AN INDEX FOR ESTIMATING FORAGE QUALITY FOR WHITE-TAILED DEER ACROSS NINE PRIMARY HABITAT TYPES IN LOUISIANA

by

LEVI BENNETT HORRELL

(Under the direction of Michael J. Chamberlain)

ABSTRACT

Land managers and researchers are constantly striving to better manage habitat for sustainable deer herds. Producing an index to assess potential forage quality across different habitat types could prove valuable to improving habitat quality. I placed 570 plant sampling exclosures across 9 habitat types during January-March of 2011 and collected plant samples from each exclosure during summer 2011 and 2012. I dried each sample and then analyzed each for nutritional content, including crude protein, digestible energy, and minerals. I used a nutritional constraints model to predict deer-days of foraging capacity for each habitat type. I also used forage intake rates and reported diet qualities necessary for body maintenance to assess the quality of deer forage within each habitat type and then created an index based on the forage species composition that can be used to index deer nutrition at a given location. Following collection of data, I observed considerable variation in the nutritional characteristics across all habitat types as well as within the species collected. Early successional habitats as well as those managed with prescribed fire in Louisiana in the Northwest and Southeast Pine-Hardwood habitat types displayed a high forage index. Severe drought conditions during 2011 appeared to have had a significant negative impact on the nutritional quality of forages sampled.

INDEX WORDS: Forage quality, habitat, Louisiana, minerals, *Odocoileus virginianus*, protein, white-tailed deer.

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LEVI BENNETT HORRELL

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LEVI BENNETT HORRELL

Major Professor: Michael J. Chamberlain

Committee: Karl V. Miller
Robert J. Warren

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Introduction

White-tailed deer (*Odocoileus virginianus*) are an economically and socially important game species. As a result, land managers and researchers are continually attempting to improve management scenarios designed to ensure sustainable deer herds. An understanding of deer ecology and nutritional requirements is needed by managers to develop sound management plans that focus on ensuring herd quality. Developing an index to assess the quantity and nutritional quality of available forage within different habitat types could be useful to deer managers and landowners by guiding actions intended to improve habitat, or for guiding hunter expectations within those habitat types.

Previous studies in the southeastern United States that assessed forage quality for deer primarily evaluated effects of vegetation management strategies on nutritional characteristics of plant communities (Edwards et al. 2004, Miller and Chamberlain 2008, Mixon et al. 2009, Lashley et al. 2011). Although these studies revealed vegetation management treatments that could assist managers in Louisiana with improving habitat quality in pine forests, a comprehensive study of Louisiana's primary deer habitat types and their respective quality has not been conducted. Deer performance can be a function of the habitat available across a given area as dictated by environmental conditions and available forage. As the predominant habitat type changes across the landscape, so should management actions and potentially harvest regulations. Assessing the potential quality of forage within each habitat type in Louisiana during the growing season could provide landowners and managers a basis for developing deer herd objectives for specific habitat types and identifying where nutritional deficiencies in forage may occur.

Literature Review

White-tailed deer are concentrate foragers, selecting the most nutritious plant species and portions of plants available, and will consume a diversity of plants to acquire nutrients needed for body maintenance and growth. When deer are overabundant, this selective browsing can have profound impacts on plant communities, shifting them towards browse-tolerant or less preferred species such as ferns, grasses, and sedges (Waller and Alverson 1997, Urbanek et al. 2012), and recovery of browse-damaged plant communities can take years (Anderson and Katz 1993). Where deer densities are high, some understory forbs can even be extirpated or shifted toward smaller plants with a reduced reproductive capacity (Augustine and Frelich 1998). Nonetheless, the adaptability of deer allows them to occupy a range of habitats and obtain necessary nutrition from various plants even when the most nutritious species are not available.

In male deer, the antler growth period is a time of greater nutritional demand because it requires an increase in body mass as well as the growth of antlers to improve fitness during the breeding season. For much of the year, female nutritional demands focus on the requirements for gestation and lactation (Verme 1969, Cothran et al. 1987). Subsequently, females have more individual impact on overall herd persistence by driving recruitment and may select for higher quality diets than males (Beier 1987).

On average, deer consume 1,360 g of dry plant matter daily (Fowler et al. 1967) to meet basic nutritional needs. Two of the most important dietary components are the levels of crude protein (CP) and digestible energy (DE) in forage, and they are positively related to the nutritional status of deer (Bahnak et al. 1979). For CP, a diet quality of 6% is sufficient to support body maintenance (Asleson et al. 1996), whereas 14% CP is necessary to support a lactating female with one fawn (Verme and Ullrey 1984) and optimal antler growth in males (Asleson et al. 1996). Asleson et al. (1997) suggested that reduced availability of dietary protein during antlerogenesis may not affect antler development initially, but rather that the effects may be cumulative through time, increasing in subsequent years. Specific to DE, 2.2 kcal DE/g dry matter intake (DMI) is considered adequate for body maintenance in deer (Hellickson and DeYoung 1997), whereas for lactation a target diet quality is acknowledged to be 3.25 kcal DE/g DMI (Moen 1978).

Overall, adult deer typically select diets high in energy when available (Berteaux et al. 1998), and yearlings in particular may select plant species higher in protein content (Dostaler et al. 2011). Tollefson et al. (2011) showed that diets higher in digestible energy (DE) given to adult female mule deer (*Odocoileus hemionus*) and their fawns during summer increased survival for those fawns, thereby increasing recruitment.

Concentrations of CP and DE in the diet are clearly important to deer, but their levels can vary seasonally in plants, depending on species and environmental conditions (Everitt and Gonzalez 1981). Due to their dietary importance, reduced CP and DE levels can have a significant impact on deer health. Bahnak et al. (1979) placed does on diets of lower quality (reduced protein and energy content) and reported reduced levels of blood urea nitrogen (BUN), a parameter positively associated with nutritional status. Does on lower quality diets that successfully nursed fawns during summer were suspected to have reduced milk production than does on higher quality diets since their fawns averaged 5 kg smaller in body weight after being weaned in October. This reduced body condition of fawns raised under poorer nutritional conditions indicates that annual recruitment could be affected by forage quality throughout the year.

Besides CP and DE concentration, minerals commonly recognized as required nutrients for body maintenance and growth include calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), copper (Cu), manganese (Mn), and zinc (Zn), among others. Each of these is required at varying levels in the diet. Nitrogen (N) is considered one of the most important nutrients and plays a significant role in body maintenance and antler development. For adult males during spring and summer, approximately 0.61 (±0.16 SE) and 1.06 (±0.15 SE) grams of digestible N per kilogram of metabolic body mass per day (g N/kg$^{0.75}$/day) is necessary to support maintenance and growth, respectively, which is equivalent to approximately 5.8 and 9.9% CP in the diet (Asleson et al. 1996). Holter et al. (1979) demonstrated that CP and N have a positive correlation and deer on diets with increased CP also have a greater N balance.

Sodium (Na) is critical for normal body function because it regulates blood volume, osmotic equilibrium, and pH. However, in some regions it occurs at levels below dietary requirements. Hellgren and Pitts (1997) estimated a daily Na intake of 3.27 mg/kg of body mass was necessary to offset daily losses in Na. Where Na is naturally deficient, physiological and behavioral adaptations of deer can help to overcome shortages (Weeks and Kirkpatrick 1976). In New Hampshire, Pletscher (1987) indicated deer obtained much greater amounts of Na than present in natural forage by accessing salt along highways. Likewise, Atwood and Weeks (2003) noted that deer routinely used salt and mineral licks to boost their attainment of Na and other minerals in Indiana. The selective foraging behavior of deer could again play a role in obtaining adequate Na where availability is low and artificial sources are not present.

Phosphorus is another mineral that may be limiting to white-tailed deer in some regions (Ullrey et al. 1975, Grasman and Hellgren 1993) and, along with Ca, is a critical component of antlers in males (Miller et al. 1985) and is important to lactation in females and growth of young deer. French et al. (1956) found that young male deer fed Ca and P supplements exhibited improved antler growth compared to deer given diets deficient in Ca and P. Additional evidence suggests young deer grow optimally when their diet contains concentrations of approximately 0.40-0.51% (4,000-5,100 ppm) Ca and 0.25-0.27% (2,500-2,700 ppm) P (Ullrey et al. 1973, 1975). However, browse plants in the southern United States often contain low P concentrations (<0.25%, 2,500 ppm). Grasman and Hellgren (1993) investigated this low presence of P in deer browse and subsequently estimated the annual dietary requirement of P for adult males was 0.14% (1,400 ppm), helping to explain how deer still thrive in the southern United States. Notably, P may often be present at low concentrations, particularly for younger growing deer, but also varies seasonally in deer forage, allowing deer to obtain more at certain times of the year (Varner et al. 1977, Barnes et al. 1990).

Requirements for many trace minerals found in forage for white-tailed deer are relatively poorly understood. Most studies have focused on micronutrients known to be of greater dietary value (primarily Na, P, Ca, and to a lesser extent K) and less attention has been given to other minerals such as Mg, Mn, Cu, and Zn with regard to deer dietary requirements. Copper and Zn may influence growth and immune function in wildlife, but effects of deficiency or toxicity are not well understood. Bartoskewitz et al. (2007) investigated the effects of dietary Cu and Zn concentrations on antler growth, body size, and immune system function of male deer and did not observe any significant effect on antler growth or body size, but noted improved immune response when higher levels of Cu and Zn were present.

Although numerous minerals are important to deer health, their concentration varies among plant species and season of the year. Barnes et al. (1990) analyzed mineral content of various deer forages in southern Texas, noting forbs contained greater levels of Cu and Zn than grasses or woody browse, whereas browse contained less Iron (Fe), P, and K than forbs or grasses, and grasses displayed lower concentrations of Ca and Mg than browse or forbs. These findings emphasize the importance of plant diversity in ensuring high quality foraging habitats for deer.

Numerous spatial and temporal factors affect the nutritional quality and quantity of available forage, and can have important implications for the health of deer herds. Keyser et al. (2006) proposed that the relative density of deer across the landscape can be a function of habitat type and recommended assessing habitat quality relative to regional characteristics such as soils to predict potential herd health and productivity. Precipitation and soil fertility in particular have a distinct positive relationship with plant biomass productivity (De Deyn et al. 2004, Zhou et al. 2009) and soil fertility has been shown to enhance the nutrient content of available forage (Hundley 1959, Krueger and Donart 1974). In fact, the pine flatwoods habitat of Florida, which is characterized by poor soils, is recognized as providing low quality forage and deer found there exhibit low body weights and poor antler development (Harlow and Jones 1965).

Many states have variable habitat types across the landscape and the performance of deer varies across those habitat types. In Louisiana, bottomland hardwood habitat along the Mississippi and Atchafalaya River basins has high soil fertility, and male deer found there display greater average body weights and antler measurements than deer found in other regions of the state (Moreland 2005). Data collected by Louisiana's Deer Management Assistance Program (DMAP) suggest subtle trends in antler and body weight measurements from deer harvested in the other regions may also exist (Durham 2011). Similarly, Strickland and Demarais (2000) reported body mass of deer harvested in Mississippi can in fact be correlated to the fertility of soils and the body mass growth rate was found to be slower in less fertile regions.

Within habitat types, other factors beyond soil fertility, including natural and anthropogenic disturbances such as fire, soil disturbance, and herbicide use, can also affect deer health by influencing forage quality and abundance. For example, Schindler et al. (2004) noted that hackberry (*Celtis pallida*) leaves exhibited an increase in CP, blackbrush acacia (*Acacia rigidula*) sprouts decreased in DE, and honey mesquite (*Prosopis glandulosa*) sprouts increased in DE after fire in Texas. In landscapes managed intensively for wood fiber production, herbicide use has increased and in some cases replaced the use of fire (Wigley et al. 2002). In eastern Louisiana, Miller and Chamberlain (2008) determined that combining herbicide applications (a combination of imazapyr and triclopyr) with fire during initial site preparation resulted in a different successional trajectory for treated sites as compared to sites only treated with fire during 3 years post-treatment. The addition of herbicide appeared to increase the herbaceous plant component and prolong the length of time a stand remained in an early successional state. Prescribed fire alone allowed the woody component of emerging vegetation to maintain a greater presence. Mixon et al. (2009) found similar results in Mississippi and determined treating mid-rotation pine plantations with both herbicide and fire gave a distinct improvement to deer forage during the subsequent 2 years by promoting understory growth of forbs and decreasing mid-story hardwood coverage.

Deer may be capable of occupying a wide range of habitats, but each habitat type varies in forage characteristics. In some cases, the preference of browse species may even change because forage selection depends on the characteristics of all plants available rather than any individual plant (Belovsky and Schmitz 1994). Thus, the nutritional value of forage available to deer can change among habitat types.

The abundance and quality of forage available within a given habitat dictates carrying capacity. Based on this, Hobbs and Swift (1985) demonstrated that a nutritional constraints model using an assessment of habitat production and quality combined with an understanding of the species' nutritional demands could be used to estimate nutritional carrying capacity for herbivores in a given area. Incorporating forage quality and quantity into estimates of carrying capacity could improve evaluations of habitat potential because forage quality and abundance are not only important but often inversely correlated (White 1978). Numerous studies have since applied this technique to evaluate habitat quality and the effects of various habitat manipulation treatments (McCall et al. 1997, Beck et al. 2006, Jones et al. 2009, Iglay et al. 2010, Lashley et al. 2011). However, most previous research assessing forage quality for deer has focused on effects of silvicultural treatments on forage production and nutrition, rather than assessing the nutritional characteristics of deer forage plants as they occur across multiple habitat types.

Within Louisiana, Moreland (2005) delineated 9 primary habitat types according to vegetative composition and physiographic region, which included Northwest Pine-Hardwood, Southeast Pine-Hardwood, Bottomland Hardwood, Swamp Hardwood, Upland Hardwood, Longleaf Flatwoods, Historic Longleaf, Coastal Prairie, and Coastal Marsh. Each habitat type was characterized by its own unique array of topography, vegetative composition and structure, and soil fertility; hence habitat quality was expected to vary among them. Although deer condition and productivity vary among these habitat types, an assessment of deer nutritional quality in each of these regions has not been conducted. In Mississippi, Jones et al. (2008) conducted a region-wide assessment of forage quality and reported that the influence of soils on the nutritional quality of forage can be significant. However, their study focused on CP content of 8 specific forage species sampled within 5 different soil regions. This project was designed to provide a comprehensive assessment of both forage production and quality including CP, DE, and minerals across 9 habitat types in Louisiana, and ultimately to improve understanding about the potential nutritional value of habitats managed for deer.

Objectives

The specific objectives of this study are:

1. Assess nutritional quality of woody and herbaceous forage plants important to white-tailed deer in Louisiana's primary deer habitat types.
2. Compare the biomass production of deer forage plants within each primary deer habitat type.
3. Assess habitat quality according to the quantity and quality of available forage for white-tailed deer across primary deer habitat types in Louisiana.

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CHAPTER 2

NUTRITIONAL QUALITY OF FORAGE PLANTS IMPORTANT TO WHITE-TAILED DEER IN LOUISIANA[1]

[1]Horrell, L.B. and M.J. Chamberlain. 2013. To be submitted to the Journal of Wildlife Management.

Abstract

Land managers and researchers strive to understand factors influencing white-tailed deer populations and develop methods to improve habitat. Evaluating forage quality across habitat types could prove valuable to land managers interested in improving habitat quality. We placed 570 plant sampling exclosures across 9 primary habitat types in Louisiana during January-March of 2011. We collected plant samples representing consumable forage from each exclosure during summer 2011 and 2012. Each sample was then dried and those with ≥10 g of dry matter were analyzed for crude protein, total digestible nutrients, and trace minerals. We used these data to assess the quality of forage within each major habitat type across Louisiana. Nutritional content of forage species appeared to be negatively influenced by drought in 2011 and varied considerably across habitat types as well as within species. The protein content of some species in the same year ranged by several orders of magnitude across samples tested [e.g., during 2012 common ragweed (*Ambrosia artemisiifolia*) tested near 5% for 1 sample to as high as 16% for another]. The Longleaf Flatwoods habitat type exhibited the poorest nutritional quality, whereas forage in the Bottomland Hardwood habitat type generally had greater protein and mineral levels.

Introduction

White-tailed deer are selective foragers and will consume a wide range of plant species. Deer typically select the most nutritious plants and portions of plants first depending on the species available and their chemical or physical defenses (i.e., presence of plant secondary compounds or thorns), before consuming less nutritious plants. On average, deer consume 1,360 g of dry plant matter daily (Fowler et al. 1967) to meet basic nutritional needs. The levels of crude protein and digestible energy in the forage intake are 2 of the most important dietary components and they have been shown to have a positive relationship with the nutritional status of deer (Bahnak et al. 1979). Crude protein varies seasonally in plants, often dependent on species and environmental conditions (Everitt and Gonzalez 1981), and energy as well can vary according to the same factors or even with habitat treatments such as fire (Schindler et al. 2004).

