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History of Carolina Grasslands: Waltzing with Fire

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Anywhere you stand in today's rural Carolina piedmont, you find yourself surrounded by trees and thickets, making it quite a stretch to imagine the vast, open piedmont described by the European explorers of the 1500s through 1800s. Try to picture yourself in the York County landscape described by J.H. Logan, writing in 1859: "In the cane brakes of the [rivers and streams] . . . and on the extensive prairie ridges, the early pioneers and hunters found large herds of buffaloes and elks . . . The trees were generally larger [than today] and stood so wide apart that a deer or a buffalo could easily be seen at a long distance—there being nothing to obstruct the view but the rolling surface . . . The pea-vine and grasses occupied the place of the bushes and young forest that render the woods of the present time so gloomy and intricate." Well, that's certainly a sharp contrast to the forested landscape you'd see there now.

Today, only on a very few intensively managed preserves can one get a glimpse of the landscape described by Logan, and even there, the scene is incomplete—there are no bison or elk, and the postage-stamp-size acreage brings to mind the term meadow more than it does prairie. So what are we to make of the detailed accounts of Logan and his cohorts who describe so well a land more reminiscent of the American Great Plains than of our contemporary Carolina piedmont?

Historical documents and present-day knowledge of ecology support the claims by early explorers like Logan—believe it or not, their descriptions most likely reflect what they really saw on their travels—and also offer clues as to what caused the unique grassland ecosystems they described to disappear. To understand the rise and fall of the vast Carolina grasslands, let's step back in time and walk forward through the years, gaining a clearer perspective on the Palmetto State's ever-changing landscape.

Toward the end of the last major glaciation, 10,000 to 20,000 years ago, most of the species common in the Carolinas today lived farther south, in present day Florida and other areas, some now under the sea. Analysis of pollen in undisturbed, isolated freshwater wetlands from sites such as White Pond, near Elgin, indicate that about 13,000 years before present (BP), the climate of South Carolina's midlands caused a dramatic shift from boreal species now found in Canada—spruce and jack pine, for example—to deciduous species such as oak, hickory, beech, birch, elm, maple and ironwood. These findings, coupled with the study of fossils from places such as Edisto Island of about the same time, show that in the late Pleistocene Epoch the area that is now South Carolina was made up of three distinct faunal zones that were much like today's East African Serengeti in terms of megafauna (vertebrates weighing 220 lb or more).

The upper part of the state, from about Columbia northward, was in the boreal zone, characterized by tundra with a few scattered trees. The notable megafauna of the boreal zone included walruses, horses, bison and caribou, and its chief grazer, the wooly mammoth. Below the boreal zone southward to the Charleston area lay the temperate zone, a highly diverse region of mixed temperate forests and grasslands. This area contained both wooly and Columbian mammoths, as well as other grazers, and the paramount browsing species of the temperate zone was the American mastodon. Since grazers like mammoths mostly use grasslands and browsers such as mastodons mostly use woodlands, we can gain some idea of the ratio of open land to forest by looking at the ratio of mammoth-to-mastodon fossil finds. This ratio suggests that the coastal plain was dominated by grasslands and the piedmont contained more woodlands.

Below the temperate zone was the subtropical zone, with its mixture of aquatic (for example, muskrats, giant beavers, alligators) and terrestrial fauna (grazers and browsers), which indicates a mosaic of grassland savanna and deciduous woodlands interlaced by large, meandering streams. The White Pond site shows, too, that about 9,500 years BP the oak/hickory forest was replaced by "Southern" pines and oaks, with oak dominating until about 7,000 years BP, when pine took over and led to the forest we have today.

So what? Well, consider these changes, largely the results of climatic shifts, and then factor in the arrival of the first Americans and their impact on the landscape. Scientists differ in their views of how long humans have been in the New World, with estimations ranging from more than 40,000 years ago to as recently as 12,000 years ago. Though the human-habitation timeline is hotly debated, evidence strongly suggests that the Amerindians of the Southeast began intensive and purposeful manipulation of the land 3,000 to 5,000 years BP, and that fire was their primary tool. Through the use of fire, Native Americans gave rise to the South's most recent grasslands.

Like many of today's remaining Carolina grasslands, the grassland landscape of that time included native warm-season grasses, which grow during the spring and summer, rather than in the fall and winter, when invasive exotic species like fescue grow. These native grasses include Indiangrass (South Carolina's state grass), switchgrass, big and little bluestems and other "broomsedges," and Eastern gammagrass. Growing alongside grass species are forbs, or non-grasslike herbaceous plants, which play a vital role in grassland ecology. Legumes, ecologically vital forbs that "fix" nitrogen, are one important example. They harbor in their roots bacteria that transfer nitrogen, an important nutrient for grass species, from the atmosphere to the soil.

Grasses pay back their fire-tolerant legume neighbors by carrying fire, which keeps trees and other competitors at bay, so their relationship is mutually beneficial. (See "Grasslands and Humans: The ancient and inextricable link" for more on how grasses and legumes complement each other.)

