VEGETATION AS AN INDICATOR OF PASTURE AND WETLAND CONDITION ON A SOUTH FLORIDA RANCHLAND

By

JULIA H. MAKI

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

UNIVERSITY OF FLORIDA

2011

To Earl, for your support of this endeavor and many others

ACKNOWLEDGMENTS

This thesis would not have been possible without the support and advice of my supervisory committee. I am extremely grateful to my committee chair, Dr. James Jawitz, for allowing me the opportunity and freedom to develop this project and explore a topic of interest to me, and two my committee members, Dr. Mark Clark and Dr. Maria Silveira for their thoughtful feedback and valuable discussion of experimental design and methods.

I am indebted to everyone at Buck Island Ranch for their tremendous support of my research and fieldwork. I am especially thankful to Gene Lollis, the ranch manager, and Dr. Betsey Boughton, the research director, for the opportunity to complete this project on the ranch, and their generosity in providing me with resources and support in the field. I would also like to thank Dr. Boughton for all her assistance with developing my sampling methodologies, plant identification, and statistical analyses. I appreciated the assistance of all the interns and staff who took turns spending the day in the field with me, and would specifically like to thank Lauren Barth, Chad Carter, Derek Hendrie, Mike McMillan, Ernie Wang, and Aaron Weaver. I have enjoyed the friendship and support of many others whom I have gotten to know during my time at the ranch, and would especially like thank Christen Steele, for opening her home up to me during my many stays.

Finally, I am grateful for the love and guidance my family has provided me with over the years, especially my parents, and for the support of my boyfriend Earl, who was always willing to take on all the responsibilities at home while I stayed at the ranch.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Science

VEGETATION AS AN INDICATOR OF PASTURE AND WETLAND
CONDITION ON A SOUTH FLORIDA RANCHLAND

By

Julia H. Maki

December 2011

Chair: James W. Jawitz
Major: Soil and Water Science

Florida ranchlands and the wetlands distributed throughout them are valued as both ecological and agronomic resources. Across a ranch landscape, there are a range of management practices applied at the pasture scale, including mowing, chopping, and stocking rate, as well as variation in landscape characteristics like ditch density, and relative wetland area. These practices and characteristics cumulatively contribute to rangeland condition. Understanding their influence in more specific detail is valuable in developing strategies that incorporate both agronomic and ecological aspects of management.

Using vegetation as an indicator of relative condition, this study aimed to quantify current wetland and pasture condition, and examine the relationships that exist between pasture management, landscape characteristics, and condition. On Buck Island Ranch, a cow-calf operation in south Florida, 30 seasonal isolated wetlands, ranging in size from 0.12 to 5.03 ha, were randomly selected, and macrophytes were surveyed in back-to-back quadrats along transects in each cardinal direction. Vegetation was also inventoried in 12 pastures, ranging in size from 51.07 to 211.83 ha. Using a nested

subplot design, a series of measurements including species presence, percent cover, and average height were recorded across four spatial scales.

Quantitative condition scores were calculated for pastures and wetlands, and analyzed against the variables predicted to have the greatest influence on condition. Across both pastures and wetlands there were significant effects of pasture type on plant community composition and condition. Management practices, including stocking density and mechanical treatments (such as mowing and chopping) were significantly related with both wetland and pasture condition scores. The results suggested that management practices influence both agronomic and ecological condition, and specific responses can be elucidated at a landscape scale.

CHAPTER 1
INTRODUCTION AND RESEARCH OBJECTIVES

Florida's Ranches and Grazing Lands

In Florida, grasslands are an important ecosystem, supporting ranching operations throughout the state. Grasslands are ecosystems in which grasses play a dominant role in the ground vegetation, and woody species do not exceed 40% of the total cover (Mannetje 2000). Grasslands may be further classified as rangelands or improved grasslands. Rangelands are grasslands containing native or naturalized species, and pasture management is usually limited to activities like grazing, burning, and woody species control (Mannetje 2000). Improved grasslands are generally planted with species selected to optimize forage production, and more intensive management practices are applied. In addition to grazing, burning, and the control of woody vegetation, improved grasslands may receive fertilization and weed and pest control and these pastures may also be drained (Mannetje 2000).

Cattle ranching is a major component of Florida's economy and landscape. The majority of Florida's ranches are cow-calf operations, and every year Florida exports stocker calves which support beef production in states like Texas, Oklahoma, and Kansas. In 2010, Florida ranked 11th nationally in beef cows, with 926,000 head on Florida farms and ranches, and cash receipts from cattle and calf marketings totaling \$502 million, almost half of the total gross receipts of Florida's livestock industry (NASS 2011). Beef cattle are raised in every county in the state of Florida, but many of the about 1 million cow-calf units are supported on 2.1 million hectares of grazing land in south central Florida (Figure 1-2).

In addition to the major economic benefit to the state, cattle ranches provide valuable ecosystem services. Much of Florida’s remaining natural habitat is located on cattle ranches (Main 2003) and these ranch ecosystems provide a habitat for wildlife, open space, and contain large watershed areas. While the ecosystem services provided are valuable, the way in which the landscape of these ranches is managed can influence the quality of the habitat and ecosystem services, particularly the aquatic features. The rangelands in Florida are largely privately owned, and overlap geographically with some of the state’s most sensitive wetland ecosystems (Swain et al. 2007). Historically, much of southern Florida was native, subtropical, wet-prairie ecosystems, and although large areas have been drained and converted to improved pastures, large wetland areas still exist (Arthington et al. 2007). Seasonally flooded wetlands formed in landscape depressions from the collapse of underlying karst material, and are a dominant landscape feature in the Lake Okeechobee basin (Gathumbi et al. 2005). These wetlands provide a range of ecosystem services, including maintenance of regional biodiversity, water quality enhancement, flood abatement, carbon sequestration, biogeochemical cycling, and wildlife habitat (Zedler and Kercher 2005; Lane et al. 2003). In addition to ecosystem services, freshwater marshes provide high quality forage, and many ranchers in Florida depend on marsh grazing in their operations, utilizing wetland areas during the winter months when forage productivity is low in upland improved pastures (Arthington et al. 2007). Freshwater marshes produce high levels of native forage, such as *Panicum hemitomon, Amphicarpum muhlenbergianum,* and *Leesaria hexandra* as well as non-native forages like *Panicum repens.* These species are dominant within marsh communities, and desirable for grazing because of their relatively high nutritive value and preference by cattle (Tanner et al. 1984).

Pasture Management and Vegetation Structure

The ways in which a pasture is managed can influence and alter the structure of vegetation, both managed forage species and native communities. Two of the primary components of management which have been shown to influence vegetation communities are cattle grazing and the mechanical treatments applied to pastures.

Cattle grazing is an integral part of any ranching operation, and ranchers rely on their pastures to provide a sufficient quality and quantity of forage. The literature suggests that the influence of grazing on plant communities can be variable. Cattle have been shown to feed preferentially on different plant species in both pastures and wetlands (Howe 1994; Tanner et al. 1984), which can affect the dominance and relative abundance of plant species. Over time, this can alter species composition. In pastures, differences in grazing management have been shown to lead to responses in vegetation communities (Harnett et al. 1996) and moderate grazing can lead to greater species diversity of desirable species (Milchunas et al. 1988). In wetlands, Horung and Rice (2003) found that cattle grazing substantially reduced vegetation species richness in 16 repeatedly surveyed wetlands, while Blanch and Brock (1994) found that low-density grazing in rangeland helps maintain species richness. Trampling of wetland vegetation by grazing cattle has also been attributed to alterations in community composition (Vulink et al. 2000).

Mechanical treatments of the pasture, which encompasses practices like mowing, chopping, aerating, and rolling, can create large changes in plant community structure. Chopping is a method that is frequently used to control woody species, and it can disrupt non-woody, native species (Hilmon and Hughes 1965). Chopping may also contribute to an increase in undesirable weedy species.

Monitoring Condition

Monitoring pastures and wetlands provides a means to quantify the effects of management or environmental variation on a site over time. Although condition is a value-laden term, some scale of condition or value is a useful component of monitoring. It allows a basis by which comparisons can be made between sites or management activities. A common way to define condition is by using a series of indices which individually capture important site attributes and cumulatively describe overall characteristics of the site. Across a ranch landscape, there are a range of management practices applied at the pasture scale, including variations in stocking density and mechanical treatments, as well as variation in landscape characteristics, such as ditch density, wetland area, and soil type. These practices and characteristics cumulatively contribute to the overall condition of a pasture. Understanding their influence in more specific detail is valuable in developing strategies that incorporate both agronomic and ecological aspects of management.

Agronomic vs. Ecological Condition

Although the dual agronomic and ecological benefits of Florida's ranches are recognized, the relationship between these two types of value is not always clear. Frequently, monitoring methods are developed to capture a specific interest in ranch condition, and the indices incorporated into the condition scoring method are typically designed with only that interest in mind. Since monitoring methods are used to quantify the effects of management or environment, one result of monitoring is often changes in how management is applied to a pasture. If the measurements included in the monitoring method are too narrow in scope, the changes that are applied may not be both agronomically and ecologically beneficial. When the emphasis is solely on production, pasture alterations may be made that are detrimental to the ecological community. When the focus is on the ecological aspects, alterations in how pastures are managed may be suggested which overlook critical components of production, and ecological benefit is gained while agronomic value declines.

A conceptual diagram of the relationship between agronomic and ecological value is presented in Figure 1-2. As the intensity of pasture management increases, the hypothesis is that the ecological value of the landscape will decrease, while the agronomic value will increase, but only to a certain point, where additional intensification will not increase the productivity of the pasture, and the agronomic value could potentially decline. The intersection of the curves is important, because it reflects a level of management where both agronomic value and ecological value have equal weight. Although this theoretically represents a balanced approach to management, the intersection may occur at a point where neither the agronomic or ecological condition scores are acceptable. Because the primary emphasis of ranch management is production, ranchers will have a level of agronomic condition that meets their requirements. If ecological condition is found to be strongly tied to the intensity of pasture management, the best way to achieve a balanced management approach would be to understand to what degree management can be scaled back without hurting agronomic output. Applying this approach would require a more specific understanding of how management alters vegetation and over what period of time the response occurs.

Research Objectives and Hypotheses

The response of plant communities to both past and current management and the subsequent ability to use vegetation as an indicator of these effects was a central component of this study. The central hypothesis was that differences in wetland and pasture condition can be assessed at the scale of an individual pasture, and condition can be explained by differences in management practices and landscape characteristics in the pastures and wetlands. Based on this hypothesis, three main research objectives were developed: 1) using vegetation as an indicator, quantify current agronomic condition of pastures, and current ecological condition of pastures and wetlands, 2) examine the relationships that exist between pasture management, landscape characteristics, and condition, and 3) compare the agronomic and ecological pasture scores. To fulfill these objectives an ecologically based scoring method was selected and applied to both pastures and wetlands, and a limited agronomic assessment of condition was completed in the pastures. Nine variables predicted to influence pasture and/or wetland condition were selected (Table 1-1), and were used in the analyses of the condition scores.

Site Description

This study was conducted at the MacArthur Agro-ecology Research Center at Buck Island Ranch (BIR), a division of the Archbold Biological Station. Buck Island Ranch is a 4,290-ha ranch located near Lake Placid, Florida (lat 27°09'N; long 81°12'W) managed at commercial production levels with approximately 3,000 head (Figure 1-3). It is among the top 20 cow-calf producers in the state. BIR has flat topography, poor natural drainage, and a high wet-season groundwater table.

The pastures at BIR are managed as two different groups, which for the purpose of this study will be referred to as improved (IMP) and semi-native (SNP). The term improved is used to indicate that the pastures have been agronomically improved by practices like planting and fertilizing. There are large differences in vegetative cover, grazing pressure, pasture treatment, and hydrology between the two pasture types. Improved pastures have been planted with the introduced forage bahiagrass (*Paspalum notatum* Flügge) and were annually fertilized with NPK fertilizer before 1987. Since that time, they have been fertilized annually with N fertilizer. These pastures are typically grazed most heavily during the summer wet season. Semi-native pastures contain higher cover of native grasses like the bunch grasses *Andropogon* spp. and *Panicum* spp, and the carpet grasses (*Axonopus* spp.) in addition to the bahiagrass. The semi-native pastures have never been fertilized, and they are grazed most heavily during the winter dry season.

Distributed over the ranch property are 628 isolated, seasonal wetlands. These wetlands range in size from 0.01 to 41.9 hectares (mean: 0.86± 2.42ha) and account for 13% of the ranch area. The wetlands are distributed evenly among the improved and semi-native pasture types. These wetlands are typically flooded during the wet season, but depending on rainfall, the hydroperiod can vary from less than three months to more than ten months. During the months leading up to the sampling season for this study, precipitation was below average, especially during April, May and June, which generally coincides with the start of the summer wet season.

From a group of comparable pastures at Buck Island, twelve wetlands were randomly selected for this study, six improved pastures and six semi-native pastures. Within those 12 pastures, 30 wetlands were also randomly selected, 15 in each pasture type, and a minimum of two wetlands in each pasture (Figure 1-4). The chosen pastures ranged in size from 51.07 to 211.83 hectares, and the wetlands ranged in size from 0.12 to 5.03 ha. Site names followed nomenclature previously established at Buck Island, with a name for each pasture and a number for each wetland (Figure 1-5).

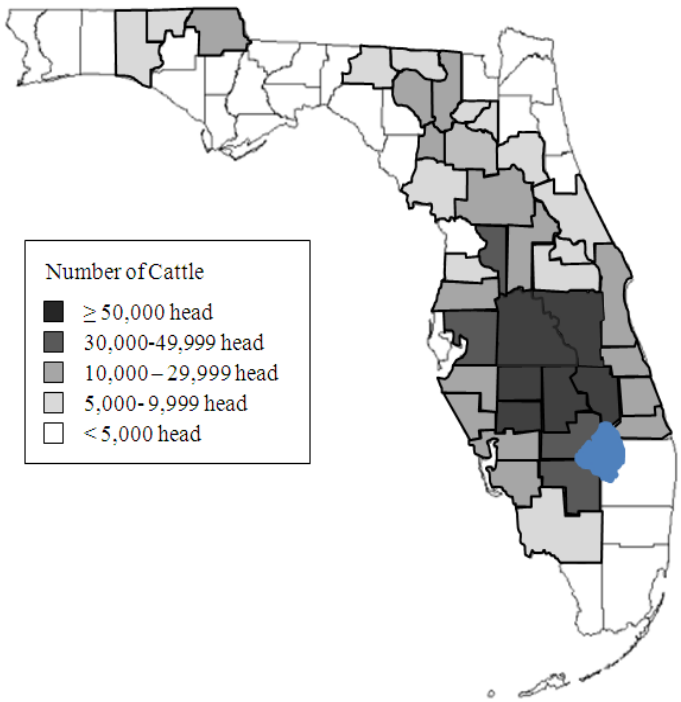

Figure 1-1. Florida beef cattle inventories by county, 2010. Source: NASS, 2011.

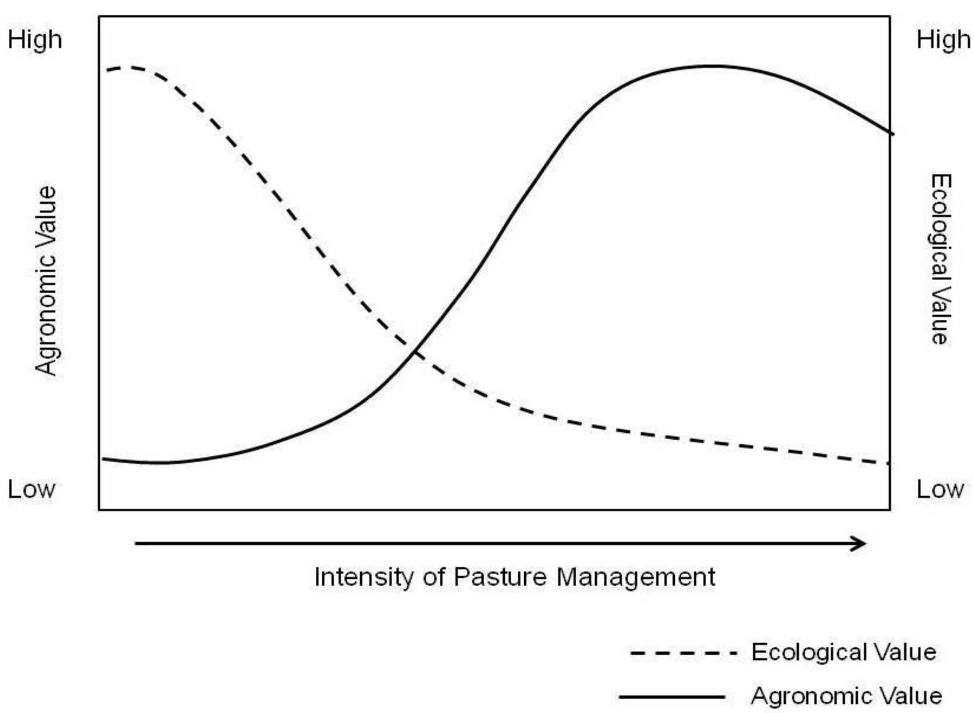

Figure 1-2. Conceptual diagram illustrating a hypothesized relationship between the intensity of pasture management, agronomic value, and ecological value.

Table 1-1. Definitions and calculation methods for predictor variables.