Berteaux et al. (1998) conducted a study on deer forage selection as related to protein and energy content and found that deer selected diets higher in energy. In contrast, Dostaler et al. (2011) reported that protein content may have more influence on food selection by yearling males during the growing season. Regardless of the proportionate importance, both protein and energy are essential for deer health, as are a number of trace minerals. Minerals commonly recognized as required for body maintenance and growth include calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), copper (Cu), manganese (Mn), and zinc (Zn), among others. Each of these has varying levels of requirement in the diet as well as availability in browse. Barnes et al. (1990) analyzed mineral content of various deer forages in southern Texas, and found that forbs contained greater levels of Cu and Zn than grasses or woody browse. Conversely, browse contained less Fe, P, and K than forbs or grasses, and grasses displayed lower concentrations of Ca and Mg than browse or forbs. Although browse may at times be deficient in certain nutrients, it is suspected that deer can overcome lower availability by becoming more selective in the food they consume and possibly using post-ingestive feedback cues to influence future food selection (Provenza 1995, Villalba et al. 2002).

In Louisiana, as in other states, the occurrence and quality of plant species differs across habitat types, and the importance of different plants to deer herds is similarly variable. Moreland (2005) identified 9 primary habitat types important to deer in Louisiana: Northeast Pine-Hardwood, Southeast Pine-Hardwood, Bottomland Hardwood, Upland Hardwood, Swamp Hardwood, Historic Longleaf, Longleaf Flatwoods, Coastal Prairie, and Coastal Marsh. Moreland (2005) then used browse surveys and rumen examinations across several decades to develop a list of plant species considered to be important for deer. However, the nutritional quality of the species identified by Moreland (2005) is not well understood, particularly in regard to potential variability across different habitat types. Quantifying the nutritional quality of plant species and each major habitat known to be important to deer in Louisiana could provide a basis for assessing the ability of available browse species to sustain healthy deer populations.

Methods

We selected study sites at state-operated Wildlife Management Areas (WMAs), national wildlife refuges, national forest, or private properties within each habitat type region of Louisiana. We selected a greater number of study sites within habitat types with greater deer productivity or deer harvest (i.e., Northwest and Southeast Pine-Hardwood and Bottomland Hardwood habitat types; Table 2.1). Following selection of study sites, we randomly placed 1-m diameter circular exclosures across each of the 9 different habitat types during winter 2011 at ≥40 m from roadways or access trails to avoid effects of edge habitat. Exclosures were placed according to predetermined strata (see below) and constructed of 1.22 m, high wire fencing with 10.16 × 10.16 cm openings to prevent deer from browsing new plant growth.

Within the Northwest and Southeast Pine-Hardwood habitat types, strata were assigned according to stand age, thinning, and burn history. We placed 10 exclosures within stands 1-5 years old, 6-15 years old, 16-24 years old thinned and without a burn history, 16-24 years old non-thinned and with a burn history, 25+ years old with a burn history, and 25+ years old without a burn history. These strata were chosen to ensure sampling occurred across the range of representative seral stages in that particular habitat type. Each of the strata was sampled at 3 study sites in the Northwest Pine-Hardwood habitat region and at 2 sites in the Southeast Pine-Hardwood habitat type (for a total of 30 and 20 exclosures respectively in each stratum).

Within the Bottomland Hardwood habitat type, strata included stands aged 1-10, 11-20, 21-30, and 31+ years old. These strata were sampled at 3 study sites. All other habitat types (Historic Longleaf, Longleaf Flatwoods, Upland Hardwood, Swamp Hardwood, Coastal Prairie, and Coastal Marsh) were sampled within a single stratum because habitats on these study sites were dominated by a single seral stage. The Historic Longleaf, Upland Hardwood, and Swamp Hardwood habitat types were sampled at 2 study sites with 20 exclosures each (1 study site in the Upland Hardwood region was an exception with only 10 exclosures due to small area of habitat available) since they were suspected to be less productive for deer than the Bottomland Hardwood, Southeast and Northwest Pine-Hardwood habitat types and more productive than Coastal Prairie and Coastal Marsh (each with 1 study site and 10 exclosures).

Table 2.1. Number of exclosures sampled within each habitat type and stratum in Louisiana during 2011 and 2012.

Habitat Type	Strata Description	Number of Exclosures
Northwest Pine-Hardwood	1-5	30
Northwest Pine-Hardwood	6-15	30
Northwest Pine-Hardwood	16-24 thinned, without burn history	30
Northwest Pine-Hardwood	16-24 non-thinned, with burn history	30
Northwest Pine-Hardwood	25+ with burn history	30
Northwest Pine-Hardwood	25+ without burn history	30
Southeast Pine-Hardwood	1-5	20
Southeast Pine-Hardwood	6-15	20
Southeast Pine-Hardwood	16-24 thinned, without burn history	20
Southeast Pine-Hardwood	16-24 non-thinned, with burn history	20
Southeast Pine-Hardwood	25+ with burn history	20
Southeast Pine-Hardwood	25+ without burn history	20
Bottomland Hardwood	1-10	30
Bottomland Hardwood	11-20	30
Bottomland Hardwood	21-30	30
Bottomland Hardwood	31+	30
Upland Hardwood		30
Swamp Hardwood		40
Historic Longleaf		40
Longleaf Flatwoods		20
Coastal Prairie		10
Coastal Marsh		10
Total		570

Data Collection and Analysis

After allowing new plant growth to occur during spring of 2011 and 2012, we clipped all new plant growth from each exclosure, separated by species, to represent consumable forage in each habitat type and stratum. We sampled study sites beginning in southern Louisiana in early May and ending in late June at northern sites to compensate for time since greenup. Upon collection of samples during 2011, we repositioned exclosures adjacent to the original point to prevent sampling of the same plants in both years. During 2012, we attempted to collect species not analyzed for nutritional characteristics during 2011 so that nutritional data could be gathered on as many observed species as possible. When necessary, we collected additional samples that did not appear to have been browsed from outside the exclosures to help obtain enough of a sample to be analyzed for nutrition.

Plant samples were frozen and then dried for 72 hours in a forced-air oven. We dried samples during 2011 at 70°C and samples in 2012 at 60°C. The change to a lower drying temperature was a result of unexpectedly low crude protein (CP) results received for samples collected in 2011. Previous research has noted that higher drying temperatures may contribute to negative effects on nutritional analyses by inflating estimated lignin content (Nastis and Malechek 1988, Davis and Wilkins 1998). All samples collected were weighed once the drying period was complete. Samples collected from outside the exclosures did not contribute to weights recorded for the species sampled from within.

During 2011, composite samples of species from each study site which met a required weight minimum of 10 g were sent to the Louisiana State University (LSU) Agricultural Center Forage Quality Laboratory at the Southeast Research Station (Franklinton, LA) for nutritional analysis. Due to the required weight minimum, samples of the same species collected from the same study site were combined to increase the number of samples which could be submitted for analysis. Samples from different study sites within the same habitat type, but of the same species, were treated as separate samples to account for potential differences due to local environmental conditions (Krueger and Donart 1974, Jones et al. 2008). All 2012 samples were analyzed by the Texas A&M University Soil, Water and Forage Testing Laboratory (College Station, TX).

Nutritional analyses included CP concentrations, dry matter (DM), acid and neutral detergent fiber (ADF, NDF), and minerals (including Ca, P, Mg, K, Cu, Mn, and Zn). All data reported from the analyses are presented on a dry matter basis (kg/ha). In addition to evaluating mean CP levels, we calculated a weighted CP value for each habitat type by multiplying the CP of each sample analyzed by its respective quantity collected, summing those subsequent values for each deer forage species, and then dividing by the overall amount of forage collected in the habitat type. This provided a relative comparison of the habitat types by reflecting the abundance and quality of each forage species analyzed across the study sites.

The values for CP and ADF for each of the samples analyzed were used to produce an estimate of total digestible nutrients (TDN) and then further converted into estimates of digestible energy (DE) on the assumption that 1 g of TDN contained 4.41 kcal of DE (Burroughs et al. 1958). The LSU Southeast Research Station provided 3 formulas for TDN, a cool-season formula (TDN=87.46+0.2*((CP*0.816)-2.38)-(ADF*0.91)), a warm-season formula (TDN=87.6+0.38*((CP*0.876)-3.36)-(ADF-0.8)), and an alfalfa formula (TDN=4.898+(NEL* 89.796), NEL=1.044-(0.0119*ADF)). Forage testing labs typically only analyze samples from agricultural settings. As a result, formulas used to calculate TDN values are not necessarily intended for use with forest plants; therefore, the values generated from the 3 formulas provided by LSU were instead averaged for each sample and the subsequent average value converted to DE.

We compared mean CP and DE of all samples analyzed within each habitat type within year using a one-way analysis of variance (ANOVA) with the GLM procedure in SAS ®, Version 9.3 (SAS Institute, Inc. 2012). We used Tukey's (HSD) test to identify significant separations among the means with α=0.05. Nutritional differences between years were not evaluated statistically due to changes in drying temperature and the testing labs used for reporting nutritional results.

Results

Louisiana experienced a record drought during 2011 with a 34.7 cm departure from average in rainfall during the period from December 2010 to May 2011. As a result, samples from 2012 are given more emphasis as they are apt to more closely represent normal foraging conditions for deer. Not surprisingly, nutritional quality and plant productivity generally increased during 2012. Drought is suspected to be the main influence in nutritional differences between years, but the use of different testing labs and drying temperatures also may have contributed to the observed differences between years.

We observed considerable variability in nutrient availability across plant species and habitat types as well as individual study sites. A complete listing of weighted CP according to stratum and study site for each year is included in Appendix A. Likewise, Appendix B provides CP for every species analyzed within each habitat type. Japanese honeysuckle (*Lonicera japonica*), common ragweed (*Ambrosia artemisiifolia*), sawtooth blackberry (*Rubus argutus*), and common greenbrier (*Smilax rotundifolia*) each are important browse species for deer and their results for CP demonstrate the degree of nutritional variability observed (Figures 2.1 and

2.2). Common ragweed, for instance, ranged from 5.36 to 16.26 % CP across all samples analyzed for nutrition during 2012. Sawtooth blackberry likewise ranged from 5.99 to 11.60%.

Northwest Pine-Hardwood was characterized with the greatest number of plant species sampled (Table 2.2) which was likely influenced by the greater sampling intensity, as reflected by the lower SE. Swamp Hardwood was characterized by fewer plant species sampled than other habitat types, most notably during 2011, but had the greatest weighted CP during 2012 (Figure 2.3). The plant species observed in the Swamp Hardwood habitat type during 2012 were present during 2011, but the drought conditions appeared to reduce the availability of species relative to more normal conditions present during 2012. This notable change in availability of plant species paralleled the observed difference in CP values between years.

Statistical differences between the overall mean CP of each habitat type during 2012 indicated that differences existed ($F_{8,428} = 6.97$, $P<0.001$). The pine-hardwood and hardwood-dominated habitat types displayed greater levels of CP except Northwest Pine-Hardwood, which was significantly lower than the Bottomland Hardwood and Swamp Hardwood habitat types (Table 2.3). Among habitat types, Bottomland Hardwood was consistently near the top of the nutritional quality spectrum and tended to follow expectations as compared to 10-year averages (2001-2010) of weights and antler measurements for deer harvested in that habitat type (Table 2.4). The Historic Longleaf and Longleaf Flatwoods habitat types were each among the lowest quality habitats. Exceptionally low values of 5.92% and 5.90% weighted CP were observed for Longleaf Flatwoods during 2011 and 1 of the study sites in Historic Longleaf during 2012, respectively. The deficiency exhibited by each longleaf habitat indicates their reduced forage potential for sustaining healthy deer populations.

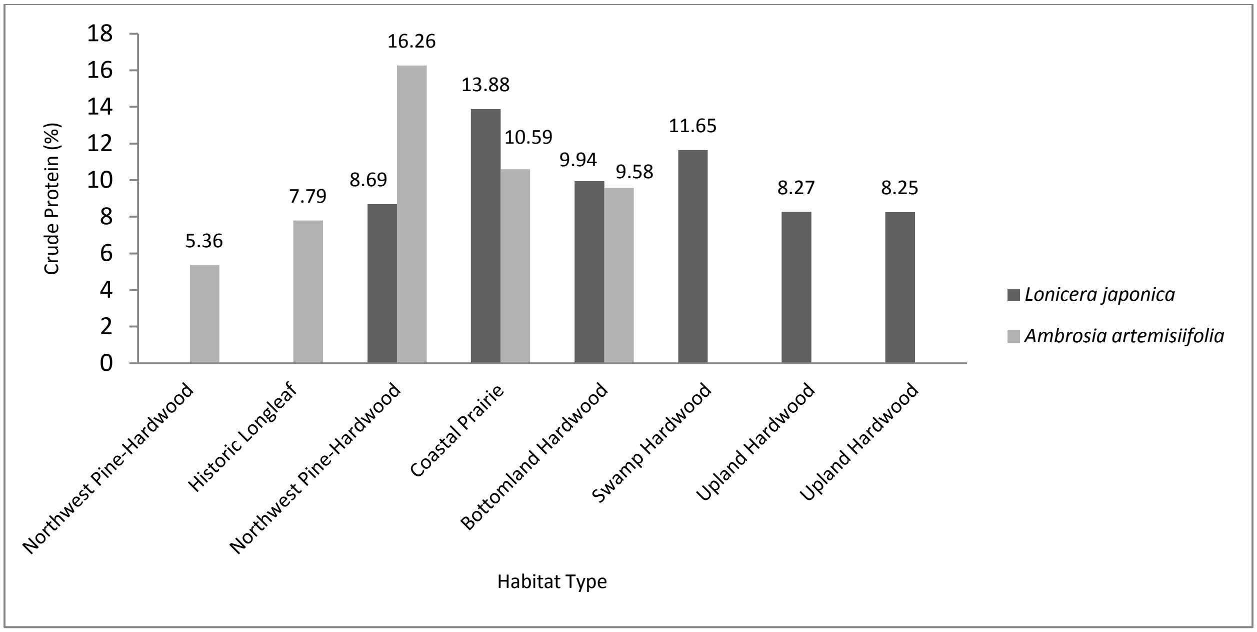

Figure 2.1. Crude protein levels for each sample of Japanese honeysuckle (*Lonicera japonica*) and common ragweed (*Ambrosia artemisiifolia*) submitted for nutritional analysis during 2012 in Louisiana. Samples of the same habitat type are from different study sites.

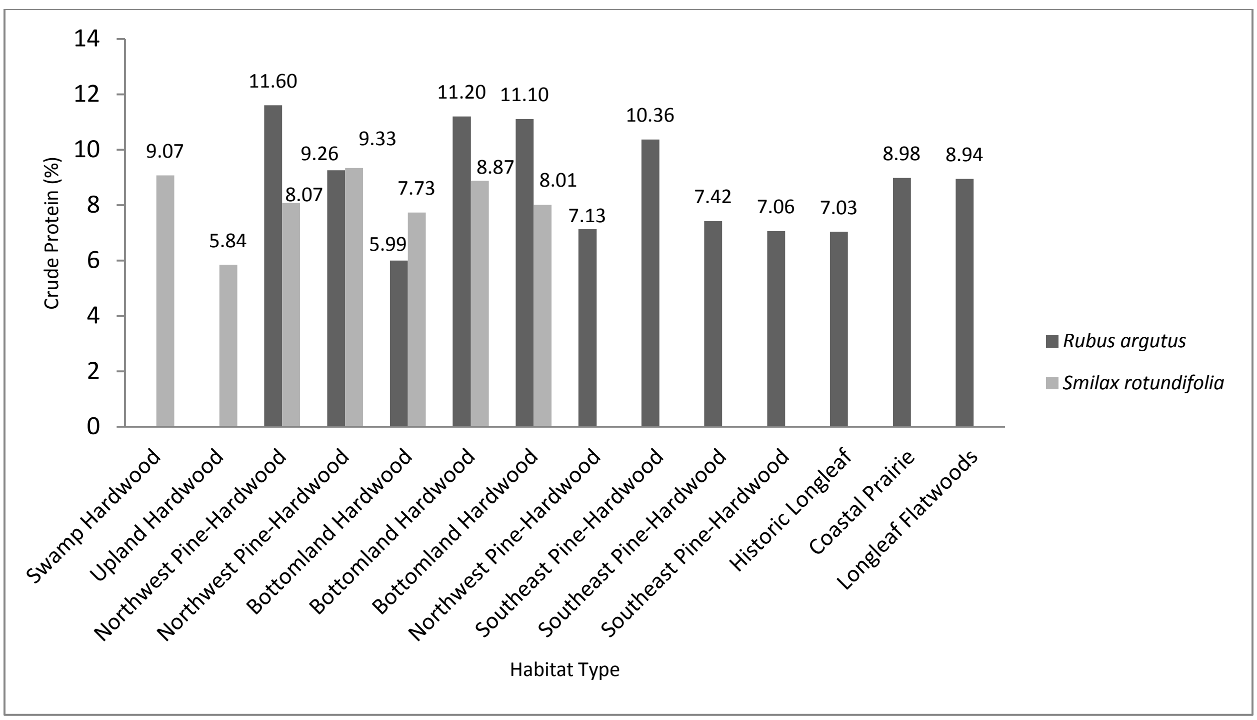

Figure 2.2. Crude protein levels for each sample of sawtooth blackberry (*Rubus argutus*) and common greenbrier (*Smilax rotundifolia*) submitted for nutritional analysis during 2012 in Louisiana. Samples of the same habitat type are from different study sites.