This land of six-foot grasses is where, according to historian David Ramsay writing in his 1858 book, *The History of South-Carolina from its First Settlement in1670, to the Year 1808, Volume II,* "In the year 1750, when the settlement of the upper country [South Carolina piedmont] began, there were so many buffaloes, which have long disappeared, that three or four men with their dogs could kill from ten to twenty in a day." Buffalo and elk were much less common in the pre-Columbian Southeast, but they moved in quickly and their populations exploded after native people were violently depopulated by diseases introduced by Europeans. Fewer people meant less human predation pressure and the abandoned agricultural fields became ideal habitat for these big grazers. However, the buffalo's tenure in the Carolinas was short; settlers wiped them out by 1775. These vast lands would no doubt have been a small-game hunter's and birdwatcher's paradise, as well. Bobwhite quail and rabbits would have flourished alongside nongame species such as loggerhead shrikes, meadowlarks and many species of grassland sparrows.

Grasslands—largely maintained by fire and/or grazing, direct sunlight and soils—must have all of these elements or they will be overtaken by forests. Fire and grazing, of course, suppress tree growth, allowing sunlight to reach the land surface. Prairie species require this full sunlight to flourish; they cannot prosper under the shade of trees. Soil characteristics, including chemistry, density and texture, are also a major factor in keeping trees in their place. Some piedmont soils shrink and bake brick-hard when dry and swell to mush when wet. This seems to benefit certain grassland-associated herbaceous plants and discourage tree growth.

Prairie species also tend to have extensive, very deep root systems that help them out-compete trees, especially during droughts. The roots of big bluestem, for example, often reach deeper than the plant is tall! Chemical warfare, or allelopathy, is another factor that plays a vital role in determining what grows where. Allelopathic plants exude chemicals through their roots and other tissues that act as selective "herbicides" to inhibit the growth of competitors. Thanks in part to these unique characteristics, individual clumps of some grass species may live for decades, and may be older than the much larger trees around them!

These days, intact temperate grasslands, savannas and shrublands are the most endangered ecosystems in North America and the world. They are more imperiled, in fact, than the tropical rainforests that capture so much attention. Fire suppression and other habitat destruction are primarily responsible for the decline of these ecosystems. Fortunately, in the Southeast, there is a rapidly growing movement to slow or reverse this trend.

Increasingly, land-grant universities, extension services, natural resource agencies and private landowners are restoring and managing grasslands for wildlife habitat, livestock forage and aesthetic values. Because they are disturbance-dependent ecosystems, grasslands require active management in the form of burning, grazing or mowing. Carefully timed and regulated grazing by livestock can mimic the periodic feeding patterns of the long-gone buffalo and elk, making it a good management option for some grassland sites. Fire, the tool of our Amerindian predecessors, and mowing also provide the type of tree-preventing, soil-enriching disturbance required by delicate grassland ecosystems. With wise use of our knowledge and the tools we have to manage them, we can restore Carolina grasslands to at least a little bit of their former glory.

So You Want To Restore Grasslands?

If you're interested in restoring and managing grasslands on your land, check out *Native Warm Season Grasses: Identification, Establishment, and Management for Wildlife and Forage Production in the Mid-South* by Harper et al., which is available from the University of Tennessee Extension Web site. Access the land manager version at: *www.utextension.utk.edu/publications/fee-based/pb1752.htm*. Access the landowner version at: [*www.utextension.utk.edu/publications/pbfiles/PB1746.pdf*](http://www.utextension.utk.edu/publications/pbfiles/PB1746.pdf).

Financial assistance to restore grasslands is available from several sources, including the U.S. Fish and Wildlife Service's Partners for Wildlife program and the Natural Resources Conservation Service's Environmental Quality Incentives Program, helping to bring grassland restoration within grasp of landowners of all economic levels.

One key thing to remember when restoring grassland is that it's always best to use local seed or other plant material sources rather than bringing them in from more distant areas. A local population of a species can become genetically distinct from a distant population of the same species as it adapts over time to a specific geographic location and set of ecological conditions. So, seed from a local population will be better suited to a nearby location than seed from a faraway locale. Plus, bringing in genetically unique stock from a distant location can lead to swamping and degradation of the local stock.

Get Out and Explore the Grasslands

You can check out modern Carolina grasslands at these S.C. Department of Natural Resources properties: Rock Hill Blackjacks HP/WMA in York County; Aiken Gopher Tortoise HP/WMA; Lynchburg Savanna HP/WMA in Lee County; Webb Wildlife Center/WMA in Hampton County and Tillman Sand Ridge HP/WMA in Jasper County. Information on these sites is available from the DNR Web site, *www.dnr.sc.gov*. You can also view grasslands at the Indian Creek area of the Sumter National Forest, the Francis Marion National Forest (*www.fs.fed.us/r8/fms/*) and Carolina Sandhills National Wildlife Refuge (*www.fws.gov/refuges/*). In North Carolina, check out Mecklenburg County Parks, *www.charmeck.org/Departments/Park+and+Rec/Parks/Home.htm*, for even more Carolina grasslands.

Grasslands and Humans: The Ancient and Inextricable Link

Some of the earliest and most profound human art has a subtle, yet overarching grassland theme. The mammoths, horses, aurochs (ancestor of cattle) and other Pleistocene megafauna painted more than 25,000 years ago in the caves of southwestern Europe are grazers dependent on extensive grasslands. The most prominent human civilizations have tended to arise in grasslands, and grasses remain the most important plants for humans and our domestic animals. In fact, grain, the seed of grasses, is a cornerstone of bread and brewing.

At first humans collected wild grass seeds, and we of course chose those that were most palatable and nutritious. Then we began domesticating these grasses. Our love of lawns and open, park-like groves of trees may be an atavistic trait from our primordial past, when grasslands meant grain for food, forage for grazing livestock and game animals, and open vistas, which provided clear views surrounding our dwellings, preventing surprise raids.

