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Restoring the Longleaf Pine (*Pinus palustris*) Forests Using Pineywoods Cattle Grazing in Conjunction with Prescribed Burning

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by

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Abstract

The longleaf pine (*Pinus palustris*) is major forest constituent of the Southern Coastal Plains of the United States. Ecologically, a virgin longleaf pine forests supports increased species richness. Since the 1800s, longleaf pine forests have been exploited as a massive source of commercial products (e.g., lumber, pulp, and naval stores). A decrease in species richness has been recorded following this vast decrease in longleaf pine presence. Rebuilding the longleaf pine ecosystem is essential for restoring species richness and maintaining the ecological health of many Costal Plains habitats. Presently, the most popular restoration and management method utilized is prescribed burning. Prescribed burnings allow small, controlled fires to safely mimic the effects of naturally occurring wildfires. More recently, interest in the use of prescribed burning in the longleaf pine forests has increased because of the potential applications for reducing forests floor fuel loads and increasing species richness. A lesser-known practice of restoration is the implementation of grazing by cattle populations. Previous studies have shown an increase in species richness and a decrease in litter-cover when sites were introduced to grazing. Little research studying the interactions between grazing and prescribed burning has been conducted, however. We studied the effects of prescribed burns and grazing at the Longleaf Preserve, located in the Lake Thoreau Environmental Research Center (LTEC) in Hattiesburg, Mississippi. A series of treatment sites were constructed to determine the influence of grazing by pineywoods cattle and prescribed burns on plant diversity and physiognomy of the forest floor. These sites were subjected to four different treatments in an attempt to replicate current environmental conditions.

Fuel loads (i.e., available material for burning) were assessed by collecting data on fine and course litter (e.g., fallen leaves, twigs, branches), as well as, understory plant species richness. The litter samples were collected, dried, and placed on a scale to determine weight. The plant species within each sample were then separated based on morphology. The preliminary results indicate that combining pineywoods cattle grazing with a prescribed burning regimen is an effective means of decreasing leaf-litter cover and increasing species richness on the forest floor.

Key Words: longleaf pine, *Pinus palutris*, species richness, restoration, management, prescribed burning, grazing, litter-cover, pineywoods cattle, fuel loads

Dedication

To Lance, Ida, & Ryan Albin

Thank you for your unwavering love and compassion.

You are fundamental to my success.

Acknowledgements

I would like to thank my thesis advisor, Dr. Micheal Davis, for his tireless efforts in mentoring me during the process of completing this study. I would like to thank Knox Flowers, Jaybus Price and Brandy Purdy for their unending patience and understanding in teaching a novice undergraduate how to truly appreciate the forests.

Additionally, I would also like to pay special thanks to the men of Delta Tau Delta International Fraternity – Zeta Chi Chapter. Through your guidance and assistance, I was able to become not only a successful student, but also a successful member of society.

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Chapter 1: Introduction

The longleaf pine (*Pinus palustris*) is major forest constituent of the Southern Coastal Plains of the United States. In the 1800s, the longleaf pine forests occupied more than ninety million acres and were a massive source of commercial products (e.g., lumber, pulp, and naval stores). Today, however, longleaf pine forests occupy only three million acres or four percent of its original distribution. Mass deforestation, along with minimal restoration effort, has almost eliminated the forests. Negative ecological and economic effects have accompanied this wide-scale decrease in longleaf pine presence. Longleaf pine forests support high species diversity and the demise of these forests threatens species that are dependent upon the stability of the longleaf ecosystem. Economically, longleaf pine forests possess vast implications to natural disaster damage costs, having the potential to provide an environment conducive to natural wildfires, which can destroy surrounding households.

Nearly 200 associated taxa are directly affected by environmental alterations within the longleaf pine forests (Haywood et al., 2001). According to Croker (1979), the longleaf pine forests has long “provided an ideal habitat for deer, turkey, quail, and many other animals and birds” (p. 34). Historically, the longleaf pine forests have been characterized as “a bountiful storehouse of valuable wood products” (Croker, 1979, p. 34). Rebuilding the longleaf pine ecosystem is essential for maintaining the ecological health of many Costal Plains habitats.

We can both reduce the risk of wildfire and improve the condition of remnant longleaf pine stands by implementing practices targeted at rebuilding the longleaf pine ecosystem. Restoration methods must lower levels of wildfire fuel (leaf-litter, woody undergrowth) and encourage longleaf pine sapling growth. Fuel management presents a target for methods to abate fire losses because the intensity of forest fires is closely dependent upon fuel characteristics such as composition, moisture level and amount. A restoration method must also encourage longleaf pine sapling growth, because the slow, juvenile stage of development demonstrated by the longleaf pine places it in danger of competition from underbrush and smothering by leaf-litter (Haywood & Grelen, 2000).

Presently, the most popular restoration and management method is prescribed burning. Prescribed burnings allow small, controlled fires to safely mimic the effects of natural wildfires. This technique decreases the frequency of high-intensity wildfire occurrences by preventing leaf-litter and other fuel sources from collecting over time. Also, these burnings prevent colonization of other competitive plant species that are less tolerant to fire exposure. Prescribed burnings favor the colonization and growth of heat tolerant species (*P. palustris*) by returning nutrients into the soil (Croker, 1979). Prescribed burnings are not perfect, however. Despite the large amounts of prescribed burnings throughout the south, there is not enough fire occurring to impact the ecosystem on a large scale (Outcalt and Brockway, 2010). Also, if these burns are performed incorrectly or at improper times, they can actually be detrimental to the longleaf pine. According to Mapaure et al. (2009), if the seedlings, saplings, or small trees are not mature enough at the time of the burn, they may be killed by the fire.

Finding a practice that addresses the shortcomings found in prescribed burning would provide a great deal of assistance in longleaf pine forests restoration. A possible enhancement to the current practice of prescribed burning is through implementation of grazing by pineywoods cattle. According to Borchard & Eldridge (2011), “cattle grazing and trampling can change the quantity and composition of plant species” (p. 63) and “alter surface litter cover” (p. 63). Spanish settlers introduced Pineywoods cattle into the United States during the fifteenth century (Pitts & Sponenburg, 2010). As a result of environmental and human selection, pineywoods cattle are “heat tolerant, long-lived, resistant to parasites and diseases, and able to be productive on marginal forage” (Pitts & Sponenburg, 2010, p. 3). The diet of pineywoods cattle differ from typical cattle, in that pineywoods cattle are adapted to be able to consume low-quality forage (pine needles, bark) and subsist. Allowing the pineywoods cattle to roam freely through the forest floor greatly alters the plant diversity and physiognomy of these areas.

Previous studies have shown that introducing a site to grazing can produce significant effects on plant species richness and leaf-litter levels. Not much research has been conducted investigating the use of grazing within the longleaf pine forests, however. In 2010, the opportunity arose to establish a cattle grazing experiment in the longleaf pine forests. The site used for this study is designated as the Longleaf Preserve at the Lake Thoreau Environmental Center (LTEC) in Hattiesburg, Mississippi. This site was chosen for its 90+ year old longleaf pine forest spread across a 100+ acres of land. The site had originally been subjected to prescribed burning but this ceased more than 20 years ago.

In this paper, I introduce the concept of combining prescribed burning and grazing, with aims of achieving more effective restoration methods within the longleaf pine forests. A series of treatment sites were established to determine the influence of prescribed burnings and cattle grazing on leaf-litter levels and plant species richness. These plots were subjected to an array of factors in an attempt to replicate current environmental conditions. Fuel loads (i.e., available material for burning) were assessed by collecting data on fine and course litter (e.g., fallen leaves, twigs, branches), as well as understory plant diversity. Our hypothesis is that combining pineywoods cattle grazing with cycles of prescribed burnings will serve as an effective means of improving longleaf pine forest understory structure and diversity.