Table 2.2. Number of plant species collected and samples analyzed for nutrition within 9 habitat types across Louisiana during 2011 and 2012.

Habitat Types	Number of Exclosures	2011 Sampled	2011 Analyzed[1]	2012 Sampled	2012 Analyzed[1]
Northwest Pine-Hardwood	180	96	78	115	134
Southeast Pine-Hardwood	120	83	67	82	76
Bottomland Hardwood	120	88	57	79	79
Upland Hardwood	30	56	16	55	30
Swamp Hardwood	40	16	5	36	26
Historic Longleaf	40	36	27	55	39
Longleaf Flatwoods	20	37	17	33	19
Coastal Prairie	10	16	7	27	21
Coastal Marsh	10	18	10	19	13
Total	570	446	284	501	438

[1]The number of species analyzed included some duplicates of the same species except for Longleaf Flatwoods, Coastal Prairie, Coastal Marsh, and Swamp Hardwood (only in 2011) since multiple study sites were sampled and differences in nutritional value may have existed between study sites even within the same habitat type.

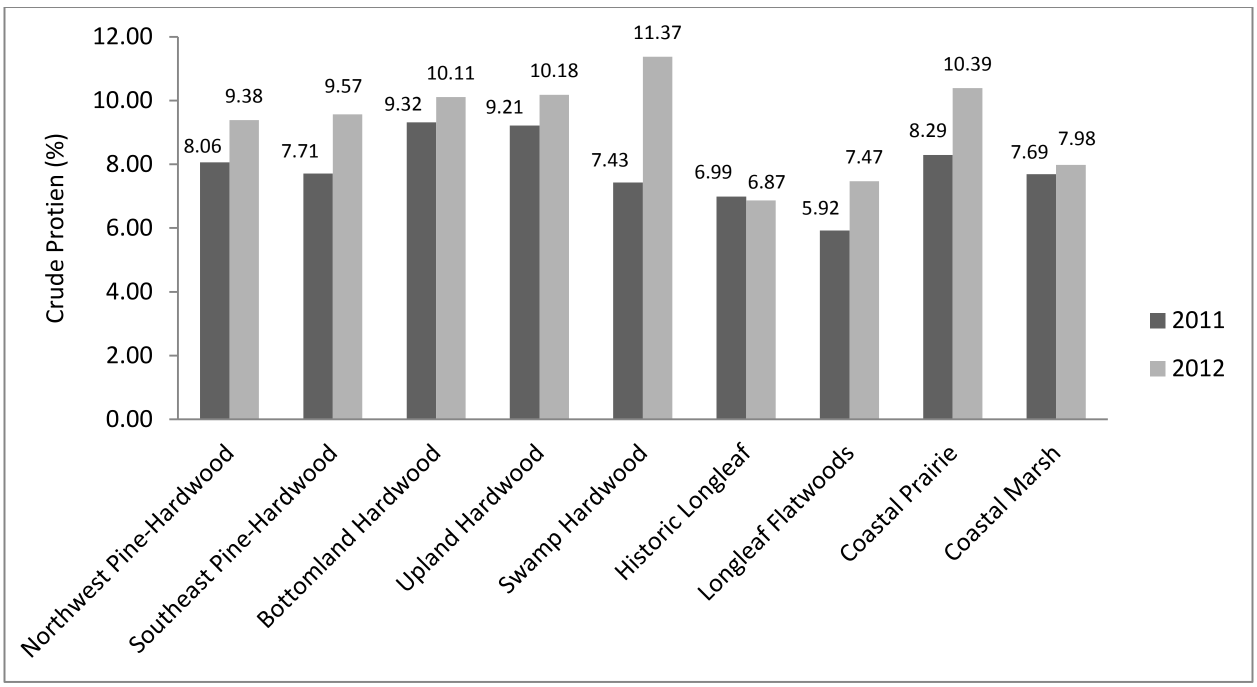

Figure 2.3. A weighted calculation of crude protein (CP) levels for all samples analyzed for nutrition in each habitat type during 2011 and 2012 in Louisiana. Calculations are CP levels weighted by the amounts of each sample collected and exclude samples of species not considered deer forage.

Table 2.3. Mean crude protein (CP) concentrations ±SE and range in CP across all samples analyzed in 9 habitat types in Louisiana during 2012. Habitat types with the same letter are not significantly different (α=0.05).

Habitat Type	CP (%)	SE	Range	Sample Size	Significant Differences
Swamp Hardwood	11.87	1.50	6.1 – 22.9	26	A
Upland Hardwood	10.37	0.82	5.8 – 16.4	30	A, B, C
Bottomland Hardwood	10.16	0.69	5.4 – 20.6	79	A, B
Southeast Pine-Hardwood	9.47	0.60	5.0 – 16.9	76	B, C
Coastal Prairie	9.43	1.30	4.6 – 19.5	21	A, B, C, D
Coastal Marsh	9.43	1.55	5.6 – 16.0	13	A, B, C, D
Northwest Pine-Hardwood	8.90	0.44	5.3 – 17.0	134	C, D
Longleaf Flatwoods	8.25	1.34	4.7 – 18.4	19	B, C, D
Historic Longleaf	7.43	0.78	3.5 – 12.8	39	D

Table 2.4. Comparison of mean CP during 2012 to 10-year averages of weights and antler measurements for 4.5+ year old male deer harvested in each habitat type (except Coastal Prairie) from 2001-2010 for the Deer Management Assistance Program in Louisiana.

			Antler Measurements (cm)		
Habitat Type	CP (%)	Weight (kg)	Base	Length	Spread
Swamp Hardwood	11.87	73.5	9.91	41.40	33.53
Upland Hardwood	10.37	82.6	11.94	46.48	37.59
Bottomland Hardwood	10.16	87.1	11.43	48.77	39.88
Southeast Pine-Hardwood	9.47	77.1	11.18	46.74	38.10
Coastal Marsh	9.43	69.4	10.41	41.40	33.53
Northwest Pine-Hardwood	8.90	78.5	10.16	45.72	37.08
Longleaf Flatwoods	8.25	68.5	9.40	37.08	32.51
Historic Longleaf	7.43	76.7	10.41	45.72	37.85

Across all habitat types, DE levels were greater during 2011 than during 2012 (Figure 2.4), contrary to what was observed for CP. Some inconsistencies were noted between years, with some habitat types having comparatively high observed values in 1 year and very low in the other (i.e., the Coastal Prairie habitat type decreased from 3.02 kcal/g in 2011 to 2.11 in 2012), but the overall range of values in each given year was relatively small. During 2012 there was no statistical difference among habitat types ($F_{8,428}$=0.90, P=0.51); particularly, calculations for DE weighted by the amounts collected for each of the forage species sampled ranged from 2.03 kcal/g (Swamp Hardwood) to 2.29 kcal/g (Coastal Marsh); however, the values for the other habitat types were all very similar.

Mean overall concentration of minerals, reported in parts per million (ppm), was also calculated to identify any trends or differences among each of the habitat types (Table 2.5). Like CP, concentrations of P, Ca, Mg, Zn, and Mn each generally increased from 2011 to 2012. Concentrations of P tended to be greatest in Bottomland Hardwood and Swamp Hardwood sites with respective means of 2,698 and 2,340 ppm during 2011 and 2,727 and 2,965 ppm during 2012. Overall, the Longleaf Flatwoods and Historic Longleaf habitat types were consistently among those with the lowest levels of most minerals (particularly P, Ca, and Mg) during both years.

Nutritional tests revealed a wide variation in concentrations of minerals among species. Using samples collected at 1 of the study sites in the Southeast Pine-Hardwood habitat type as an example, during 2012 values ranged from 3,431 (yellow jessamine, *Gelsemium sempervirens*) to 13,454 (arrowwood, *Viburnum dentatum*) for Ca, 3 (waxmyrtle, *Morella cerifera*) to 16 (American beautyberry, *Callicarpa americana*) for Cu, 692 (tree sparkleberry, *Vaccinium arboreum*) to 2,377 (Goldenrod, *Solidago* sp.) for P, 3,910 (tree sparkleberry) to 21,345

(Goldenrod) for K, 794 (horseweed, *Conyza canadensis*) to 6,384 (roundleaf thoroughwort, *Eupatorium rotundifolium*) for Mg, 71 (horseweed) to 3,150 (yaupon, *Ilex vomitoria*) for Mn, 5 (yellow jessamine) to 6,375 (eastern baccharis, *Baccharis halimifolia*) for Na, and 24 (persimmon, *Diospyros virginiana*) to 241 (*Andropogon* sp.) for Zn.

Additionally, some consistencies were noted between years. During 2011, of the samples analyzed for the same study site in the Southeast Pine-Hardwood habitat type, American beautyberry was 1 ppm from being the highest in Cu, tree sparkleberry was the lowest in K, persimmon was the lowest in Zn, roundleaf thoroughwort was the second highest in Mg (behind only American pokeweed, *Phytolacca americana*), and yaupon was also the highest in Mn. During both years, yaupon exhibited high concentrations of Mn and eastern baccharis contained consistently high levels of Na (only tested for in 2012) across all habitat types and study sites.

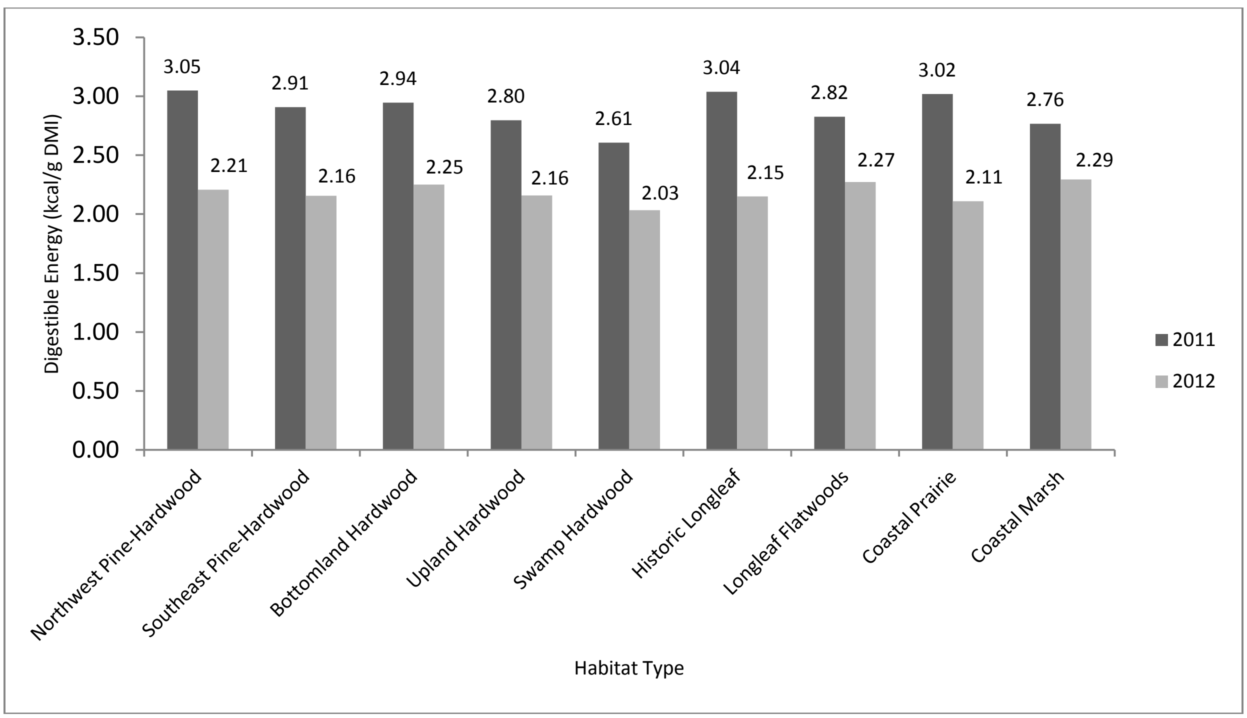

Figure 2.4. A weighted calculation of digestible energy (DE) levels measured in kilocalories/gram of Dry Matter Intake (DMI) for all samples analyzed in each habitat type in Louisiana during 2011 and 2012. Calculations are DE levels weighted by the amounts of each sample collected and exclude samples of species not considered deer forage.

Table 2.5. Summary of mean concentration in ppm (±SE) of selected minerals present within plant samples collected in each habitat type in Louisiana during 2011 and 2012. Sample size represents the number of samples submitted for nutritional analysis. Abbreviated habitat types are: Northwest Pine-Hardwood (NWPH), Southeast Pine-Hardwood (SEPH), Bottomland Hardwood (BH), Historic Longleaf (HL), Longleaf Flatwoods (LF), Coastal Marsh (CM), Coastal Prairie (CP), Swamp Hardwood (SH), and Upland Hardwood (UH).

	Sample Size		Phosphorus		Potassium		Calcium		Magnesium	
Habitat Type	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
NWPH	78	134	753 (151)	1048 (117)	11026 (1769)	13745 (979)	7679 (1071)	9576 (1089)	2319 (333)	2931 (280)
SEPH	70	76	790 (160)	1156 (156)	12433 (1868)	11135 (1299)	6417 (1130)	8118 (1446)	2381 (352)	2771 (372)
BH	57	79	2698 (178)	2727 (153)	22077 (2070)	17709 (1275)	11661 (1253)	14517 (1418)	2861 (390)	3540 (366)
UH	18	30	1833 (316)	2374 (248)	22894 (3684)	19266 (2069)	10683 (2229)	12518 (2302)	3622 (694)	3300 (593)
SH	5	26	2340 (600)	2965 (267)	33820 (6989)	22747 (2223)	7560 (4229)	10551 (2473)	3560 (1316)	3462 (636)
HL	27	39	415 (258)	881 (217)	8993 (3007)	18775 (1814)	6274 (1820)	8367 (2019)	2019 (566)	2502 (520)
LF	17	19	388 (129)	982 (276)	9106 (1882)	14657 (1850)	3906 (1774)	5167 (913)	1359 (335)	2058 (353)
CP	7	21	643 (174)	1240 (183)	14857 (1968)	10345 (1066)	8429 (3234)	9932 (2682)	2571 (675)	3703 (778)
CM	10	13	1565 (330)	1668 (344)	13910 (2251)	14262 (1874)	5450 (1957)	7830 (1564)	2580 (933)	3237 (427)

Table 2.5 continued.

	Sample Size		Zinc		Copper		Manganese	
Habitat Type	2011	2012	2011	2012	2011	2012	2011	2012
NWPH	78	134	27 (12)	57 (13)	8.91 (1.13)	6.72 (0.83)	340 (50)	568 (105)
SEPH	70	76	25 (13)	50 (18)	5.56 (1.19)	6.91 (1.10)	451 (53)	812 (139)
BH	57	79	44 (14)	93 (17)	8.77 (1.32)	9.25 (1.08)	105 (58)	187 (136)
UH	18	30	29 (26)	84 (28)	8.61 (2.35)	8.94 (1.75)	248 (104)	346 (221)
SH	5	26	60 (49)	70 (30)	5.40 (4.46)	8.33 (1.88)	705 (197)	405 (238)
HL	27	39	14 (21)	48 (25)	4.26 (1.92)	5.66 (1.54)	375 (85)	483 (194)
LF	17	19	27 (8)	70 (18)	5.35 (1.74)	6.53 (1.04)	354 (99)	754 (264)
CP	7	21	25 (11)	87 (20)	7.57 (1.59)	8.01 (1.10)	227 (154)	321 (124)
CM	10	13	19 (8)	60 (11)	2.60 (0.84)	3.09 (0.67)	98 (61)	115 (34)

Discussion

Many species which are generally regarded as important browse species for deer across Louisiana exhibited nutrient levels lower and more variable than anticipated. The high degree of variability in CP, DE, and the minerals we observed may be due to a variety of reasons including inherent differences among plant species, differing soil types and physiographic location, unequal levels of rainfall, and anthropogenic influences (e.g., thinning or herbicide application). Likewise, differences in shade intensity can alter the nutrient quality and digestibility of browse leaves (Blair et al. 1983). It is apparent that some nutrient levels are not closely associated with the other metrics evaluated. For instance, a higher CP did not correspond to higher DE. During 2011, the Northwest Pine-Hardwood habitat type did not have a particularly high weighted calculation of CP, whereas its weighted DE calculation was the greatest. However, during 2012 both CP and DE levels for the same habitat type were moderately low, suggesting a lack of correlation between these 2 measures of nutrition. Additionally, the use of different forage testing labs between years may have had an influence on the differences in data observed between years.

