to identify them beyond the level of genus. Starting such experiments in early spring may allow more time for species to flower under natural light conditions and perhaps provide a greater distinction among species of genera such as *Carex, Cyperus, Rhynchospora, Dichanthelium, and Fimbrystylis*.

Restoration Implications

Common management practices that include a combination of burning, clearing woody vegetation, and herbicide treatments are insufficient to restore native groundcover in severely degraded pinelands that have been fire suppressed for decades. For example, thirty year old unmanaged pine stands in South Carolina still had hardwood resprouting issues after twenty years of prescribed burning, and the only prescribed burn treatment that controlled resprouting was annual summer burns (Lewis and Harshbarger, 1976). Burning and chopping was ineffective at removing woody species in north Florida flatwoods (Lewis et al. 1988). On many sites, the ability to burn every summer is difficult due to rapid resprouting of shrubs, lack of herbaceous cover to carry fire, economic feasibility, and drought leading to bans on burning. In addition to showing that simply clearing and burning was not effective in controlling titi and other woody shrubs, our study revealed that herbicide may not be effective in controlling that vegetation, even after several applications. Herbicide can temporarily reduce woody material, but it did not appear to control resprouting sufficiently to allow herbaceous species to germinate and spread.

This study suggests that a disking treatment may help solve several problems encountered when trying to restore wet flatwoods. The disking treatment significantly reduced woody resprouting and increased herbaceous cover. Due to the relatively short duration of the study (relative to multi-year vegetation succession scales), we could not determine whether the woody reduction was permanent, but results did suggest that disking will at least control resprouting in the short term. Even if the control of woody vegetation and increase in herbaceous cover is of limited duration, this could allow for prescribed burns to be executed more frequently. The ability to burn annually would reduce the need for constant herbicide application to control woody resprouting.

Controlling resprouting by a onetime disking treatment could be significantly more economical than spraying herbicide multiple times over several years.

The disking treatment also appeared to enhance germination from the seed bank and increase species richness. Recruitment from the seed bank was not sufficient to completely restore the native groundcover community, yet the method can be a valuable tool to facilitate restoration efforts. The lessons learned from our results could be easily applied to management practices by simply disking an area after clearing and burning a site, in order to determine to the viability, composition, and emergence potential of the existing seed bank. This would provide restoration practitioners with early knowledge of the potential species composition, and thus information on what species may need to be planted at the site on a later date. With this information, the lengthy and labor-intensive process of the greenhouse seedling emergence method could be avoided. Vigor of resprouting could also be tested by an early disking treatment that would help determine the need for herbicide applications to treat resprouting.

It is likely that seeding or transplanting will be required to successfully restore the groundcover community to reference conditions. Further research is needed into economically feasible methods for transplanting or seeding. Direct seeding of wet flatwoods sites is unproven at this time, seed purchases are very expensive, and many seeds are not available for local ecotypes. Purchasing large quantities of containerized seedlings to plant across large sites is likewise very expensive. Further research into the establishment of seed collection areas, estimates of seed dispersal rates and distances for individual species and effective protocols for direct seeding are all subjects that could aid in successful restoration of wet flatwoods in the future.

Conclusion

The restoration of degraded wet flatwoods communities can be a complex and difficult process that may have more obstacles than restoration of other pineland communities. Resprouting of aggressive woody wetland species has limited the restoration success in these habitats. Removal of the undesirable woody vegetation via Gyro-Trac mulching, prescribed burning, and multiple herbicide treatments had mediocre success in preventing woody vegetation from resprouting. Restoration of the herbaceous understory was inhibited by the presence of woody cover, accumulation of organic matter, lack of suitable germination substrates, and an insufficient or suppressed seed bank.

The addition of a soil disturbance via disking appears to be an important aid to overcome many of these obstacles. Disking significantly reduced resprouting of woody vegetation, increased herbaceous vegetation, helps break down organic litter, and has the potential to express, or enhance germination from, the seed bank. However, after decades of habitat degradation caused by fire suppression, the limited diversity of the seed bank was insufficient to restore the native groundcover plant community to reference conditions. Therefore, the seed bank should be examined early on in the restoration process, as understanding seed bank composition can guide managers tasked with restoration of these important habitats.

APPENDIX A
SPECIES PERCENT COVER OF EXTANT VEGETATION BY TREATMENT

Appendix A-1.