Chapter 2: Review of Related Literature

History of the Longleaf Pine

Longleaf pine (*Pinus palustris*) has historically been a dominant tree in the southeastern coastal plains of the United States. Longleaf pines can take more than one-hundred years to fully mature and may live for as long as five-hundred years. Prior to European colonization, these forests were present throughout the entire southeastern U.S.; ranging all the way from southeast Virginia to central Florida and westward to eastern Texas (Haywood, 2009). This vast resource was commercialized in the late 1800s. Following the Civil War, the longleaf pine served as a major source of restoration income in the south. For more than a century, *P. palustris* was harvested for the production of lumber, pulp, and lands. Living longleaf pines were tapped for their oleoresin. Two extremely valuable products, turpentine and rosin, were extracted from this oleoresin (Croker, 1979). The presence of longleaf pine forests across the country was reduced from over 90 million acres to under 3 million acres by 1993 (Haywood, 2009). Massive exploitation of the longleaf pine for commercial applications has eliminated much of this forest type throughout its distribution. By the early 1950s, most of the forests had been clear-cut and replaced with other species of pines (Croker, 1979).

Importance of the Longleaf Pine

The longleaf pine has long been important to the daily lives and fortunes of southern people (Croker, 1979). The longleaf pine is very important, both ecologically and economically. Ecologically, longleaf pine forests host a tremendous amount of species diversity. Longleaf pine forests harbor a wide array of vascular plants and invertebrates. Nearly 200 associated taxa are directly affected by environmental alterations within the longleaf forests (Haywood et al., 2001). These forests have long provided the ideal habitat for game animal, such as deer, turkey, quail, and many other birds and animals (Croker, 1979). The demise of longleaf pine forests threatens many species, such as the red-cockaded woodpecker, that are heavily dependent on the stability of the longleaf ecosystem (Outcalt & Brockway, 2010). Protecting the established longleaf pine forests and restoring the surrounding longleaf pine forests are essential for conserving these species (Haywood, 2009).

In order to maintain its proper understory structure, a longleaf pine must burn on a regular basis (Mapaure et al., 2009). The longleaf pine is classified by ecologists as a fire climax type, meaning that regular fires maintain the tree (Croker, 1979). Prior to European settlement, either lightning strikes or Native Americans ignited these fires. The southeastern United States experiences a large amount of thunderstorms every year, each with the potential to create wildfire-yielding lightning (Outcalt & Brockway, 2010). Many human practices have influenced fire frequency over the last 150 years. From the post-Civil War years to the 1920s, most of the longleaf pine forests were logged. After logging these lands were either left fallow, converted to agriculture, or replanted with a different native species that lacked tolerance to fire (e.g., loblolly pine (*Pinus taeda*)). In addition, the U.S. Forest Service has had a history of suppressing fires dating back to the 1940s. The reductions in fire frequency were accompanied by a concomitant increase in forest fuels. As the human populations have increased in these areas, human sources of ignition have been on the rise (Mapaure et al., 2009). Thus when fires do occur, the increased fuels result in increased fire intensities, and the larger presence of humans results in increased economic impacts from fire damages (Mercer et al., 2007). In response to these more intense wildfires, expenditure in the United States to prevent, manage, and decrease wildfire has been rapidly expanding (Mercer et al., 2007).

<u>Restoration of the Longleaf Pine</u>

Despite all the damage done to the longleaf forests, recent developments suggest that it is not too late for the longleaf pine and that the process can be reversed. We can both reduce the risk of wildfire and improve the condition of remnant longleaf pine stands by implementing practices targeted at rebuilding the longleaf pine ecosystem. By restoring the longleaf pine forests, one addresses both the ecological and economical issues accompanying the decrease in longleaf presence. Restorations methods must address fire management in order to be successful. Because the intensity of forest fires is very dependent upon fuel characteristics such as composition, moisture level and amount, fuel management presents a target for methods to abate fire losses.

Aside from wildfire fuel levels, restoration methods must also address longleaf pine colonization. The main focus of this restoration aspect is to prevent competitive, invasive plant species from limiting longleaf pine growth. Many claim that it is difficult to restore the longleaf forests due to their difficulty of reproduction and their slow juvenile growth (Croker, 1979). Because of the slow, juvenile stage of the longleaf pine, rapidly growing loblolly pine and hardwood brush can negatively affect the longleaf saplings (Haywood, 2009). During the “grass stage” of development, longleaf pine seedlings are in danger of competition from underbrush and smothering by leaf-litter (Haywood & Grelen, 2000). In many existing forests, longleaf density has been shown to increase rapidly upon the removal of understory growth.

Prescribed Burning

By far, one of the most well-known and effective forms of longleaf pine restoration is prescribed burnings. In fact, the practice of prescribed burning was first developed in the longleaf pine forests (Croker, 1979). Periodic burnings utilize a small, induced fire to consume the woody understory vegetation and leaf-litter located within the longleaf pine forests (*Illustration I*). By implementing periodic burnings, the available fuel with the potential to feed a wildfire, is kept at a low level. Prescribed burnings have long been demonstrated since early settlers of North America adopted the Native American practice and continued to burn longleaf pine areas annually (Outcalt and Brockway, 2010). Periodic burnings favor longleaf pine by preventing the colonization of other competitive species, that are less tolerant to fire exposure (Outcalt and Brockway, 2010). Longleaf seedlings possess a great resistance to fire damage and their survival is dependent on these fires. Without them, aggressive hardwoods and other competitive pine species would choke out the longleaf (Croker, 1979). In addition to destroying competitive species, prescribed burnings return nutrients to the soil; where they can be absorbed by the longleaf pine and used for further growth. Regardless of season, periodic burning of southern pine forests can assist in lowering the hardwood fuel source of wildfires (Haywood and Grelen, 2000). Prescribed burnings have been found to mitigate the impacts of elevated fuel loads on wildfire occurrence and intensity

(Mercer et al., 2007). In regards to species diversity, the overall richness of the system is generally increased by the use of intermediate fire frequencies (Scudieri et al., 2010). Executing these burnings, however, is a complex process. The results from a prescribed fire are dependent upon many environmental conditions and application techniques (Hills, 1957). If performed correctly, prescribed burnings are effective in controlling wildfire outbreak and encouraging longleaf pine colonization. Some factors that influence the effectiveness of prescribed burnings are yearly season, quantity of fuel available, moisture of the fuel, temperature, wind patterns, and precipitation history (Hills, 1957).

Despite the large amounts of prescribed burning throughout the south, there are not enough fires occurring to impact the ecosystem on a large scale (Outcalt and Brockway, 2010). Controlled burnings, if performed incorrectly or at improper times, can even be detrimental to the longleaf pine. In order for periodic burnings not to injure the longleaf pine, the seedling must possess a well-developed root collar (Haywood and Grelen, 2000). If the seedlings, saplings, or small trees are not mature enough at the time of the burn, they may be killed by the fire (Mapaure et al., 2009). Also, the implementation of prescribed burnings throughout the country in an ordeal that requires a great deal of man-power. Over the previous thirty years, fire suppression expenditures have increased by nearly $600 million dollars (Mercer et al., 2007). Also, prescribed burns are not always feasible due to adverse weather conditions and lack of resources (Haywood, 2009). The increasing number of forest areas occupied or located within close proximately of housing, furthermore, complicates the burning process (Outcalt and Brockway, 2010).

Research into improving fire management and longleaf pine restoration is needed. Current methods of prescribed burning are useful, but are not perfect. As previously mentioned, prescribed burnings can be risky, expensive, and at times, complex. By finding a safe-cost effective enhancement, or alternative, to prescribed burnings, great assistance would be granted to local individuals and communities.

Illustration I. Prescribed burning consuming understory vegetation in the longleaf pine forests.

Pineywoods Cattle

An alternative measure for fire fuel reduction in longleaf pine forests is use of pineywoods cattle (*Illustration II*). Pineywoods cattle are a land race of cattle that was introduced in the sixteenth century by Spanish conquistadors to supplement their food supply (Croker, 1979). The Pineywoods is one of the oldest cattle breeds in the United States (Pitts & Sponenberg, 2010). These cattle were allowed to free graze throughout the forests until the mid-nineteenth century. This particular breed of cattle is much different from other types of commercial cattle. Because pineywoods are relatively unaffected by heat, humidity, and biting insects, they are highly adapted for life in the longleaf pine forests of the southeastern United States (Pitts & Sponenberg, 2010). Pineywoods also possess the ability to eat low-quality forage (leaf-litter, bark, and woody undergrowth). Most commercial cattle breeds are incapable of this and would die subsisting on a diet of forest understory browse. The diet of pineywoods cattle is somewhat similar to the diet of a common deer; consisting of woody plants (Thill and Martin, 1986).