Grasses such as wheat were among the first plants cultivated; many of the first domestic animals were grassland-dependent grazers. Grasses and legumes tended to be cultivated together, their ecological compatibility being only one cultural benefit of this nexus. They also complement each other in the human diet, one providing the nutrients lacking in the other, and between them delivering much of what we require in terms of nutrition. Dietary staples of most, if not all, major civilizations were based on a cereal (grass seed) and a legume. Grass/legume dyads include corn and beans in the "New World," wheat and lentils in the Mediterranean, rice and soybeans in Asia and millet and peas in Africa.

Over the past fifty years, five of the six most widely planted food crops in the world have been grasses: barley, corn, rice, sorghum and wheat. Soybeans, a legume, is the other. Even today, we often alternately grow soybeans and wheat on the same field, this "double-cropping" allowing farmers to grow two crops a year on the same land.

In addition to their dietary roles, certain grassland plants historically played an important role in folk medicine. According to Richard Porcher, retired herbarium curator for The Citadel and author of *Wildflowers of the Carolina Low Country and Lower Pee Dee*, forbs such as rattlesnake master were used by Native Americans and settlers alike to treat a variety of ailments. Just as humans have evolved with grasslands, fire and grasslands are also inextricably linked. For more than one million years (about 40,000 human generations), going back to the savannas of East Africa from whence we sprang, humans have used fire to shape the landscape. Fire enabled us to easily manipulate our surroundings on a grand scale, and this mutually beneficial link between our species and fire, the ecological imperative, has created and maintained the world's grasslands, which in turn served both fire and humans. Together throughout the eons we have waltzed with fire, and the grasslands have been the music that drove our dance.

Clarifying Long-Term Impacts of Fire Frequency and Fire Season in Southeastern Pine Savannas

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Introduction. Southeastern USA woodlands and savannas are recognized for high floristic diversity (Peet and Allard 1993). Maintaining this diversity is one goal of natural resource managers on public and some private lands. Historically, frequent fires ignited by lightning or set by Native Americans maintained high levels of plant diversity. In the absence of fire, open woodlands and savannas succeed to dense forests with substantially reduced floristic richness (e.g. Lemon 1949, Gilliam et al. 2006). Today, prescribed, or "controlled" fire is without question the single most important tool for biological resource management in southeastern pinelands.

Despite the widespread use of prescribed fire, important questions remain concerning the optimal burn regime. The two aspects of prescribed burning most easily manipulated are fire frequency and fire season. Traditionally, southeastern land managers have tended to burn very frequently, generally every 1-2 yrs. Most of the fires are lit in the so-called dormant season lasting from November to February when deciduous trees are leafless (Robbins and Myers 1992). The main goal of traditional woods burning in the south is to increase game populations (Robbins and Myers 1992), but a byproduct is the maintenance of high vascular plant richness. Firsthand observations (Lawson 1709) and reconstructions of fire history from tree rings (Henderson 2006) document that anthropogenic burning primarily during the dormant season extended back before the period of Afro-European occupancy in southeastern USA.

Traditional fire management of southeastern pinelands has maintained high quality diverse ground layer flora (Waldrop et al. 1992, Kirkman and Mitchell 2006). Nevertheless, arguments have arisen in recent decades for a more "natural" prescribed burn regime. Since most lightning ignitions occur from late May through September (Chen and Gerber 1990) this period can be considered the natural fire season to which, presumably, most native plants are adapted. It has further been hypothesized that the greatest amount of landscape area burned during the transitional period from spring drought to the onset of the lightning season in late May-early June (Gilliam et al. 2006). One important influence of fire season may be on dominance of woody plants in ground-layer plant communities. Burns occurring during the period of physiological dormancy are presumably less damaging to hardwood shrubs and trees than are growing season fires (Glitzenstein et al. 1995, and references therein). Hence long-term dormant season burning may lead to proliferation of woody plants with detrimental impacts to native herbaceous ground layer (Robbins and Myers 1992).

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Indeed, several studies have demonstrated negative effects of growing season fires on woody plant survival or stem densities in southeastern pinelands (Robbins and Myers 1992, Glitzenstein et al. 1995, Drewa et al. 2006, and references therein). On the other hand, it is commonly observed that season of burn effects are quite variable, and statistical inferences from short-term observations (< 5 treatment cycles) may be confounded by time of sample effects and day of burn effects (Streng et al. 2003). The last issue is particularly problematic since the common practice in prescribed fire studies is to burn all replicates on the same day. Another point is that stem density data by itself is not an especially good indicator of woody plant competition. For example, following four decades of annual burning in the Santee Fire Plots near Charleston, SC, woody stems were abundant in the winter-burn plots but virtually absent from the summer burn plots. However, surviving stems in both treatments were small, and Waldrop et al. (1992) noted that overall vascular plant species richness of annually burned winter-burn plots appeared to be equal to or greater than vascular plant richness in the summer burn plots.

In addition to fire season, another important management issue concerns frequency of burning. As noted above, land managers in the south have traditionally burned very frequently. Fire history evaluations based on lightning strike data and landscape information have tended to support the suggestion that very frequent fires were "natural" in this system (Frost 1995). On the other hand, actual reconstructions from tree-ring data indicated surprisingly long mean fire intervals ranging from 4.4 to 16.3 years at six different sites (Henderson 2006). Henderson (2006) noted that his estimates were based on relatively few trees per site and he likely underestimated fire frequencies. Nevertheless, his results showing increases rather than decreases in fires following Afro-European settlement in longleaf pine forests tend to challenge conventional assumptions about pre-settlement fire regimes.