Crude protein is generally the most commonly used variable in nutrient analyses and, therefore, is easily compared to past observations. Our results for CP were lower than those reported in other studies for the same species (Edwards et al. 2004, Iglay 2010). During 2011, Louisiana experienced a historical drought with a departure from normal of 34.7 cm in precipitation during the December 2010-May 2011 period, which could have resulted in lower levels of CP and higher variability. Lashley and Harper (2012) reported that extreme drought could reduce CP concentrations, with some species declining to less than half their reported CP during a normal precipitation year (i.e., American pokeweed, *Phytolacca americana*, ranged from 11.06% CP during a drought year to 29.81% during a normal precipitation year). However, the lower CP levels reported during the drought year of their study were noticeably higher than some levels observed in ours. For instance, Lashley and Harper (2012) reported a CP of 7.76% for *Vaccinium* sp., whereas samples from the Southeast Pine-Hardwood habitat type during 2011 ranged from 3.74 to 6.74%.

Grace (2010) collected nutritional data on 2 study sites we used (1 each in the Northwest and Southeast Pine-Hardwood habitat types) and also observed CP levels lower than the 14% level necessary for lactation. Grace (2010) reported 12.46% CP for brambles (*Rubus* spp.), whereas we observed values ranging from 5.78 to 9.26% on the same study sites. Specifically, for sawtooth blackberry across all study sites, we obtained values in 2012 ranging from a sample in the Bottomland Hardwood habitat type with a low of 5.99% to another with a high of 11.6% in the Northwest Pine-Hardwood habitat type. Likewise, Grace (2010) reported 7.24% CP for bracken fern, whereas we observed values ranging from 3.66 to 10.49%. This degree of variation indicates the wide difference in nutrition deer can potentially obtain not only from year to year depending on environmental condition, but also from the same plant species in the same year. The common ragweed samples that were analyzed also displayed a wide range in CP, but even for the sample reported with 5.36% it is possible portions of that particular plant may have had higher CP than other portions and, thus, deer could still obtain necessary nutrition by only selecting the higher quality portions.

We only sampled the succulent portions of plants that deer would presumably consume, but deer are more selective in their browsing than we were in our sample collection, particularly for plants in later growth stages. The variability we observed could have partially resulted from the stage at which plants were collected in their growth cycle. Nutrient composition may decrease as an individual plant increases in maturity (Kilcher 1981). Kilcher and Troelsen

(1973) found that smooth bromegrass (*Bromus inermis*) ranged from as much as 25% CP in the early stage of growth to near 8% at maturity. Smooth bromegrasss may be an extreme example, but it demonstrates the potential for variability in nutrient composition as plants age. We sampled study sites in approximately a 40-day time period which generally progressed from 1 habitat type to the next and because different plants have different rates of maturity, definitively identifying effects of plant maturity on the samples we collected proved infeasible. Nonetheless, plant maturity could have contributed to the nutritional variability we observed.

Very few data have been reported regarding mineral levels for many of the species we analyzed. As was noted for CP, a wide range was apparent in the levels for each mineral across the habitat types and study sites. However, the Bottomland Hardwood habitat type appeared to have consistently greater levels of most minerals (particularly P, K, and Ca) than other habitat types, as well as an overall CP level among the greatest observed. This may be expected considering age-specific antler development is greater in Bottomland Hardwood than in the other habitat types in Louisiana (Moreland 2005). Study sites in the Bottomland Hardwood, Swamp Hardwood, and Upland Hardwood (only 1 of 2 study sites) habitat types were above the 2,500 ppm level of P determined by Ullrey et al. (1975) to be necessary for optimal growth in young deer. All other habitat types exhibited levels below 2,500 ppm, although each contained 1 or more species which exceeded the 1,400 ppm level deemed necessary for adult deer by Grasman and Hellgren (1993). For Ca, all habitat types except Longleaf Flatwoods had mean levels that exceeded the 4,000-5,100 ppm requirement for growing fawns listed by Ullrey et al. (1973).

Not surprisingly, the habitat types which have greater observed nutrient levels and those seemingly more deficient correlated with data collected for the Deer Management Assistance Program in Louisiana. Ten-year averages of measurements for male deer harvested in the

Longleaf Flatwoods and Historic Longleaf habitat types display lower body weights and smaller antler measurements than male deer harvested in other regions of the state (Durham 2011). Likewise, the measurements recorded for deer harvested in the Bottomland Hardwood habitat type, including antler scores using the Boone and Crockett system, are generally the highest. This also follows what has been found in Mississippi where body mass of both male and female deer harvested across the state has been correlated to the fertility of soils and the body mass growth rate was found to be slower in less fertile regions (Strickland and Demarais 2000). As a result, it is logical to conclude that soil fertility and subsequent forage quality in different habitat types across Louisiana does influence deer productivity and performance.

The subtleties of various nutrients and their impact and occurrence are complex, especially when combining them with the influences from other factors that contribute to carrying capacity. Our results reveal that some nutritional differences do exist among predominant habitat types across the landscape in Louisiana, but levels of nutrients can vary considerably, even for the same nutrient within the same plant species depending on location, individual plant age, and environmental conditions. As a result, management efforts focused on improving habitat quality for deer should focus on promoting plant diversity. The apparent disproportionate concentration of nutrients in forage across the landscape suggests that although some species may be deficient in certain nutrients, others may provide higher levels and, thus, an alternate avenue of attaining necessary nutrition. Regardless of the observed variation in nutrients, evaluating the nutritional quality in a given area can prove useful by providing a relative idea of the habitat's ability to sustain deer and where nutritional deficiencies in forage may exist.

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CHAPTER 3

AN INDEX FOR ASSESSING HABITAT CAPABILITY FOR WHITE-TAILED DEER ACROSS NINE MAJOR HABITAT TYPES IN LOUISIANA, USA[1]

[1] Horrell, L.B. and M.J. Chamberlain. 2013. To be submitted to the Journal of Wildlife Management.

Abstract

Many states are faced with the challenge of managing white-tailed deer (*Odocoileus virginianus*) herds across diverse habitat types and variable physiographic regions. Using forage quality and abundance to produce an index of habitat capability during the growing season could prove valuable to land managers by guiding actions intended to improve habitat quality. We selected study sites distributed across 9 primary habitat types and placed 570 exclosures within various forest successional stages during January-March 2011. We collected samples representing consumable plant forage from each exclosure during May-June of 2011 and 2012. Samples were dried and weighed to estimate biomass production and then analyzed for crude protein, dry matter, acid and neutral detergent fiber, and total digestible nutrients. We entered these data into a nutritional constraints model to predict deer-days of foraging capacity for each primary habitat type as an index to assess their ability to support deer populations. We then created an index based on the forage species composition that could be used to assess habitat quality. Early successional habitats and those managed with fire in the Northwest and Southeast Pine-Hardwood habitat types each displayed a high forage index. Coastal Marsh and Coastal Prairie revealed the greatest difference in forage production between years, increasing by more than 200% in their estimated forage production and calculated forage index in 2012.

Introduction

White-tailed deer (*Odocoileus virginianus*) are of significant economic and recreational importance in the United States. In Louisiana, there were approximately 158,600 deer hunters during the 2010-2011 season and they harvested an estimated 133,000 deer (Durham et al. 2012). The importance of deer hunting in Louisiana necessitates a thorough understanding of deer populations and factors that influence those populations.

White-tailed deer are capable of persisting across a wide range of habitats. However, densities vary among physiographic regions, due in part to differences in habitat composition and forage quality (Potvin and Huot 1983, Roseberry and Woolf 1998, Mixon et al. 2009, Lashley et al. 2011). Within the past 20 years, wildlife managers and deer enthusiasts have become increasingly focused on habitat management. With the increasing emphasis on improved habitat quality, there is recognition that not all habitats are equal in their capabilities to support sustainable deer herds. Because deer are herbivores, the level and quality of forage production in a given habitat dictates carrying capacity (Edwards et al. 2004, Marshal et al. 2005, Mixon et al. 2009, Iglay et al. 2010) and increases in population size above this limit are likely to reduce herd health (Potvin and Huot 1983, Landete-Castillejos 2002).

In the temperate latitudes of the United States, deer are adapted to acquire appropriate forage to meet seasonally variable nutritional demands (Moen 1978). These needs range from base-level body maintenance, to lactation and support of fawns, to survival through the breeding season and winter when forage availability decreases. Inadequate nutrition during spring and summer may reduce fawn recruitment and compromise future breeding and survivability in adults (Moen 1978, Therrien et al. 2007). Incorporating forage quality and quantity into estimates of carrying capacity could improve evaluations of habitat potential (White 1978, Hobbs and Swift 1985).

Determining the appropriate population size for an area through estimation of a nutritional carrying capacity can prove beneficial to deer management. Hobbs and Swift (1985) demonstrated that a nutritional constraints model using an assessment of habitat production and quality combined with an understanding of the species' nutritional demands could be used to estimate nutritional carrying capacity for herbivores. Numerous studies have since applied this technique to evaluate habitat quality and the effects of various habitat manipulation treatments (McCall et al. 1997, Beck et al. 2006, Iglay et al. 2010, Lashley et al. 2011).

In Louisiana, Moreland (2005) delineated 9 primary deer habitat types, including Northwest Pine-Hardwood, Southeast Pine-Hardwood, Bottomland Hardwood, Upland Hardwood, Swamp Hardwood, Historic Longleaf, Longleaf Flatwoods, Coastal Prairie, and Coastal Marsh. Each of these habitat types is unique and requires a respective understanding of their composition so deer management programs can be formulated that are situation- and location-specific. The 9 habitat types are comprised of different plant communities with variable levels of production in terms of vegetation quantity and quality. Assessing the potential quality of forage within each habitat type during the growing season could provide landowners and managers a tool for improving the management of native plant communities for deer. Therefore, the objectives of this study were to evaluate the production of plants sampled within each primary deer habitat type and produce an index to assess habitat quality based on the quantity and quality of forage available for deer across the primary habitat types in Louisiana.

Methods

Study Sites

Louisiana is characterized by a warm and moist climate. Mean annual rainfall ranges from 190.88 cm (75.15 inches) in the southeastern portion of the state to 122.53 cm (48.24 inches) in the northwestern portion. Temperatures range from a daily mean temperature of 21.1°C (70°F) in the southeastern portion to 17.3°C (63.1°F) in the northwestern portion (National Oceanic and Atmospheric Administration 2012).

We selected study sites within each deer habitat type as defined by Moreland (2005; Figures 3.1 and 3.2). We selected a greater number of study sites and sampling intensity within habitat types where deer productivity or harvest was greater. As a result, the Pine-Hardwood and Bottomland Hardwood habitat types were sampled the most intensively.

Habitat Descriptions

The Northeast and Southeast Pine-Hardwood habitat types are dominated by managed loblolly pine (*Pinus taeda*) forests with varying degrees of a hardwood component often controlled with the use of prescribed fire and herbicide applications. These forests are generally managed intensively using mid-rotation thinning, clearcut timber harvest, artificial reforestation, and fertilization. Common understory species include brambles (*Rubus* spp.), American beautyberry (*Callicarpa americana*), winged sumac (*Rhus copallinum*), grapes (*Vitis* spp.), and yaupon (*Ilex vomitoria*).

Figure 3.1. Primary habitat types for white-tailed deer in Louisiana as described by Moreland (2005).

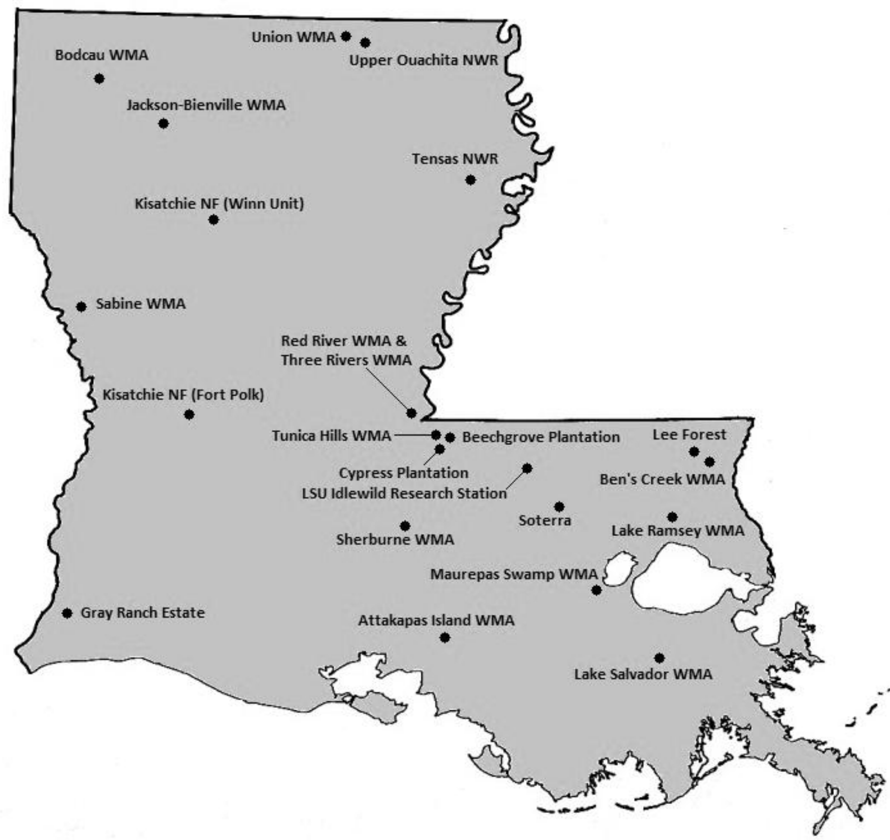

Figure 3.2. Location of study sites in Louisiana where vegetation samples were collected and analyzed for nutritional quality for white-tailed deer during 2011-2012.

The Bottomland Hardwood habitat type is generally regarded as the most productive for deer and supports a diversity of plants. The alluvial floodplains of the Mississippi and Atchafalaya Rivers represent the region of the state where this habitat type is mostly found. Prominent overstory species include sugarberry (*Celtis laevigata*), sweetgum (*Liquidambar styraciflua*), oaks (*Quercus* spp.), elms (*Ulmus* spp), hickories (*Carya* spp.) and maples (*Acer* spp.) The understory is often dominated by poison ivy (*Toxicodendron radicans*), greenbriers (*Smilax* spp.), and palmetto (*Sabal minor*; Wall and Darwin 1999) but varied among study sites. Palmetto is abundant on some sites and virtually absent on others, following a general trend of decreasing abundance as the river basins proceed south.

The Coastal Prairie and Coastal Marsh habitat types are at or near the Louisiana coast. Both habitat types are near sea level with Coastal Prairie being farther inland and restricted to the southwestern region of the state. Coastal Prairie typically contains more agricultural activity, such as cattle grazing and farming of rice or sugar cane. The Coastal Marsh habitat type represents the transition from salt to freshwater marshes along the coast, and is often comprised of a fully saturated and sometimes floating base referred to as floatant. Both habitat types are predominantly open-canopy and exhibit a dense understory layer including grasses (*Dichanthelium* and *Paspalum* spp.), sedges (*Carex* spp.), reeds (including *Juncus* and *Typha* spp.), and woody shrubs (waxmyrtle, *Morella cerifera*, and eastern baccharis, *Baccharis halimifolia*) with tolerance for moist soils.

The Swamp Hardwood habitat type is characterized by saturated soils, with forest communities comprised primarily of bald cypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*). Hydrophytic vegetation is prominent and includes alligator weed (*Alternanthera philoxeroides*), green arrow arum (*Peltandra virginica*), and smartweed (*Polygonum* spp.). This region of the state is primarily restricted to the lower drainage of the Atchafalaya and Mississippi River basins.