Prior to the 1500s, American Bison roamed southeast Mississippi. European settlers quickly extirpated these bison. However, in the Gulf Coastal Plain, pineywoods cows replaced the bison. From the mid-1500s until the late 1800s, early settlers utilized pineywoods cattle to clear woody underbrush from the longleaf pine forests. According to Croker (1979), the historic southern landscape resembled "huge wooden soldiers lined up in battle formation, the massive trees dotted the rolling coastal plains in a sea of grass" (p. 32). The understory of longleaf pine forests in in the 1500s closely resembled the grasslands of the Midwestern United States (*Illustration III*), whereas today's forests floor is highly crowded with woody undergrowth and leaf-litter *(Illustration IV*).

Fire and grazing are important disturbances that possess the ability influence the structure and function of an ecosystem (Augustine & Milchunas, 2009). Cattle grazing and trampling can alter the composition and quantity of plant species while also changing surface litter levels (Borchard & Eldridge, 2011). Previous studies have shown that there were significantly more plant species in sites of high cattle usage than sites of low cattle usage (Borchard & Eldridge, 2011) (Humphrey & Patterson, 2000). Not only was there a difference in plant species composition, but also there were more species of grasses found in the high cattle use sites (Bochard & Eldridge, 2011). Litter cover in the ungrazed cattle plots was found to be significantly higher than the grazed plots (Humphrey & Patterson, 2000). There are also good examples in both Britain and Europe of using livestock to achieve conservation objectives. Both of these occur in woodlands and contribute to helping maintain and restore species-rich grasslands (Humphrey & Patterson, 2000). Grazing is of great potential value to restoration and management methods aimed at regaining species-rich grasslands in forests. A possible management technique might be to reintroduce some form of grazing, but this has not been tested in the longleaf pine forests.

In theory, by coupling two techniques of wildfire management and forests restoration, such as prescribed burnings and grazing, a new and more effective means of addressing these issues can be devised. According to Croker (1979), prescribed fire and grazing have long helped maintain the open nature of the longleaf pine forests. The hypothesis of this research is that combining pineywoods cattle grazing with a prescribed burning regimen will serve as an effective means of lowering fuel levels on the longleaf pine forests floor by removing woody underbrush. It is also believed that combining grazing and prescribed burning will increase the species richness of the observed areas.

Illustration II. Pineywoods cattle roaming through the longleaf pine forests.

Illustration III. Historical, grassland floor of the longleaf pine forests.
Adopted from http://www.tarleton.edu/Departments/range/Woodlands%20and%20Forest/Longleaf%20Pine/longleafpine.htm

Illustration IV. Current, crowded floor of the secondary longleaf pine forests.
Adopted from Hendrix (2012).

Chapter 3: Methodology

Overview

Our hypothesis was tested using four separate, plots at the Lake Thoreau Environmental Center (LTEC). The Longleaf Preserve at LTEC contains a 90+ year old, 100+ acre longleaf pine forest. Prior to the first series of prescribed burns in this experiment, the Longleaf Preserve had not been subjected to any form of restoration in more than twenty years. This experiment utilized four different sets of treatments. Experimental treatments include:

1. No fire, no cattle
2. No fire, cattle present
3. Prescribed fire, no cattle
4. Prescribed fire, cattle present

For statistical replication, each of these plots were further divided into three subplots. Data collected included forest litter mass, density of woody understory vegetation, and understory species composition.

Selection of Treatment Sites

To initiate this process at the Longleaf Preserve at LTEC, specific treatment sites needed to be defined. To assist with this task, a dendrology sampling grid (*Illustration V*) was obtained. This grid was constructed using the MSTM coordinate system and featured a transverse Mercator projection. This layout allowed for us to transform the Longleaf Preserve property into a quantifiable sampling grid. To successfully treat all of the assigned treatments, four different treatment zones were established. These zones within the Longleaf Preserve were chosen based upon similarities in vegetation diversity, soil quality, and topography.

Of the four assigned treatment zones, two would house the pineywoods cattle. To ensure that the cattle remained in their assigned treatment area, a barbed wire fence was constructed around the perimeter of the treatment site (*Illustration VI*).

Illustration V. Dendrology sampling grid created to demonstrate the Longleaf Preserve at LTEC.

Illustration VI. Barbed wire fence used to contain pineywoods cattle in their designated treatment zone.

Establishing the Permanent Sampling Points Within Each Treatment

Within each of the treatment zones, three permanent sampling points were chosen randomly from the dendrology sampling grid (*Illustration VII*). These points were selected to improve the statistical representation of the findings. A reference for the permanent testing points and their relation to the treatment series can be found looking at *Table I.*

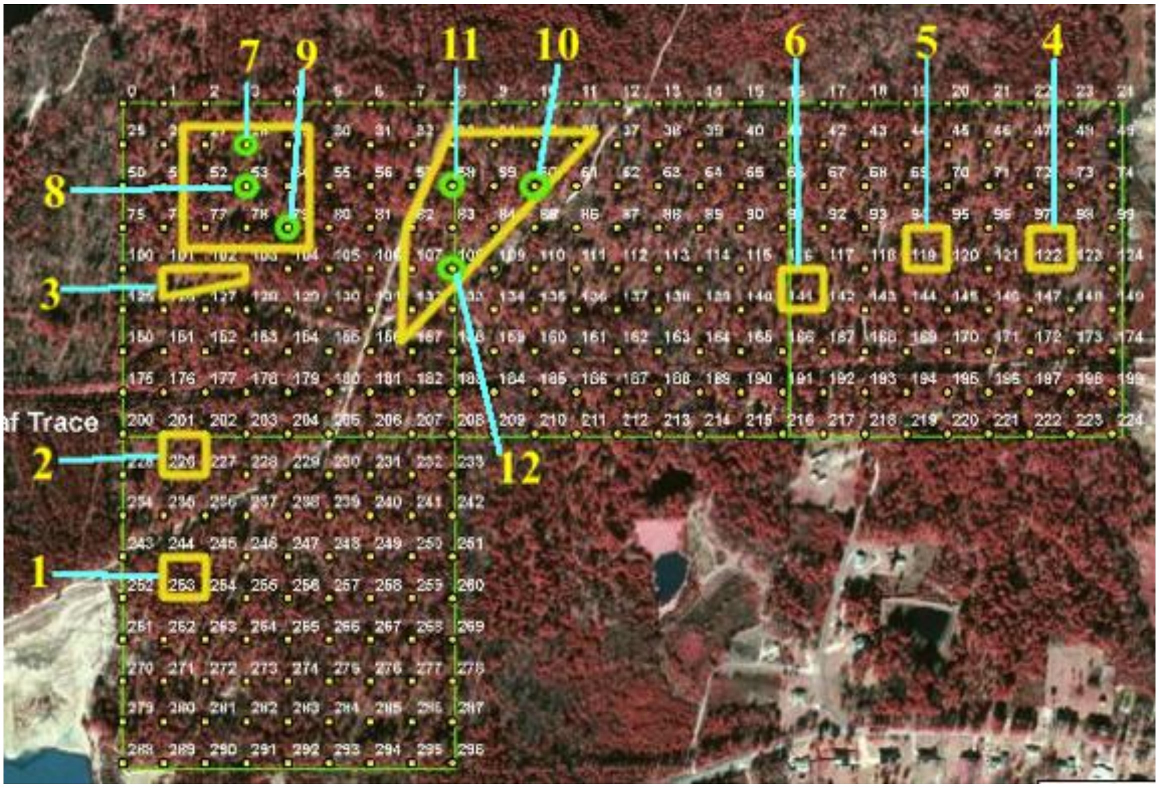

Illustration VII. Permanent sampling points within each treatment area.

Table I

Reference of Permanent Testing Points within the Treatment Areas

Plot #	Burned	Cattle
1-3	–	–
4-6	+	–
7-9	–	+
10-12	+	+

Specifications of Each Treatment

Control:

Permanent testing point 1, 2, and 3 were designated as the control areas for this study. In this group of points, nothing was altered throughout the length of the experiment.