In another provocative study, Beckage and Stout (2000) examined fire frequency effects on ground-layer vegetation in xeric *Pinus palustris-Quercus laevis* sandhills and in the long-term Stoddard fire plots at Tall Timbers Research Station. In the sandhill sites the null hypothesis of no effect on fire frequency was determined to have the highest likelihood using maximum likelihood statistics. At the Stoddard plots, species richness increased with fire frequency but then tended to plateau at fire return intervals of approximately 7 years. Thus burning more frequently than once every seven years was postulated to have little additional benefit for species richness.

Glitzenstein et al. (2003) studied fire frequency effects on vegetation in long-term fire treatment plots in north Florida and South Carolina. Like the Santee Plots, the Glitzenstein et al. (2003) SC plots were in Francis Marion National Forest near Charleston. Frequency of burn treatments included annual, biennial, triennial and quadrennial. Fire treatments had been maintained since the mid 1950's and vegetation data were collected in 2000-2001. In contrast to the Beckage et al. (2000) study, significant effects of fire frequency on species richness were detected on these treatments of less than seven yr intervals. However, the results were scale dependent (see Figure 6 in Glitzenstein et al. 2003). The most significant effects of fire frequency on species richness were detected at spatial scales of less than 100 m^2. At the largest plot size of

1000 m^2 trends in overall species richness, though still evident, were not statistically significant ($P > 0.05$).

The Stoddard data examined by Beckage et al. (2000) consisted of whole plot (0.3 ha) floristic surveys carried out by R.K. Godfrey in 1973, approximately 13 years after initiation of this long-term and still ongoing survey (Mehlman 1992, Hermann 1995). Glitzenstein et al. (2003) suggested the seemingly disparate results of their study and the Beckage et al. (2000) study could potentially be resolved by an examination of scale effects in the Stoddard Plots. Furthermore, significant differences may have emerged in those plots in the 25 years since Godfrey collected his data. In 2007 Tall Timbers provided the opportunity for a resurvey of the surviving Stoddard Plots using methods identical to those used in Glitzenstein et al. (2003). Results of this most recent survey, presented herein, support our suggestion that when scale is considered the results of the two studies are largely, though not entirely, reconciled.

The most comprehensive study of season of burn effects on longleaf pine savanna vegetation was carried out between 1980 and 2004 at the St. Marks National Wildlife Refuge, south of Tallahassee, in north FL (Streng et al. 1993, Glitzenstein et al. 1995). Among the data collected were long-term re-measurements of standing biomass components. These data allow a close to conclusive test of the hypothesis that growing season fires differentially reduce woody plants and increase grasses and forbs. For the first time, we present herein the results of the entire 25 yr record of biomass changes. The hypothesis of differential season of burn impacts on woody plants is rejected for this site. However, there is some indication of seasonal burn effects on grass/forb relationships particularly in drier longleaf pine habitats.

Methods:

Stoddard Fire Plots The original Stoddard fire study consisted of 84 plots distributed across the Tall Timbers landscape (Hermann 1995). The study was initiated during 1959-1960. During the 1990's a large number of the plots were discontinued and converted to other uses. However, three blocks of four treatments (1, 2, 3, 4 year between fire intervals) were retained. There is no within blocks replication. Three plots that had never been burned were also saved, but two of these were not directly associated with the blocks. The 2007 vegetation data were collected using the method of Peet et al. (1998) utilized also by Glitzenstein et al. (2003). In this method, data on species occurrences are collected in a set of nested plots varying in scale by an order of magnitude at each change in level. The method is ideal for quantifying scale effects on species richness. *A priori* contrast analysis (Rosenthal and Rosnow 1985) was used to test Beckage and Stout's (2000) finding of no significant differences in species richness among short-interval fires. We compared annual/biennial burns with triennial/quadrennial burns. This was judged to be the most conservative comparison since it makes no assumptions about the shape of the relationship among the fire frequency treatments. Species richness responses were tested for all native species, all woody plants, and all native herbs. Results for native plants only are shown herein since there is little interest in promoting diversity of exotics; in any case, including the exotics did not change the basic conclusions. We examined woody and herbaceous plants separately to test the assumption that these two groups represent opposite ends of a gradient of adaptation to disturbance from repeated fires. This comparison is also of management interest since it might be of desirable in certain cases to maximize either herbaceous richness or woody richness rather than overall richness.

St Marks Biomass Changes The St. Marks experiment consisted of 32 2-5 ha fire treatment plots. Sixteen plots were in a dry sandhill habitat and the other 16 were in a moister pine flatwoods (see Glitzenstein et al. 1995 for habitat descriptions). The season of burn treatments were as follows: late November, early January, late February, early April, late May, early July, late August, and early October. Initially there was also a fire frequency treatment (annual vs. biennial) but annual burning was discontinued early in the study (see Table 2 in Glitzenstein et al. 1995 for a summary of treatments and burn cycles for the first eight years of the study). Treatment combinations were randomly assigned to plots within habitats. After annual burning was discontinued following the second treatment cycle the experimental design was reduced to a randomized blocks design with 2 blocks (the habitats) and two within block replicates of each season of burn treatment.