Variable	Definition	Wetlands	Pastures
Pasture Type	Intensively-managed pasture or Semi-native pasture	x	x
Mechanical Treatment	Count of mechanical treatments each pasture received from May 2007 to May 2011. Treatments include mowing, chopping, aerating, and rolling	x	x
Long-Term Stocking Density	Average daily stocking density for each pasture from May 2006 to May 2011	x	x
Short-Term Stocking Density	Average daily stocking density for each pasture from May 2010 to May 2011	x	x
Individual Wetland Area	Area (in ha) for each wetland	x	
Pasture Area	Area (in ha) for each pasture		x
Relative Wetland Area	Sum of the area for all wetlands in the pasture (ha) divided by pasture area (ha)	x	x
Ditch Density	Total length (meters) of all ditches divided by pasture area	x	x
Wetland Ditch Interactions	Count of the number of unique ditches interacting with each wetland	x	

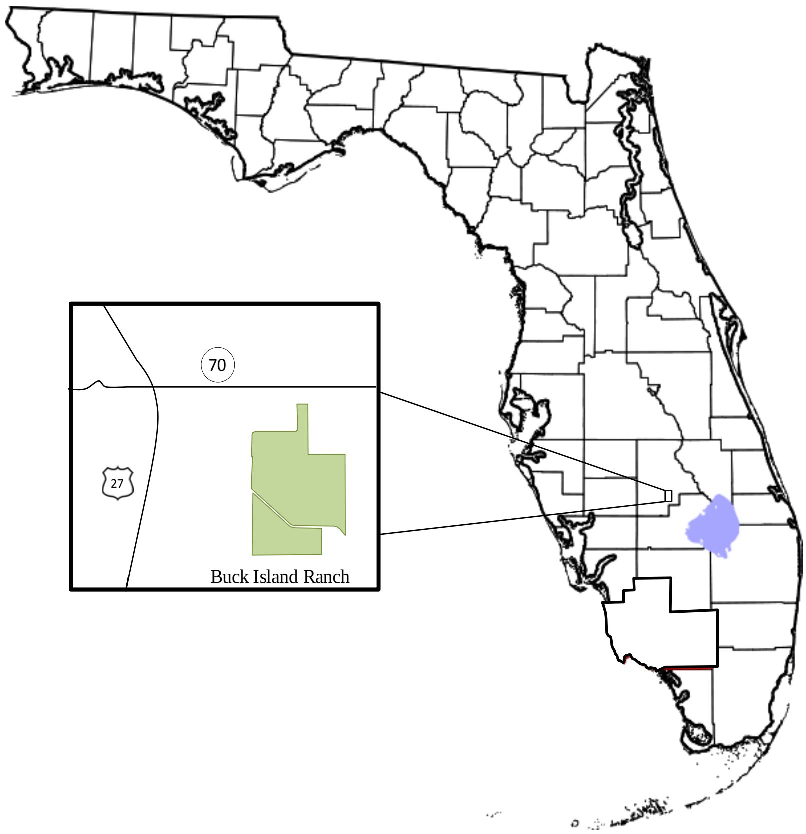

Figure 1-3. Location of the MacArthur Agro-ecology Research Center at Buck Island Ranch.

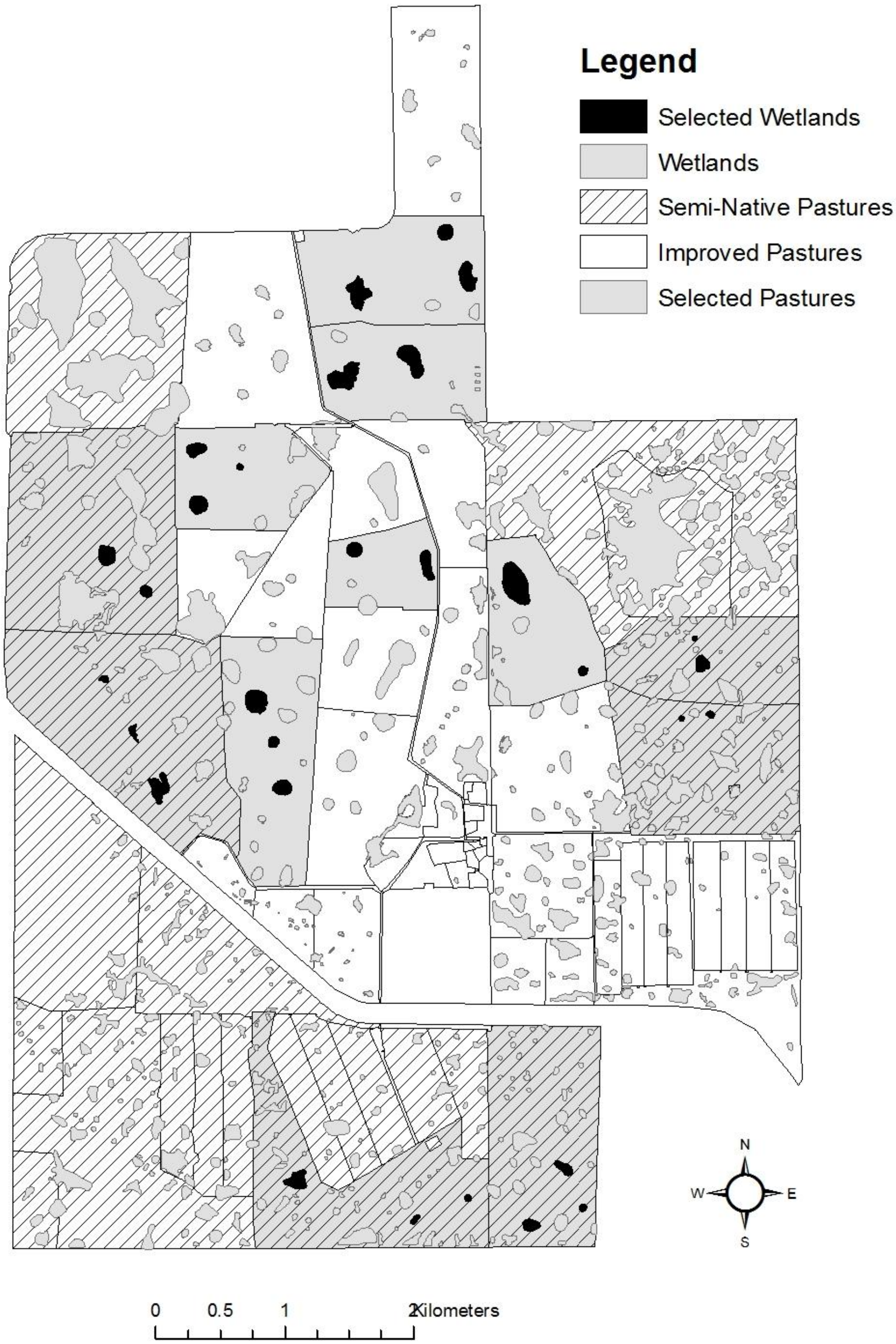

Figure 1-4. Selected study sites at the MacArthur Agro-ecology Research Center

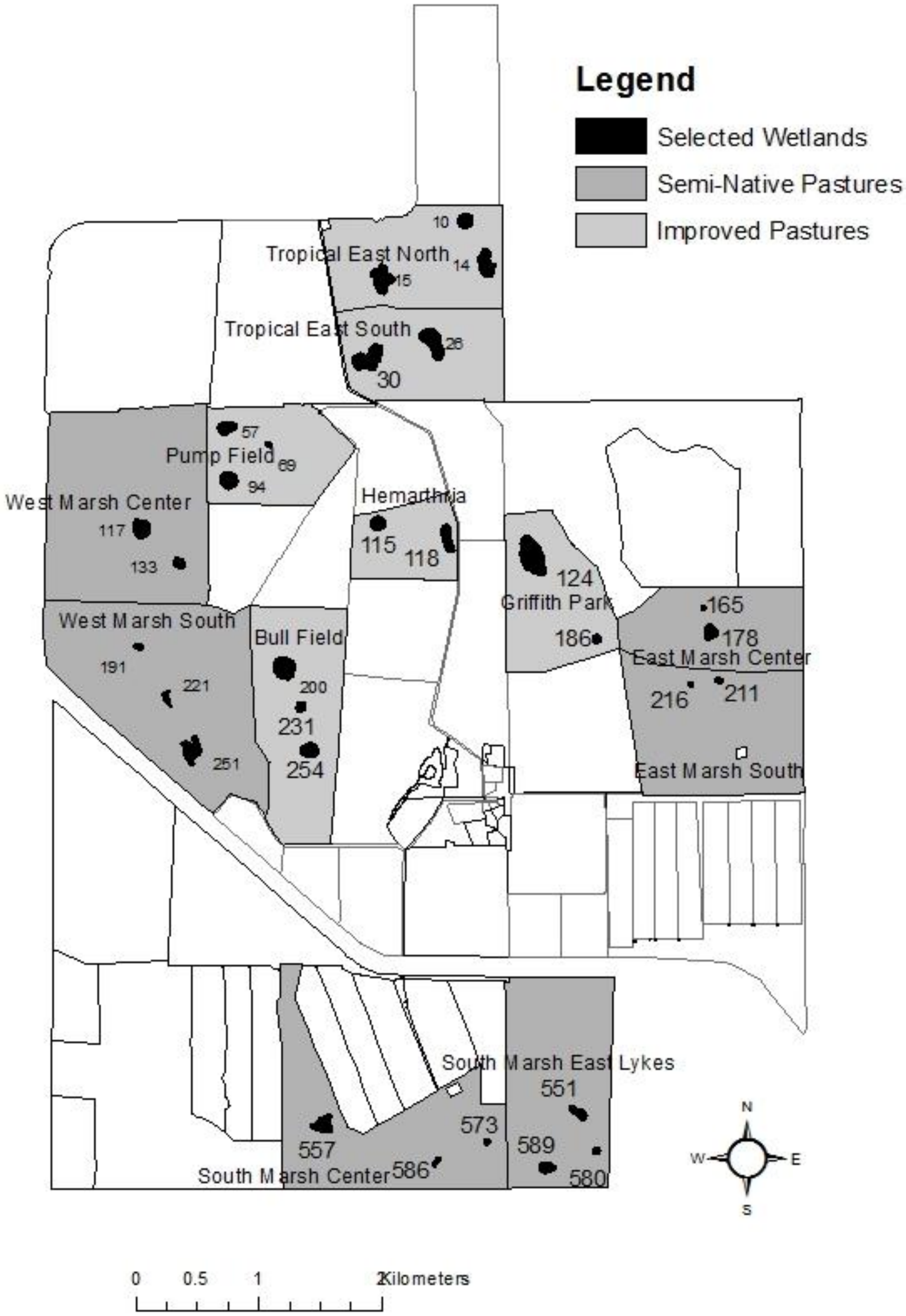

Figure 1-5. Site ID's for wetlands and pastures.

CHAPTER 2
PASTURE CONDITION DETERMINATION

Mannetje (2004) suggest three main reasons for monitoring vegetation in grassland research: ‘1) describing the distribution and relationships of plant species, ground cover, and the amount and quality of dry matter, 2) assessing changes in vegetation caused by changes in management or climate, and 3) determining the ability of vegetation to provide feed for livestock.’ Because the botanical composition of grasslands reflects many factors, including past management (Whalley and Hardy 2000), the measurements of greatest interest and value are generally those that can be used to describe the whole plant community, rather than individual plants (Mannetje 2000). Vegetation patterns occur in grasslands at a range of scales (Whally and Hardy 2000), and it is important that this is accounted for in the selection of a monitoring method.

The success of beef cattle operations is directly tied to the amount and quality of forage, as pasture or hay, available to the animals, so ranchers must make educated decisions about the forage species they utilizing on their land. Agronomically, grasses are the most important vegetation on landscapes for grazing, and although there are 332 native grasses that grow in Florida, only 10-15 species produce most of the forage for cattle (Kalmbacher 1992).

Methods for Assessing Pasture Condition

Across the many different types of grazing lands, a variety of methodologies have been used to assess condition (Cosgrove et al. 1996; Stohlgren et al.1998). These methods include both field techniques, and methods that synthesize the field data into a score or management recommendation. Multiple studies have also attempted to compare rangeland vegetation sampling techniques (Stohlgren et al. 1998). Each of these methods makes certain assumptions about the landscape. For example, the use of linear transects on a small-scale, requires the assumption that the site is representative of the larger landscape. The main objective of each of these methods is to utilize parameters observed or measured in the field to make inferences about condition and understand if and where changes in management are necessary.

The Modified-Whittaker Plot

The Modified-Whittaker plot (Stohlgren et al. 1995) is based on the sampling technique of R.H. Whittaker (1977), and like the original Whittaker plot is a nested subplot design. The benefit of this design is that it allows for sampling at multiple spatial scales. The plot design (Figure 3-1) features a 20x50m (1,000m^2) rectangle with a series of smaller plots (100m^2, 10m^2, and 1m^2) systematically arranged within the large plot. The length to width ratio of the larger plot is maintained in the smaller plots. When applying the method, the plot is placed parallel to the major environmental gradient. In the 1m^2 plots, species presence, percent cover, and average height are recorded. Cumulative additional species are subsequently recorded in the remainder of the plots.

In developing the method, Stohlgren et al. (1995) describes several clear benefits to multi-scale sampling. These include: the ability to evaluate the effect of spatial-scale of local species richness, providing better comparisons of species-richness than single scale methods (Whittaker 1977), and allowing for the development of species-area curves to estimate patterns of species richness at larger scales. There were three primary objectives for the design: 1) accurately quantify the mean and variance of foliar cover and height of most plant species at a site; 2) provide cover and frequency data less influence by spatial correlation; and 3) develop species-area curves to predict the number of native and exotic species in a larger area (Stohlgren et al.1997).

The design of the Modified-Whittaker plot is especially useful in detecting and monitoring locally rare species in a landscape. While detecting new or rare species at a site may not be a primary objective of rangeland sampling, it can help develop practices that protect native plant diversity, manage for rare habitats, and monitor the spread of exotic species (Stohlgren et al. 1998). Early detection of exotic species and noxious weeds is a critical component of range management-eradication and restoration is easier and more economical when the affected area is smaller. The design of the main plot is a 20x50 meter rectangle, and the shape and dimensions of the plot are an important component of its utility. In a heterogeneous landscape, recorded species richness is influenced by plot shape (Stohlgren et al. 1995), and because they have a reduced perimeter to surface area ratio, circular and square plots have generally been found to have fewer species than a longer narrow plot (Bormann 1953).

Ecological Pasture Condition

Four vegetation-based metrics correlated with landscape development intensity were used to create an ecologically based assessment of relative pasture condition. The four metrics selected were: 1) annual to perennial ratio, 2) percent exotic taxa, 3) percent sensitive species, and 4) percent tolerant species. Because BIR contains two distinct pasture types (intensively managed and semi-native), pasture type was used to represent two different levels of management intensity. These metrics were specifically selected because they are four of the five components of the Vegetative Index of Wetland Condition (Lane et al. 2003), which was applied to the wetland data and is presented in Chapter 3. Not only are these metrics applicable to ecological pasture condition, but using similar metrics and methods will facilitate an ecologically-based comparison between wetlands and pastures. A brief description and the rationale for each metric are described below, while the details of the calculation of each metric are described in the methods section.

Annual to perennial ratio

Annual species are defined as species that live for one year, while perennial species are defined as species that live three or more years (Tobe et al. 1998). Whether a species was annual or perennial was determined using Tobe et al. (1998).

Percent exotic taxa

Exotic species are generally defined as those not present at a particular location before the European settlement of North America. This study specifically defined those species exotic to Florida, and whether a species was native or exotic was determined using Tobe et al. (1998) and Wunderlin (1998). Because ranches need to be able to provide consistent levels of high quality forage, pastures are regularly planted with exotic forages that fulfill certain requirements. Compared to native species, these improved grass species may provide greater nutritive value and yields, or tolerate greater grazing. Outside of the species planted as a component of management, additional exotic species are present on the ranch landscape, and studies have suggested that increases in disturbance and improper pasture management can allow for the introduction of these species. Of particular concern are exotic invasive species. The Florida Exotic Pest Plant Council (FLEPPC) groups invasive species of concern into two categories. Category I exotics are species which alter native plant communities by displacing native species, change the structure or ecological functions of a community, or hybridize readily with native species . Category II exotics are those which are increasing in abundance in Florida, but to this point have not affected natural areas. In this study, intensively managed pastures were expected to have higher numbers of exotic species than the semi-native pastures, due to the higher levels of landscape disturbance.

Sensitive and tolerant species

For the purpose of this study, sensitive and tolerant species are defined as species indicative of particular landscape condition, represented here by pasture type. Since the agronomically improved pastures are a more disturbed landscape, species indicative of these pastures are classified as tolerant species. The semi-native pastures represent a less-disturbed landscape, and therefore species indicative of the these pastures are classified as sensitive species. Because the different pastures are incorporated into the computation of the metric, differences in the percent sensitive and percent tolerant species are expected among types.