Species	Cleared June	Cleared November	Cleared May	Disked June	Disked November	Disked May	Thicket November	Thicket May
Groundcover								
Andropogon spp.	0.9	5.15	4.93	0.78	1.07	3.27	0	0
Bidens mitis	0	0	0	0	0	0.25	0	0
Centella asiatica	0.17	0.08	0.05	0	0	0.033	0	0
Clethra alnifolia	0	0	0	0.27	0	0	0.5	0.33
Cliftonia monophylla	11.14	18.38	26.7	8.72	0.67	1.28	5.58	6.5
Cyrilla racemiflora	2.75	2.75	4.5	1.95	0.25	0.116	3.33	2.92
Dichanthelium spp.	0.41	1.33	1.1	0.75	0.73	4.22	0	0
Drosera capillaris	0	0	0	0	0	0.17	0.03	0
Eriocaulon spp.	0	0	0	0	0	0	0.08	0
Eupatorium capilliolium.	0.22	0.08	0	0.33	0	0.1667	0	0
Gaylussacia moseri	0.66	1.25	1.5	0.58	0	0	0.37	5.8
Gordonia lasianthus	0	0	0	0	0	0	0.33	0.333
Hypericum sp.	0	0	0	0	0.03	0.73	0	0
Ilex coriacea	1.1	0.62	0.98	0.35	0.08	0.05	1	0.917
Ilex myrtifolia	0	0	0	0	0	0	0.51	0.5
Lachnanthes caroliana	3.19	1.92	1.5	1.1	0.77	5.3	0.13	0
Lyonia lucida	1.63	3.77	6.08	1.75	0.47	1.17	6.7	9.03
Magnolia virginiana	0	0	0	0	0	0	0.08	0.116
Morella heterophylla	0	0	0	0	0.02	0	0.25	0.5
Persea palustris	0	0	0	0	0	0.08	4	4
Pieris phillyreifolia	0	0	0	0	0	0	4.73	4.91

Appendix A-1 cont.

Species	Cleared June	Cleared November	Cleared May	Disked June	Disked November	Disked May	Thicket November	Thicket May
Pinus elliottii	0	0	0.167	0	0	0.417	0	0
Photinia pyrifolia	0.03	0	0	0.03	0	0	0.27	0.25
Polygala cruciata	0	0	0	0	0	0	0.17	0
Rhynchospora sp.	4.02	8.05	2.95	2.73	6.93	12	0.33	0
Rhexia spp.	0	0	0.05	0	0.03	0.6	0	0
Rubiaceae	0	0	0	0	0	0.267	0	0
Rubus sp.	0.03	0	0	0.05	0	0	0	0
Smilax laurifolia	0.14	0.38	0.133	0.05	0.12	0.033	0	0
Syngonanthus flavidus.	0	0	0	0	0	0.1667	0	0
Vaccinium corymboum.	0	0	0.05	0.17	0.02	0.021	1.58	1.416
Vitus rotundifolia	0	0	0	0.03	0	0	0	0
Xyris spp.	0	0	0	0	0	0.77	0.05	0
Canopy								
Cliftonia monophylla	0	0	0	0	0	0	88.25	89.75
Cyrilla racemiflora	0	0	0	0	0	0	9.23	8.12
Ilex myrtifolia	0	0	0	0	0	0	2.7	2.13
Total Herbaceous	9.03	16.65	10.58	5.12	9.74	27.05	0.79	0
Total woody	17.48	27.18	40.11	14.28	1.66	4.05	128.71	135.5
Litter cover	73.49	55.85	49.7	80.6	88.6	67.8	70.5	67.5

Complete species list and mean cover values of extant vegetation at all dates and treatments. Thicket – shrub thickets with no modification; Cleared – above-ground woody vegetation removal via GyroTrac + prescribed fire + herbicide applied to woody resprouts; and Disked – same as Cleared, but followed by soil disking.

APPENDIX B
SPECIES PERCENT COVER OF EXTANT VEGETATION BY MICRORELIEF

Appendix B-1.