Biomass samples were collected from eight permanently marked locations in each plot. Four locations were near to longleaf pine trees and four locations were away from trees, but this factor will not be considered at this time. At each sample date all standing biomass was harvested from a 0.25 m^2 circular plot randomly located within a 1 m radius of the central point in each sample area. The same area was not sampled twice in succession. Biomass was harvested immediately prior to the next scheduled fire so as not to confound frequency of disturbance effects. Since the biomass collection for a particular burn treatment was always collected at the same time of year the repeated samples are also not confounded with time since sampling effects. However, due to seasonal differences in species development, the composition for any given date was not directly comparable. We are not interested in differences at any single time but rather in whether there is divergence over time.

At the beginning of the study biomass was sorted into three major groups: woody, forb (including legumes and Cyperaceae), and grass. Beginning in 1987-1988 biomass samples were sorted to individual species. We present herein only the group data spanning the entire period of the study. The plot-level observation is the sum of the biomass of each group across the eight subplots. We use the structured multivariate approach to repeated measures analysis (Gurevitch and Chester 1986, Hand and Taylor 1987) to test for divergence over time in each group. The simplest example of this approach is when two samples are collected for each "subject" or sampling location, e.g. before and after treatment application. One then simply takes the difference of the two sample periods and analyzes the differences with respect to the experimental factor effects. The fundamental idea is that two data points are transformed into a single variate which is then easily analyzed as part of a typical "between subjects" ANOVA. For multiple sample dates, orthogonal polynomials represent equivalent transformations of repeated measurements into individual variates. In our study, as in many studies, the linear contrast is of greatest interest since a significant ANOVA result indicates significant systematic divergence of trend lines over time (Gurevitch and Chester 1986, Hand and Taylor 1987).

Biomass data were collected at from the St Marks plots at ten different sample dates: 1982,1983,1984,1985, 1988, 1989, 1990, 1994, 1998, and 2004. Linear contrast weights for unequal sample intervals were calculated as discussed in Landram and Alidaee (1997). The between subject analysis compared traditional dormant season burning (November, January, February) to lightning season burning (May, July, August). This single degree of freedom contrast most straightforwardly compares the evolutionarily appropriate prescribed burn season with that utilized by land managers for the last several centuries. Incorporating the other two burn seasons (April and October) is perhaps of some interest, but the analysis is complicated by unequal sample sizes and consideration of those results is deferred to a later publication.

Results and Discussion:

Fire Frequency: Stoddard Plots Glitzenstein et al. (2003) predicted that significant effects of the fire frequency treatments on overall vascular plant species richness would emerge from the Stoddard plot data if species richness could be sampled at smaller spatial scales. This prediction is confirmed by results of the present study. Statistically significant ($P < 0.05$) differences were detected between annual/biennial fire treatments and triennial/quadrennial treatments at all scales less than or equal to 10 square meters. Beckage and Stout's (2000) conclusion is also confirmed, however, inasmuch as our analysis of the current Stoddard Plot data also failed to demonstrate even close to significant fire frequency effects at the larger spatial scales. This result contrasts with Glitzenstein et al. (2003), who found significant or close to significant effects of fire frequency even at the largest spatial scales. Two explanations may be suggested for this discrepancy. First, large-scale woody species richness in the Stoddard plots declined substantially and significantly with increases in fire frequency (Figure 2), whereas fire frequency did not significantly impact woody plant species richness in the two studies discussed by Glitzenstein et al. (2003). Thus increases in herb richness related to increases in fire frequency that occurred in both studies (Glitzenstein et al. 2003, Figure 3 herein) were counterbalanced by losses in woody species in the Stoddard Plots but not in the other studies. The two studies described by Glitzenstein et al. (2003) were carried out in intact native groundcover with rather high diversity of highly fire adapted small clonal shrubs. These small shrubs appear able to tolerate even very high very frequencies with little if any negative impact. The Stoddard Plots in contrast are located in sites with a history of agricultural disturbance and/or repeated ground layer disturbances from management operations (K. Robertson, Tall Timbers Research Station Fire Ecologist, personal communication). This history of disturbance has reduced or eliminated the small shrubs and the main woody ground layer component consists of sprouts of mesic forest trees, e.g. *Acer rubrum, Liquidambar styraciflua*, and *Quercus nigra*. These species seem less able to tolerate the highest fire frequencies.

The other major difference between the Tiger Corner and Osceola sites studied by Glitzenstein et al. (2003) and the Stoddard Plots is that as a consequence of the history of agriculture and soil disturbance the Stoddard plots have a much enhanced component of "weedy" ruderal species. These ruderals maintain large seed banks and consequently are buffered to a larger extent against longer inter-fire intervals.

Glitzenstein et al. (2003, p.34) concluded that "our results overall strongly supported the Most Frequent Fire Hypothesis and will perhaps serve to further emphasize to ecologically oriented land managers the need for short interval burns in southern pinelands". We submit that, despite some differences discussed above, this conclusion has been further validated by our re-examination of the Stoddard Plots.

Fire Season: St. Marks Plots Hypothesized woody plant decline with repeated lightning-season fires (Drewa et al. 2006) was not supported by results of the St. Marks season of burn study (Table 1, Figure 4). Indeed, after 25 years of biennial burns, woody plant biomass in both habitats appears to have shown a pattern of decreasing oscillation, indicating gradual equilibrium convergence on the long-term mean (Figure 4). We can conclude at this point that even had the study been continued there is little likelihood that lightning season fires would have substantially reduced woody plants in these habitats. Other fire season effects on biomass trends were mostly non-significant (Table 1, Figures 4-6). The season of burn effect on grass biomass trends approached significance (Table 1). This was explained by the significant decline of grass biomass in the growing season burn plots (Figure 5). It is well known that lightning season burns stimulate sexual reproduction of dominant grasses (Streng et al. 1993). It is plausible that closely spaced lightning season fires result in excessive investment in reproductive effort, leading to negative carbon balance and gradual long-term declines.