Agronomic Pasture Condition

A limited assessment of agronomic condition was implemented in this study, based on the 'Pasture Condition Scoring' method originally developed by Cosgrove et al. (1998). The method requires the assessment of ten indicators, which each influence pasture condition. A numerical rating ranging from 1 to 5, with one representing the lowest score and 5 representing the highest score, is applied to each indicator, creating a total score ranging from 0 to 50. The cumulative score for each pasture is interpreted as the degree to which changes in management are needed. Most of the indicators in this method are visually assessed, which can lead to some sampler bias, but the indicators could be assessed more intensively using methodical pasture sampling. Five of the indicators, all based on plant characteristics, were incorporated into an agronomic-based assessment of condition for this study. The indicators were: 1) percent desirable plants, 2) plant cover, 3) plant diversity, 4) plant residue, and 5) percent legumes. How each of the indicators relates to pasture condition is described below, and the criteria that were used to rate each metric are summarized in the methods section. Because one of the original objectives was to use an established method to evaluate condition, these indicators were first assessed as published in the Cosgrove et al. (1990) method. Although this method has been used around the country, specific components may not be appropriate for Florida's landscape. Therefore, a modified version of the method was also applied to the data, attempting to tailor the initial criteria to reflect conditions on Florida's grazing lands. The scoring for the plant diversity metric was reversed, with higher scores going to pastures with a mono-dominant stand, reflecting how pastures in Florida are planted and managed. Plant stubble height, which is a criteria frequently measured in Florida, was added as an additional metric.

Percent desirable plants

This indicator is used to assess whether a pasture has the types of vegetation that cattle or livestock will graze readily. Cosgrove et al. (1990) describes a desirable species as one that is readily consumed, persistent, and is able to provide both high tonnage and quality for a significant part of the growing season. Undesirable plants include woody invaders, noxious weeds, and toxic plants. These species are avoided by livestock, can have negative side effects when consumed, and also crowd out more desirable species.

Plant cover

The amount of vegetative cover, quantified as canopy cover, in a pasture is important not only important for the quantity of forage available for grazing, but also protects the pasture’s soil and water characteristics. Dense stands of vegetation are best for forage growth, while bare spots can allow undesirable weeds to encroach, cause water to run off the pasture, and can lead to erosion (Cosgrove et al. 1990). Canopy cover can change drastically in a short period of time from influences like grazing or fire (Whalley and Howdy 2000), and other attributes of the pasture can influence how quickly re-growth occurs.

Plant diversity

Plant diversity describes how well different forage species and functional groups are represented in a pasture. Pastures that are well-established, and moderately grazed are expected to have a greater number of forage species, and species from different functional groups. Having different functional groups in a pasture helps to maintain consistent forage supply throughout the season, but a moderate number of different species is better than a higher number (Cosgrove et al. 1990).

Plant residue

The plant residue metric looks at both plant residue on the soil surface and standing dead material in the stand. Limited amounts of plant residue are beneficial to the pasture, because they provide protection of the soil surface and introduce organic matter into the soil. High amounts of standing dead material in the pasture reduces the value of the forage consumed, and areas with a lot of standing dead may be rejected or avoided by the grazing animal (Cosgrove et al. 1990). The accumulation of plant residue is primarily related to how productive the plant communities are, as well as how much biomass is removed by grazing, insects, or climatic factors like wind and water, and the rate of decomposition at the site (NRPH, 2008).

Percent legume

This metric assesses how much legumes contribute to each pasture. Legumes are important for their ability to fix nitrogen, and when they contribute 20% of the air dry weight of a pasture, can greatly improve the forage quality (Cosgrove et al. 1990). Nitrogen limitation is a frequent challenge in pasture management, so when legumes are not a significant contributor to pasture composition, alternative methods, such as fertilization, are needed to supplement the nitrogen levels.

Methods

Field Methods

The Modified-Whittaker plot design was used to assess pasture vegetation across the selected sites in the winter and summer of 2011. Winter surveys were completed in February, and summer surveys were completed in May and June. Plots were placed randomly in each pasture, with a minimum distance between plots. For the winter sampling, 27 total plots were sampled across 12 pastures, with each pasture serving as an experimental unit. Because winter burns were being conducted during this time frame, the entire area of each pasture could not be sampled. In the summer, 4 plots were set up in each pasture, for a total of 48 plots. Figure 3-2 illustrates the locations of all the sampled plots. Plots were placed parallel to the major environmental gradient in each pasture, which depending on the specific location was either ditching or an elevation gradient. Percent cover was estimated using the Braun-Blanquet percent cover classes (Table 3-1). The average height for each species was recorded in centimeters. In addition to living species, percent cover values were also recorded for standing dead, litter, and bare ground.

Analysis

All species encountered were characterized by growth form and functional group. Because predominantly warm season grasses were encountered during the sampling, warm and cool season grasses were combined into one functional group. Species were also characterized by their potential forage value, as desirable, intermediate, poor, avoided, and potentially toxic. Additional data added included whether a species was annual or perennial, and native or exotic. To examine the differences between seasons, differences in length of successional vectors were calculated in PC-ORD (v.6, McCune and Grace 2002) by comparing the composition of pastures in the winter and the summer. The vector length represents the magnitude of change in species composition, from the beginning to the end of sampling. Summary measures of sample richness, evenness, Shannon's diversity and Simpson's diversity were calculated for each site. These measures can be used to look at differences in species distributions across land uses, which for this analysis is specifically pasture type. Species richness, which is the simplest measure of species diversity, is the total number of taxa found in a sample, while species evenness measures the distribution of the taxa at a site. The Shannon's (H') and Simpson's (D') diversity indices measure the diversity of a site based both on the number and abundance of species (Brower et al. 1990).

Using PC-ORD, nonmetric multidimensional scaling (NMS) was used to test community similarities between the intensively managed and semi-native pasture types. The effect of long and short-term stocking densities, mechanical treatments, ditch density and pasture area were compared using a joint plot and correlations with axis scores. The ordination was based on the data collected in the $1m^2$ subplots. NMS was selected over other ordination methods for this analysis because it avoids assumptions that are rarely met with community data, such as a linear relationship between variables, and is useful for heterogeneous data sets with many shared zeros between sample units (McCune and Grace 2002). The ordination was calculated using the Sorenson (Bray-Curtis) distance measure. Random starting configurations with 50 runs of real data and 250 runs of randomized data. To test whether NMS extracted stronger axes than expected by chance, a Monte Carlo test of significance was performed.

Log-log species area curves were created to compare species richness for each cumulative area sampled. Because the data were non-normal for the $1m^2$ sample areas in both the intensively managed and semi-native pasture types, a Mann-Whitney U test was used to test for a significant effect of pasture on the four different levels of area.

Ecological condition scoring

To evaluate you the ecological condition of each pasture, a cumulative score was calculated based on the four included metrics. The method for calculating each metric is summarized in Table 2-3, and a more detailed description how the sensitive and tolerant species were determined is described below. A Welch's t-test was used to test for significant differences between the scores in the intensively managed and semi-native pastures.

Indicator Species Analysis. Indicator Species Analysis (ISA, Dufrene and Legendre, 1997) has frequently been used to identify species with specificity and fidelity to particular ecological conditions (Chytry et al. 2002). This method assesses the degree to which a species indicates a group based on its constancy and distribution of abundance based on an indicator value (IV) that summarizes the relative abundance and frequency of each species in each treatment:

$$IV_{kj} = RA_{kj} \times RF_{kj} \times 100$$

where RA is the relative abundance of a given species *j* in a given group *k*, and RF_{kj} is the proportion of plots in each treatment that contain species *j* (Chytry et al. 2002). Because the *RA* and *RF* are multiplied, both must be high for an IV to be high. In this analysis, ISA was used to identify species significantly associated with disturbed or natural landscapes, represented by pasture type. The ISA was performed using the relative frequency of species by pasture. A Monte Carlo randomization test with 4,999 permutations and a p-value of 0.05 was used to test the significance value of each indicator species. Based on the ISA, significant indicators of intensively managed pastures are classified as tolerant species, while significant indicators of semi-native conditions are classified as sensitive species.

Ecological Condition Score. The calculation of the ecological condition score follows the methodology of the Wetland Condition Index (Lane et al. 2003), and is identical to the method applied to the wetlands (Chapter 3). The cumulative pastures were calculated from the data set (n=12) based on the 95th percentile of each metric. Each metric was scored into four categories, corresponding to the four quartiles of the data set, and assigned a numerical value of 0, 3, 7, or 10 (Table 2-2). In three of the metrics, a 10 score is assigned to the lowest quartile of the data set, because higher numbers or tolerant, exotic, and annual species correspond with poorer condition. Because a higher number of sensitive species is more ecologically desirable, a 10 score is assigned to the highest quartile of the data set. Based on this calculation, a score of ‘0’ represents the lowest possible score, and a score of ‘40’ represents the highest possible score.

Agronomic condition scoring

Using the species presence, percent cover, and average height measurements taken in the $1m^2$ plots, two agronomic condition scores were calculated. First, the score was calculated based on the five criteria taken directly from the Cosgrove et al. (1990) method. For each pasture, a score of 2,4,6,8, or 10 was assigned to each metric based on the criteria described in Table 2-3. To calculate the cumulative agronomic score the score of the individual metrics were summed. Based on this method, a score of ‘0’ represents the lowest possible score, and ‘50’ represents the highest possible score. Next, the score was calculated based on the six modified criteria, and a score of 2,4,6,8, or 10 was assigned to each metric based on the criteria described in Table 2-4. The individual metrics were summed to calculate a cumulative score. Based on this method, a score of ‘0’ represents the lowest possible score, and ‘60’ represents the highest possible score. It is important to clarify the major difference between how the ecological and agronomic scores were calculated. The ecological method assigned scores to metrics based on the quartiles of the entire data set, making the scores relative, while the score for each agronomic indicator was independently assigned to each pasture. Therefore, although both methods have similar numerical scales, the more meaningful interpretation is the relationships between the different scores and pasture type, rather than the specific numerical value.

To further evaluate the condition scores, the ecological and agronomic condition scores were each used as a dependent variable in an analysis of covariance (ANCOVA) to assess the influence of stocking density, mechanical treatment, ditch density, and area on scores. The predictor variables were calculated as described in Chapter 1, and the values for each of them are presented in Table 2-6. These analyses were performed using R software (v. 2.13.1; R Development Core Team 2011). Pasture type was a fixed effect, and the remaining predictor variables were covariates. Thirty-one possible models were tested, iteratively fitting models beginning with the full factorial model and systematically assessing three-way, and two-way interactions, a main effects model, and the single main effects of each of the six covariates. The Akaike Information Criterion (AIC) was used to identify the most useful model based on explanatory power and likelihood. The AIC is defined as:

$$AIC = -2\log\big(\pounds(\theta|y)\big) + 2K$$

where $\big(\pounds(\theta|y)\big)$is the numerical value of the log-likelihood at its maximum point, and K is the number of estimable parameters in the model (Burnham and Anderson 2002). The AIC is a useful tool for selecting the best model, because it accounts for both the explanatory power of the model and the number of parameters included. Using the AIC method, the most parsimonious model is one with the most explanatory power with the fewest number of parameters. Selecting a model with a lower number of parameters increases its utility by simplifying the interpretation. Model weights were also calculated to indicate the likelihood of the model in comparison to all other considered models. For this analysis, the best model was chosen as the model with the lowest AIC score and the highest model weight.

Results

General Patterns of Species Richness

Sixty-eight unique species were encountered during the pasture sampling. Specifically for the summer period, pastures contained 17 grasses, 9 sedges, 32 forbs, 6 shrubs, 1 rush, and 3 vines. Perennial grasses contributed the greatest percentage of cover in all pasture types. Summary statistics for the summer data set are reported in Table 2-4. The vector analysis indicated that although there were compositional changes between the winter and summer, there was not a significant difference between pasture types. The NMS ordination resulted in 2 axes which cumulatively explained 95% of the variance. Both axes were significant ($P = 0.004$). Most of the variance was explained by axis 1 (73%), while 13% was explained by axis 2. The final stress of the best solution was 5.05, and there were 55 iterations in the final solution. The ordination indicated two distinct plant communities defined by pasture type (Figure 2-2). Axis 1 of the ordination was associated with pasture area, which increased towards the area of the semi-native pastures. Axis 2 was associated with short-term stocking density and mechanical treatments, but these variables were not clearly related to pasture type. Long-term stocking density and ditch density were associated with axis 1 and axis 2, with both variables increasing towards the area of the improved pastures. Species-area curves (Figure 2-3) indicated that for both the improved and semi-native pastures, new species were added as sample area increased. At all four plot levels, a higher number of species were encountered in the semi-native pastures. There was a significant effect of pasture type on species richness at all four spatial scales.

Metric Results

Annual to perennial ratio

The majority of the species encountered (88%) were defined as perennial species. Across both pasture types, the mean annual to perennial ratio was 0.095(±0.06). The mean was higher in the improved pastures (0.128±0.06), and lower in the semi-native pastures (0.062±0.03). The mean (±SD) and t-test results for this metric and the additional three are summarized in Table 2-6.

Percent exotic taxa

Ten (12.7%) of the 79 species encountered in the pasture sampling were identified as exotic to Florida. Three of these species, bermudagrass (*Cynodon dactylon),* bahiagrass (*Paspalum notatum),* and white clover *(Trifolium repens)* are intentionally planted forage species. Many of the exotic species encountered are classified by the FLEPCC as Category I or Category II invasive species (Table 2-5). Across all sites, the average percentage of exotic taxa was 21.99(±12.28). For the improved pastures, the mean was 32.50(±6.38), and for the semi-native pastures 11.48(±4.20).

Sensitive and tolerant species

Four species (Table 2-6) were determined to be significant indicators of the improved pastures, and were therefore classified as tolerant species. Seven species (Table 2-7) were determined to be significant indicators of the semi-native pastures, and therefore classified as sensitive species. Both the percent sensitive and percent tolerant metrics had significant differences between pasture types (*P* <0.001). For all pastures, the mean percentage of sensitive species was 17.16 (±7.28), and the mean percentage of tolerant species was 16.86(±9.71). In the improved pastures, the mean percentages were 25.00±6.23 for the tolerant species, and 11.39(±5.22) for the sensitive species. In the semi-native pastures, the mean percentages were 8.72(±3.08) for the tolerant species, and 22.94(±3.05) for the sensitive species.

Ecological condition score

Computed scores ranged from 0 to 37. Across both pasture types, the mean ecological condition score was 19.75(±14.59). Scores were significantly different between the two pasture types (*P*<0.001) The mean score for the improved pastures was 7.00(± 6.51) and the mean score was 32.50 (±4.75) in the semi-native pastures (Figure 2-3).

Agronomic scoring

For the original scoring method, the specific values assigned to each metric, and the cumulative agronomic score is summarized in Table 2-8. There was a significant effect of pasture type on the agronomic score (*P*=0.002). The mean agronomic score for the improved pastures was 19.67(±4.27), and for the semi-native pastures the mean score was 17.50(±1.76). For the modified scoring method, the metric and cumulative scores are summarized in Table 2-9. There was not a significant effect of pasture type on the scores, with a mean score of 29.33(±4.50) for the improved pastures and 27.16(±1.83) for the semi-native pastures.

Analysis of Covariance

The best model predicting ecological pasture condition score included the main effects of type and mechanical treatments. The adjusted r^2 of the model was 0.89, and the model weight was 0.39. In this model, the coefficient for pasture type was significant, with higher scores in the semi-native pastures. The coefficient for mechanical treatment was also significant, and the strength of the relationship was related to pasture type. The ecological condition score increased with the number of mechanical treatments in both pasture types, but there was a stronger relationship in the improved pastures. The best model predicting agronomic pasture condition was the main effect of type, and the coefficient for type was not significant in the model. The top five models all include the individual main effects, suggesting that none of the models had valuable explanatory power.

Discussion

The results of ecological condition analysis support the predictions for the individual metrics. As expected, the improved pastures had a higher annual to perennial ratio than the semi-native pastures, corresponding with the hypothesis that increased landscape disturbance would result in higher numbers of annual species. A higher percentage of exotic species was also encountered in the intensively managed pastures, suggesting that increases in disturbance can allow for the introduction of exotic taxa. The significantly lower percentage of exotic taxa in the semi-native pastures may indicate that because the semi-native pastures are characterized by less landscape disturbance, the plant communities are more stable and exotic species don’t have the same opportunity to come into the landscape. The semi-native pastures were expected to have higher numbers of sensitive species, and lower numbers of tolerant species, and the reverse was expected for the intensively managed pastures. This hypothesis was supported by significant differences between pasture type for both the percentage of sensitive and tolerant species.

The NMS ordination, ecological condition score, and agronomic condition score verify that significant differences exist between pasture types. The NMS ordination confirms that there are significant differences in the plant communities in the improved pastures, and semi-native pastures, while condition scores indicated that synthesizing the vegetation data into unique metrics also results in significant differences between pasture type.

Although only two different levels of pasture management intensity were represented by the pasture types in this study, the relationship between the agronomic and ecological scores supports initial predictions about the relationship between agronomic and ecological condition. The mean agronomic scores were highest in the improved pastures, and lowest in the semi-native pastures, while the semi-native pastures recorded the highest ecological scores and lowest agronomic scores.

Both versions of the agronomic scoring method resulted in condition scores that were all very close in range, limiting the analysis of the results. Because the scores were so similar, the ANCOVA analysis did not lead to a model with useful explanatory power, and even the differences between pasture types were not as strong as the ecological method. The differences in how the vegetation indicators were compiled into scores is one reason why the impact of pasture type was so much stronger for the ecological scores. By categorizing the data into four quartiles, and assigning a score to each quartile, the differences between sites were magnified. Additionally, although five indicators were measured for each pasture, all of the pastures received the same score for the percent of legumes, which were not prominent in any of the pastures. The percent residue indicator was also influenced by the lack of precipitation. Although the pastures were surveyed in June, new growth in the pastures was limited, and large areas of standing dead forage, that had been present since the winter, were still present. If the surveys had been conducted under more typical summer conditions, standing dead may have accounted for a smaller percentage of the cover in each pasture, and different species and compositional patterns may have existed.