Species	High June Cl. + Ds.	Low June Cl.+ Ds	High Nov. Thicket	Low Nov. Thicket	High May Thicket	Low May Thicket	High May Cleared	Low May Cleared	High May Disked	Low May Disked
Groundcover										
Andropogon spp.	1.05	0.78	0	0	0	0	4.5	5.37	4	2.53
Bidens mitis	0	0	0	0	0	0	0	0	0.5	0
Centella asiatica	0	0.17	0	0	0	0	0	0.1	0.07	0
Clethra alnifolia	0.27	0	0.33	0.67	0.33	0.33	0	0	0	0
Cliftonia monoph.	12.73	6.93	8.5	2.67	8.67	4.33	28.6	24.83	1.17	1.4
Cyrilla racemiflo.	3.55	1.1	2.83	3.83	3	3	5.67	3.33	0.233	0
Dichanthelium sp.	0.7	0.45	0	0	0	0	1.67	1.03	3.8	4.63
Drosera capillaris	0	0	0.07	0	0	0	0	0	0.17	0.17
Eriocaulon sp.	0	0	0	0.17	0	0	0	0	0	0
Eupatorium capillifolium	0.55	0	0	0	0	0	0	0	0.33	0
Gaylussacia moseri	0.87	0.37	0.33	0.4	0.5	0.67	2.17	0.83	0	0
Gordonia lasianus.	0	0	0	0.67	0	0.67	0	0	0	0
Hedyotis sp.	0	0	0	0	0	0	0	0	.13	.4
Hypericum sp.	0	0	0	0	0	0	0	0	0.73	0.73
Ilex coriacea	0.82	0.62	0.33	1.67	0.33	1.5	1.7	0.267	0	0.1
Ilex myrtifolia	0	0	1	0	1	0	0	0	0	0
Lachnanthes car.	0.08	4.15	0.1	0.17	0	0	0.33	2.67	2.93	7.7
Lyonia lucida	2.45	1.07	7	6.4	8.9	9.17	7.23	4.93	1.57	0.77
Magnolia virginana	0	0	0	0.17	0	0.233	0	0	0	0

Appendix B-1 cont.

Species	High June Cl. + Ds.	Low June Cl.+ Ds	High Nov. Thicket	Low Nov. Thicket	High May Thicket	Low May Thicket	High May Cleared	Low May Cleared	High May Disked	Low May Disked
Morella heterophyla.	0	0	0.33	0.17	0.5	0.5	0	0	0	0
Persea palustris	0	0	7.33	0.67	7.17	0.83	0	0	0.1	0.067
Pieris phillyreif.	0	0	6.47	3	6.73	3.1	0	0	0	0
Pinus elliottii	0	0	0	0	0	0	0	0.33	0.13	0.7
Photinia pyrifolia	0.03	0.03	0	0.53	0	0.5	0	0	0	0
Polygala cruciata	0	0	0.33	0	0	0	0	0	0	0
Rhynchospora sp	1.22	5.47	0.33	0.33	0	0	0.77	5.13	8.37	15.37
Rhexia spp.	0	0	0	0	0	0	0.1	0	0.67	0.53
Rubiaceae	0	0	0	0	0	0	0	0	0.13	0.4
Rubus sp.	0	0.83	0	0	0	0	0	0	0	0
Smilax laurifolia	0.08	0.1	0	0	0	0	0	0.267	0	0.067
Syngonanthus fl.	0	0	0	0	0	0	0	0	0	0.33
Vaccinium corymbosum	0.17	0	1.17	2	1.5	1.33	0.1	0	0.43	0
Vitus rotundifolia	0.03	0	0	0	0	0	0	0	0	0
Xyris spp.	0	0	0	0.1	0	0	0	0	0.43	1.1
Canopy										
Cliftonia monop.	0	0	89.13	87.66	0	0	0	0	0	0
Cyrilla racemif.	0	0	9.55	8.88	0	0	0	0	0	0
Ilex myrtifolia	0	0	2.59	2.85	0	0	0	0	0	0
Total Herbaceous	3.42	11.44	0.68	0.65	0	0	7.37	14.3	21.07	32.76
Total woody	20.98	10.26	135.62	122.95	138.63	126.16	45.47	34.8	4.36	3.83
Litter cover	75.6	78.3	63.7	76.4	61.5	73.3	48.5	50.9	73.6	62

Complete species list and mean cover values of extant vegetation at all dates and treatments, separated by microrelief. Thicket - shrub thickets with no modification; Cleared - above-ground woody vegetation removal via GyroTrac + prescribed fire + herbicide applied to woody resprouts; and Disked - same as Cleared, but followed by soil disking.

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BIOGRAPHICAL SKETCH

David K. Mitchell was born in 1977 in Pensacola, Florida. He received his B.S. in Horticulture, with a minor in Wildlife Ecology from the University of Florida in 2008. He went on to earn his M.S. in Soil and Water Science from the University of Florida in 2011.

David worked for himself in different fields before entering the horticulture field in 2005. In 2008, he was hired as Nursery Manager of the Ecosystem Restoration Section with the Florida Department of Environmental Protection, where he managed vegetative restoration efforts throughout the Florida panhandle until 2011. In September of 2011, David left Florida to work with various international ecological restoration efforts.