The interactive effect of habitat and season on forb plus sedge biomass also fell just short of significance (Table 1). Graphing these results, we see that forb/sedge biomass in the flatwoods habitat was not affected by fire season, but that biomass of forbs plus sedges increased significantly in the sandhills. Decreases in grasses in this habitat may perhaps have competitively released the forbs (Brewer et al. 1996).

Conclusions Frequent burning is critical for maintaining the well known small scale species richness of southern pine savannas and woodlands. Fires at any season will accomplish this objective. Evolutionary considerations suggest that fires during the lightning season should be part of the prescribed burn mixture. However, unnaturally invariant short-interval growing season fires may have some unintended negative consequences for dominant pine savanna grasses.

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Table 1. ANOVA results for trend analyses of biomass groups. These results are for the contrast between traditional dormant season burns (November, January, February) and lightning-season (May, July, August) fires. The other factor is habitat, i.e. the contrast between sandhill and flatwoods. A significant (P < .05) result indicates divergence over time.

Source of Variation	*df*	*ss*	*F*	*P*
		Woody		
Habitat	1	51990000	18.24	0.00
Season	1	508199	0.18	0.67
Habitat x Season	1	12096	0.00	0.95
Residual (E)	20	57000000		
		Grass		
Habitat	1	1008059	0.35	0.56
Season	1	9740928	3.35	0.08
Habitat x Season	1	1535305	0.53	0.48
Residual (E)	20	58120000		
		Forb + Sedge		
Habitat	1	514485	0.85	0.36
Season	1	19210	0.03	0.86
Habitat x Season	1	2353059	3.91	0.06
Residual (E)	20	12040000		

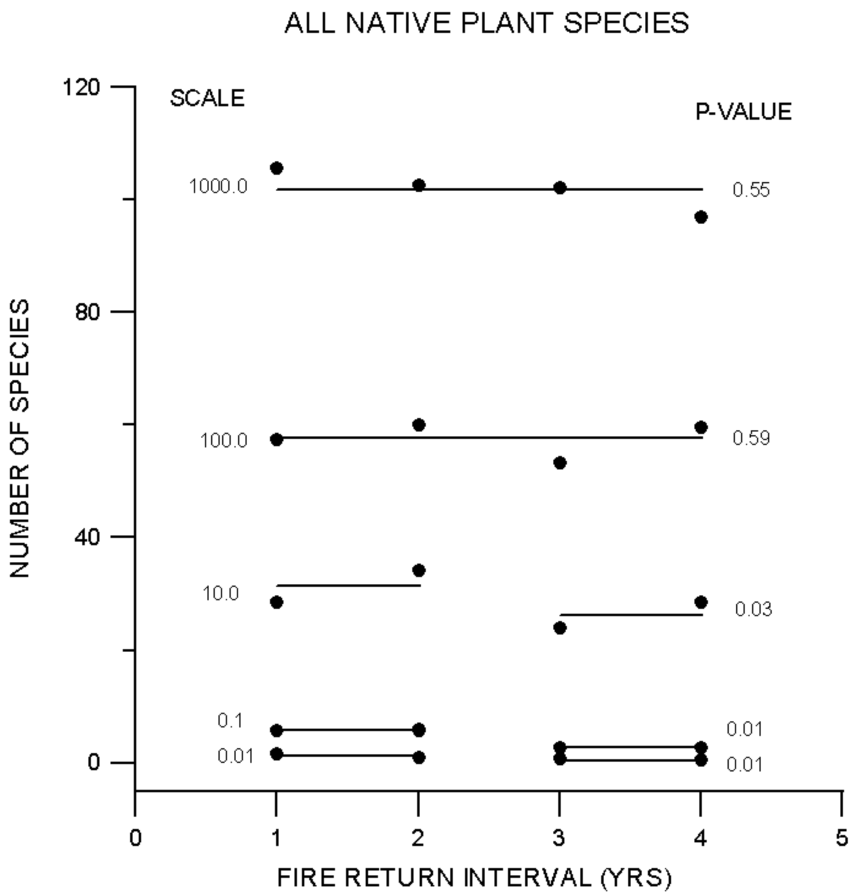

Figure 1. Results of contrast analysis for Stoddard Fire plot burn treatments. Continuous lines indicate contrast is non-significant and the overall mean best fits all the points.