For the ecological condition scores, the result of the ANCOVA emphasized the importance of pasture type, which is consistent with the results of NMS ordination and species-area curves. In addition to pasture type, the best models predicting ecological condition score also included the main effects of mechanical treatment and stocking density, suggesting that factors beyond pasture type are useful for explaining variation in condition. Mechanical treatment and stocking density each represent a direct alteration of vegetation, so it was interesting that while both factors were useful for explaining condition, they influenced scores differently. In both pasture types, condition scores increased with the number of mechanical treatments that have been applied over the past five years. Condition scores declined as stocking density increased, consistent with previous research that has shown that grazing alters plant communities (Harnett et al.1996). That the effects of management were significant in each of the best models suggests that management practices influence pasture condition more strongly than landscape characteristics.

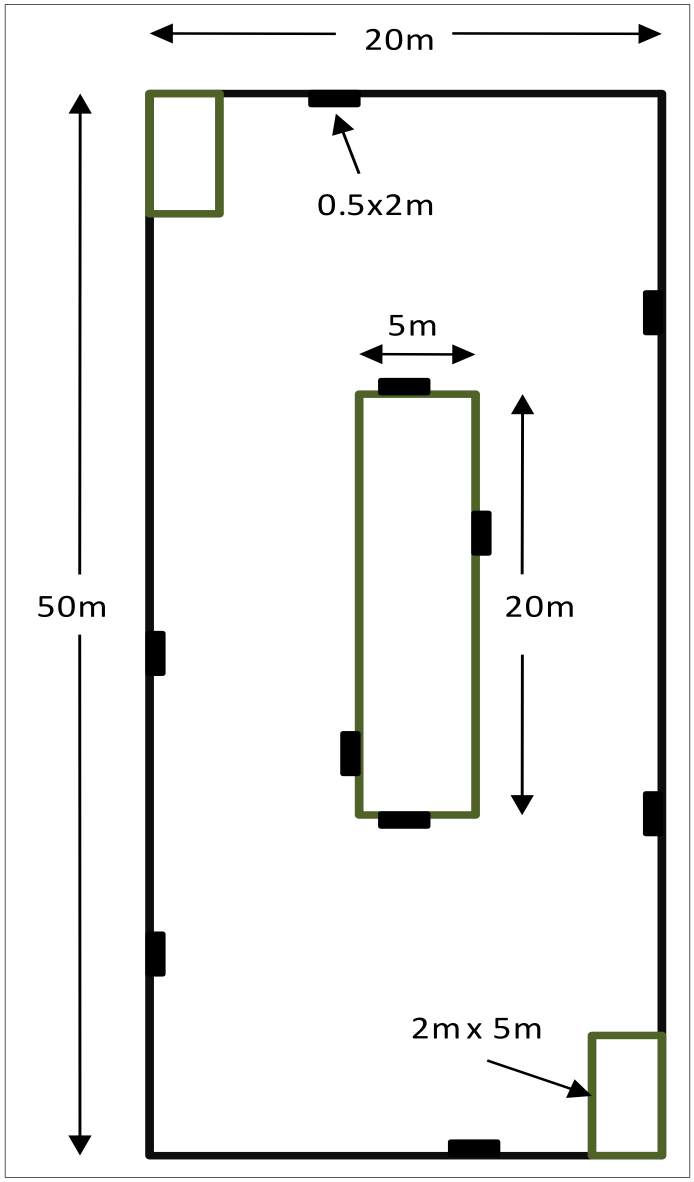

Figure 2-1. Design of the Modified-Whittaker Plot

Figure 2-2. Plot locations for sampling

Table 2-1. The Braun-Blanquet Cover Abundance Scale

Value	Percent Cover
R	Rare, solitary
0	A few
1	Numerous, <5%
2	5-25%
3	25-50%
4	50-75%
5	>75%

Table 2-2 . Indicators included in the original agronomic condition method, and the criteria used to evaluate each indicator and assign a score (Cosgrove et al. 1990).

	Score				
Indicator	2	4	6	8	10
% Desirable Plants	Desirable species <20% of stand. Annual weeds/and or woody species dominate.	Desirable species 20-40% of stand. Mostly weedy annuals and/or woody species.	40-60% desirable species. Undesirable broadleaf weeds and annual grasses invading. Some woody species.	60-80% of plant community desirable species. Remainder mostly intermediates, and a few undesirables present.	Desirable species exceed 80% of plant community. Scattered intermediates.
Plant Cover (Live stems and green leaf cover of all desirable and intermediate species)	Canopy:< 50% Photsynthetic area very low. Very little plant cover to slow or stop runoff.	Canopy 50-70%. Photosynthetic area low, vegetal retardance to runoff low.	Canopy 70-90%. Most forages grazed close, little leaf area to intercept sunlight. Moderate vegetal retardance .	Canopy 90-95%. Spot grazed low and high, so some loss of photosynthetic potential. Vegetal retardance still high.	Canopy 95-100%. Forages maintained in leafy condition for best photosynthetic activity. Very thick stand, slow or no runoff
Plant Diversity	One dominant species (>75%), or over 5 species (each <20%) from one functional group.	Two to five forage species from one functional group. At least one avoided by livestock. Species in patches.	Three forage species, each >20%, from one functional group, none avoided. Or one species each from two function groups, but supplying 25-50% of DM.	Three to four species (each >20%) with at least one being a legume. Well intermixed, compatible growth habit and comparable palatability.	Four to five forage species representing three functional groups (each >20%) with at least one beinga legume. Well intermixed, compatible growth habit, comparable palatability.

Table 2-2. Continued

Indicator	Score 2	4	6	8	10
Plant Residue	Ground cover: No identifiable residue present on soil surface. Standing dead forage: >25% of cover.	Ground cover: 1-10% covered with dead leaves or stems. Standing dead forage 15-25%.	Ground cover: 10-20% covered with dead residue. Standing dead 5-15%.	Ground cover: 20-30% covered with dead residue. Standing dead forage: some but <5%	Ground cover 30-70% covered with dead residue but no thatch buildup. Standing dead forage: none available to grazing animals.
% Legumes	<10% by weight	10-19% legumes	20-29% legumes	30-39% legumes	40-60% legumes, no grass loss

Table 2-3. Indicators selected for the modified agronomic scoring method and criteria used to evaluate each indicator.

	Score				
Indicator	2	4	6	8	10
% Desirable Plants	Desirable species <20% of stand. Annual weeds/and or woody species dominate.	Desirable species 20-40% of stand. Mostly weedy annuals and/or woody species.	40-60% desirable species. Undesirable broadleaf weeds and annual grasses invading. Some woody species.	60-80% of plant community desirable species. Remainder mostly intermediates, and a few undesirables present.	Desirable species exceed 80% of plant community. Scattered intermediates.
Plant Cover (Live stems and green leaf cover of all desirable and intermediate species)	Canopy:< 50% Photsynthetic area very low. Very little plant cover to slow or stop runoff.	Canopy 50-70%. Photosynthetic area low, vegetal retardance to runoff low.	Canopy 70-90%. Most forages grazed close, little leaf area to intercept sunlight. Moderate vegetal retardance .	Canopy 90-95%. Spot grazed low and high, so some loss of photosynthetic potential. Vegetal retardance still high.	Canopy 95-100%. Forages maintained in leafy condition for best photosynthetic activity. Very thick stand, slow or no runoff
Plant Diversity	Four to five forage species representing three functional groups (each >20%) with at least one beinga legume. Well intermixed, compatible growth habit, comparable palatability.	Three to four species (each >20%) with at least one being a legume. Well intermixed, compatible growth habit and comparable palatability.	Three forage species, each >20%, from one functional group, none avoided. Or one species each from two function groups, but supplying 25-50% of DM.	Two to five forage species from one functional group. At least one avoided by livestock. Species in patches.	One dominant species (>75%), or over 5 species (each <20%) from one functional group.

Table 2-3. Continued

Indicator	Score 2	4	6	8	10
Plant Residue	Ground cover: No identifiable residue present on soil surface. Standing dead forage: >25% of cover.	Ground cover: 1-10% covered with dead leaves or stems. Standing dead forage 15-25%.	Ground cover: 10-20% covered with dead residue. Standing dead 5-15%.	Ground cover: 20-30% covered with dead residue. Standing dead forage: some but <5%	Ground cover 30-70% covered with dead residue but no thatch buildup. Standing dead forage: none available to grazing animals.
% Legumes	<10% by weight	10-19% legumes	20-29% legumes	30-39% legumes	40-60% legumes, no grass loss
Stubble Height	All desirable species below target stubble height.	75% of species at or below target stubble height.	About half of species at or above target stubble height.	75% of species at or above target stubble height.	All desirable species above target stubble height.

Table 2-4. Calculation methods for the ecological condition score metrics (Lane et al. 2003).

Metric	Calculation
% Sensitive Spp.	Indicator Species Analysis (Dufrene & Legendre, 1998)
% Tolerant Spp.	Indicator Species Analysis (Dufrene & Legendre, 1998)
% Exotic Taxa	(# Exotic Species)/(Total # of Species Found)
A:P Ratio	(# Annual Species)/(# Perennial Species)

Table 2-5. Corresponding quartiles and scores for the four ecological condition metrics.

Metric	0 Scores	3 Scores	7 Scores	10 Scores
% Sensitive Spp.	1st quartile	2nd quartile	3rd quartile	4th quartile
% Tolerant Spp.	4th quartile	3rd quartile	2nd quartile	1st quartile
% Exotic Taxa	4th quartile	3rd quartile	2nd quartile	1st quartile
A:P Ratio	4th quartile	3rd quartile	2nd quartile	1st quartile

Table 2-6. Values for predictor variables.

Pasture	Pasture Type	Pasture Area	Relative Wetland Area	Long-Term Stocking Density	Short-Term Stocking Density	Mechanical Treatment	Ditch Density
Bull Field	IMP	93.89	0.16	0.44	0.08	12	183.88
East Marsh South	SNP	92.27	0.11	0.60	0.72	1	177.08
East Marsh Center	SNP	144.88	0.14	0.29	0.29	1	138.22
Griffith Park	IMP	92.67	0.10	0.49	0.67	2	192.18
Hermathria	IMP	50.99	0.08	0.37	0.42	6	206.12
Pump Field	IMP	83.77	0.10	0.49	1.08	6	174.75
South Marsh Center	SNP	155.80	0.11	0.23	0.30	1	84.76
South Marsh East Lykes	SNP	146.50	0.09	0.27	0.04	2	102.15
Tropical East North	IMP	112.50	0.07	0.33	0.53	5	218.12
Tropical East South	IMP	96.72	0.09	0.53	1.21	2	182.17
West Marsh Center	SNP	206.79	0.17	0.18	0.67	2	82.56
West Marsh South	SNP	211.65	0.07	0.20	0.66	4	102.64

Table 2-7. Summary statistics of total and native richness, evenness (E) Shannon's Diversity (H) and Simpson's Diversity (D')

Pasture	Total Richness	Native Richness	E	H	D'
BF	16	12	0.614	1.703	0.645
EMC	29	25	0.766	2.580	0.882
EMS	30	24	0.803	2.732	0.888
GP	11	8	0.527	1.265	0.501
HER	18	11	0.778	2.248	0.837
PF	19	14	0.755	2.224	0.813
SMC	31	25	0.751	2.580	0.868
SMEL	26	24	0.843	2.748	0.914
TEN	16	10	0.759	2.105	0.794
TES	15	9	0.666	1.802	0.691
WMC	36	33	0.842	3.017	0.930
WMS	28	25	0.773	2.576	0.881

Table 2-8. Species determined to be significant indicators of improved pastures (tolerant species) through Indicator Species Analysis with a significance level of 0.05

Species	Observed IV	p
Cirisium vulgare	81.8	0.049
Cynodon dactylon	81	0.0422
Desmodium rotundifolum	83.3	0.0174
Paspalum notatum	57.2	0.0132

Table 2-9. Species determined to be significant indicators of semi-native pastures (sensitive species) through Indicator Species Analysis with a significance level of 0.05.

Species	Observed IV	p
Axonopus fissifalis	93.1	0.0036
Axonopus furcatus	83.3	0.0154
Dicanthelenium spp	83.3	0.0162
Diodia virginica	78.3	0.02
Euthamia minor	84.6	0.022
Sabal palmetto	100	0.0036
Spartina bakerii	100	0.0036

Table 2-10. Mean (±SD) and significance levels for the two pastures types at the four spatial scales of the Modified Whittaker Plot. Significance was assessed with a Mann-Whitney U test.

	IMP	SNP	p
$1m^2$	4.46±2.30	8.96±3.47	<0.001
$10m^2$	5.38±2.90	10.50±3.65	<0.001
$100m^2$	7.17±3.28	12.63±4.32	<0.001
$1000m^2$	10.04±3.78	16.08±5.36	<0.001

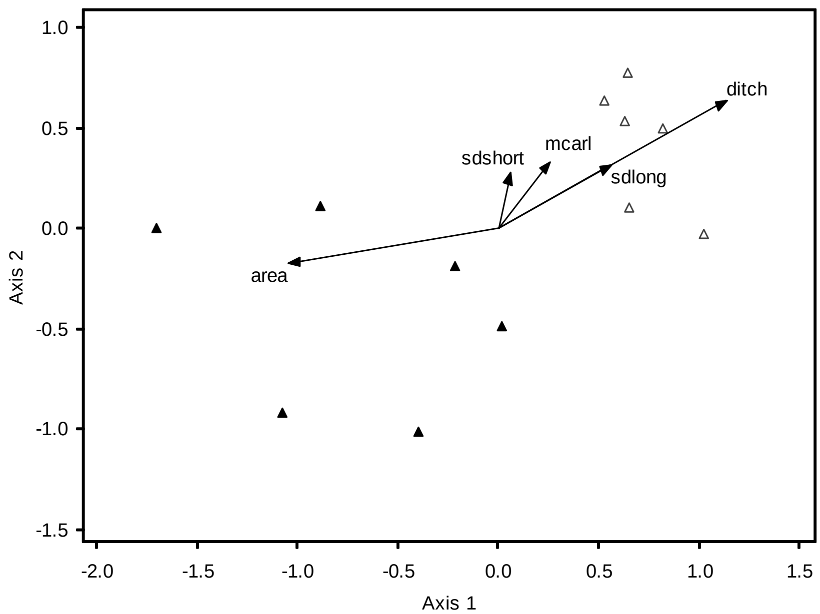

Figure 2-3. NMS ordination of pastures in plant species space with joint plot of pasture area, long and short-term stocking density (sdlong, sdshort), mechanical treatment (mcarl), and ditch density (ditch). Radiating lines indicate the strength and direction of correlations between pasture type and individual variables. Each symbol represents one pasture. Black triangles represent semi-native pastures, and white triangles represent improved pastures. Axis values represent Sorenson distance.

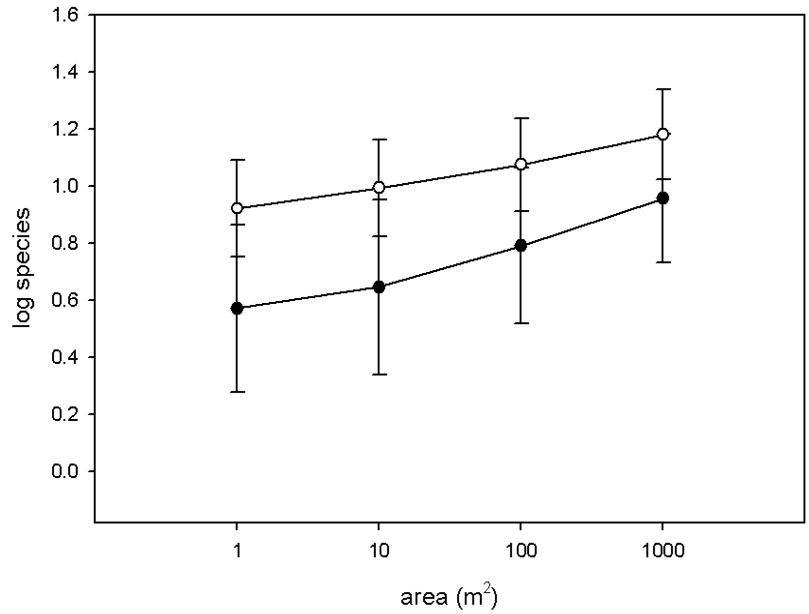

Figure 2-4. Log of mean species number by area (± SD) for all improved and semi-native pasture sites. White circles represent semi-native pasture plots and black circles represent intensively managed pasture plots.

Table 2-11. Metric and cumulative ecological condition scores.

Pasture	Type	A:P Ratio	% Exotic	% Sensitve	% Tolerant	Score
BF	IMP	7	3	7	3	20
EMC	SNP	10	7	10	7	34
EMS	SNP	7	7	10	7	31
GP	IMP	3	0	0	0	3
HER	IMP	0	0	0	0	0
PF	IMP	0	3	3	3	9
SMC	SNP	3	3	7	10	23
SMEL	SNP	3	10	10	10	33
TEN	IMP	0	0	3	0	3
TES	IMP	7	0	0	0	7
WMC	SNP	10	10	7	10	37
WMS	SNP	10	10	10	7	37

Table 2-12. Metric and cumulative agronomic condition scores.