Prescribed Burning:

Permanent testing points 4, 5, and 6 were designated as the prescribed burning treatment plots. Up until the beginning of the experiment in 2009, all of the permanent treatment plots had the same burn history. Prior to the first burn, these was a period of at least 20 years where no burning occurred. Over the course of the experiment, three sets of prescribed burns occurred. The initial fuel reduction burn took place in the dormant season (late winter, early spring) on 2009. This burn was conducted to drastically reduce the 20 years of fuel accumulation. The second burn took place in the dormant season of 2010. In 2012, a two year burn rotation was implemented with the final burn occurring during the growing season (summer) (*Illustration VIII*).

Pineywoods Cattle:

Permanent testing points 7, 8, and 9 were designated as the pineywoods cattle treatment zone. In March of 2013, the pineywoods cattle were placed into the fenced treatment area. The cattle were placed into the plot at a density of 1 head of cattle per every 2.5 acres of land. The cattle remained in the plot for two months, being removed in May 2013. After removing the cattle in May, data collection on species composition and diversity immediately began. In August 2013, all cattle in the experiment (6 head of adult and 2 calves) were placed back into this plot. This was done in an attempt to see how much more vegetation the pineywoods cattle could reduce. In September 2013, all but two head of cattle were removed from the treatment area (*Illustration IX*).

Prescribed Burning & Pineywoods Cattle:

Permanent testing points 10, 11, and 12 were assigned a combination of both prescribed burning and pineywoods cattle grazing. The methods for prescribed burning followed the guidelines stated previously in this section with a series of three different burnings taking place from 2009 until 2012. The 2009 and 2010 burns occurred during the dormant season with the 2012 burn taking place during the growing season. In March 2013, pineywoods cattle were placed into the treatment area at a density of 1 head of cattle for every 2.5 acres. The cattle were removed from the plot in May 2013, and data collection on vegetation species diversity and composition began.

Illustration VIII. Prescribed burning during 2012 growing season in the Longleaf Preserve at LTEC.

Illustration IX. Pineywoods cattle grazing on longleaf pine forests floor in the Longleaf Preserve at LTEC.

Collecting the Litter Samples

Leaf litter samples were collected from each of the permanent testing sites using a 0.25 m^2 metal frame and a kitchen knife (*Illustration X*). The first series of collections took place in April 2012, while the second series of collections took place in April 2014. The metal frame was placed on the ground and stabilized using four stakes. The knife was used to cut out litter within the frame. All litter samples were placed into individual paper bags and labeled. At each of the permanent testing sites (1-12), 8 litter samples were collected. To establish a very clear pattern during collection, coordinates were mapped out using directions (*Illustration XI*). Relative to the center of the permanent testing sites, samples were collected at 5m and 10m in NE, NW, SE, and SW.

Illustration X. 0.25 m^2 metal frame & kitchen knife used for collecting litter samples.

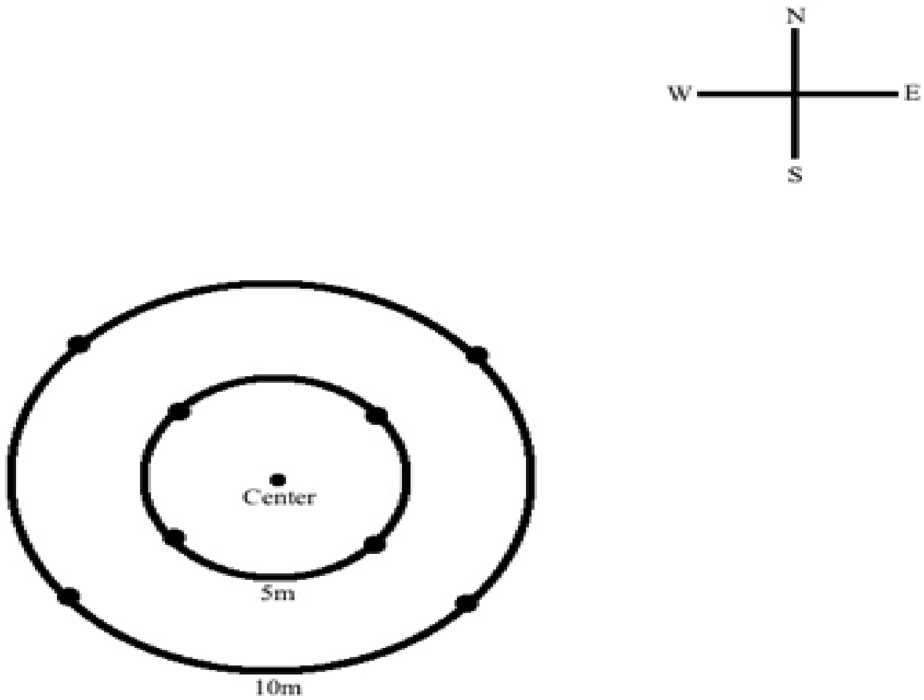

Illustration XI. Coordinate system used for consistent litter sample collection.

Removing Insects from the Samples

After collecting the samples from LTEC, they immediately entered the first step of analyzation. The leaf litter samples were placed into a series of Berlese apparatuses (*Illustration XII*) in an attempt to remove the invertebrate populations. There are many different forms of Berlese funnels, but the ones utilized in this project consisted of a bucket, funnel with a screen in it, aluminum reflector, and a 25 watt light bulb. The Berlese apparatus operates under the premise that arthropods generally live in soil and litter, thus responding negatively to light. The funnel utilizes a light source to force the arthropods down throughout the litter. After they migrate through the litter, they fall through the screen and into a container of 190-proof ethyl alcohol (95% EtOH).

Each of the collected litter samples were placed into the funnels within four hours of collection. The samples remained in the funnel for 72 hours. While in the funnels, the intensity of the light bulb was gradually increased every six hours using a common household dimmer switch. As the light intensity increased, the resulting temperature of the leaf litter also increased. Through this process, two objectives were achieved. First, the invertebrate population was removed from the samples. And second, the heat from the light bulb helped to dry the samples.

At the conclusion of the 72-hour period, the samples were placed back into their original bags. The specimen cups containing the insects from each sample were sealed and labeled according to their specific collection area.

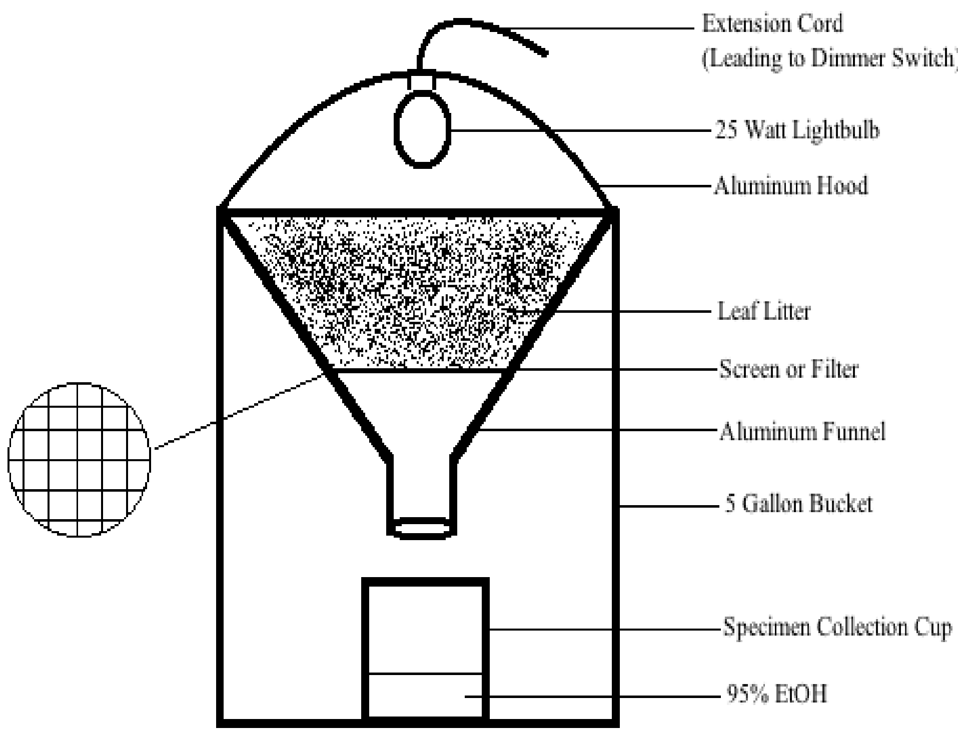

Illustration XII. Berlese apparatus used to remove invertebrates from litter samples.