Historic Longleaf and Longleaf Flatwoods habitat types are both dominated by mature longleaf pine (*Pinus palustris*) forests and routinely managed using frequent prescribed fire. The Longleaf Flatwoods habitat type is located in southeastern Louisiana, whereas Historic Longleaf is found in the central and west-central region of the state. Longleaf Flatwoods have a lower topographic gradient and are characterized by shallow, sandy soils and high soil moisture that promotes species adapted for those conditions such as pale pitcher plant (*Sarracenia alata*) and sundews (*Drosera* spp.). Both habitat types typically have an open, savannah-like structure, with understory plant communities dominated by grasses such as bluestems (*Andropogon* spp.), bracken fern (*Pteridium aquilinum*), and scattered hardwoods.

The Upland Hardwood habitat type is restricted to the eastern side of the Mississippi River north of St. Francisville, LA and its most noted feature is the rugged terrain and hardwood forest. Dominant canopy species are deciduous hardwoods including oaks (*Quercus* spp.) and hickories (*Carya* spp.) with a shade-tolerant understory including silverbells (*Halesia* spp.), devil's walking stick (*Aralia spinosa*), laurel cherry (*Prunus caroliniana*), Virginia creeper (*Parthenocissus quinquefolia*), and woodoats (*Chasmanthium* spp.), among others.

Sampling Design

We selected study sites at state-operated wildlife management areas (WMAs), national wildlife refuges, national forest, or private properties within each habitat type region of Louisiana. Following selection of study sites (Figure 3.2), we randomly placed 1-m diameter circular exclosures across each of the 9 different habitat types from January to March 2011 at a minimum of 40 m from roadways and access trails in an attempt to avoid effects of edge habitat. Exclosures were constructed of 1.22 m, high wire fencing with 10.16 x 10.16 cm openings to prevent deer from browsing within them. The number of exclosures placed at each study site was based upon predetermined strata (see below) and biased toward habitat types suspected to have greater forage value for deer (Table 3.1).

Within the Northwest and Southeast Pine-Hardwood habitat types, strata were assigned according to stand age, thinning, and burn history. We placed 10 exclosures within stands which were 1-5 years old, 6-15 years old, 16-24 years old thinned and without a burn history, 16-24 years old non-thinned and with a burn history, 25+ years old with a burn history, and 25+ years old without a burn history. These strata were chosen to ensure sampling occurred across all representative seral stages in that particular habitat type. Each of these strata was sampled at 3 study sites in the Northwest Pine-Hardwood habitat region and at 2 sites in the Southeast Pine-Hardwood habitat type (for a total of 30 and 20 exclosures respectively in each stratum).

Within Bottomland Hardwood sites, strata included stands aged 1-10, 11-20, 21-30, and 31+ years old. These strata were sampled at 3 study sites. All other habitat types (Upland Hardwood, Swamp Hardwood, Historic Longleaf, Longleaf Flatwoods, Coastal Prairie, and Coastal Marsh) were sampled within a single stratum because habitats on the study sites were dominated by a single seral stage. The Historic Longleaf, Upland Hardwood, and Swamp Hardwood habitat types were sampled at 2 separate study sites with 20 exclosures each (1 study site in the Upland Hardwood region being an exception with only 10 exclosures due to the small area of habitat available) since they were suspected to be less productive for deer than the Bottomland Hardwood and Southeast and Northwest Pine-Hardwood habitat types and more productive than Coastal Prairie and Coastal Marsh (each with 1 study site and 10 exclosures).

Table 3.1. Number of exclosures sampled within each habitat type and stratum during 2011 and 2012 in Louisiana.

Habitat Type	Strata Description	Number of Exclosures
Northwest Pine-Hardwood	1-5	30
Northwest Pine-Hardwood	6-15	30
Northwest Pine-Hardwood	16-24 thinned, without burn history	30
Northwest Pine-Hardwood	16-24 non-thinned, with burn history	30
Northwest Pine-Hardwood	25+ with burn history	30
Northwest Pine-Hardwood	25+ without burn history	30
Southeast Pine-Hardwood	1-5	20
Southeast Pine-Hardwood	6-15	20
Southeast Pine-Hardwood	16-24 thinned, without burn history	20
Southeast Pine-Hardwood	16-24 non-thinned, with burn history	20
Southeast Pine-Hardwood	25+ with burn history	20
Southeast Pine-Hardwood	25+ without burn history	20
Bottomland Hardwood	1-10	30
Bottomland Hardwood	11-20	30
Bottomland Hardwood	21-30	30
Bottomland Hardwood	31+	30
Upland Hardwood		30
Swamp Hardwood		40
Historic Longleaf		40
Longleaf Flatwoods		20
Coastal Prairie		10
Coastal Marsh		10
Total		570

Data Collection and Analysis

After allowing new plant growth to occur during spring of 2011 and 2012, we clipped all new plant growth from each exclosure, separated by species, to represent consumable forage in each habitat type and stratum. We sampled study sites beginning in southern Louisiana in early May and ending in late June at northern sites to compensate for time since greenup. Upon collection of samples during 2011, we repositioned exclosures adjacent to the original point to prevent sampling of the same plants in both years.

All samples we collected were frozen and then dried for 72 hours in a forced air oven at 70°C in 2011 and 60°C in 2012 due to realization that higher drying temperatures can negatively influence plant nutrition. We then weighed dried samples so that an estimate of biomass production for each observed species could be calculated. Biomass production was estimated for each species in each habitat type and stratum by adding the dried weights of all samples collected within each stratum and habitat type and then dividing by the area encompassed by the respective number of exclosures sampled.

Once samples collected during 2011 had been dried and weighed, we sent composite samples of species from each study site which met a required weight minimum of 10 g to the Louisiana State University (LSU) Agricultural Center Forage Quality Laboratory at the Southeast Research Station (Franklinton, LA) for nutritional analysis. Due to the required weight minimum, samples of the same species collected from the same study site were combined to increase the number of samples which could be submitted for analysis. Samples from different study sites, but of the same species, were still treated as separate samples to account for nutritional differences that may have occurred due to variable local environmental conditions such as soil type (Hundley 1959; Krueger and Donart 1974; Jones et al. 2008).

For analysis of samples collected during 2012, we attempted to give greater attention to species not analyzed for nutritional characteristics from 2011 so nutritional data could be gathered on as many observed species as possible. When observed species were present at amounts clearly less than 10 g, we collected additional samples which did not appear to be browsed from outside the exclosures when possible to obtain enough of a sample for analysis. We kept amounts from inside and outside the exclosures separate so as not to overestimate biomass production. All samples collected during 2012 were analyzed by Texas A&M University Soil, Water and Forage Testing Laboratory (College Station, TX). Data received from the nutritional analyses included levels of crude protein (CP), dry matter (DM), and acid and neutral detergent fiber (ADF, NDF). All nutritional data reported are presented on a dry matter basis (kg/ha).

The values for CP and ADF for each of the samples analyzed were used to produce an estimate of total digestible nutrients (TDN) and then further converted into estimates of digestible energy (DE) on the assumption that 1 g of TDN contained 4.41 kcal of DE (Burroughs et al. 1958). The LSU Southeast Research Station provided 3 formulas for TDN, a cool-season formula (TDN=87.46+0.2*((CP*0.816)-2.38)-(ADF*0.91)), a warm-season formula (TDN=87.6+0.38*((CP*0.876)-3.36)-(ADF-0.8)), and an alfalfa formula (TDN=4.898+(NEL* 89.796), NEL=1.044-(0.0119*ADF)). Forage testing labs typically only analyze samples from agricultural settings. As a result, formulas used to calculate TDN values are not necessarily intended for use with forest plants; therefore, an average of the values generated from the 3 formulas provided by LSU was instead calculated and the subsequent average value for each sample converted to DE.

Forage Quality Evaluation

We used an explicit nutritional constraints model (Hobbs and Swift 1985) to determine nutritional carrying capacity across strata within each habitat type by estimating deer-days of foraging capacity according to diet quality necessary for body maintenance. These calculations should be viewed as an index to the potential value of each habitat and stratum rather than a comprehensive annual carrying capacity because data are based on forage available only during the growing season.

Following Jones et al. (2009), we assumed a daily dry matter intake (DMI) of 1,360 g. We then calculated nutritional carrying capacity based on maintenance requirements for DE (measured in kcal/g DMI) and CP. Specific to DE, we considered a target diet quality for maintenance of 2.2 kcal DE/g DMI (Hellickson and DeYoung 1997), whereas for lactation a target diet quality is acknowledged to be 3.25 kcal DE/g DMI (Campbell et al. 2002, Jones et al. 2009). For CP, we used a target diet quality of 6% CP for body maintenance (Asleson et al. 1996). Previous research has indicated that 14% CP is sufficient to support a lactating female with one fawn (Verme and Ullrey 1984) and antler growth in males (Jones et al. 2009).

Additionally, we calculated a total forage value (TFV) for each stratum within each habitat type by multiplying projected biomass for each species by either 0 (for species not considered browse), 0.5 (for low preference browse), 1 (moderately preferred), or 2 (heavily preferred), and then summing the products within each stratum to yield one value (Jones et al. 2009). Preference ratings were based on S. Durham and D. Moreland (Louisiana Department of Wildlife and Fisheries, personal communication) and supported by published literature (Warren and Hurst 1981, Miller and Miller 1999, Edwards et al. 2004). The subsequent values we calculated for TFV were compared among strata and habitat type, and related to estimates of nutritional carrying capacity to further evaluate the quality of the habitat types.

Results

Louisiana experienced a record drought during 2011 with a 34.7 cm departure from average rainfall during the period from December 2010 to May 2011. As a result, samples from 2012 are given more emphasis as they are apt to more closely represent normal foraging conditions for deer. Not surprisingly, nutritional quality and plant productivity generally increased during 2012. Drought is suspected to be the main influence in nutritional differences between years, but the use of different testing labs may have also had an influence.

Several species were common among habitat types (grapes, brambles, and greenbriers), but overall composition and most prevalent species differed (Table 3.2). Muscadine grape (*Vitis rotundifolia*) and American beautyberry were each among the most prominent species in the Pine-Hardwood habitat types, whereas the Bottomland Hardwood habitat type was dominated by goldenrod (*Solidago* spp.), sawtooth blackberry (*Rubus argutus*), and southern dewberry (*Rubus trivialis*).

During both years, the Northwest Pine-Hardwood habitat type exhibited the greatest number of different species sampled (Table 3.3); however, it was also sampled the most intensively. The Bottomland Hardwood and Southeast Pine-Hardwood habitat types each also displayed a greater number of species than the remaining 6. Coastal Prairie and Coastal Marsh consistently had the fewest number of species sampled; however, these 2 habitats were among the most productive when considering estimated biomass production, most notably during 2012 when more normal precipitation was observed as compared to the drought year of 2011 (Figure 3.3).

Table 3.2. The top 4 species contributing to estimated biomass production (kg/ha) as observed during 2012 at all study sites within each habitat type in Louisiana.

	Primary Plant Composition	
Habitat	Top 4 Contributing Species	Biomass Estimate (kg/ha)
Northwest Pine-Hardwood	*Vitis rotundifolia*	41.3
	Callicarpa americana	41.1
	Liquidambar styraciflua	36.5
	Rhus copallinum	24.3
Southeast Pine-Hardwood	*Rubus argutus*	71.2
	Vitis rotundifolia	66.2
	Ilex vomitoria	55.8
	Callicarpa americana	29.4
Bottomland Hardwood	*Solidago* spp.	56.2
	Rubus trivialis	42.6
	Rubus argutus	37.5
	Desmanthus illinoensis	30.3
Upland Hardwood	*Chasmanthium sessiflorum*	101.9
	Prunus caroliniana	37.4
	Arundinaria gigantea	24.5
	Polystichum acrostichoides	23.5
Swamp Hardwood	*Polygonum punctatum*	108.1
	Rubus trivialis	71.6
	Peltandra virginica	71.2
	Aster spp.	52.8
Historic Longleaf	*Pteridium aquilinum*	116.6
	Rhus copallinum	95.3
	Toxicodendron pubescens	43.2
	Smilax glauca	38.4
Longleaf Flatwoods	*Ilex glabra*	65.1
	Morella cerifera	48.6
	Quercus virginiana	43.1
	Cyrilla racemiflora	41.9
Coastal Prairie	*Morella cerifera*	461.2
	Rosa bracteata	165.5
	Ilex vomitoria	135.1
	Lonicera japonica	105.3
Coastal Marsh	*Sagittaria lancifolia*	992.1
	Thelypteris kunthii	308.9
	Alternanthera philoxeroides	256.9
	Leersia oryzoides	149.7

Table 3.3. Number of plant species collected and analyzed for nutrition within each habitat type in Louisiana during 2011 and 2012.

	2011		2012	
Habitat Types	Sampled	Analyzed[1]	Sampled	Analyzed[1]
Northwest Pine-Hardwood	96	78	115	135
Southeast Pine-Hardwood	83	67	82	76
Bottomland Hardwood	88	57	79	79
Upland Hardwood	56	16	55	30
Swamp Hardwood	16	5	36	26
Historic Longleaf	36	27	55	39
Longleaf Flatwoods	37	17	33	19
Coastal Prairie	16	7	27	21
Coastal Marsh	18	10	19	13
Total	446	284	501	438

[1]The number of species analyzed in the Northwest Pine-Hardwood, Southeast Pine-Hardwood, Bottomland Hardwood, Upland Hardwood, Swamp Hardwood (only in 2012), and Historic Longleaf habitat types included some duplicates of the same species since multiple study sites were sampled and differences in nutritional value may have existed between study sites even in the same habitat type.

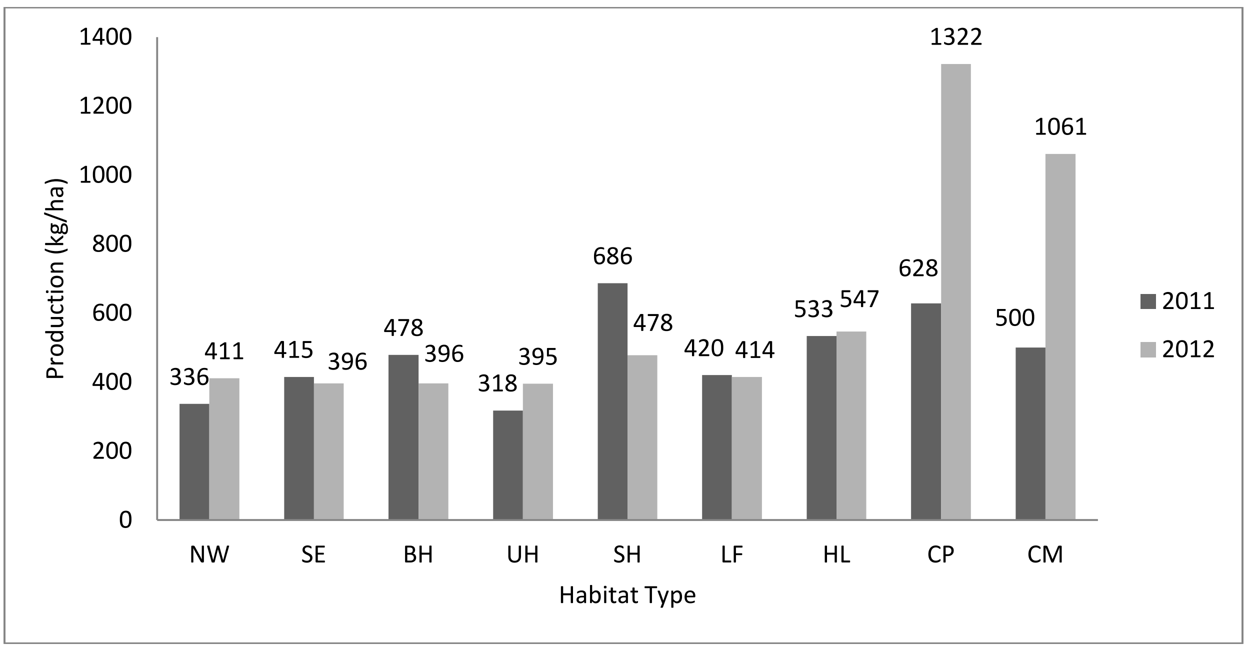

Figure 3.3. Estimated biomass production between 2011 and 2012 based on the amount of plant matter collected in each habitat type in Louisiana. Estimates for Coastal Marsh (CM) and Swamp Hardwood (SH) exclude *Sagittaria lancifolia* and *Peltandra virginica* respectively due to unequal collections between years. Abbreviations on the x-axis indicate habitat type: Northwest Pine-Hardwood (NW), Southeast Pine-Hardwood (SE), Bottomland Hardwood (BH), Upland Hardwood (UH), Swamp Hardwood (SH), Longleaf Flatwoods (LF), Historic Longleaf (HL), Coastal Prairie (CP), and Coastal Marsh (CM).