Pasture	Type	% Desirable	Plant Cover	Plant Diversity	Plant Residue	% Legume	Score
BF	IMP	8	6	4	6	2	26
EMC	SNP	4	6	6	2	2	20
EMS	SNP	4	4	2	4	2	16
GP	IMP	6	6	2	4	4	22
HER	IMP	4	8	2	6	2	22
PF	IMP	4	4	2	4	2	16
SMC	SNP	4	2	4	6	2	18
SMEL	SNP	6	2	6	2	2	18
TEN	IMP	6	2	2	4	2	16
TES	IMP	6	4	2	2	2	16
WMC	SNP	4	2	4	3	2	15
WMS	SNP	8	2	4	2	2	18

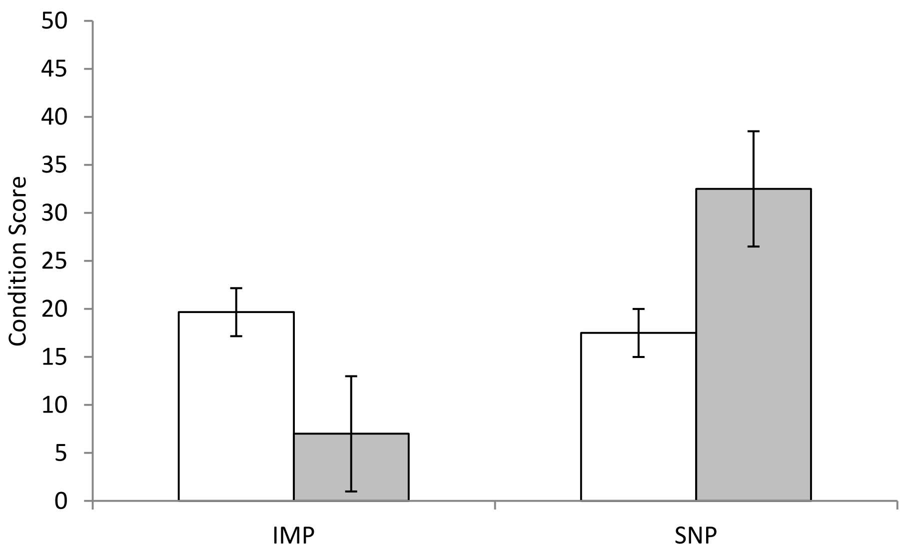

Figure 2-5. Comparison of agronomic and ecological condition scores by pasture type, where IMP= improved pastures, and SNP=semi-native pastures.

Table 2-13. Top five models and the main effects model from AIC model comparisons for pasture scores. Log(£)=maximized log likelihood, K=number of parameter, AIC=Akaike Information Criterion value, Δ_l= difference between lowest AIC value and AIC_l, w_l = model weight given the data. M: Mechanical treatment, T: pasture type, SS: short-term stocking density, P: pasture area, D:ditch density

Model	Log(£)	K	AICc	Δ_l	w_l	r^2
M+T	-34.11	3	79.22	0.00	0.386	0.89
LS+M+T	-32.15	4	80.01	0.79	0.260	0.91
SS+M+T	-32.88	4	81.47	2.25	0.125	0.9
T	-37.90	2	83.14	3.92	0.054	0.82
P+LS+M+D+T	-26.18	6	83.16	3.94	0.053	0.96

Table 2-14. ANOVA table of significance of predictor variables in the best model predicting pasture scores.

	Estimate	SE	DF	t	p	r^2
Mechanical Treatment	1.57	0.56	1	2.82	0.02	0.17
Pasture Type	32.15	3.43	1	9.09	<0.001	0.72

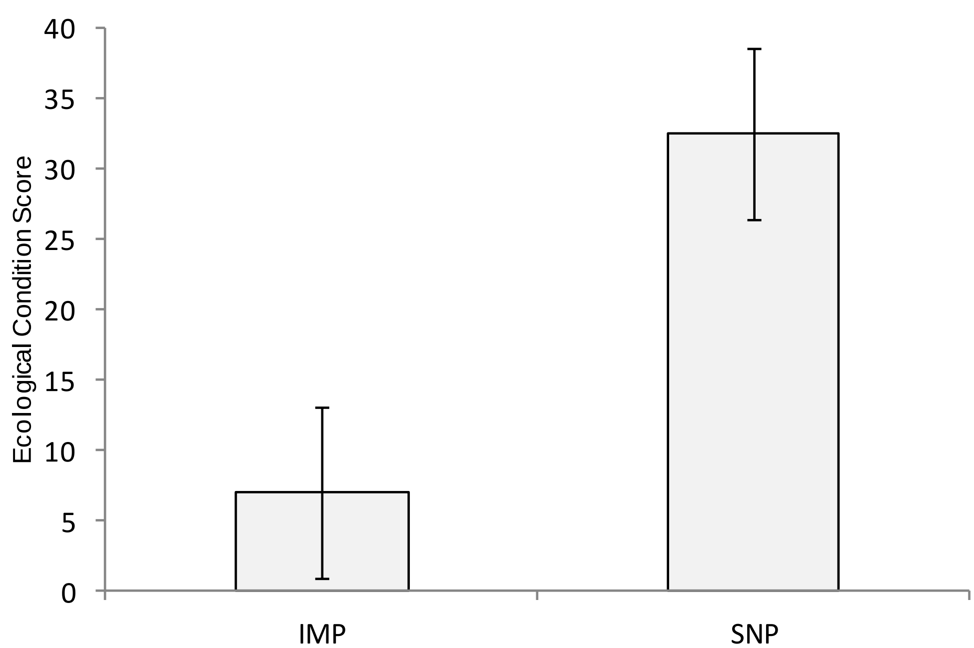

Figure 2-6. Ecological condition score is significantly related to pasture type, with higher scores in the semi-native pastures (SNP) than the improved pastures (IMP).

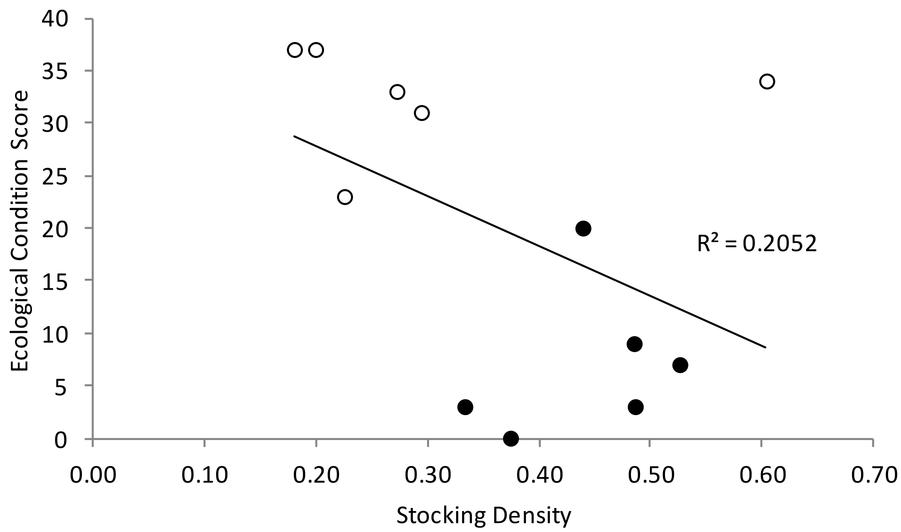

Figure 2-7. The ecological condition score is negatively related to stocking density, but the relationship appears to be driven by pasture type, with white circles representing the semi-native pastures and black circles representing the improved pastures.

.

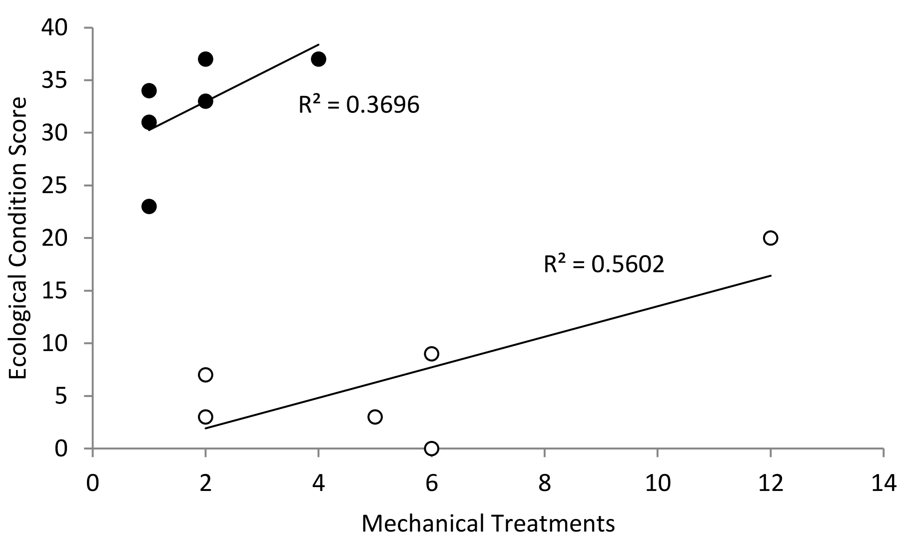

Figure 2-8. The ecological condition score is significantly positively related to mechanical treatments in both the semi-native pastures (black) and improved pastures (white), but the strength of the relationship is greater in the intensively managed pastures.

CHAPTER 3
WETLAND CONDITION DETERMINATION

Assessing Wetland Condition

There are a range of methods and protocols that can be used to assess different wetland characteristics, and measures of vegetation often play a central role. In addition to collecting data on physical parameters of water and soil, many aspects of vegetation can be characterized. Species richness, presence and absence, cover, and biomass are all methods frequently applied in studies of wetlands. Depending on the objective of the study, it is often suitable to use vegetation as an indicator of other processes that are occurring on the landscape. Wetland macrophytes, which are defined as plants “growing in water or on a substrate that is at least periodically deficient in oxygen as a result of excess water” (Cowardin et al. 1979), are especially suitable to serve as a vegetative indicator. Wetland macrophytes are present across depressional wetlands throughout Florida and are characteristic of the wetlands located on Buck Island Ranch. Many of the species are sessile (Lane et al. 2003), and changes in community composition can be indicative of previous disturbances and current conditions (Adamus et al. 2001).

The Wetland Condition Index

The Wetland Condition Index (WCI, Lane et al. 2003) was developed for wetland ecosystems in Florida to assess assemblage-specific indices of condition for diatoms (Diatom Index of Wetland Condition), macroinvertebrates (Macroinvertebrate Index of Wetland Condition), and macrophytes (Vegetative Index of Wetland Condition). The WCI uses these biological indicators to assign numeric condition scores to wetlands. The protocol links metrics that are strongly correlated with the Landscape Development

Intensity index (Brown and Vivas 2003), a method that assesses the intensity of various land uses and assigns a Landscape Development Intensity (LDI) coefficient for each land use. The original dataset used in developing the index included 75 herbaceous depressional wetlands throughout peninsular Florida, across a range of land uses and LDI scores.

In this study only the Vegetative Index of Wetland Condition was applied, because the primary objective was to look at vegetation as an indicator of relative wetland condition. Because the original study encompassed wetlands across a variety of land uses and LDI scores, there are some differences in how the index was applied in this study. The wetlands included in this study (n=30) were all located on ranchland, so the main land use was consistent across all sites. Because Buck Island Ranch contains two distinct pasture types (intensively managed and semi-native), pasture type was used to represent two different levels of landscape development intensity. The application of the VIWC index in this study was used to determine the relative condition of the 30 selected wetlands. Because variation in landscape characteristics and management practices across individual pastures and pasture types were hypothesized to explain variation in wetland condition score, the use of a relative condition method is especially useful.

The VIWC score is calculated based on five metrics: 1) percent sensitive species, 2) percent tolerant species, 3) percent exotic taxa, 4) annual to perennial ratio, and 5) average Coefficient of Conservatism score. A brief description and the rationale for each metric are described below, while the details of the calculation of each metric are described in the methods section.

Percent sensitive and tolerant species

For the purpose of this study, sensitive and tolerant species are defined as species indicative of particular landscape condition, represented here by pasture type. Since the improved pastures are a more-disturbed landscape, species indicative of these pastures are classified as tolerant species. The semi-native pastures represent a less-disturbed landscape, and therefore species indicative of the these pastures are classified as sensitive species. Because the different pastures are incorporated into the computation of the metric, differences in the percent sensitive and percent tolerant species are expected among types.

Percent exotic species

This study specifically defined those species exotic to Florida, and whether a species was native or exotic was determined using Tobe et al. (1998) and Wunderlin (1998). Several studies have suggested that increased development can promote the spread of exotic species into wetlands, which can result in changes in community composition, processes, and functioning (Leibowitz and Brown 1990; Hobbs and Huenneke 1992). Based on the findings of these studies, improved pastures, representative of increased development, were expected to have higher numbers of exotic species than the semi-native pastures.

Annual to perennial ratio

Whether a species was annual or perennial was determined using Tobe et al. (1998) and Wunderlin (1998). Previous research (Edwards and Weakley 2001; Lane et al. 2003) has suggested that the proportion of annual species relative to the number of perennial species increases as the degree of disturbance to the landscape increases. Similar results were expected with this study.

Average coefficient of conservatism score

The Coefficient of Conservatism (CC) developed by Wilhelm and Ladd (1988) was based the opinion of expert botanists on the fidelity of a plant to particular environments. Since then, CC scores have been frequently used to assess wetland condition based on the species present. The CC scores database used in this analysis was developed by Lane et al. (2003) and Cohen et al. (2004) by sending 10 expert botanists a list of species encountered during two sampling seasons (n=397) and asking them to score the species based on the criteria listed in Table 2-1. A species with a CC score of 10 would be expected to have a limited tolerance to disturbance, and a high degree of fidelity to a particular native condition. A score of 0 would indicate either exotic taxa or opportunistic native taxa (Cohen et al. 2004). Based on this, the improved pastures, which are more disturbed, would be expected to have a lower average CC score than the semi-native pastures, which are less disturbed and closer to native conditions.

Methods

Field Surveys

Following the procedure established by Lane et al. (2003) and Cohen et al. (2004), vegetation surveys were conducted in the 30 selected wetlands in winter (January and February) and summer 2011 (May and June). Wetland macrophytes were identified and recorded along the entire length of two transects that traversed the entire length of each wetland along cardinal axes (North-South and East-West) dividing the wetland into four approximately equal sections (Figure 2-1). Transects were discretized into 5-m long x 1-m wide quadrats. The wetland edge was determined in the field based on the percentages of obligate and facultative species. All species present in each quadrat were recorded, and data were collected along the entire length of each transect. Because the wetlands varied in size, the length of the transects varied between wetlands. During the winter sampling period, 1,310 quadrats were surveyed, and 1,288 quadrats were surveyed during the summer sampling. Unknown species were collected for later identification, and all plants were identified to the lowest level possible, preferably species. All species observed then classified as annual or perennial, native or exotic, and by their growth form and Coefficient of Conservatism score.

Ancillary Statistical Analyses

To examine the differences between seasons, differences in length of successional vectors were calculated in PC-ORD (v.6, McCune and Grace 2002) by comparing the composition of wetlands in the winter and the summer. The remaining analyses were completed exclusively for the summer season data, because it represents peak phenology for the majority of the species. Summary measures of sample richness, evenness, Shannon diversity and Simpson diversity were calculated for each site. These measures can be used to look at differences in species distributions across land uses, which for this analysis is specifically pasture type. Species richness represents the total number of taxa found in a sample, while species evenness measures the distribution of the taxa at a site. The Shannon's (H') and Simpson's (D') diversity indices measure the diversity of a site based both on the number and abundance of species (Brower et al. 1990).

Using PC-ORD, nonmetric multidimensional scaling (NMS) was used to test community similarities between the improved and semi-native pasture types. The effects of short and long-term stocking density, mechanical treatments, ditch density, and area were compared with a join plot and correlations with axis scores. The ordination was based on the relative frequency data collected in the 1x5m subplots. The ordination was calculated using the Sorenson (Bray-Curtis) distance measure, and the analysis was completed using random starting configurations with 50 runs of real data and 499 runs of randomized data. To test whether NMS extracted stronger axes than expected by chance, a Monte Carlo test of significance was performed.

Vegetative Index of Wetland Condition Scoring

To fulfill the primary objective of using the WCI method, a VIWC score was calculated for each wetland. The method for calculating each metric is summarized in Table 2-3, and more details about the calculation of sensitive and tolerant species, and the average CC score are included below. The final VIWC score represents a cumulative sum of the five separate metrics. To test for significant differences between pasture type, a Welch’s t-test was run for each metric and the VIWC score.

Sensitive and tolerant species

Indicator Species Analysis (ISA, Dufrene and Legendre, 1997) was used to identify sensitive and tolerant species. The ISA was performed using the relative frequency of species by wetland. A Monte Carlo randomization test with 4,999 permutations and a p-value of 0.05 was used to test the significance value of each indicator species. Based on the ISA, significant indicators of improved pastures are classified as tolerant species, while significant indicators of semi-native conditions are classified as sensitive species.

Average coefficient of conservatism score

Thirteen of the species (out of 99) identified in the summer vegetation surveys were not encountered by Cohen et al. (2004) and therefore not included in their database. For the purpose of this analysis, these species were excluded from the calculation of the average CC scores.