Removing Residual Moisture from the Samples

After the litter samples had all run their 72-hour course through the Berlese funnels, they were prepped for a more intense drying stage. Each of the litter samples was placed into drying ovens to ensure that the residual moisture had been completely removed from the samples (*Illustration XIII*). The samples were placed into the drying ovens and heated at a temperature a 65º C. The samples remained in the oven for a period of 24 hours.

Illustration XIII. Litter samples placed in the drying oven at 65º C for 24 hours.

Weighing the Samples

Because the litter samples consisted mostly of organic material, they needed to be weighed immediately following their removal from the drying ovens. Each of the samples were removed from their designated paper bag and placed into a plastic container. The plastic container had been previously placed unto the scale and zeroed. The weight of each litter sample was obtained and recorded. After obtaining the dry weight of the samples, the leaf litter was returned to their specific paper bag, where they remained until the next step in the experiment.

Categorizing the Samples

After obtaining the dry weight of all the samples, each of the specimens within the leaf-litter was categorized. The goal of this portion of the research was to gain insight into the understory diversity and morphology in each of the permanent testing sites. Using a funnel with a metal screen in it (similar to the funnel apparatus used in the Berlese funnel) the litter samples were categorized (*Illustration XIV*). The funnel and metal screen was used a mechanism to determine whether or not a leaf specimen was large enough to be correctly identified. The leaf specimen within each litter sample was categorized as either pine leaf, broad leaf, or other (*Illustration XV*).

The litter sample was emptied out into the funnel on top of the metal screen. The samples were then sifted, allowing the smaller pieces of the samples to migrate to the bottom and fall through the screen. All specimens that fell through the screen were considered too small or mangled to be correctly identified. These filtered particles were placed into the “other” category of leaf samples (*Illustration XV D*). The leaf specimens remaining in the funnel was sorted according to their morphology. The specimens placed into the "pine" portion were leaves (needles) belonging to any species of pine tree (*P. taeda*, *P. palustris*) (*Illustration XV A*). The specimens placed into the "broad" category were leaves belonging to any species other than pine trees (*Illustration XV B*). Any other specimen remaining in the funnel that did not fit the criteria as either a pine of broad leaf were grouped into the "other" category (*Illustration XV C*). Specimens placed into this

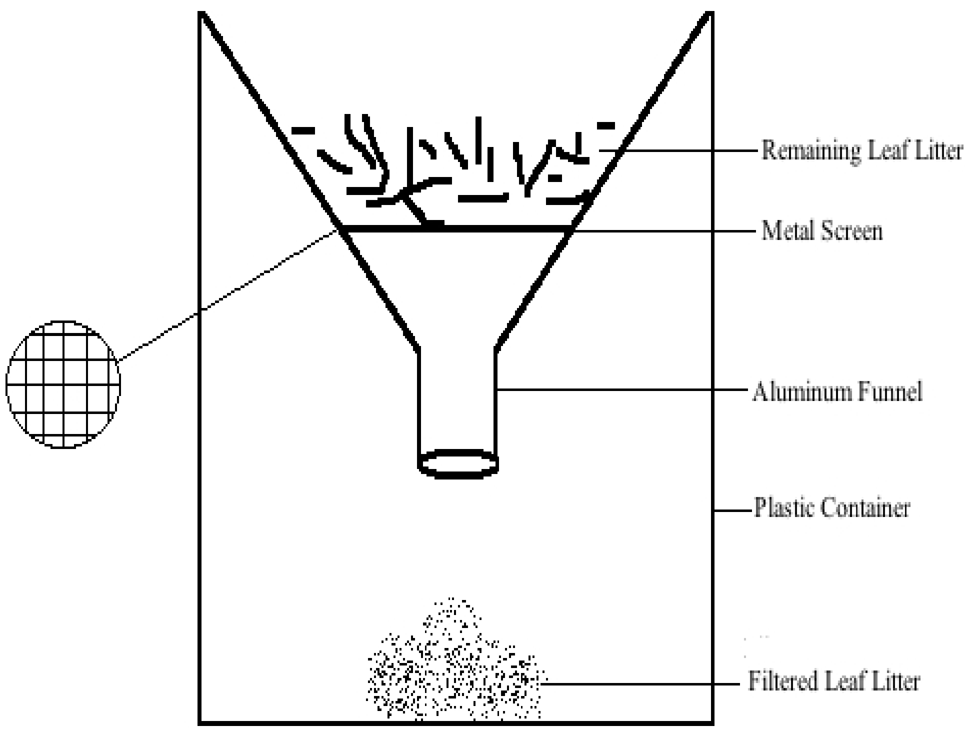

Illustration XIV. Funnel apparatus used to categorize litter samples.

category were grasses, tree limbs, seeds, and bark.

Illustration XV A-D. Categorization of litter samples. (A) Pine needle specimen; (B) Broad leaf specimen; (C, D) Other specimen that did not meet the requirements of pine needle or broad leaf.

Weighing the Categorized Samples

After categorizing every specimen within the litter samples, each of the individual categories within each sample was weighed. These weights were then placed into a table, where the percentile of each category within each sample could be calculated. This data gave us an insight into the affect of each treatment on the species composition and diversity of the litter samples.

Chapter 4: Results

Litter Dry Weight

For the four years that the burn studies were conducted, the data was collected and analyzed using the techniques listed in the previous chapter. Upon looking at the data presented in *Illustration XVI* and *Table III*, we were able to gather insight into the leaf litter amounts prior to the 2012 burn cycle. The raw data was input into statistical software for analysis. The following information was obtained from two-way ANOVA tests for litter data dry weight from April 2012. The results include the effects of fire, cattle, and cattle/fire interaction. Viewing this data confirmed that the treatments delivered to each zone did affect the leaf-litter mass collected.

When looking at the data, you find that the cattle treatment area (permanent treatment zones 7-9) possessed a mean dry litter mass of $1743.1325 g \cdot m^{-2}$. The burn treatment area (4-6) had a mean dry litter weight of $1226.3900 g \cdot m^{-2}$. The final treatment area, cattle and burn (10-12) was found to have a mean of $922.0667 g \cdot m^{-2}$. The control area (1-3) possessed a mean value of $1499.0475 g \cdot m^{-2}$. The standard error for all of the treatment zones was determined to be 154.02041.

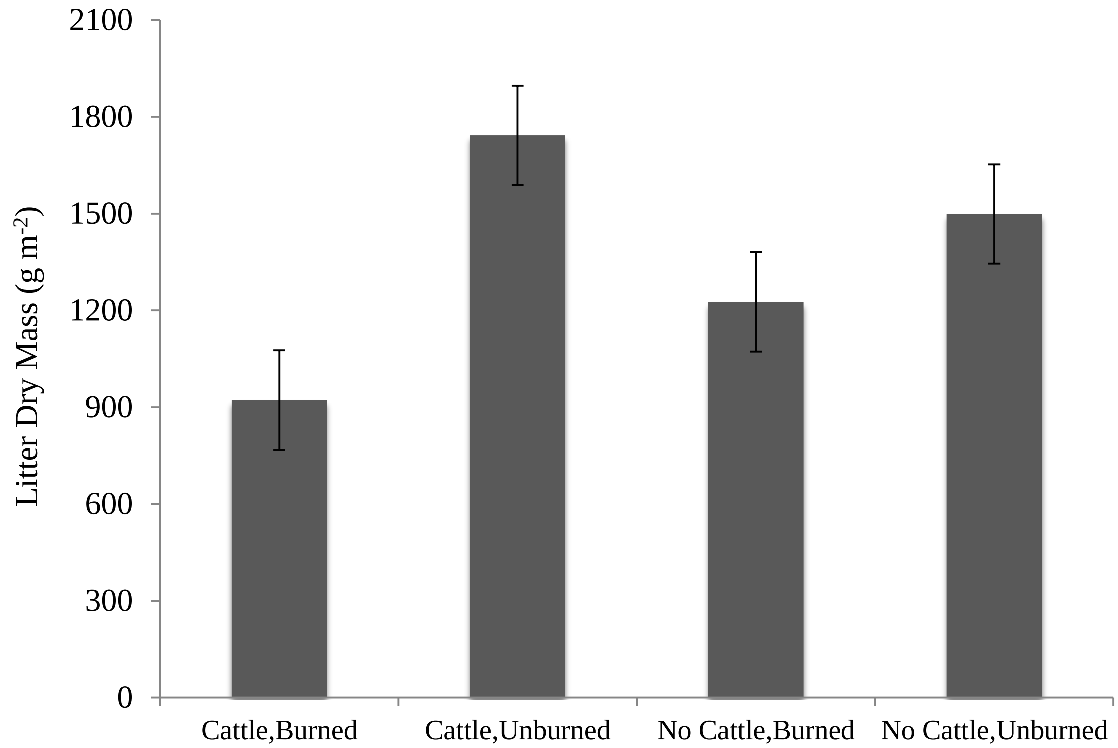

Illustration XVI. Dry litter mass obtained from the Longleaf Preserve at LTEC during April 2012.