The 1-10 year old Bottomland Hardwood stands consistently had the highest TFV among all habitat types during both years (Table 3.5). Strata A, D, and E (descriptions in Table 3.5) in both the Northwest and Southeast Pine-Hardwood habitat types also showed high TFV estimates, suggesting greater forage availability in early successional timber stands and those which are managed with fire. Coastal Marsh and Coastal Prairie saw the greatest increase in TFV from 2011 to 2012, increasing by more than 200%.

Unexpectedly low test results regarding DE and CP made carrying capacity calculations at the respective lactation levels impractical since very few samples were at or above the levels necessary for lactation, which led to relative comparisons being drawn at only the basal body maintenance levels. Calculations regarding nutritional carrying capacity and TFV tended to agree in relative comparison between habitat types (Table 3.4). The results, however, should not be viewed as absolute because the sampling design and other factors likely had an influence on the results. For instance, the Bottomland Hardwood habitat type was sampled at a much more intensive rate than Coastal Prairie, thus the results for Bottomland Hardwood are more likely to give an accurate representation of the potential habitat quality.

Table 3.4. Summary of calculations made for each habitat type in Louisiana regarding weighted crude protein (CP, measured in %), weighted digestible energy (DE, measured in kcal/gram of dry matter intake), nutritional carrying capacity (NCC) estimates at both 6% CP and 2.2 DE (measured in deer-days/hectare), and total forage value (TFV) during each study year.

	2011					2012				
Habitat Type	CP	DE	NCC (CP)[1]	NCC (DE)[1]	TFV	CP	DE	NCC (CP)	NCC (DE)	TFV
Northwest Pine-Hardwood	8.06	3.05	229.84	229.84	456.05	9.38	2.21	303.45	265.63	613.33
Southeast Pine-Hardwood	7.71	2.91	277.43	277.43	594.42	9.57	2.16	276.35	248.47	587.40
Bottomland Hardwood	9.32	2.94	326.29	326.29	619.29	10.11	2.25	281.58	276.51	560.51
Upland Hardwood	9.21	2.80	187.77	187.77	400.03	10.18	2.16	222.23	171.57	378.82
Swamp Hardwood	7.63	2.61	483.32	483.32	858.70	11.37	2.03	333.92	247.60	627.72
Historic Longleaf	6.99	3.04	366.22	366.22	541.48	6.87	2.15	377.08	334.28	617.87
Longleaf Flatwoods	5.92	2.82	262.61	271.69	528.55	7.47	2.27	280.49	280.49	457.35
Coastal Prairie	8.29	3.02	410.62	410.62	485.49	10.39	2.11	888.37	773.43	1254.71
Coastal Marsh	7.69	2.76	343.31	343.31	562.58	7.98	2.29	655.06	580.15	1279.86

[1]2011 NCC estimates for both CP and DE were the same except for Longleaf Flatwoods since weighted values of CP and DE exceeded the minimum threshold for body maintenance.

Table 3.5. Calculated total forage value (TFV) for each habitat type and stratum during 2011 and 2012 in Louisiana. Calculations are biomass projections weighted by preference ratings of plant species as forage. Letters following the habitat names represent the different strata sampled. Numbers in the strata description indicate age in years of the timber stand.

Habitat Type	Strata Description	2011 TFV	2012 TFV
Northwest Pine-Hardwood A	1-5	651	1142
Northwest Pine-Hardwood B	6-15	238	314
Northwest Pine-Hardwood C	16-24 thinned, without burn history	400	491
Northwest Pine-Hardwood D	16-24 non-thinned, with burn history	463	555
Northwest Pine-Hardwood E	25+ with burn history	720	792
Northwest Pine-Hardwood F	25+ without burn history	264	511
Northwest Pine-Hardwood Total		456	613
Southeast Pine-Hardwood A	1-5	509	421
Southeast Pine-Hardwood B	6-15	211	281
Southeast Pine-Hardwood C	16-24 thinned, without burn history	643	762
Southeast Pine-Hardwood D	16-24 non-thinned, with burn history	961	1189
Southeast Pine-Hardwood E	25+ with burn history	865	640
Southeast Pine-Hardwood F	25+ without burn history	377	231
Southeast Pine-Hardwood Total		594	587
Bottomland Hardwood A	1-10	1023	1014
Bottomland Hardwood B	11-20	598	382
Bottomland Hardwood C	21-30	428	434
Bottomland Hardwood D	31+	428	412
Bottomland Hardwood Total		619	561
Upland Hardwood		400	379
Swamp Hardwood		859	627
Historic Longleaf		541	618
Longleaf Flatwoods		529	457
Coastal Prairie		485	1255
Coastal Marsh		563	1280

Discussion

All results from this study should be interpreted as relative rather than absolute. Although there were 10 exclosures sampled for each habitat stratum, not all plant species present in the various habitat types were observed or could be sampled at amounts necessary for nutritional analysis. Thus, the estimates represent a relative comparison of each habitat type's forage quality and subsequent ability to support deer.

Many factors affect habitat value, but quantity and quality of desirable plant foods is a critical determinant. Despite this recognition, the true overall quality of habitat is dependent on a variety of environmental and anthropogenic variables such as human disturbance and competition from other wildlife. Additionally, deer need sufficient habitat to provide cover from predators and harsh weather events (particularly for northern regions of the U.S. during winter months). As a result, the actual carrying capacity of a given area is not just a function of food availability or quality (Hobbs and Hanley 1990).

Although not all habitats are of equal quality, the level of habitat use by herbivores such as deer may sometimes not be reflective of quality in ways as would normally be expected (i.e., greater quality might not result in greater use). As an example, plant defenses are intended to deter herbivory, but cannot guarantee prevention because forage selection is conditionally dependent on the characteristics of all plants available rather than any individual plant (Belovsky and Schmitz 1994). Theoretical simulations by Hobbs and Hanley (1990) demonstrated the potential for habitats deemed of lesser quality to actually receive greater use by wildlife populations as compared to nearby habitats which may be judged better simply because of higher quality forage.

Findings from Hobbs and Swift (1985) help corroborate the prediction of greater use of lower quality habitats under some circumstances. In their study, burned habitat of mountain shrub in Utah provided higher nutritional forage but at lesser amounts than the lower quality forage found in unburned habitat. As a result, mule deer (*Odocoileus hemionus*) could exist at higher densities in the unburned habitat although the nutritional quality of the available food was not as high as in the burned areas. Our findings show parallels to those of Hobbs and Swift (1985). All but 2 of the study sites provided an overall mean CP sufficient enough to meet needs for body maintenance for deer. The Longleaf Flatwoods study site (in 2011) and 1 from the Historic Longleaf habitat type (in 2012) were the only sites that displayed levels below the 6% threshold Asleson et al. (1996) suggested is necessary to support body maintenance in deer. However, those habitat types did have some species with CP levels above 6% and a relatively significant amount of forage available, thus deer still are able to thrive there.

Not surprisingly, the Longleaf Flatwoods habitat type was one of the most nutritionally deficient habitat types sampled even though it did exhibit predominantly open canopy, moist soil conditions, and relatively similar forage quantity to that of other habitat types. In Florida, the pine flatwoods habitat in the northwestern part of the state has very low nutritional value and deer found there exhibit low body weights and poor antler development (Harlow and Jones 1965). This study correlates with past evaluations of the Florida flatwoods in that relatively significant amounts of deer forage may be available but the nutritional quality is exceptionally low (Harlow 1959; Wood and Tanner 1985). Keyser et al. (2005) cautioned that although physical condition can be dependent on deer density across many landscapes, populations on poor range cannot necessarily be managed traditionally since the physical condition of deer does not explicitly respond to changes in density. In fact, Shea et al. (1992) observed that reductions in deer density in the pine flatwoods of Florida did little to improve physical condition of resident deer. Poor range, such as that of the flatwoods, is typically dictated by the dominant habitat type, but can also be influenced by susceptibility to fluctuations in environmental conditions.

Variations in environmental conditions, whether annual or seasonal, can have important effects on deer carrying capacity. The conditions observed during 2011 were unique in that the growing season experienced a historical drought, whereas that of 2012 experienced more normal precipitation. During 2010-2011, Louisiana had the driest December-September period on record for the state, dating to 1895 (NOAA 2011). By measure of the Palmer Hydrological Drought Index (PHDI), drought intensity reached record levels in the northwest and central regions of Louisiana during September 2011 even though other past drought events were longer in duration (NOAA 2011).

The drought likely caused the consistently lower CP levels during 2011 and the dramatic increases observed in biomass projections and TFV for both the Coastal Marsh and Coastal Prairie habitat types during 2012, both of which increased by more than 200% in TFV. The estimated TFV for 2012 made both Coastal Prairie and Coastal Marsh appear to be the 2 best habitat types. However, the forage found in those habitat types was comprised of fewer species and not of greater nutritional value than that of forage in many of the other habitat types. The dramatic differences in forage production between years also suggest the coastal habitats may have a reduced ability to maintain stable deer populations over long periods of time since forage production can drop dramatically in drought years. The estimates for these habitat types may have also been affected by the reduced sampling rate. Because fewer exclosures were sampled, the potential that individual exclosures could affect our results is greater.

For the most part, forage production did not seem to be significantly affected by the drought outside of Coastal Prairie and Coastal Marsh. The Swamp Hardwood habitat type was an interesting exception. Total forage production in the Swamp Hardwood habitat type was contrary to expectations as it was higher in 2011; this may have resulted from lower water levels in these forested wetlands, which would allow greater soil exposure, seed germination, and subsequent forage growth.

Overall, the habitat types with the most biomass were the areas with the greatest nutritional carrying capacity even though the available forage did not necessarily have the highest nutritional quality. In other words, those areas may be capable of supporting the highest density of deer but not necessarily the most well-nourished deer. By this standard of evaluation, during 2012 the Swamp Hardwood habitat type and the 1-10-year-old Bottomland Hardwood stand would appear to be among the most capable habitats of supporting well-nourished deer, whereas the habitat types that appear to support the greatest number of deer would be Coastal Prairie, and the early successional stands as well as those with a burn history in the Northwest and Southeast Pine-Hardwood habitat types. One particular 1-5-year-old stand in the Northwest Pine-Hardwood habitat region exhibited very high carrying capacity estimates even though it displayed low CP levels. Additionally, the estimates made for Coastal Prairie come with a caveat, because the sampling intensity was very low and much of that habitat is exposed to cattle grazing and farming. As a result, the biomass projections could overestimate the quantity of forage actually available to deer.

For each of the habitat types, the nutritional carrying capacity estimates appear to be higher than expected. For instance, during 2011 and 2012 the combined estimate at the 6% CP level for all 3 study sites and strata in the Bottomland Hardwood habitat type indicated 326 and

282 deer-days of forage per hectare was available in each respective year. This translates to approximately 1.1-1.3 ha of habitat needed to support 1 deer for a year. Expectations according to past knowledge and surveys are that approximately 2-4 ha is necessary to support 1 deer for a year in the Bottomland Hardwood habitat type (Scott Durham, Louisiana Department of Wildlife and Fisheries, personal communication). However, it is important to note that the estimated nutritional carrying capacity estimates were made at the body maintenance level, not the higher lactation level needed to sustain a more healthy population. Furthermore, the samples collected for our study were only collected during the growing season, providing only a snapshot in time and are not fully representative of forage quality during other times of the year. As a result, the calculations are likely a best-case scenario for the number of hectares necessary to support a deer during only late spring and summer. The amount of land needed for an entire year is undoubtedly higher.

Management actions like thinning and burning are often successful ways of increasing habitat potential by encouraging greater forage production. By promoting sunlight to the forest understory and encouraging plant growth, the availability of nutrients in forage should increase (Conroy et al. 1982). Among the study sites, most habitats with a predominantly open canopy with moist soils (such as the sites representing Coastal Prairie, Coastal Marsh, and the 1-10-year-old stands in the Bottomland Hardwood habitat type) displayed greater biomass production and calculated TFV. The TFV calculations, primarily for the strata in the Pine-Hardwood and Bottomland Hardwood habitat types, seemed to agree with expectations since early successional habitats and those treated with prescribed fire are generally regarded as having the greatest forage value to deer in hardwood and mixed pine-hardwood forests (Blair and Enghardt 1976, Conroy et al. 1982, Lashley et al. 2011).

Even though some clear differences seemed to exist among the strata sampled in the Bottomland Hardwood, Northwest, and Southeast Pine-Hardwood habitat types, the uneven sampling design made it difficult to discern clear differences between the values for the 9 habitat types as a whole. An important point to note is that the 3 habitat types with the greater sampling intensity were sampled more intensively because they have greater structural diversity across the landscape and harvest data collected by Louisiana Department of Wildlife and Fisheries indicates they tend to exhibit deer with greater body weights and antler measurements, particularly in the Bottomland Hardwood habitat region (Durham 2011). The fact that these habitat types are more structurally diverse likely contributes to improved deer productivity since different timber stands are available to address the needs of deer whether from a foraging standpoint or that of cover from predators (i.e., the 6-15-year-old stands in the Northwest and Southeast Pine-Hardwood habitat types which are very dense with little available forage, as reflected by their low TFV). Additionally, a more diverse composition of stands can contribute to presence of different forage species within those stands which are adapted for changes in conditions such as shade intensity. These localized subtle differences in plant communities can in turn potentially provide food for deer at different times of the year and thereby improve overall carrying capacity.

The quantity and nutritional quality of forage available to deer is undeniably important. However, the dynamic nature of overall habitat value for deer makes evaluating the potential carrying capacity of a given area difficult. The overall plane of nutrition for one habitat may be lower than another, but it could still have the ability to provide greater amounts of forage which accommodates the selective browsing behavior of deer and allow them to obtain adequate nutrition. The reverse could also be true. As a result, land managers should assess habitat quality comprehensively (including measures of nutritional quality and quantity of available forage) and their management goals and expectations should be habitat-type specific. The calculation of TFV for a given area could be used as an additional metric for evaluating the general quality of habitat for deer. Such an approach to evaluating habitat quality could be used by land managers to guide where action(s) may be necessary to improve habitat quality for deer, whether it is by adding treatments such as prescribed fire and thinning of timber or providing food plots with forage species of higher nutritional quality.

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CHAPTER 4

SUMMARY AND CONCLUSIONS

This study highlights the complexity of evaluating the quality of habitat for white-tailed deer. Rather than relying on one particular type of measurement for a given area, such as mean levels of CP, multiple aspects of the habitat should be considered when assessing quality. Evaluating habitat quality should consider the quantity of available forage, mean levels of DE, TFV (predicted by level of preference for each forage species available), and prevalence of necessary minerals for body function in addition to mean CP. In this approach, however, estimates do not account for competition from other species, effects of predators, or the needs of deer beyond a nutritional standpoint, all of which can negatively affect potential habitat value by increasing interspecific interactions and further demands on the habitat. Nutritional quality of forage is important but only represents one piece of the management puzzle.

Land management decisions are based on various factors and objectives, but in terms of management for white-tailed deer, practices that promote a diversity of plant species are important, regardless of the habitat type. The single best recommendation for improving habitat quality is to promote a diverse habitat structure and a high volume of plant growth based on the species appropriate for the respective habitat type. Vangilder et al. (1982) reached a similar conclusion and recommended land be managed to stimulate habitat production of a range of forage types rather than an individual type (e.g., not just forbs). Land managers should recognize the importance of evaluating habitat quality and implement strategies to do so. For instance, walking transects and noting plant diversity would allow managers to selectively remove less valuable species (i.e., sweetgum) and promote more valuable and nutritious species using various vegetation management practices, such as prescribed fire or selective herbicides.

The evaluation of the habitat types in this study presents valuable data regarding the relative nutritional quality of forage in each habitat type and how land owners may go about assessing habitat on their property. However, interpretation of the results should include several caveats. For instance, the sampling design provided greater emphasis on 3 of the 9 habitat types important to deer in Louisiana. Likewise, we only evaluated forage during the growing season and forage availability and composition is not a constant throughout the year. Future research efforts could focus on evaluating the nutritional metrics we measured in 1 habitat type with a greater sampling intensity, and with forage collections throughout the year, to more fully evaluate habitat quality.

Deer need sufficient nutrition throughout the year for body maintenance and to increase their competitive fitness during higher demand times of the year such as the growing season when lactation for females and antler growth for males is critical. The range in nutrition in this study brings greater light to the ability of different browse plants to address different nutrient needs of deer. Some species provide greater levels of CP while others that are lower in CP may still contribute by providing higher levels of DE. The same can be said of the concentrations of minerals found in browse. For instance, some species are low in sodium but still hold value by compensating with high levels of calcium.