VIWC score

The Vegetative Index of Wetland Condition (VIWC) score was calculated for the data set (*n*=30) based on the 95th percentile for each metric. Each metric was scored into four categories, corresponding to the four quartiles of the data set, and assigned a numerical value of 0, 3, 7, or 10 (Table 2-2). Note that depending on the metric, the '10' scores may correspond with either the 4th quartile of the 1st quartile of the data set, and vice versa for the '0' scores. This is because a higher percentage of sensitive species and a high average Coefficient of Conservatism score are indicative of better condition, while high numbers of tolerant, exotic, and annual species suggest poorer condition. Once the 95th percentiles and quadrisect values were calculated for each metric (Table 2-3) the five scores for each wetland were summed to achieve the cumulative VIWC score. Based on this calculation, a cumulative score of '0' represents the lowest possible score and a cumulative score of '50' represents the highest possible score. After the VIWC scores were calculated, the mean wetland condition score was compared with the ecological condition score for each pasture to examine whether pasture and wetland condition are related.

Analysis of Covariance

In order to further evaluate condition, the VIWC score was used as the dependent variable in an analysis of covariance (ANCOVA) to assess the influence of stocking density, mechanical treatments, ditch density, wetland-ditch interactions, and wetland area. The analysis was completed using R software (v 2.13.1; R Development Core Team, 2011). Pasture type was used as a fixed effect, and the other predictor variables were covariates. The raw data for the predictor variables is located in Table 2-3. Forty-five possible models were tested, iteratively fitting the models beginning with the full factorial model and systematically assessing all four-way, three-way, and two-way interactions, a main effects model, and the single main effects of each of the covariates. The Akaike Information Criterion (AIC) was used to identify the most useful model based on explanatory power and likelihood, and model weights were calculated to indicate the likelihood of the model in comparison to all other considered models. The best model was selected as the one with the lowest AIC score and highest model weight.

Results

General Patterns of Species Composition

In total, 99 unique species were identified between the two sampling seasons. Eighty different taxa were encountered during the winter sampling, and 91 taxa were encountered in the summer. There were 10 species that were only present during the winter sampling, and 20 species that were only encountered in the summer. Summary statistics for the summer data set are reported in Table 2-4. The vector analysis showed changes in composition between the winter and summer, but there was not a significant effect of pasture type on the compositional changes. The NMS ordination resulted in 2 axes which cumulatively explained 86% of the variance. Both axes were significant (p= 0.004). Most of the variance was explained by axis 1 (73%), while 13% was explained by axis 2. The axes reflect Sorenson distance, and show the relationships between the wetlands in plant species space. The final stress of the best solution was 14.50 (Figure 2-1), and there were 63 iterations in the final solution. The ordination indicated two distinct plant communities defined by pasture type. Axis 1 of the ordination was associated with ditch density and short-term stocking density, with both variables increasing towards the area of the improved pastures.

VIWC Scoring

Percent exotic species

Of the 91 species encountered in the summer, 13 (14.3%) were exotic to Florida. Five of the exotic species identified are listed as either Category I or Category II by the FLEPCC (Table 2-5). Across all sites, the average percentage of exotic species was 12.0 (±9.97) and significant differences were observed between pasture type ($p<0.001$). For the improved pastures, the average percentage of exotic taxa was 19.0±7.68, while for the semi-native pastures the mean was 4.98±4.66. The mean (±SD) values and t-test results for this and the additional four metrics, as well as the VIWC score are summarized in Table 2-9.

Sensitive and tolerant species

Eight species were identified by ISA as significant indicators in the IMPs, which were therefore classified as tolerant species (Table 2-6), with 18 species identified as significant indicators of SNPs (Table 2-7), which were classified as sensitive species. Both the percent sensitive and percent tolerant species had significant differences between the pasture type ($p<0.001$, and $p=0.022$, respectively). For the improved pastures, the average percent sensitive species was 17.1±6.98, and the average percent tolerant species was 25.2±8.34. For the semi-native pastures, the average percent sensitive species was 47.2±10.6, and the average percent tolerant species was 17.1±9.72.

Annual to perennial ratio

From the summer data set, 16 species (17.6%) were defined as annuals, and 75 were defined as perennials (82.4%). The mean A:P ratio across all wetlands was 0.12±0.07. There was a significant difference in the A:P between the IMP and SNP types ($p=0.012$). For the improved pastures, the mean A:P ratio was 0.15±0.07, and for the semi-native pastures, 0.09±0.05.

Coefficient of conservatism score

The coefficient of conservatism scores assigned to the summer data in this study ranged from 0 to 9.04. The mean CC score for all the species encountered was 3.83±2.41. Figure 2-3 illustrates the relative frequency distribution for these CC scores. Across all wetlands, the mean of the CC score metric was 3.58±0.79. The mean score varied significantly by pasture type ($p<0.001$). For the improved pastures, the mean score was 2.97±0.52, and for the semi-native pastures, 4.20±0.45.

VIWC score

Computed VIWC scores ranged from 0 to 50. Across both pasture types, the mean VIWC score was 23.9(±16.44). Like each of the metrics that comprised this cumulative score, there were statistically significant differences in the VIWC score between pasture types ($p<0.001$). For the improved pastures, the mean VIWC score was 9.87±7.62, and for the semi-native pastures the mean score was 37.93±8.91 (Figure 2-4).

Analysis of Covariance

The model selected as best model predicting VIWC score included the main effects of pasture type, mechanical treatments, short-term stocking density, and relative wetland area. In this model, the coefficient for the main effect of type was significant, with higher VIWC scores in the semi-native pasture wetlands. The coefficients for the short-term stocking density and relative wetland area were also significant, and for each of these there was a strong interaction with pasture type. The coefficient for mechanical treatments was mildly significant. For the mechanical treatments, condition decreased as the number of treatments increased in the semi-native pastures, but there was no relationship between the variable and score in the improved pastures. Condition also decreased with stocking density in the semi-native pastures, with no relationship between the variable and scores in the intensively managed pastures. The relationship between the VIWC and relative wetland area appeared to be driven by pasture type, with score increasing with area in the improved pastures, and only a weak relationship in the semi-native pastures.

Discussion

The vector analysis results indicate that there were changes in species composition between the winter and summer sampling events. While differences in Sorenson distance were expected between pasture types, it is possible that the high variability in the data can be explained by limitations to plant identification that occurred during the winter season. Since many species naturally lack fruiting bodies or vegetative characteristics necessary for complete identification at this time, not all of the plants encountered could be identified to the species level. This is supported by the higher number of unique species encountered in the summer sampling.

The results of the VIWC scoring supported the assumptions of the individual metrics. Higher levels of exotic species were predicted in disturbed conditions, and the data showed a significantly higher percentage of exotic species in the improved pastures. This is consistent with the previous work of Lane et al. (2003) and supports the argument that increasing landscape development can result in the introduction of exotic species into wetland habitat. In addition to a higher number of exotic species, a significantly higher A:P ratio was found in the IMPs than the SNPs, supporting the initial hypothesis that the proportion of annual species would be higher under more disturbed landscape conditions. Based on the method by which the Coefficient of Conservatism scores were assigned, the mean score was expected to be lower in more-disturbed conditions and higher in less-disturbed conditions, and the data showed a significantly higher score in the semi-native pastures. Finally, differences in the percentages of sensitive and tolerant species were expected between pasture types, with an inverse relationship between metrics. This hypothesis was supported by significant differences in the data for both the sensitive and tolerant species.

Multiple analyses confirmed that significant differences exist between the intensively managed and semi-native pastures. The NMS ordination indicates that there are significant differences in the plant communities between pasture types, while the results of the VIWC score demonstrate that when incorporating all five metrics into the condition determination there is a significant effect of pasture type on the score.

The result of the ANCOVA also emphasizes the importance of pasture type on condition, but the inclusion of the additional variables of mechanical treatment, stocking density, and relative wetland area in the best model predicting the VIWC score indicates that factors beyond pasture type are necessary to explain condition.

The influence of the mechanical treatments on the wetland condition score is an interesting result, because the mechanical treatments were not applied in the wetlands in the study, only in the upland pasture area. This suggests that the plant communities in the wetlands respond to manipulations of vegetation in the pastures.

Table 3-1. Criteria used to assign a Coefficient of Conservatism score to a particular species (Lane et al. 2008).

C of C	Description
0	Alien taxa and native taxa that are opportunistic invaders or common components of disturbed communities
1-3	Widespread taxa that are found in a variety of communities, including disturbed sites
4-6	Taxa that display fidelity to a particular community, but tolerant of moderate disturbance to that community
7-8	Taxa that are typical of well-established communities that have sustained only minor disturbances
9-10	Taxa that exhibit a high degree of fidelity to a narrow set of ecological conditions

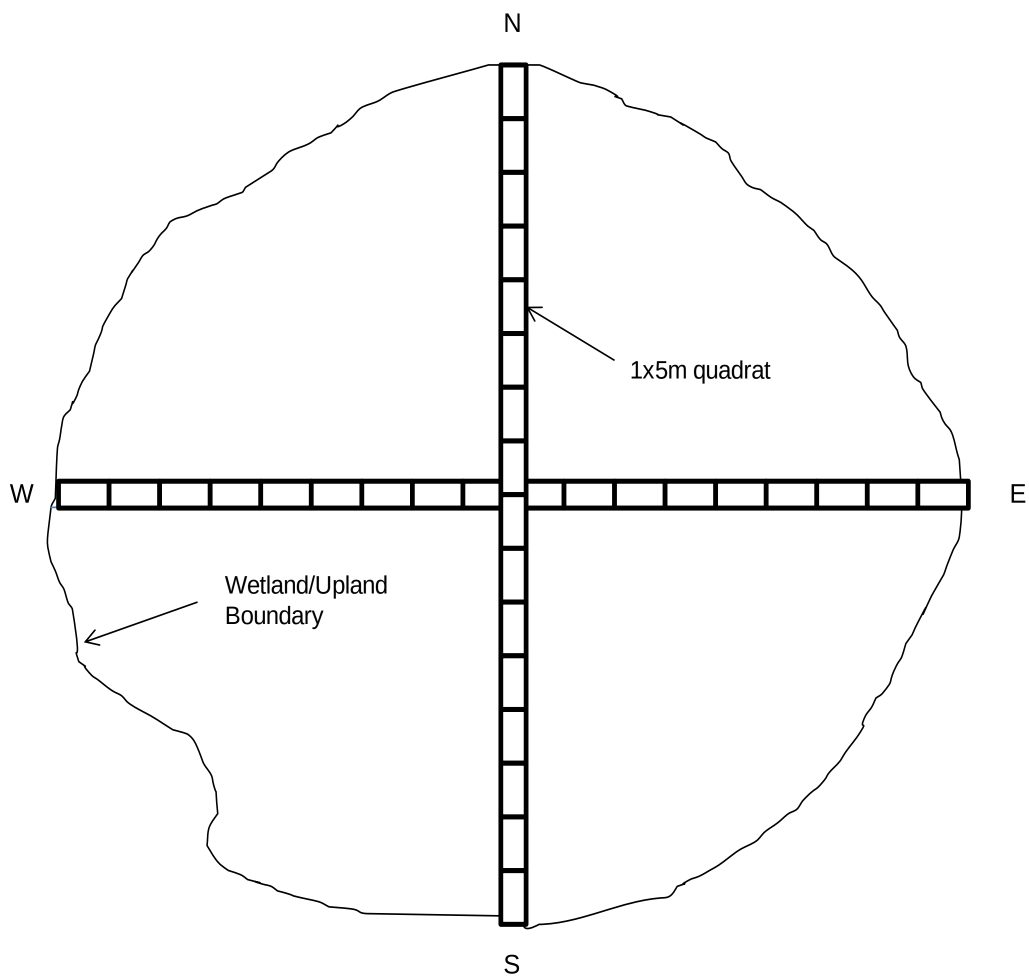

Figure 3-1. Arrangements of wetland sampling quadrats along two primary transects.

Table 3-2. Calculation method for metrics in the VIWC method (Lane et al. 2003).

Metric	Calculation
% Sensitive Spp.	Indicator Species Analysis (Dufrene & Legendre, 1998)
% Tolerant Spp.	Indicator Species Analysis (Dufrene & Legendre, 1998)
% Exotic Taxa	(# Exotic Species)/(Total # of Species Found)
A:P Ratio	(# Annual Species)/(# Perennial Species)
Average CC	(Sum CC value for each species)/(number of species)

Table 3-3. Corresponding quartiles and scores for the five VIWC metrics.

Metric	0 Scores	3 Scores	7 Scores	10 Scores
% Sensitive Spp.	1st quartile	2nd quartile	3rd quartile	4th quartile
% Tolerant Spp.	4th quartile	3rd quartile	2nd quartile	1st quartile
% Exotic Taxa	4th quartile	3rd quartile	2nd quartile	1st quartile
A:P Ratio	4th quartile	3rd quartile	2nd quartile	1st quartile
Average CC	1st quartile	2nd quartile	3rd quartile	4th quartile

Table 3-4. Values for predictor variables.

Pond	Type	Pasture Area	Individual Wetland Area	Relative Wetland Area	Long-Term Stocking Density	Short-Term Stocking Density	Mechanical Treatment	Ditch Density	Wetland Ditch Interactions
10	IMP	112.50	1.24	0.00	0.33	0.53	5	218.12	1
14	IMP	112.50	2.25	0.00	0.33	0.53	5	218.12	2
15	IMP	112.50	2.78	0.00	0.33	0.53	5	218.12	3
26	IMP	96.72	3.10	0.00	0.53	1.21	2	182.17	8
30	IMP	96.72	3.42	0.00	0.53	1.21	2	182.17	2
57	IMP	83.77	1.31	0.00	0.49	1.08	6	174.75	0
69	IMP	83.77	0.21	0.00	0.49	1.08	6	174.75	0
94	IMP	83.77	1.65	0.00	0.49	1.08	6	174.75	1
115	IMP	50.99	1.12	0.00	0.37	0.42	6	206.12	1
117	SNP	206.79	1.73	0.00	0.18	0.67	2	82.56	2
118	IMP	50.99	1.68	0.00	0.37	0.42	6	206.12	2
124	IMP	92.67	5.03	0.00	0.49	0.67	2	192.18	3
133	SNP	206.79	0.71	0.00	0.18	0.67	2	82.56	1
165	SNP	92.27	0.12	0.00	0.60	0.72	1	177.08	0
178	SNP	92.27	1.07	0.00	0.60	0.72	1	177.08	1
186	IMP	92.67	0.42	0.00	0.49	0.67	2	192.18	2
191	SNP	211.65	0.33	0.00	0.20	0.66	4	102.64	0
200	IMP	93.89	2.56	0.00	0.44	0.08	12	183.88	0
211	SNP	144.88	0.29	0.00	0.29	0.29	1	138.22	0
216	SNP	144.88	0.16	0.00	0.29	0.29	1	138.22	1
221	SNP	211.65	0.53	0.00	0.20	0.66	4	102.64	0
231	IMP	93.89	0.58	0.00	0.44	0.08	12	183.88	1
251	SNP	211.65	2.25	0.00	0.20	0.66	4	77.20	0
254	IMP	93.89	1.41	0.00	0.44	0.08	12	183.88	1
551	SNP	146.50	0.98	0.00	0.27	0.04	2	102.15	1
557	SNP	155.80	1.79	0.00	0.23	0.30	1	84.76	0

Table 3-4. Continued

Pond	Type	Pasture Area	Individual Wetland Area	Relative Wetland Area	Long-Term Stocking Density	Short-Term Stocking Density	Mechanical Treatment	Ditch Density	Wetland Ditch Interactions
573	SNP	155.80	0.24	0.00	0.23	0.30	1	84.76	0
580	SNP	146.50	0.30	0.00	0.27	0.04	2	102.15	0
586	SNP	155.80	0.34	0.00	0.23	0.30	1	84.76	0
589	SNP	146.50	1.00	0.00	0.27	0.04	2	102.15	0

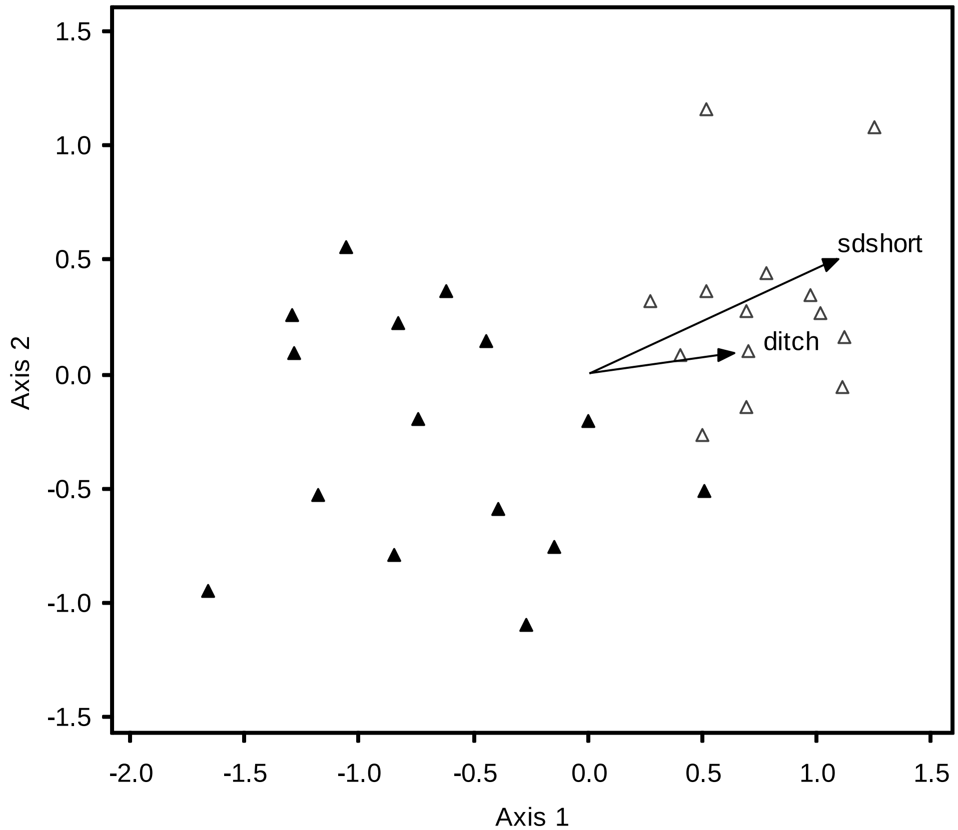

Figure 3-2. NMS ordination of wetlands in plant species space with a joint plot of short-term stocking density and ditch density. Radiating lines indicate the strength and direction of correlations between individual variables and the strongest gradient in species composition (pasture type). Each symbol represents one wetland. Black triangles represent semi-native pasture wetlands and white triangles represent improved pasture wetlands. Axis units express Sorenson distance.