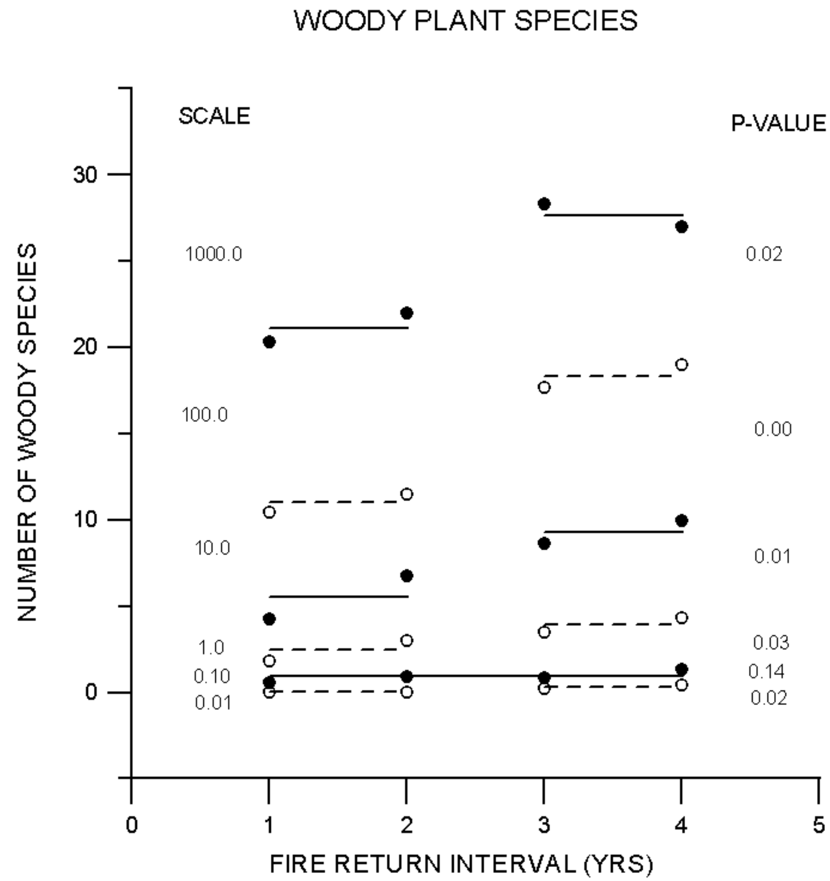

Figure 2. Results of contrast analysis for Stoddard Fire plot burn treatments. Continuous lines indicate contrast is non-significant and the overall mean best fits all the points.

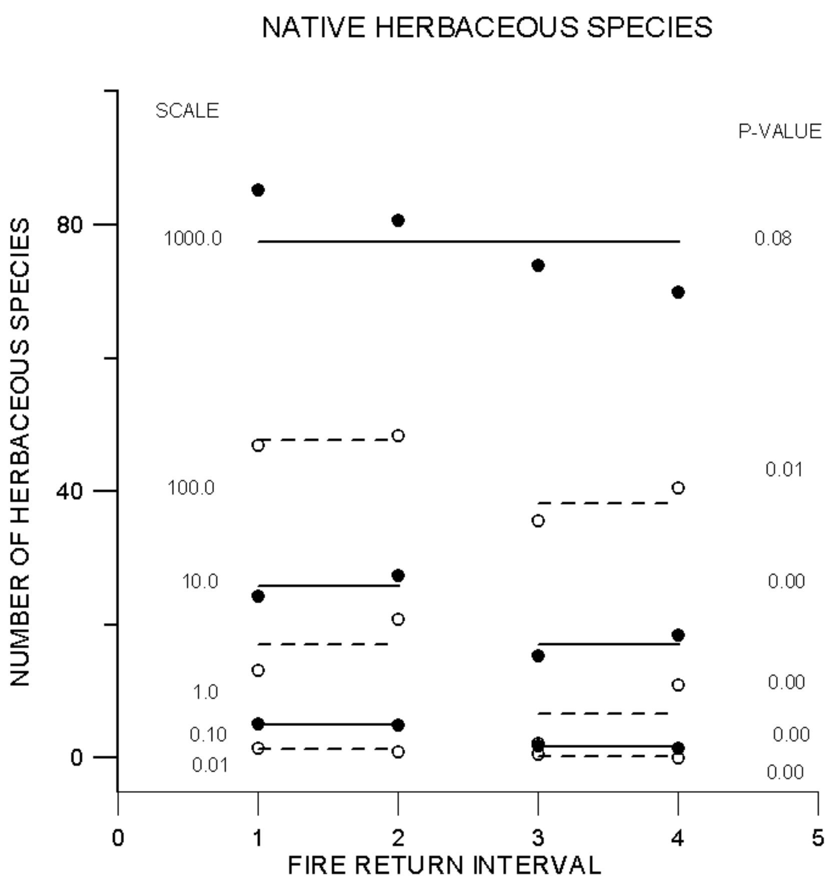

Figure 3. Results of contrast analysis for Stoddard Fire plot burn treatments. Continuous lines indicate contrast is non-significant and the overall mean best fits all the points.