The surprising degree of variability observed demonstrates the importance of providing a diversity of forage species for deer and due to the differences in rates of maturity for different plant species, a greater variety of forage available to deer can extend the presence of high quality forage over a longer period of time. This study did not control for nutritional variation in the plants sampled and, as a result, could provide another avenue for further research. Specifically, many forest plants we collected do not have published data on their nutritional quality as it relates to state of maturity. It could prove useful to track nutritional quality in plant species considered important to deer over time, since improved knowledge in this area could allow for identification of species either with a sustained high level of nutrition, versus those that have high nutrition during limited windows of time. Likewise, such an evaluation would allow managers to recognize species that emerge at different times in the growing season and provide valuable nutrition when other plants are not yet present or already senescent.

In addition to the maturity state of plants at time of collection, drought was another factor that appeared influential during our study. Our results agree with the findings of other studies regarding the influences of drought on forage quality (Peterson et al. 1992, Lashley and Harper 2012). Drought appeared to have a negative effect on the CP content and quantity of available forage in this study and thus drive down estimates of habitat value. When possible, management actions should be flexible enough to react to reductions in carrying capacity as a result of events such as severe drought conditions (i.e., reduce harvest goals). The density at which a habitat can support deer fluctuates from year to year and fine-tuning harvest goals accordingly should improve herd health. Land managers can follow the approach taken in this study to collect data by randomly placing exclosures (or perhaps walking transects) on an annual basis to track the quantity and presence or absence of deer forage, and then use that data to identify effects of events such as drought and incorporate that knowledge into management decisions.

Deer are selective foragers and providing them with a variety of food options increases their ability to maintain a healthy body condition throughout the year as needs and environmental pressures change. Numerous studies have consistently shown diverse habitats are beneficial for deer as well as many other wildlife species. With a growing level of attention and concern for nongame species, management that encourages diverse habitats is not only positive for deer populations, but also addresses multiple wildlife and environmental issues at once.

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APPENDIX A

SUMMARY OF WEIGHTED CRUDE PROTEIN CALCULATIONS FOR EACH STUDY SITE AND STRATUM SAMPLED

Table 1. Summary of crude protein weighted by the amounts of each sample collected (WCP) within each study site and strata sampled during 2011 and 2012. Numbers within strata description represent stand age in years. Abbreviated habitat types are: Northwest Pine-Hardwood (NWPH), Southeast Pine-Hardwood (SEPH), Bottomland Hardwood (BH), Upland Hardwood (UH), Swamp Hardwood (SH), Longleaf Flatwoods (LF), Historic Longleaf (HL), Coastal Prairie (CP), and Coastal Marsh (CM).

Habitat Type	Study Site	Strata Description	2011 WCP	2012 WCP
NWPH	Jackson-Bienville	1-5	6.73	7.86
NWPH	Jackson-Bienville	6-15	9.56	10.03
NWPH	Jackson-Bienville	16-24 thinned, without burn history	8.94	11.19
NWPH	Jackson-Bienville	16-24 non-thinned, with burn history	9.88	9.97
NWPH	Jackson-Bienville	25+ with burn history	6.08	8.29
NWPH	Jackson-Bienville	25+ without burn history	8.41	9.93
NWPH	Union	1-5	9.81	10.38
NWPH	Union	6-15	8.33	9.73
NWPH	Union	16-24 thinned, without burn history	9.16	10.78
NWPH	Union	16-24 non-thinned, with burn history	8.57	10.22
NWPH	Union (Upper Ouachita NWR)	25+ with burn history	7.84	8.58
NWPH	Union (Upper Ouachita NWR)	25+ without burn history	9.60	10.95
NWPH	Sabine	1-5	6.24	6.99
NWPH	Sabine	6-15	8.42	8.87
NWPH	Sabine	16-24 thinned, without burn history	6.21	7.40
NWPH	Sabine	16-24 non-thinned, with burn history	7.16	9.64
NWPH	Sabine[1]	25+ with burn history	6.84	0.00
NWPH	Sabine	25+ without burn history	7.29	8.70
SEPH	Beech Grove	1-5	7.88	9.80
SEPH	Beech Grove	16-24 thinned, without burn history	8.95	10.68
SEPH	Beech Grove	25+ with burn history	6.94	9.08
SEPH	Beech Grove	25+ without burn history	6.09	10.08
SEPH	Soterra[2]	25+ without burn history	11.85	11.23
SEPH	Ben's Creek	1-5	6.24	8.64
SEPH	Ben's Creek	6-15	7.38	8.40
SEPH	Ben's Creek	16-24 thinned, without burn history	7.15	8.48
SEPH	Ben's Creek	16-24 non-thinned, with burn history	6.76	8.93
SEPH	Lee Forest	25+ with burn history	7.50	8.80
SEPH	Lee Forest	6-15	7.75	10.18
SEPH	Lee Forest	16-24 non-thinned, with burn history	8.08	10.55
BH	Sherburne	1-10	10.39	11.43
BH	Sherburne	11-20	10.71	11.26
BH	Sherburne	21-30	10.74	10.36
BH	Sherburne	31+	11.76	10.28
BH	Red River	1-10	8.53	11.69
BH	Red River	11-20	7.03	9.82

BH	Red River	21-30	10.35	9.37
BH	Red River	31+	9.72	10.54
BH	Tensas	1-10	6.45	8.88
BH	Tensas	11-20	7.06	7.80
BH	Tensas	21-30	9.52	9.69
BH	Tensas	31+	9.57	10.15
UH	Cypress		8.91	10.56
UH	Tunica Hills		9.52	9.81
SH	Maurepas		7.63	12.38
SH	Attakapas[3]		0.00	10.36
LF	Lake Ramsey		5.92	7.47
HL	Kisatchie (Vernon)		7.18	5.90
HL	Kisatchie (Winn)		6.79	7.83
CP	Gray Ranch		8.29	10.39
CM	Lake Salvador		7.69	7.98

[1]Sabine Strata 25+ stand with a burn history was eliminated due to harvest of the timber stand.
[2]Soterra was sampled in 2011 and replaced with Idlewild during 2012.
[3]Attakapas was flooded during 2011 and unable to be sampled.

APPENDIX B

CRUDE PROTEIN RESULTS AND PREFERENCE RATINGS FOR EACH PLANT SPECIES SUBMITTED TO FORAGE TESTING LABS FOR ANALYSIS DURING 2011 AND 2012

Table 1. Crude protein percentages and preference ratings for each plant species analyzed for nutrition during 2011 and 2012. In cases where multiple samples of the same species were submitted for analysis in the same year from the same habitat type, a calculated average is provided so that a single crude protein value could be reported. Each species collected was assigned either 0 (for non-browse species), 0.5 (low), 1 (moderate), or 2 (high) to indicate level of preference by white-tailed deer.

				Crude Protein	
Habitat Type	Common Name	Species	Preference Rate	2011	2012
Northwest Pine-Hardwood	Red maple	*Acer rubrum*	1	7.4	8.6
	Red buckeye	*Aesculus pavia*	0		8.2
	Common ragweed	*Ambrosia artemissifolia*	2	15.6	10.8
	Devil's walking stick	*Aralia spinosa*	2	5.7	7.3
	Eastern baccharis	*Baccharis halimifolia*	1	7.4	6.1
	Alabama supplejack	*Berchemia scandens*	2	4.4	6.6
	Crossvine	*Bignonia capreolata*	1		9.0
	American beautyberry	*Callicarpa americana*	2	9.3	12.9
	Hickory sp.	*Carya sp.*	0.5	7.4	9.7
	Partridge pea	*Chamaecrista fasciculata*	2		12.0
	Oatgrass sp.	*Chasmanthium sp.*	0.5	5.2	
	Fringetree	*Chionanthus virginicus*	1		10.8
	Soft goldenaster	*Chrysopsis pilosa*	0		5.3
	Horseweed	*Conyza canadensis*	0.5		7.6
	Hawthorn sp.	*Crataegus sp.*	2	4.7	7.3
	Croton sp.	*Croton sp.*	0.5	7.8	11.8
	Ticktrefoil sp.	*Desmodium sp.*	2	8	9.4
	Rosette grass sp.	*Dichanthelium sp.*	1	4.9	5.6
	Boykin's clusterpea	*Dioclea multiflora*	0	12.1	12.8
	Persimmon	*Diospyros virginiana*	1	9.7	9.9
	Elephantsfoot	*Elephantopus carolinianus*	2		17.0
	Thoroughwort sp.	*Eupatorium sp.*	1	5.6	7.0
	Goldentop sp.	*Euthamia sp.*	0	11.1	
	Green ash	*Fraxinus pennsylvanica*	2		9.8
	Bedstraw	*Galium sp.*	1		5.4
	Yellow jessamine	*Gelsemium sempervirens*	2	5.9	7.5
	Two-wing silverbell	*Halesia diptera*	1	7.1	
	Witch hazel	*Hamamelis virginiana*	1	5.3	9.0
	Shortleaf sneezeweed	*Helenium brevifolium*	0.5		7.6
	Sunflower sp.	*Helianthus sp.*	2		7.8
	St. Andrew's cross	*Hypericum hypericoides*	1	5.1	7.0
	Deciduous holly	*Ilex decidua*	2		7.1
	American holly	*Ilex opaca*	1	6.3	7.3
	Yaupon	*Ilex vomitoria*	1	9.6	8.9
	Morning-glory sp.	*Ipomoea sp.*	0.5		7.6
	Bicolor lespedeza	*Lespedeza bicolor*	1		8.7
	Trailing lespedeza	*Lespedeza procumbens*	1		11.5
	Lespedeza sp.	*Lespedeza sp.*	1	9.2	9.9
	Sweetgum	*Liquidambar styraciflua*	0.5	6.6	8.8
	Japanese honeysuckle	*Lonicera japonica*	2	6.8	8.7
	Littleleaf sensitive-briar	*Mimosa microphylla*	1		14.3
	Partidge berry	*Mitchella repens*	1		6.9
	Waxmyrtle	*Morella cerifera*	0.5	7.4	11.0
	Black gum	*Nyssa sylvatica*	2	6.8	7.8
	Hophornbeam	*Ostrya virginiana*	0.5	6.9	
	Yellow woodsorrel	*Oxalis stricta*	1		9.7

Virginia creeper	*Parthenocissus quinqifolia*	1		9.3
Purple passionflower	*Passiflora incarnata*	1	16.6	15.3
American pokeweed	*Phytolaca americana*	2		6.9
Loblolly pine	*Pinus taeda*	0.5		8.9
Plum sp.	*Prunus sp.*	1		8.4
Dense-spike blackroot	*Pteracaulon pycnostachyum*	0	4.2	
Bracken fern	*Pteridium aquilinum*	1	4.1	7.7
Hoary mountain mint	*Pycnanthemum incanum*	0.5		7.3
White oak	*Quercus alba*	2	11	10.7
Southern red oak	*Quercus falcata*	1	7	12.1
Blackjack oak	*Quercus marilandica*	1	7.5	10.6
Water oak	*Quercus nigra*	2		11.0
Willow oak	*Quercus phellos*	2		11.5
Oak sp.	*Quercus sp.*	1		8.1
Post oak	*Quercus stellata*	1	7.9	
Winged sumac	*Rhus copallinum*	1	6.3	5.2
Dollarleaf	*Rhyncosia reniformis*	0		12.2
Sawtooth blackberry	*Rubus argutus*	2	8.1	9.3
Northern dewberry	*Rubus flagellaris*	2		7.7
Southern dewberry	*Rubus trivialis*	2		7.5
Sassafras	*Sassafras albidum*	1		10.9
Saw greenbrier	*Smilax bona-nox*	2	6	7.9
Cat greenbrier	*Smilax glauca*	2	6.5	7.8
Laurel greenbrier	*Smilax laurifolia*	2	5.6	
Common greenbrier	*Smilax rotundifolia*	2	9.1	8.7
Lanceleaf greenbrier	*Smilax smallii*	2	13.7	15.0
Carolina horsenettle	*Solanum carolinense*	1		9.3
Goldenrod sp.	*Solidago sp.*	1	5.1	6.6
American snowbell	*Styrax americanus*	1		7.9
Sweetleaf	*Symplocos tinctoria*	1	8.9	11.2
Poison ivy	*Toxicodendron radicans*	1	5.6	9.4
Climbing dogbane	*Trachelospermum difforme*	1		8.3
Winged elm	*Ulmus alata*	2	10.2	6.9
Elm sp.	*Ulmus sp.*	2		8.9
Tree sparkleberry	*Vaccinium arboreum*	1	6.5	8.3
Elliot's blueberry	*Vaccinium elliottii*	1	5.7	7.4
Blueberry sp.	*Vaccinium sp.*	1		7.0
Deerberry	*Vaccinium stamineum*	1	4.5	5.9
Brazilian vervain	*Verbena brasiliensis*	2		10.0
Arrow wood	*Viburnum dentatum*	2		5.8
Vetch sp.	*Vicia sp.*	1		11.8
Summer grape	*Vitis aestivalis*	2	5.7	7.2
Muscadine grape	*Vitis rotundifolia*	2	8.5	9.5

Habitat Type	Common Name	Species	Preference Rate	Crude Protein 2011	Crude Protein 2012
Southeast Pine-Hardwood	Red maple	*Acer rubrum*	2	6.9	8.4
	Broomsedge bluestem	*Andropogon virginicus*	1		7.3
	Red chokeberry	*Aronia arbutifloia*	1		6.2
	Aster sp.	*Aster sp.*	2	10.0	
	Eastern baccharis	*Baccharis halimifolia*	1	4.4	10.0
	American beautyberry	*Callicarpa americana*	2	9.4	15.2
	Hickory sp.	*Carya sp.*	0.5	9.3	11.3
	Spurred butterfly pea	*Centrosema virginianum*	2		11.0
	Horseweed	*Conyza canadensis*	0.5		5.0
	Parsley hawthorn	*Crataegus marshallii*	2		8.8
	Ticktrefoil	*Desmodium sp.*	2	7.9	9.8
	Persimmon	*Diospyros virginiana*	1	8.3	12.5
	Roundleaf thoroughwort	*Eupatorium rotundifolium*	1	6.8	5.3
	Goldentop sp.	*Euthamia leptocephola*	0	10.7	
	Huckleberry	*Gaylussacia dumosa*	1		5.5
	Yellow jessamine	*Gelsemium sempervirens*	2	5.2	7.4
	Sunflower sp.	*Helianthus sp.*	2	5	7.1
	Comfortroot	*Hibiscus aculeatus*	1	9.9	11.7
	Inkberry	*Ilex glabra*	1	5.9	
	Yaupon	*Ilex vomitoria*	1	8	9.5
	Trailing lespedeza	*Lespedeza procumbens*	1		13.0
	Chinese privet	*Ligustrum sinense*	2	9.4	
	Sweetgum	*Liquidambar styraciflua*	0.5	8.3	10.3
	Taperleaf water horehound	*Lycopus rubellus*	1	7.5	
	Japanese climbing fern	*Lygodium japonicum*	1	10.3	10.4
	Magnolia	*Magnolia virginiana*	1	8.1	
	Waxmyrtle	*Morella cerifera*	0.5	7.1	9.9
	Black gum	*Nyssa sylvatica*	2		6.1
	Virginia creeper	*Parthenocissus quinqifolia*	1	8.4	11.0
	American pokeweed	*Phytolaca americana*	2	17.0	
	Bracken fern	*Pteridium aquilinum*	1	6	9.5
	White oak	*Quercus alba*	2	8.3	10.2
	Southern red oak	*Quercus falcata*	1	8.6	
	Blackjack oak	*Quercus marilandica*	1	7.6	9.7
	Water oak	*Quercus nigra*	2	5.7	9.7
	Willow oak	*Quercus phellos*	2	6.6	
	Oak sp.	*Quercus sp.*	1		6.2
	Rhododendron sp.	*Rhododendron sp.*	1	5.4	
	Winged sumac	*Rhus copallinum*	1	8.8	7.5
	Sawtooth blackberry	*Rubus argutus*	2	7.0	8.3
	Little bluestem	*Schizachyrium scoparium*	1	9.7	
	Saw greenbrier	*Smilax bona-nox*	2		12.5
	Cat greenbrier	*Smilax glauca*	2	5.2	7.7
	Laurel greenbrier	*Smilax laurifolia*	2	13.2	
	Common greenbrier	*Smilax rotundifolia*	2	5.5	
	Lanceleaf greenbrier	*Smilax smallii*	2	15.3	12.9
	Greenbriar	*Smilax sp.*	2		8.2
	Goldenrod sp.	*Solidago sp.*	1	8.9	8.7
	Sweetleaf	*Symplocos tinctoria*	1	8.9	8.5
	Spiked hoarypea	*Tephrosia spicata*	0.5		11.4
	Virginia tephrosia	*Tephrosia virginiana*	0.5	10.1	16.9
	Poison oak	*Toxicodendron pubescens*	0.5		10.8
	Poison ivy	*Toxicodendron radicans*	1		10.8
	Elm sp.	*Ulmus sp.*	2		10.0
	Tree sparkleberry	*Vaccinium arboreum*	1	5.4	6.4
	Elliot's blueberry	*Vaccinium elliottii*	1	5.3	6.7
	Blueberry sp.	*Vaccinium sp.*	1		6.7
	Deerberry	*Vaccinium stamineum*	1	4.2	6.0
	Arrowwood	*Viburnum dentatum*	2		8.7
	Possumhaw	*Viburnum nudum*	1	8.3	
	Muscadine grape	*Vitis rotundifolia*	2	7.1	9.4