Table 3-5. Summary statistics of total and native richness, evenness (E) Shannon's Diversity (H) and Simpson's Diversity (D').

Wetland	Total Richness	Native Richness	E	H	D'
10	12	9	0.79	1.963	0.837
12	20	13	0.821	2.461	0.893
15	19	16	0.784	2.308	0.877
26	23	17	0.74	2.321	0.858
57	22	20	0.774	2.392	0.886
69	20	14	0.905	2.71	0.923
94	20	18	0.779	2.334	0.882
115	30	23	0.818	2.781	0.915
117	41	40	0.854	3.173	0.941
118	23	19	0.801	2.51	0.893
124	33	28	0.775	2.71	0.916
133	32	31	0.849	2.941	0.926
165	18	17	0.915	2.644	0.913
178	28	26	0.862	2.872	0.931
186	20	16	0.896	2.684	0.916
191	19	16	0.841	2.477	0.895
200	22	19	0.754	2.331	0.875
211	25	22	0.857	2.757	0.915
216	23	22	0.877	2.748	0.917
221	23	21	0.866	2.715	0.917
231	20	17	0.851	2.55	0.904
251	27	25	0.865	2.852	0.921
254	20	16	0.848	2.541	0.903
551	27	27	0.916	3.018	0.942
557	19	19	0.836	2.462	0.895
573	20	19	0.897	2.687	0.92
580	14	14	0.885	2.335	0.88
586	30	29	0.879	2.99	0.935

Table 3-6. Species determined to be significant indicators of improved pastures with Indicator Species Analysis, and a significance level of 0.05.

Species	Observed IV	p-value
Alternanthera philoxeroides	93.3	0.0002
Amaranthus retroflexus	42.9	0.0062
Cynodon dactylon	50.0	0.0022
Eupatorium capillifolium	63.5	0.0250
Juncus effuses	81.1	0.0002
Paspalum notatum	66.1	0.0086
Polygonum punctatum	66.6	0.0036
Solanum viarum	42.9	0.0074

Table 3-7. Species determined to be significant indicators of semi-native pastures with Indicator Species Analysis and a significance level of 0.05.

Species	Observed IV	p-value
Andropogon virginica var. virginica	68.9	0.0008
Axonopus furcatus	73.3	0.0004
Bacopa carolineana	59.4	0.0016
Centilla asiatica	75.8	0.0002
Dicanthelium erectifolium	40.0	0.0168
Diodia virginiana	80.4	0.0012
Eleocharis vivipara	65.2	0.0090
Euthamia minor	83.3	0.0002
Hypericum fasciculatum	33.3	0.0400
Panicum virgata	33.3	0.0412
Pluchea rosea	38.1	0.0472
Pontederia cordata	62.1	0.0312
Proserpinaca palustris	46.7	0.0052
Proserpinaca pectinata	72.9	0.0002
Rhexia cubensis	53.3	0.0018
Rhynchospora fascicularis	66.7	0.0004
Rhyncospora odorata	40.0	0.0174
Sagittaria lancifolia	57.9	0.0080

Table 3-8. Quadrisect values and 95th percentiles for metric scoring.

Metric	95th Percentile	0 Scores	3 Scores	7 Scores	10 Scores
% Sensitive Spp.	55.84	<18.83	18.83-31.65	31.66-48.61	>48.61
% Tolerant Spp.	37.75	>26.14	19.99-26.14	14.05-20.00	<14.05
% Exotic Taxa	28.24	>15.79	9.29-15.79	4.09-9.30	<4.09
A:P Ratio	0.24	>0.16	0.10-0.15	0.07-0.11	>0.11
Average CC	4.70	<3.19	3.18-3.63	3.63-4.23	>4.23

Table 3-9. Metric and cumulative VIWC scores by site.

Site	% Sensitive Spp.	% Tolerant Spp.	% Exotic Taxa	Average C.C.	A:P Ratio	VIWC Score
10	0	0	0	0	0	0
14	0	0	0	0	10	10
15	3	0	3	3	3	12
26	0	0	0	0	0	0
30	3	7	3	3	0	16
57	0	3	7	3	0	13
69	0	0	0	0	0	0
94	3	7	3	0	0	13
115	0	0	0	0	3	3
117	7	10	10	10	10	47
118	0	3	0	0	0	3
124	3	3	3	7	7	23
133	10	10	10	7	0	37
165	7	7	7	10	10	41
178	7	7	7	7	3	31
186	0	0	0	0	7	7
191	3	3	3	3	3	15
200	0	0	3	0	7	10
211	10	7	3	7	7	34
216	10	10	7	10	10	47
221	10	3	7	7	7	34
231	3	3	3	3	10	22
251	7	7	7	7	3	31
254	3	0	0	3	10	16
551	7	10	10	10	7	44
557	7	7	10	7	3	34
573	10	7	7	3	10	37
580	10	10	10	10	7	47
586	7	10	10	10	3	40
589	10	10	10	10	10	50

Table 3-10. The mean (±SD) values of the five VIWC metrics and the VIWC score for each pasture type. IMP: improved pastures, SNP: semi-native pastures.

	IMP	SNP	t	p
% Exotic Taxa	19.00 ± 7.68	4.98±4.66	6.0462	3.59E-06
% Sensitive Species	17.09±6.98	47.23±10.61	-9.1901	2.31E-09
% Tolerant Species	25.21±8.34	17.14±9.72	2.4387	0.0215
A:P Ratio	0.15±0.07	0.09±0.05	2.7023	0.01212
Average C.C. Score	2.97±0.52	4.20±0.45	-6.9053	1.82E-07
VIWC Score	9.87±7.62	37.93±8.91	-9.2661	6.31E-10

Table 3-11. Top five models and the main effects model from AIC model comparisons for wetland scores. Log(£)=maximized log likelihood, K=number of parameter, AIC=Akaike Information Criterion value, Δ_I= difference between lowest AIC value and AIC_I, w_I = model weight given the data. M: Mechanical treatment, T: pasture type, SS: short-term stocking density, R: relative wetland area, D:ditch density.

Model	Log(£)	K	AICc	Δ_I	w_I	r^2
T+M+SS+R	-99.50	5	213.4954	0	0.222	0.80
T+R	-102.62	3	214.1659	0.670549	0.158	0.77
T+SS	-103.03	3	214.9828	1.487451	0.105	0.77
T+SS+LS+D	-100.66	5	215.8234	2.328053	0.069	0.79
T+R+M	-102.27	4	216.1303	2.634907	0.059	0.77

Table 3-12. ANOVA table of significance of predictor variables in the best model predicting VIWC score. T: Pasture type, R: relative wetland area, SS: short-term stocking density, M: mechanical treatment.

	Estimate	SE	DF	t	p	r^2
T	20.05	4.32	1	4.64	<.001	0.57
R	108.92	45.62	1	2.39	0.02	0.11
SS	-10.59	4.71	1	-2.25	0.03	0.07
M	-1.19	0.66	1	-1.8	0.08	0.05

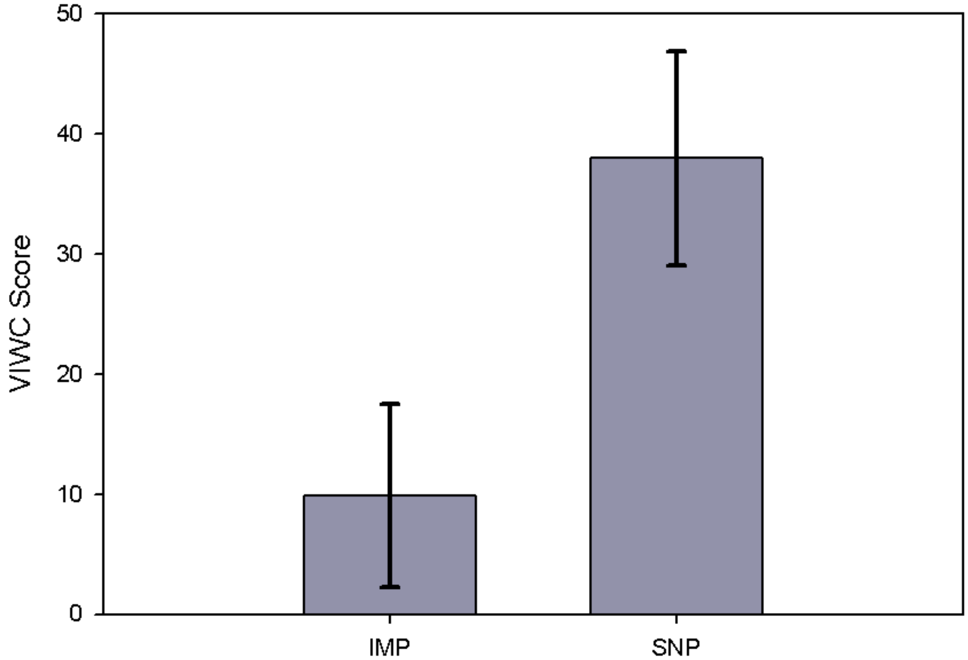

Figure 3-3. The VIWC score is significantly related to pasture type, with higher scores in the semi-native pastures (SNP) than in the improved pastures (IMP).

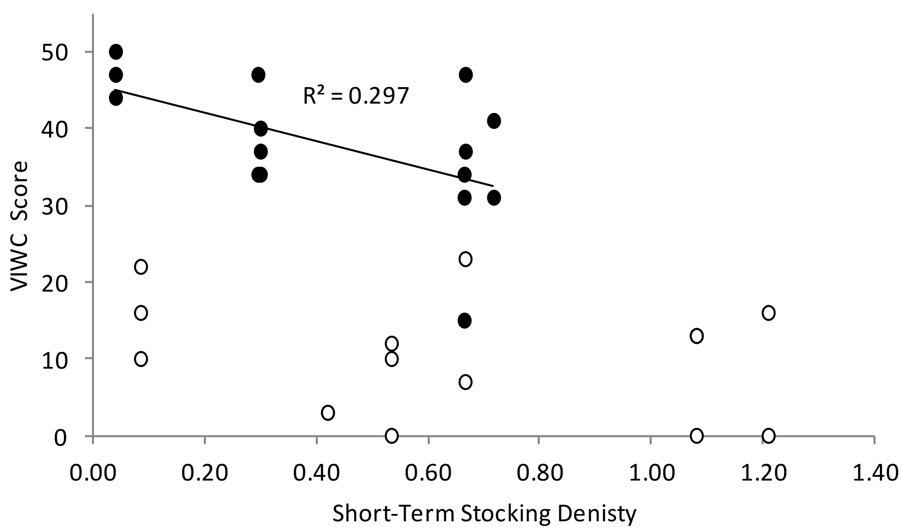

Figure 3-4. The VIWC score is significantly negatively related to stocking density, but the relationship appears to be driven by pasture type, with black circles representing the semi-native pastures and white circles representing the improved pastures.

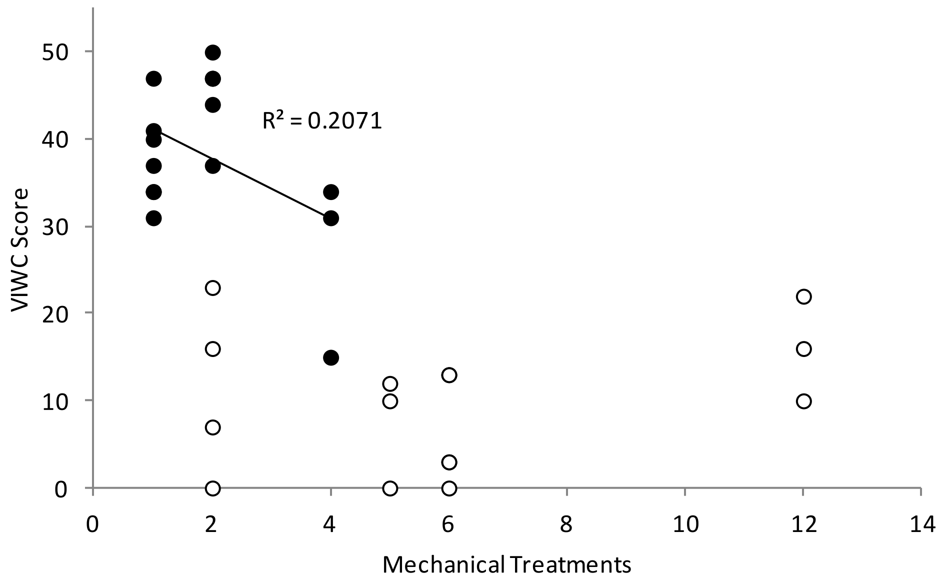

Figure 3-5. The VIWC score is negatively related to mechanical treatments and the relationship appears to be driven by pasture type, with black circles representing the semi-native pastures and white circles representing the improved pastures.

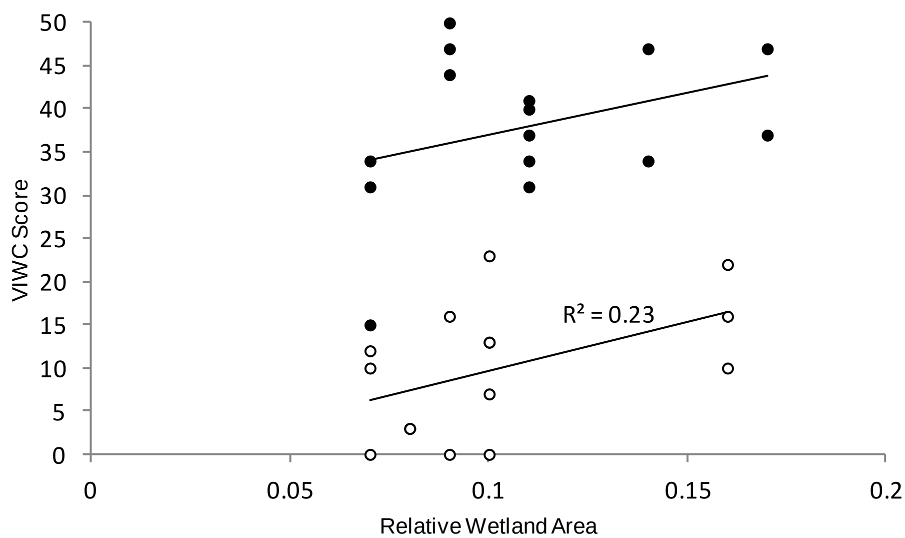

Figure 3-6. The VIWC score is positively related to relative wetland area, but the relationship appears to be driven by pasture type, with black circles representing the semi-native pastures and white circles representing the improved pastures.

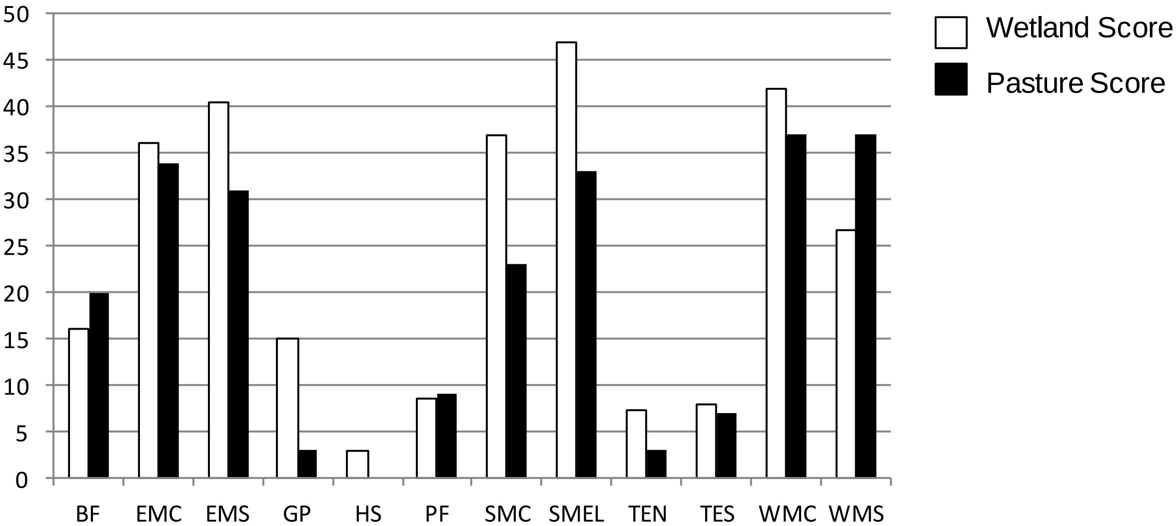

Figure 3-7. A comparison of mean ecological condition scores for pastures and wetlands by pasture.