Looking at the information presented in *Table II* gives insight into the effects test between the treatments and dry litter weight. Results from of the two way ANOVA statistical analysis display information for the cattle effect (Sum of Squares = 10885.970; F Ratio = 0.0382; DF = 1; Prob > F = 0.8498). Results from the analysis also indicate a relationship in the burn treatment (Sum of Squares = 3588692.200; F Ratio = 12.6066; DF = 1; Prob > F = 0.0075*). The final results yielded from the analysis were for the cattle and burn combination treatment (Sum of Squares = 902255.100; F Ratio = 3.1695; DF = 1; Prob > F = 0.1129*).

Table II

Effect Test, Litter Weight, Pre-Cattle, April 2012

Effect	Sum of Squares	F Ratio	DF	Prob > F
Cattle	10885.970	0.0382	1	0.8498
Burn	3588692.200	12.6066	1	0.0075*
Cattle & Burn	902255.100	3.1695	1	0.1129*

** Obtained statistical value indicative of at least one significant effect in model.*

Table III

Least Squares Means Table, Litter Weight, Pre-Cattle, April 2012

Level	Least Sq. Mean	Standard Error
Cattle, Unburned	1743.1325	154.02041
No Cattle, Burned	1229.3900	154.02041
Cattle & Burned	922.0667	154.02041
No Cattle, Unburned	1499.0475	154.02041

Denominator MS Synthesis: Plot[Cattle,Fire]&Random

The following information was obtained from two-way ANOVA tests for litter data dry weight from April 2014. The results include the effects of fire, cattle, and cattle/fire interaction. Again, viewing this data confirmed that the treatments delivered to each zone did affect the leaf-litter mass collected.

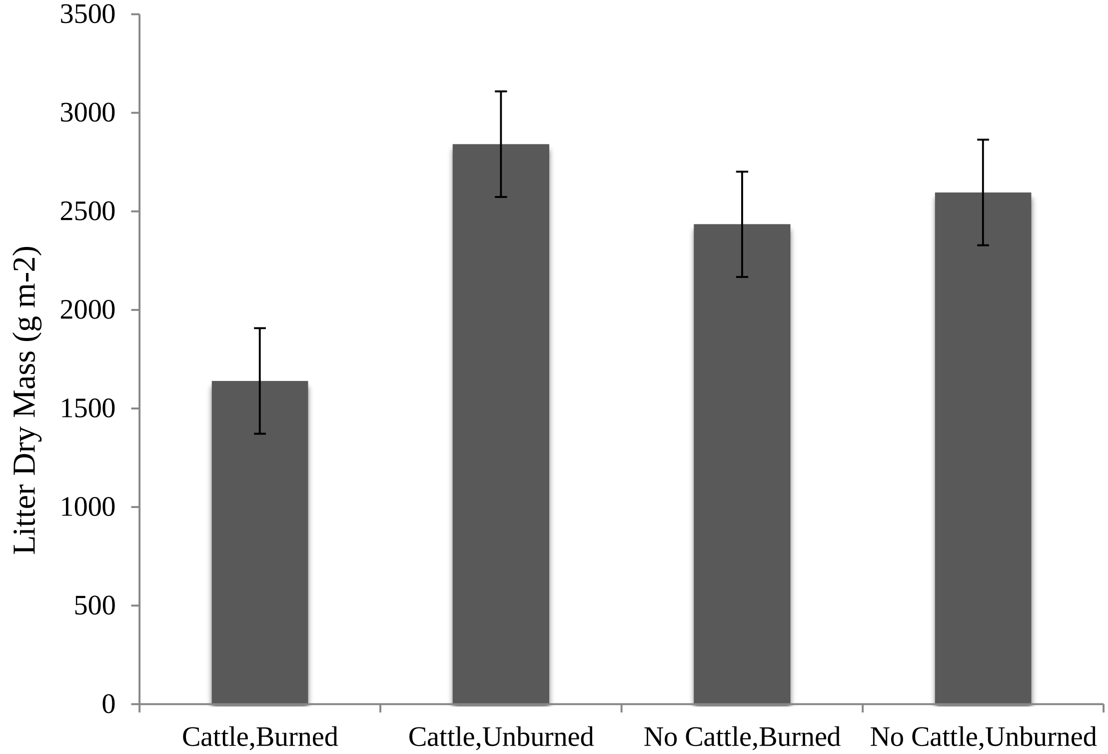

Illustration XVII. Dry litter mass obtained from the Longleaf Preserve at LTEC during April 2014.

When viewing the information presented in *Illustration XVII* and *Table V*, you find the litter dry weight values from the April 2014 collection. When looking at the data, you find that the cattle treatment area (permanent treatment zones 7-9) possessed a mean dry litter mass of 2840.0000g·m^{-2}. The burn treatment area (4-6) had a mean dry litter weight of 2433.8833g·m^{-2}. The final treatment area, cattle and burn (10-12) was found to have a mean of 1638.7500g·m^{-2}. The control area (1-3) possessed a mean value of 2594.8833g·m^{-2}. The standard error for all of the treatment zones was determined to be 267.53975.

Table IV

Effect Test, Litter Weight, Post-Cattle, April 2014

Effect	Sum of Squares	F Ratio	DF	Prob > F
Cattle	1815110.000	1.0566	1	0.3341
Burn	11134350.000	6.4815	1	0.0344*
Cattle & Burn	6492720.400	3.7795	1	0.0878

** Obtained statistical value indicative of at least one significant effect in model.*

Looking at the information presented in *Table IV* gives insight into the effects test between the treatments and dry litter weight. Results from of the two way ANOVA statistical analysis display information for the cattle effect (Sum of Squares = 1815110.000; F Ratio = 1.0566; DF = 1; Prob > F = 0.3341). Results from the analysis also indicate a relationship in the burn treatment (Sum of Squares = 11134350.000; F Ratio = 6.4815; DF = 1; Prob > F = 0.0344*). The final results yielded from the analysis were for the cattle and burn combination treatment (Sum of Squares = 6492720.400; F Ratio = 3.7795; DF = 1; Prob > F = 0.0878).

Again in the 2014 litter collections, we find a difference in dry litter mass between the treatment zones. Because of the results, we are able to determine that the combination treatment using cattle and prescribed burning was the most effective at lowering leaf litter levels on the forest floor.

Table V
Least Squares Means Table, Litter Weight, Post-Cattle, April 2014

Level	Least Sq. Mean	Standard Error
Cattle, Unburned	2840.0000	267.53975
No Cattle, Burned	2433.8833	267.53975
Cattle & Burned	1638.7500	267.53975
No Cattle, Unburned	2594.8833	267.53975

Denominator MS Synthesis: Plot[Cattle,Fire]&Random

Species Richness

Species richness of the categorized litter samples was calculated in a similar manner, using a two-way ANOVA test to measure litter composition amongst each treatment zone. When looking at the results in *Table VII*, you find that the cattle treatment area (permanent treatment zones 7-9) possessed a mean species richness of 7.2500. The burn treatment area (4-6) had a mean species richness of 10.5833. The final treatment area, cattle and burn (10-12) was found to have a mean of 13.2500. The control area (1-3) possessed a mean value of 8.8333. The standard error for the control treatment, cattle treatment, and the cattle/burn combination was found to be 1.31365. While the standard error of the burned treatment zone was determined to be 1.3847.