Habitat Type	Common Name	Species	Preference Rate	Crude Protein 2011	Crude Protein 2012
Bottomland Hardwood	Box elder	*Acer negundo*	2	13.2	
	Common ragweed	*Ambrosia artemissifolia*	2		9.6
	Giant ragweed	*Ambrosia trifeda*	2		5.7
	Peppervine	*Ampelopsis arborea*	1	9	12.1
	Broomsedge bluestem	*Andropogon glomeratus*	1	3.9	
	Aster sp.	*Aster sp.*	2		5.7
	Lady fern	*Athyrium felix-femina*	1	11.5	12.6
	Eastern baccharis	*Baccharis halimifolia*	1		10.8
	Alabama supplejack	*Berchemia scandens*	2		6.1
	Smallspike false nettle	*Boehmeria cylindrica*	1		19.7
	Ladies ear drop	*Brunnichia ovata*	1	8.8	9.4
	Sweetshrub	*Calycanthus floridus*	0.5		9.9
	Trumpet creeper	*Campsis radicans*	1	11.2	11.8
	Sedge sp.	*Carex sp.*	0.5	5	8.0
	Balloon vine	*Cardiospermum halicacabum*	1		10.1
	Hickory sp.	*Carya sp.*	0.5		9.0
	Sugarberry	*Celtis laevigata*	2	12.4	12.9
	Swamp leather flower	*Clematis crispa*	2		10.2
	Carolina moonseed	*Cocculus caroliniana*	1	12	10.6
	Swamp dogwood	*Cornus drummondii*	2		10.5
	Queen Anne's lace	*Daucus carota*	1	8.9	9.3
	Illinois bundleflower	*Desmanthus illinoensis*	2	14.9	15.5
	Persimmon	*Diospyros virginiana*	1	9.7	8.4
	False strawberry	*Duchesnea indica*	1	8	8.5
	Thoroughwort sp.	*Eupatorium sp.*	1	10.2	11.7
	Green ash	*Fraxinus pennsylvanica*	2	10.3	
	Deciduous holly	*Ilex decidua*	2	9.9	
	Annual marsh elder	*Iva anua*	1		9.2
	Canada lettuce	*Lactuca canadensis*	2	16.5	
	Everlasting pea	*Lathyrus latifolius*	1	14.8	11.9
	Chinese privet	*Ligustrum sinense*	2		14.2
	Sweetgum	*Liquidambar styraciflua*	0.5	5.6	8.1
	Japanese honeysuckle	*Lonicera japonica*	2	8.5	9.9
	Japanese climbing fern	*Lygodium japonicum*	1		9.3
	Winged lythrum	*Lythrum alatum*	1	6.4	7.3
	Guadeloupe cucumber	*Melothria pendula*	1		17.5
	Climbing hempvine	*Mikania scandens*	1		8.1
	Yellow woodsorrel	*Oxalis stricta*	1		10.6
	Virginia creeper	*Parthenocissus quinqifolia*	1	11.3	11.6
	Jumpseed	*Persicaria virginiana*	1	6.7	11.5
	Dotted smartweed	*Polygonum punctatum*	1	7.8	
	Laceflower	*Ptilimnium nuttallii*	1		9.3
	Beefsteak	*Perilla frutescens*	0	13.2	
	Carolina falsedandelion	*Pyrrhopappus carolinianus*	1		5.4
	Water oak	*Quercus nigra*	2	10.1	
	Willow oak	*Quercus phellos*	2		7.5
	Oak sp.	*Quercus sp.*	1		9.6
	Sawtooth blackberry	*Rubus argutus*	2	11.3	9.4
	Southern dewberry	*Rubus trivialis*	2	9.7	8.8
	Elderberry	*Sambucus nigra*	2	16.5	20.6
	Small's blacksnakeroot	*Sanicula odorata*	1	6.9	8.4
	Little bluestem	*Schizachyrium scoparium*	1	3.4	
	Sicklepod	*Senna obtusifolia*	0		11.1
	Roundleaf greenbriar	*Smilax rotundifolia*	2	9.3	8.2

Goldenrod sp.	*Solidago sp.*	1	7.3	9.1
Johnson grass	*Sorghum halepense*	1	5.1	5.7
Poison ivy	*Toxicodendron radicans*	1	10.1	11.7
Climbing dogbane	*Trachelospermum difforme*	1		10.5
Tallow	*Triadica sebifera*	0.5		6.6
Elm sp.	*Ulmus sp.*	2	7.5	12.6
Brazilian vervain	*Verbena brasiliensis*	2	6.4	8.8
Violet sp.	*Viola sp.*	1		15.0
Summer grape	*Vitis aestivalis*	2		8.5
Muscadine grape	*Vitis rotundifolia*	2	6.2	

Habitat Type	Common Name	Species	Preference Rate	Crude Protein 2011	Crude Protein 2012
Upland Hardwood	Red buckeye	*Aesculus pavia*	0	8.6	
	Giant cane	*Arundinaria gigantea*	0.5	10.9	10.3
	Pawpaw	*Asiminia triloba*	1	12.6	16.4
	Crossvine	*Bignonia capreolata*	1		9.1
	Hairy woodland brome	*Bromus pubescens*	1	5	7.4
	Sweetshrub	*Calycanthus floridus*	0.5		11.2
	Trumpet creeper	*Campsis radicans*	2		11.1
	Balloon vine	*Cardiospermum halicacabum*	1		10.8
	Oatgrass sp.	*Chasmanthium sp.*	0.5	10.1	10.1
	American hazelnut	*Corylus americana*	1		12.1
	Wild comfrey	*Cynoglossum virginianum*	0	6.9	9.0
	Ticktrefoil sp.	*Desmodium sp.*	2		15.4
	Rosette grass sp.	*Dichanthelium sp.*	1		11.6
	Two-wing silverbell	*Halesia diptera*	1		11.5
	Sweetgum	*Liquidambar styraciflua*	0.5	7.5	
	Japanese honeysuckle	*Lonicera japonica*	2	6.2	8.3
	Japanese climbing fern	*Lygodium japonicum*	1		12.6
	Hophornbeam	*Ostrya virginiana*	0.5	9.8	
	Virginia creeper	*Parthenocissus quinqifolia*	1		9.4
	Jumpseed	*Persicaria virginiana*	1	11.1	11.5
	Christmas fern	*Polystichum acrostichoides*	1	6.4	8.2
	Cherry laurel	*Prunus caroliniana*	1	7.8	9.0
	Plum sp.	*Prunus sp.*	1		10.0
	Water oak	*Quercus nigra*	2	8.5	
	Small's blacksnakeroot	*Sanicula smallii*	1		10.4
	Common greenbrier	*Smilax rotundifolia*	2	6.4	5.8
	Hairy white oldfield aster	*Symphyotrichum pilosum*	1		7.0
	Poison ivy	*Toxicodendron radicans*	1		12.8
	Elm	*Ulmus sp.*	2	10.6	11.6
	Muscadine grape	*Vitis rotundifolia*	2		9.1
Swamp Hardwood	Red maple	*Acer rubrum*	2	7.4	
	Alligator weed	*Alternanthera philoxeroides*	2	8.7	8.1
	Peppervine	*Ampelopsis arborea*	1		9.4
	Aster sp.	*Aster sp.*	2		7.6
	Ladies ear drop	*Brunnichia ovata*	1		8.2
	Sedge sp.	*Carex sp.*	0.5		9.4
	Asiatic dayflower	*Commelina virginiana*	1		11.5
	Thoroughwort sp.	*Eupatorium sp.*	1		15.7
	Deciduous holly	*Ilex decidua*	2		10.9
	Japanese honeysuckle	*Lonicera japonica*	2		11.7
	Japanese climbing fern	*Lygodium japonicum*	1		12.9
	Climbing hempvine	*Mikania scandens*	1		15.8
	Fall panicum	*Panicum dichotomiflorum*	1		6.1
	Green arrow arum	*Peltandra virginica*	0	12.9	22.9
	Dotted smartweed	*Polygonum punctatum*	1	7.1	13.8
	Pickerel weed	*Pontederia cordata*	1	10.7	14.0
	Southern dewberry	*Rubus trivialis*	2		9.3
	Elderberry	*Sambucus canadensis*	2		12.3
	Lizard's tail	*Saururus cenuus*	0.5		11.7
	Common greenbrier	*Smilax rotundifolia*	2		9.1
	Canada germander	*Teucrium canadense*	1		12.6
	Poison ivy	*Toxicodendron radicans*	1		10.7
	Wisteria sp.	*Wisteria sp.*	1		20.7

Habitat Type	Common Name	Species	Preference Rate	Crude Protein 2011	Crude Protein 2012
Historic Longleaf	Common ragweed	*Ambrosia artemissifolia*	2		7.8
	Peppervine	*Ampelopsis arborea*	1		8.7
	Milkweed	*Asclepias sp.*	0		8.8
	Aster sp.	*Aster sp.*	2		2.6
	Crossvine	*Bignonia capreolata*	1		7.4
	American beautyberry	*Callicarpa americana*	2	6.1	8.1
	Partidge pea	*Chamaecrista fasciculata*	2		12.8
	Purple coneflower	*Echinacea purpurea*	1		6.6
	Roundleaf thoroughwort	*Eupatorium rotundifolia*	1		5.8
	Yellow jessamine	*Gelsemium sempervirens*	2	5.7	3.5
	Deciduous holly	*Ilex decidua*	2		7.2
	Yaupon	*Ilex vomitoria*	1	7.1	7.5
	Trailing lespedeza	*Lespedeza procumbens*	1		9.8
	Lespedeza sp.	*Lespedeza sp.*	1		9.8
	Sweetgum	*Liquidambar styraciflua*	0.5	7.4	6.4
	Japanese climbing fern	*Lygodium japonicum*	1		4.7
	Waxmyrtle	*Morella cerifera*	0.5	7.4	8.8
	Bracken fern	*Pteridium aquilinum*	1	5.6	5.2
	White oak	*Quercus alba*	2		8.9
	Blackjack oak	*Quercus marilandica*	1	6.6	
	Post oak	*Quercus stellata*	1	6.6	
	Aromatic sumac	*Rhus aromatica*	1	5.6	6.1
	Winged sumac	*Rhus copallinum*	1	7.5	8.0
	Sawtooth blackberry	*Rubus argutus*	2		7.0
	Sassafras	*Sassafras albidum*	1	6.9	8.3
	Cat greenbrier	*Smilax glauca*	2	6.8	5.8
	Virginia tephrosia	*Tephrosia virginiana*	0.5	11.3	12.6
	Poison oak	*Toxicodendron pubescens*	0.5	7.9	7.6
	Tree sparkleberry	*Vaccinium arboreum*	1	6.3	6.3
	Elliot's blueberry	*Vaccinium elliottii*	1	5.9	
	Deerberry	*Vaccinium stamineum*	1		5.0
	Blueberry sp.	*Vaccinium sp.*	1	4.1	
	Summer grape	*Vitis aestivalis*	2		8.9
	Muscadine grape	*Vitis rotundifolia*	2	5.8	10.9

Habitat Type	Common Name	Species	Preference Rate	Crude Protein 2011	Crude Protein 2012
Longleaf Flatwoods	Threeawn grass sp.	*Aristida sp.*	1	3.9	
	Red chokeberry	*Aronia arbutifolia*	1	5.2	
	Oatgrass sp.	*Chasmanthium sp.*	0.5	7.1	
	Horseweed	*Conyza canadensis*	0.5		9.0
	Toothache grass	*Ctenium aromaticum*	0	4.1	
	White titi	*Cyrilla racemiflora*	2	5.4	6.5
	Rosette grass sp.	*Dichanthelium sp.*	1	4.6	6.1
	Thoroughwort sp.	*Eupatorium sp.*	1	7.7	7.6
	Lindheimer's beeblossom	*Gaura lindheimeri*	0		8.8
	Huckleberry	*Gaylussacia mosieri*	1		4.7
	Comfortroot	*Hibiscus aculeatus*	1		10.4
	Inkberry	*Ilex glabra*	1	5.4	7.8
	Waxmyrtle	*Morella cerifera*	0.5	7.6	5.9
	Bracken fern	*Pteridium aquilinum*	1	7.4	11.5
	Live oak	*Quercus virginiana*	0.5		8.2
	Beaksedge sp.	*Rhynchospora sp.*	0.5	3.9	
	Sawtooth blackberry	*Rubus argutus*	2	7.6	8.9
	Little bluestem	*Schizachyrium scoparium*	0.5	4	6.0
	Cat greenbrier	*Smilax glauca*	2	7.9	7.2
	Lanceleaf greenbrier	*Smilax smallii*	2	7.3	8.8
	Tallow	*Triadica sebifera*	0.5		18.4
	Deerberry	*Vaccinium stamineum*	1	3.3	

				Crude Protein	
Habitat Type	Common Name	Species	Preference Rate	2011	2012
Coastal Prairie	Common ragweed	*Ambrosia artemissifolia*	2		10.6
	Eastern baccharis	*Baccharis halimifolia*	1	4.6	7.8
	Wild indigo	*Baptisia bracteata*	0	12.8	19.5
	Rosette grass sp.	*Dichanthelium sp.*	1		8.0
	Thoroughwort sp.	*Eupatorium sp.*	1		9.0
	Lindheimer's beeblossom	*Gaura lindheimeri*	0		7.4
	Shortleaf sneezeweed	*Helenium brevifolium*	0.5		7.0
	Yaupon	*Ilex vomitoria*	1		8.2
	Japanese honeysuckle	*Lonicera japonica*	2	5.8	13.9
	Powderpuff	*Mimosa strigollosa*	1		12.5
	Waxmyrtle	*Morella cerifera*	0.5	8.5	10.6
	Dallisgrass	*Paspalum dilitatum*	1	5.4	7.5
	Lanceleaf frogfruit	*Phyla lanceolata*	1		9.1
	Narrowleaf mountain mint	*Pycnanthemum tenuifolium*	0.5		7.5
	Beaksedge sp.	*Rhyncospora sp.*	0.5		4.6
	McCartney rose	*Rosa bracteata*	1	7.8	9.4
	Sawtooth blackberry	*Rubus argutus*	2		9.0
	Southern dewberry	*Rubus trivialis*	2	7.9	9.0
	Fanpetal sp.	*Sida rhombifolia*	2		10.2
	Cat greenbrier	*Smilax glauca*	2		9.8
Coastal Marsh	Alligator weed	*Alternanthera philoxeroides*	2	4.8	5.6
	Lady fern	*Athyrium felix-femina*	1		9.4
	Eastern baccharis	*Baccharis halimifolia*	1	8.8	
	Blunt spikerush	*Eleocharis obtusa*	0.5	5.7	
	Water pennywort	*Hydrocotyle umbellata*	1		11.2
	Saltmarsh morning glory	*Ipomoea sagittata*	1	10.5	10.4
	Rush sp.	*Juncus sp.*	0.5	3.8	
	Winged lythrum	*Lythrum alatum*	1		6.9
	Waxmyrtle	*Morella cerifera*	2		8.7
	Maidencane	*Panicum hemitomon*	1	8.1	
	Dotted smartweed	*Polygonum punctatum*	1	6.6	9.4
	Southern dewberry	*Rubus trivialis*	2		9.2
	Bulltongue	*Sagittaria lancifolia*	0	10.9	16.0
	Goldenrod sp.	*Solidago sempervirens*	1		7.1
	Tallow	*Triadica sebifera*	0.5	11.2	10.9
	Purpletop tridens	*Tridens flavus*	1		5.9
	Cattail	*Typha latifolia*	0.5	9.2	12.0