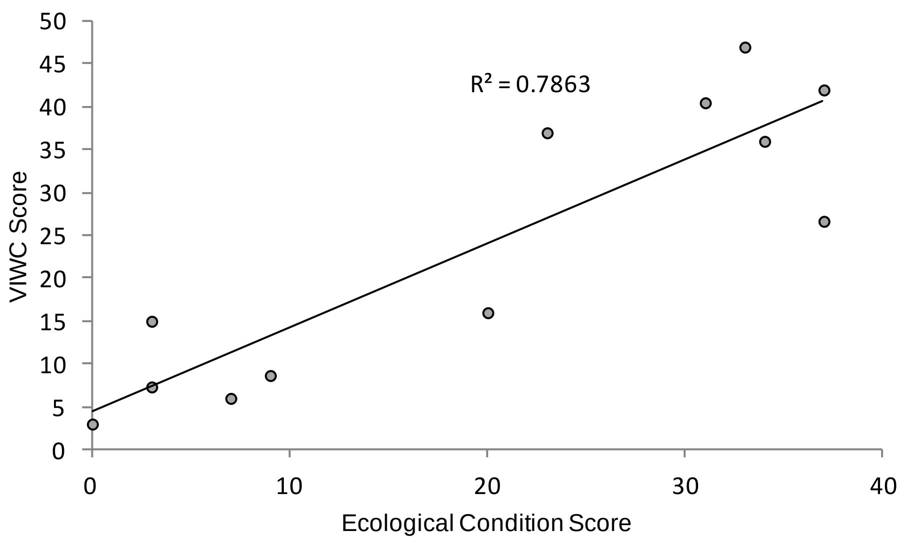

Figure 3-8. Relationship between pasture condition score and the mean score of all wetlands located in that pasture.

CHAPTER 4
CONCLUSIONS

The suite of analyses conducted here indicated that differences in plant communities in both pastures and wetlands were driven by pasture type. Because of the differences in how these pastures are managed, and the large differences in characteristics like ditch density, the influence of type was expected. Although the most significant differences in condition were attributable to pasture type, there was also variation within type for both wetlands and pastures.

The best models predicting ecological wetland and pasture condition each included effects of mechanical treatment as the main contributor after pasture type. The surprising result was that mechanical treatment influenced pasture and wetland condition differently. Wetland condition scores in the semi-native pastures decreased as the number of mechanical treatments increased, while scores in both pasture types increased with the number of mechanical treatments. Both long-term and short-term stocking densities were important components of the models, suggesting that a combination of more historic and recent management influences condition. Because the best models included variables that reflected management intensity over time, it is possible that the condition scores reflect management differences that occurred during a time frame not captured by the models.

It would be beneficial to apply a more comprehensive method for assessing agronomic pasture condition that is suitable for Florida's ranches, and a method that is appropriate for both pastures and wetlands.

Although there were limitations to the agronomic assessment, several conclusions can be drawn regarding the initial hypotheses. The intensity of pasture management was shown to influence ecological condition of pastures and wetlands, and scores were significantly and consistently lower in the improved pastures. That the agronomic scores were slightly higher in the improved pastures suggests that they benefited from the additional management they received. These results are consistent with the conceptual diagram presented in Chapter 1, suggesting that changes in both agronomic and ecological condition can be achieved by altering the intensity of pasture management. Differences in management at a pasture scale were significant in both models, suggesting that the scale at which management decisions are is influential. Additionally, the improved and semi-native pastures responded differently to the same types of management, indicating that the significant differences in plant community composition between the pasture types need to be accounted for when making management choices.

APPENDIX
COEFFICENT OF CONSERVATISM SCORES

Table A-1. List of Coefficient of Conservatism scores by species (Cohen et al. 2004).

Species	CC Score
Alternanthera Philoxeroides	0
Amaranthus retroflexus	0
Ambrosia artemisifolia	0.95
Andropogon glomeratus	3.9
Andropogon virginicus var. glaucus	3.44
Andropogon virginicus var. virginica	3.44
Asonopus furcatus	2.12
Aster subulatus	5.74
Axonopus fissifalis	1.89
Baccharis halimifolia	2.53
Bacopa carolineana	5.31
Bacopa monnieri	4.49
Bidens mitis	6.31
Centilla asiatic	1.92
Cephalantus occidentalis	7.27
Cirisium nuttallii	3.08
Cladium jamaicense	9.04
Commelina diffusa	2.02
Cynodon dactylon	0.29
Cyperus compressus	2.74
Cyperus croceus	1.3
Cyperus odoratus	4.25
Cyperus polystachyos	1.56
Cyperus retorsus	1.79
Cyperus surinamensis	2.93
Dicanthelium erectifolium	7.39
Digataria serotina	1.39
Diodia virginiana	4.96
Echinochloa walteri	3.21
Eclipta prostrata	3.21
Eichhornia crassipes	3.36
Eleocharis vivipara	3.81
Eleusine indica	0
Eriocaulon compressum	7.5
Eupatorium capillifolium	0.83

Table A-1 Continued.

Species	CC Score
Euthamia minor	3.25
Galium tinctorium	4
Gnaphalium pensylvanicum	0
Hydrocotyle umbellata	1.92
Hymenachne amplexicaulis	0
Hypericum fasciculatum	7.27
Ipomea sagittata	6.42
Iris virginicus	7.09
Juncus effusus	3.25
Lachnanthes caroliana	3.76
Leersia hexandra	5.61
Lemna minor	3.77
Limnobium spongia	4.79
Linarai canadensis	1
Lindernia grandiflora	3.6
Ludwigia arcuata	5.32
Ludwigia octovalvis	4.09
Ludwigia peruviana	0.62
Ludwigia repens	5.2
Ludwigia suffruticosa	6.23
Luziola fluitans	4.79
Mikania scandens	1.95
Myrica cerifera	3.82
Oxypolis filiformis	8.69
Panicum hemitomon	5.82
Panicum repens	0.41
Paspalum acuminatum	1.06
Paspalum notatum	0.14
Phyla nodiflora	1.92
Pluchea odorata	4.96
Pluchea rosea	5.45
Polygonum punctatum	4.02
Pontedaria cordata	5.38
Portulaca amilis	0.86
Proserpinaca palustris	5.85
Proserpinaca pectinata	5.5
Ptilimnium capillaceum	2
Rhexia cubensis	7.22
Rhynchospora fascicularis	5.92
Rhynchospora inundata	7.25
Rhynchospora microcephala	6.5

LIST OF REFERENCES

Anderson, P.M.L. and M.T. Hoffman 2007. The impacts of sustained heavy grazing on plant diversity and composition in lowland and upland habitats across the Kamiesberg mountain range in the Succulent Karoo, South Africa. J.Arid Environ. 70:686-700.

Arthington, J.D., F.M. Roka, J.J. Mullahey, S.W. Coleman, R.M. Muchovej, L.O. Lollis and D. Hitchcock 2007. Integrating ranch forage production, cattle performance, and economics in ranch management systems for southern Florida. Rangeland Ecology & Management 60:12-18.

Barnes, R. F. 2003. Forages : an introduction to grassland agriculture, 6th edition. Iowa State Press, Ames.

Barnett, D.T. and T.J. Stohlgren 2003. A nested-intensity design for surveying plant diversity. Biodivers.Conserv. 12:255-278.

Blanch, S.J. and M.A. Brock 1994. Effects of Grazing and Depth on 2 Wetland Plant-Species. Australian Journal of Marine and Freshwater Research 45:1387-1394.

Bohlen, P.J. and S.M. Gathumbi 2007. Nitorgen cycling in seasonal wetlands in subtropical cattle pastures. Soil Sci.Soc.Am.J. 71:1058-1065.

Bormann, F.H. 1953. The Statistical Efficiency of Sample Plot Size and Shape in Forest Ecology. Ecology 34:474-487.

Boughton, E.H., P.F. Quintana-Ascencio, P.J. Bohlen, D.G. Jenkins and R. Pickert 2010. Land-use and isolation interact to affect wetland plant assemblages. Ecography 33:461-470.

Brower, J. E. . 1990. Field and laboratory methods for general ecology / James E. Brower, Jerrold H. Zar, Carl N. von Ende, 3rd ed. edition. W.C. Brown Publishers, Dubuque, IA.

Brown, M.T. and M.B. Vivas 2005. Landscape development intensity index. Environ.Monit.Assess. 101:289-309.

Chong, G.W. and T.J. Stohlgren 2007. Species-area curves indicate the importance of habitats' contributions to regional biodiversity. Ecol.Ind. 7:387-395.

Chytry, M., L. Tichy, J. Holt, and Z. Botta-Dukat. 2002. Determination of diagnostic species with statistical fidelity measures. Journal of Vegetation Science 13: 79-90.

Clark, D.L. and M.V. Wilson 2001. Fire, mowing, and hand-removal of woody species in restoring a native wetland prairie in the Willamette Valley of Oregon. Wetlands 21:135-144.

Cohen, M.J., S. Carstenn and C.R. Lane 2004. Floristic quality indices for biotic assessment of depressional marsh condition in Florida. Ecol.Appl. 14:784-794.

Cosgrove, D., D. Undersander and M. Davis 1996. Determining pasture condition. University of Wisconsin Cooperative Extension Publication A3667.

Dobkin, D.S., A.C. Rich and W.H. Pyle 1998. Habitat and avifaunal recovery from livestock grazing in a riparian meadow system of the northwestern Great Basin. Conserv.Biol. 12:209-221.

Dufrene, M. and P. Legendre 1997. Species assemblages and indicator species: The need for a flexible asymmetrical approach. Ecol.Monogr. 67:345-366.

Fornwalt, P.J., M.R. Kaufmann and T.J. Stohlgren 2010. Impacts of mixed severity wildfire on exotic plants in a Colorado ponderosa pine-Douglas-fir forest. Biol.Invasions 12:2683-2695.

Gathumbi, S.M., P.J. Bohlen and D.A. Graetz 2005. Nutrient enrichment of wetland vegetation and sediments in subtropical pastures. Soil Sci.Soc.Am.J. 69:539-548.

Hartnett, D.C., K.R. Hickman and L.E.F. Walter 1996. Effects of bison grazing, fire, and topography on floristic diversity in tallgrass prairie. J.Range Manage. 49:413-420.

Hilmon, J.B. and R.H. Hughes 1965. Fire and forage in the wiregrass type. J.Range Manage. 18:251-254.

Hornung, J.P. and C.L. Rice 2003. Odonata and wetland quality in southern Alberta, Canada: A prelminary study. Odonatologica 32:119-129.

Howe, H.F. 1994. Managing Species-Diversity in Tallgrass Prairie - Assumptions and Implications. Conserv.Biol. 8:691-704.

Kalkhan, M.A. and T.J. Stohlgren 2000. Using multi-scale sampling and spatial cross-correlation to investigate patterns of plant species richness. Environ.Monit.Assess. 64:591-605.

Kalmbacher, R. S. 1979. Investigations on native range. Agricultural Research Center, Ona FL.

Keeley, J.E. and C.J. Fotheringham 2005. Plot shape effects on plant species diversity measurements. Journal of Vegetation Science 16:249-256.

Kumar, S., T.J. Stohlgren and G.W. Chong 2006. Spatial heterogeneity influences native and nonnative plant species richness. Ecology 87:3186-3199.

Lane, C.R. 2003. Biological indicators of wetland condition for isolated depressional herbaceous wetlands in Florida. Ph.D. Dissertation, University of Florida, Gainesville, Florida, USA.

Leibowitz, N. C. and M. T. Brown. 1990. Indicator Strategy for Wetlands. Pp. 5.1 – 5.15 in Environmental Monitoring and Assessment Program - Ecological Indicators. Edited by C.T. Hunsaker and D. E. Carpenter. EPA/600/3-90/060. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Long, K.R., R.S. Kalmbacher and F.G. Martin 1986. Diet Quality of Steers Grazing 3 Range Sites in South Florida. J.Range Manage. 39:389-392.

Main, M.B. and M.J. Barry 2002. Influence of season of fire on flowering of wet prairie grasses in South Florida, USA. Wetlands 22:430-434.

Main, M.B. and M.J. Barry 2001. Cover and species richness of fire-influenced pine and wet prairie habitats in southwest Florida. Fla.Sci. 64:77-94.

McCune B, and Grace JB 2002. Analysis of ecological communities.MJM Press, Gleneden Beach

McIntyre, S., K.M. Heard and T.G. Martin 2003. The relative importance of cattle grazing in subtropical grasslands: does it reduce or enhance plant biodiversity?. J.Appl.Ecol. 40:445-457.

Metzger, K.L., M.B. Coughenour, R.M. Reich and R.B. Boone 2005. Effects of seasonal grazing on plant species diversity and vegetation structure in a semi-arid ecosystem. J.Arid Environ. 61:147-160.

Milchunas, D.G., O.E. Sala and W.K. Lauenroth 1988. A Generalized-Model of the Effects of Grazing by Large Herbivores on Grassland Community Structure. Am.Nat. 132:87-106.

Sollenberger, L.E. and E.S. Vanzant 2011. Interrelationships among Forage Nutritive Value and Quantity and Individual Animal Performance. Crop Sci. 51:420-432.

Stohlgren, T.J., D. Binkley, G.W. Chong, M.A. Kalkhan, L.D. Schell, K.A. Bull, Y. Otsuki, G. Newman, M. Bashkin and Y. Son 1999. Exotic plant species invade hot spots of native plant diversity. Ecol.Monogr. 69:25-46.

Stohlgren, T.J., K.A. Bull and Y. Otsuki 1998. Comparison of rangeland vegetation sampling techniques in the central grasslands. J.Range Manage. 51:164-172.

Stohlgren, T.J., G.W. Chong, M.A. Kalkhan and L.D. Schell 1997. Multiscale sampling of plant diversity: Effects of minimum mapping unit size. Ecol.Appl. 7:1064-1074.

Stohlgren, T.J., M.B. Coughenour, G.W. Chong, D. Binkley, M.A. Kalkhan, L.D. Schell, D.J. Buckley and J.K. Berry 1997. Landscape analysis of plant diversity. Landscape Ecol. 12:155-170.

Stohlgren, T.J., M.B. Falkner and L.D. Schell 1995. A Modified-Whittaker Nested Vegetation Sampling Method. Vegetatio 117:113-121.

Swain, H.M., P.J. Bohlen, K.L. Campbell, L. O Lollis and A.D. Steinman 2007. Integrated ecological and economic analysis of ranch management systems: An example from south central Florida. Rangeland Ecology & Management 60:1-11.

Tanner, G.W., L.D. Sandoval and F.G. Martin 1984. Cattle Behavior on a South Florida Range. J.Range Manage. 37:248-251.

Tobler, M.W., R. Cochard and P.J. Edwards 2003. The impact of cattle ranching on large-scale vegetation patterns in a coastal savanna in Tanzania. J.Appl.Ecol. 40:430-444.

USDA-NASS 2010. Florida livestock dairy and poultry summary. Florida Field Office.

Vulink, J.T., H.J. Drost and L. Jans 2000. The influence of different grazing regimes on Phragmites- and shrub vegetation in the well-drained zone of a eutrophic wetland. Applied Vegetation Science 3:73-80.

Whalley, R. D. B. and M. B. Hardy. 2000. Measuring botanical composition of grasslands.

Whittaker, R.H. 1977. Evolution of species diversity in land communities. Evolutionary Biol 10:1.

Wunderlin, R. P. 1998. Guide to the vascular plants of Florida / Richard P. Wunderlin. University Press of Florida, Gainesville.

Zedler, J.B. 2003. Wetlands at your service: reducing impacts of agriculture at the watershed scale. Frontiers in Ecology and the Environment 1:65-72.

Zedler, J.B. and S. Kercher 2005. Wetland resources: Status, trends, ecosystem services, and restorability. Annual Review of Environment and Resources 30:39-74.

BIOGRAPHICAL SKETCH

Julia was raised in East Longmeadow, Massachusetts, and is the oldest of four children. Beginning in high school, Julia spent her summers working on two farms in the Connecticut valley, where she first began developing her interest in agricultural landscapes. This interest was furthered at the College of the Holy Cross, where she developed a self-designed interdisciplinary major, and sought coursework that incorporated her interests in both agriculture and ecology. She graduated with a bachelor's degree in environmental studies in 2007. Following her graduation, Julia moved to Sanibel, Florida, where she worked as an intern with the Sanibel Captiva Conservation Foundation in their native plant nursery. Living in Florida led to an opportunity at the MacArthur Agro-ecology Research Center at Buck Island Ranch, where she worked as a research assistant on multiple large-scale wetland and ecosystem services research projects. Through this, she developed a particular interest in ranch landscapes, and was able to pursue this interest further with her master's degree program at the University of Florida. In her free time, Julia enjoys being outside, keeping bees, and working in her vegetable garden.