Looking at the information presented in *Table VI* gives insight into the effects test between the treatments and dry litter weight. Results from of the two way ANOVA statistical analysis display information for the cattle effect (Sum of Squares = 3.4356757; F Ratio = 0.1654; DF = 1; Prob > F = 0.6948). Results from the analysis also indicate a

Table VI

Effect Test, Species Richness, Post-Cattle, April 2014

Effect	Sum of Squares	F Ratio	DF	Prob > F
Cattle	3.4356757	0.1654	1	0.6948
Burn	175.31757	8.4661	1	0.0195*
Cattle & Burn	52.722973	2.5460	1	0.1491

** Obtained statistical value indicative of at least one significant effect in model.*

relationship in the burn treatment (Sum of Squares = 175.31757; F Ratio = 8.4661; DF = 1; Prob > F = 0.0195*). The final results yielded from the analysis were for the cattle and burn combination treatment (Sum of Squares = 52.722973; F Ratio = 2.5460; DF = 1; Prob > F = 0.1491).

Looking at this data provided in *Table VII*, it is confirmed that that cattle/burn combination treatment areas yielded the greatest species richness of all treatment zones. The diversity in these permanent testing sites was found to be 13.250. This amount was considerably higher than the species diversity observed in any other treatment area. In light of this data, it can be assured that using cattle in conjunction with prescribed burning is the most effective way to both (1) lower fuel levels on the forest floor and (2) increase species diversity in the observed fuel samples.

Table VII

Least Squares Means Table, Species Richness, Post-Cattle, April 2014

Level	Least Sq. Mean	Standard Error
Cattle, Unburned	7.2500	1.3136547
No Cattle, Burned	10.5833	1.3847137
Cattle & Burned	13.2500	1.3136547
No Cattle, Unburned	8.8333	1.3136547

Denominator MS Synthesis: Plot[Cattle,Fire]&Random

Chapter 5: Discussion

Research Questions and Hypotheses

The key focus of this thesis was to gain further insight into the interactions between cattle grazing and longleaf forests understory morphology. To assist in this examination, the following questions have been posed to guide the progress of the experiment.

- What are the effects of pineywoods on longleaf forest understory characteristics?
  - Does the presence of cattle grazing affect forest leaf-litter levels?
  - Does pineywoods cattle grazing affect understory plant species composition and abundance?
  - Are any of these factors altered when pineywoods cattle grazing and prescribed burning are combined?

Our established hypothesis for this experimental conduction indicated below:

- Using a combination of pineywoods cattle grazing and prescribed burning will serve as an effective means of lowering fuel levels on the longleaf pine forests floor by reducing woody vegetation.

Litter Dry Weight

It is important to remember that fire and grazing are key disturbances that influence the function and structure of ecosystems (Augustine & Milchunas, 2009). Prescribed burnings have been found to mitigate the impacts of elevated fuel loads on wildfire occurrence and intensity (Mercer et al., 2007), as well as, favor longleaf pine by preventing colonization of other competitive species (Outcalt & Brockway, 2010). Cattle grazing has been shown to dramatically reduce surface leaf-litter levels when compared to non-grazed sites (Humphrey & Patterson, 2000). It should also be noted that like grazing, the effect of prescribed burnings are dependent upon an array a factors, like fire intensity, frequency of precipitation, plant growth, fire frequency, plant composition, and topography (Augustine & Milchunas, 2009).

When looking at the information presented in *Illustration XVI* and *Illustration XVII*, we find an increase in all categories when moving from the 2012 litter collection to the 2014 litter collection. The average percent increase demonstrated by these latter collections was 78.06%. It is important to view the control treatment (1-3) when comparing these individual percent increases. The control treatment zone displayed a 73.10% increase in litter mass in the 2014 collection. This value was determined using the mean litter weight from April 2012 ($1499.0475 g\cdot m^{-2}$) and the mean litter weight from April 2014 ($2594.8833 g\cdot m^{-2}$)

The effect of prescribed fire on plant production seems to depend highly on the season that the burns are conducted. When looking at the data presented in *Illustration XVI* and *Illustration XVII*, we see a noticeable difference in dry litter mass. This difference could have resulted from the different season in which the burns were conducted. In April 2012, the litter samples were collected at the end of a two-year period of no burnings, with the last burning occurring during the 2010 dormant season. The average dry litter weight from the burned plots (4-6) in 2012 was found to be $1226.3900 g\cdot m^{-2}$. The litter collected from the burned sites in 2014 showed an average dry weight of $2433.8833 g\cdot m^{-2}$. This marked a 77.73% increase in litter mass from the 2012 collection to the 2014 collection.

What was perhaps the most interesting discovery in this experiment was the affect that grazing had on the litter levels. When looking back at the information presented in *Illustration XVI* and *Illustration XVII*, we find that the grazing treatment zones (7-9) yielded the highest litter levels of all treatments. The relevancy of this data is questionable, seeing that this treatment zone contributed the highest litter levels in 2012, before the cattle were even introduced to the area. In 2012, the litter levels were found to be 1743.1325$g \cdot m^{-2}$. Following the cattle exposure in 2013, the litter levels were determined to measure 2433.8833$g \cdot m^{-2}$. The grazing treatment area displayed the lowest percent increase of all treatments with an increase of 62.93% in the 2014 collection. Despite the grazing treatment area demonstrating the highest mean litter mass in both series of litter collections, it can be seen that this treatment was the most effective in preventing further accumulation of litter.

In the final treatment, grazing and burned (10-12), we find the lowest litter weights of all treatment areas. The average dry litter weight from the 2012 collection was determined to be 922.0667$g \cdot m^{-2}$. The average weight from the 2014 collection was found to be 1638.7500$g \cdot m^{-2}$. Although the values displayed in these finding show that lowest mean litter weights of all treatment areas, the increase demonstrated when moving from the 2012 to the 2014 collection was the highest. The percent increase on this treatment was 98.46%.

When viewing the previously mentioned data, it is seen that the prescribed burning regimen (whether in ungrazed, burned or the grazed, burned treatment) was the most effective method of maintaining low forests floor litter levels. In both series of litter collections, these two treatments demonstrated the lowest mean litter weight of all treatments. The combination treatment utilizing cattle grazing and prescribed burnings showed the lowest mean litter weights of all collections in both 2012 and 2014. Although the unburned, grazed treatment demonstrated the highest mean litter weights in both collections, it can be said that this restoration method was the most successful in preventing further litter build up. The cattle only treatment demonstrated the lowest percent increase in litter mass, allowing only a 62.93% increase between the first collection in 2012 and the final collection in 2014.

<u>Species Richness</u>

Information regarding the species richness of each treatment was only conducted using leaf-litter samples from the April 2014 collection. Leaf-litter build up seems to be the likely cause for decrease species richness in the plots (Humphrey & Patterson, 2000). This seems appropriate because increased litter mass on the forest floor has been shown to smother and kill the seedlings of other plant species. These findings were further supported when viewing the information featured in *Table VI* and *Table VII*.

The average species richness of all treatment zones was determined to be 9.9791. It is important to keep this value in mind when comparing the species richness of all the different treatment areas. Using the April 2014 leaf-litter collections, it was found that the control treatment area (1-3) possessed a species richness of 8.8333. The species richness of the unburned, cattle treatment (7-9) was calculated to be 7.2500, while the value was 10.5833 for the no cattle, burned treatment (4-6). The final obtained value for species richness was 13.2500 for the combination plot of cattle and burning (10-12).

The findings presented in *Table VI* and *Table VII* completely support the findings of previous studies; that species richness is influenced by the presence of leaf-litter. When viewing the data, this negative correlation is obvious. The combination treatment zone was found to possess the highest species of richness of all treatments. This is supportive of the relationship between species richness and leaf-litter levels because this treatment was also noted having the lowest dry litter weight of all treatments. This relationship was also supported when viewing the unburned, cattle grazing treatment. This treatment area was found to possess not only the lowest species richness, but also the largest dry litter weight of all treatments.

Implications and Directions for Future Research

Prescribed burning has long been considered an important measure in restoring the longleaf pine forests. Researchers have continually found that prescribed burnings favor longleaf pine growth by preventing colonization of other competitive species, which are less tolerant to fire exposure (Outcalt & Brockway, 2010). Prescribed burning is not the only restoration method, however. The long forgotten method of natural restoration in the longleaf pine forests is through the use of grazing via pineywoods cattle. Cattle grazing and trampling are known alter the composition and quantity of plant species while altering surface litter levels (Borchard & Eldridge, 2011). Also, when researching the history of the longleaf pine forests, it is found that the virgin forests floor was frequently characterized as a "seas of grass" (Croker, 1979, p. 32). Both fire management techniques and grazing from livestock are key disturbances, which can greatly alter the structure and function of an ecosystem (Augustine & Milchunas, 2009).

Although this restoration method of combining grazing with prescribed burning has been practiced, little research has been done using this technique within the longleaf pine forests.

Perhaps, once again combining these two restoration methods could achieve a new level of productivity in restoring the longleaf pine forests. In fact, this practice of combining prescribed burning with grazing by pineywoods cattle has proven quite promising in this research. Our results indicate that the combination treatment using both cattle grazing and prescribed burning was the most effective restoration method tested in this study. This combination plan proved to be the most effective method of both lowering forest floor litter levels and increasing species richness. The pineywoods cattle grazing and prescribed burning treatment plan may possess vast implications for improving current restoration practices in the longleaf pine forests.

The findings from this study also deliver insight into the role of grazing by pineywoods cattle in the longleaf pine forests. The treatment area subjected to only grazing and no prescribed burning were indicative of high forest floor leaf-litter levels and low species diversity. Upon further analysis of the data, however, it was noticed that this treatment was the most effective method of preventing new leaf-litter from accumulating on the forests floor. The cattle grazing treatment only allowed an additional 62.93% of litter to accumulate on the forest floor; while the prescribed burning treatment allowed an additional 77.73% of litter to accumulate.

In order to further support the findings from this study, an additional study could be conducted viewing the effects of pineywoods cattle grazing and prescribed burning over a longer period time (~10 years). In addition to this proposed study, insight could be gained into the effects of cattle grazing and prescribed burning on invertebrate populations in the longleaf pine forests. Using the insects collected from the berlese apparatus, species diversity/richness could be determined and related to each treatment.

Chapter 6: Conclusion

The longleaf pine forests are an important part of the southeastern economy and ecosystem. The longleaf pine forests are essential in the support of nearly 200 threatened plant and animal species. To mitigate both the ecological (reduced quality of habitat) and economical (risk of fire damages) issues accompanying longleaf pine exploitation, we must focus our efforts on restoring the forests. The current methods of restoration rely heavily on the use of prescribed burnings. Although effective, this practice is not always feasible. Finding an improvement to prescribed burnings would allow further restoration of these forests. Combining grazing by pineywoods cattle with prescribed fire may prove as an effective means of reducing forest fuels and improving habitats.

After conducting a series of two-way ANOVA statistical analysis, it was found that using both pineywoods cattle and prescribed burning is the most effective means of reducing forests fuel levels. In April 2012, the dry litter weight of these combination treatment zones was considerably less than that of the other observed treatments, possessing a mean weight of 922.0667$g \cdot m^{-2}$. This dry weight value was accompanied with a standard error of 154.02041. In litter collections from April 2014 further supported the implications of using this combination method as a means of minimizing forests floor fuel levels. The mean weight from this series of collections was found to be 1638.7500$g \cdot m^{-2}$ with a standard error of 267.53975. The cattle and burning combination treatment was also found to yield the highest species diversity of all treatment zones. The species diversity of the combination treatment area was found to be 13.250. A standard error of 1.31365 was determined to accompany this diversity.

The results obtained from this study support the claim that both livestock grazing and prescribed burning alter the structure and function of an ecosystem. By implementing a management technique similar to the combination treatment presented in this study, a great deal of success may be found in restoring the longleaf pine forests. In conclusion, the longleaf pine forests have long played great importance to the lives of southern individuals. The longleaf pine forests has made millionaires and witnesses centuries of human drama. The longleaf pine forests have contributed to the success of our great country and will forever be in the hearts of its inhabitants. Through restoration efforts, we can restore the longleaf pine forests and ensure its presence for generations to come.

References

Augustine, D. J., & Milchunas, D. G. (2009). Vegetation responses to prescribed burning of grazed shortgrass steppe. *Rangeland Ecology & Management*, 62(1), 89-97.

Borchard, P., & Eldrigde, D. J. (2012). Vegetation changes associated with cattle (*Boas taurus)* and wombat (*Vombatus ursinus*) activity in a riparian forest. *Applied Vegetation Science*, 15(1), 62-70.

Croker, T. C. Jr. (1979). Longleaf pine: the longleaf pine story. *Journal of Forest History*, 23(1), 32-43

Haywood, J. D. (2009). Eight years of seasonal burning and herbicidal brush control influence sapling longleaf pine growth, understory vegetation, and the outcome of an ensuing wildfire. *Forest Ecology And Management*, 258(3), 295-305.

Haywood, J. D. (2009). Influence of pine straw harvesting, prescribed fire, and fertilization on a Louisiana longleaf pine site. *Southern Journal Of Applied Forestry,* 33(3), 115-120.

Haywood, J. D., & Grelen, H. E. (2000). Twenty years of prescribed burning influence the development of direct-seeded longleaf pine on a wet pine site in Louisiana. *Southern Journal Of Applied Forestry*, 24(2), 86-92.

Haywood, J. D., Pearson, H. A., Grelen, H. E., & Harris, F. L. (2001). Vegetative response to 37 years of seasonal burning on a Louisiana longleaf pine site. *Southern Journal Of Applied Forestry*, 25(3), 122-130.

Hendrix, Gail (Photographer). (2012). *Steve Barlow standing in the longleaf pine forest that he is restoring* [Photograph]. Retrieved May 07, 2013, from: http://blogs.usda.gov/2012/10/01/working-lands-for-wildlife-initiative-helps-to-improve-gulf-of-mexico-too/

Hiers, J., Grego, J. M., Loudermilk, E., O'Brien, J. J., & Mitchell, R. J. (2009). The wildland fuel cell concept: an approach to characterize fine-scale variation in fuels and fire in frequently burned longleaf pine forests. *International Journal Of Wildland Fire*, 18(3), 315-325.

Hills, J. T. (2006). Prescribed burning techniques in loblolly and longleaf pine on the Francis Marion National Forest. *Fire Management Today*, 66(1), 38.

Humphrey, J. W., & Patterson, G. S. (2000) Effects of late summer cattle grazing on the diversity of riparian pasture vegetation in an upland conifer forest. *Journal of Applied Ecology*, 37, 986-996.

Johnson, M. K., & Pearson, H. A. (1981). Esophageal, fecal and exclosure estimates of cattle diets on a longleaf pine-bluestem range. *Journal Of Range Management*, 34(3), 232-234.

Mapaure, I., Gambiza, J., & Campbell, B. M. (2009). Evaluation of the effectiveness of an early peripheral burning strategy in controlling wild fires in north-western Zimbabwe. *African Journal Of Ecology*, 47(4), 518-527.

Mercer, D., Pye, J. M., Butry, D. T., & Prestemon, J. P. (2007). Evaluating Alternative Prescribed Burning Policies to Reduce Net Economic Damages from Wildfire. *American Journal Of Agricultural Economics*, 89(1), 63-77.

Outcalt, K. W., & Brockway, D. G. (2010). Structure and composition changes following restoration treatments of longleaf pine forests on the Gulf Coastal Plain of Alabama. *Forest Ecology And Management*, 259(8), 1615-1623.

Pitts, J. B., & Sponenberg, D. P. (2010). *An overview and history of pineywoods cattle: The culture and families that shaped the breed*. Pittsboro, NC: American Livestock Breeds Conservancy.

Scudieri, C. A., Thode, A. E., Sackett, S. S., Sieg, C., & Haase, S. M. (2010). Understory vegetation response after 30 years of interval prescribed burning in two ponderosa pine sites in northern Arizona, USA. *Forest Ecology And Management*, 260(12), 2134-2142.

Thill, R. E., & Martin, A. r. (1986). Deer and cattle diet overlap on Louisiana pine-bluestem range. *Journal Of Wildlife Management*, 50(4), 707-713.

[Untitled photograph of second-growth longleaf pine]. Retrieved: April 23, 2013, from: http://www.tarleton.edu/Departments/range/Woodlands%20and%20Forest/Longleaf%20Pine/longleafpine.htm