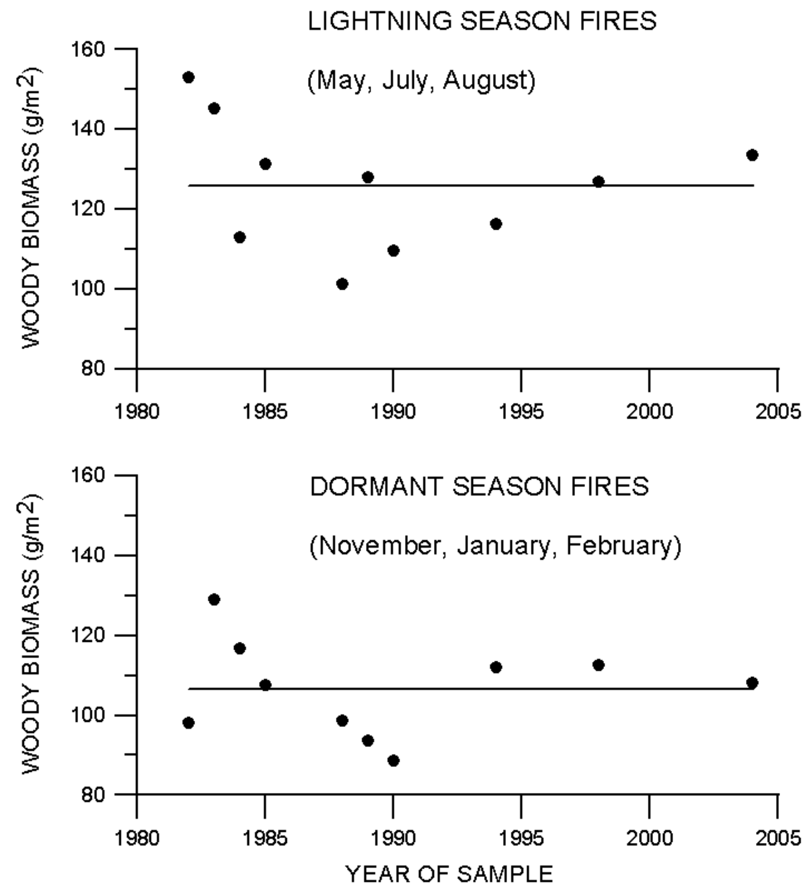

Figure 4. Results of repeated measures analysis for St Marks woody standing biomass. Lines without slope indicate no divergence between treatments and that the within treatment contrast mean did not differ significantly from null.

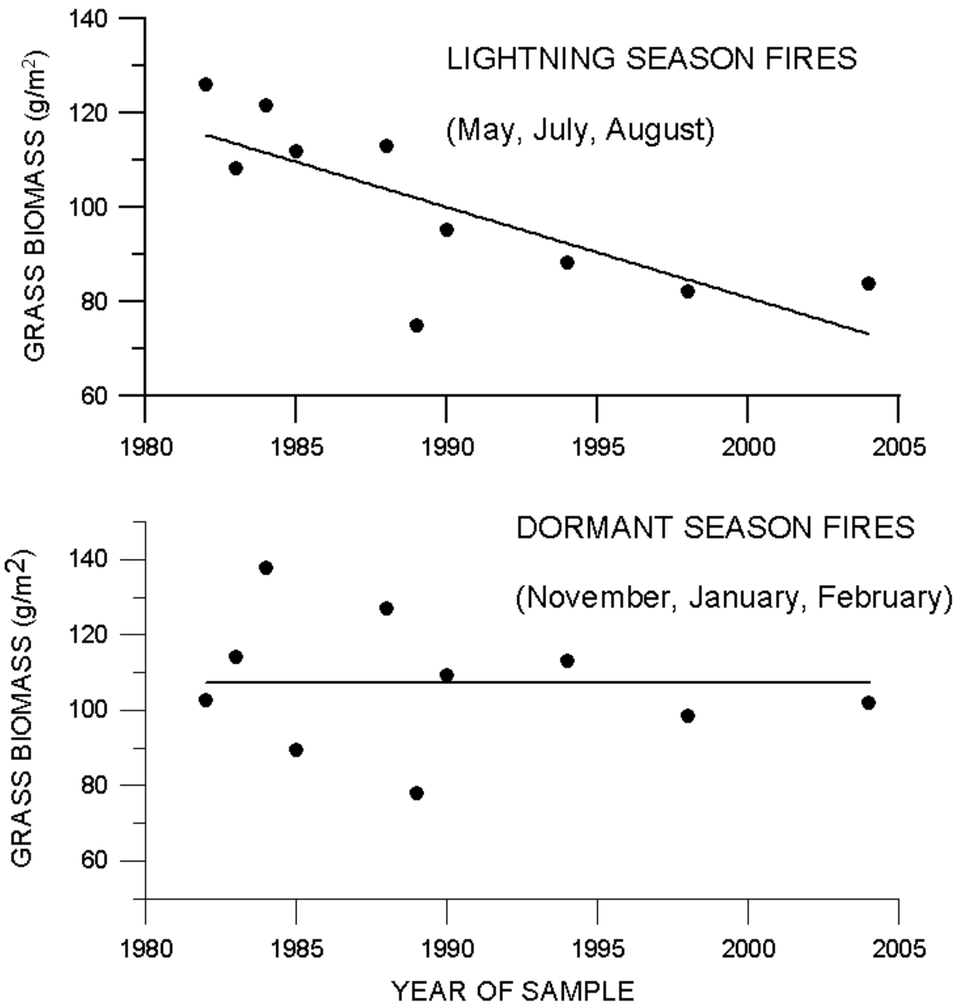

Figure 5. Results of repeated measures analysis for St Marks grass standing biomass. Lines without slope indicate that the within treatment contrast mean did not differ significantly from null.

Woods Burning in South Carolina:
The Nature and Culture of Wildland Fire and its Impact on Our State

Johnny Stowe
SC Department of Natural Resources

I'm very happy to be here today to speak to y'all, and I have high hopes that this meeting will serve as the catalyst, the springboard, and the foundation from which to launch our efforts to make Prescribed Fire a better-known, better-understood, and properly-appreciated natural and cultural phenomenon in South Carolina. I hope the fact that we're meeting here at the headquarters of the National Wild Turkey Federation is a harbinger of the success we'll achieve, since the Turkey Federation has been and is one of the most successful conservation organizations ever. The Federation's phenomenal success has largely been a result of the partnerships it has so wisely-formed and skillfully-guided. Partnerships are popular in these times of tight budgets, and the synergism they produce is always a plus. In many situations, partnerships are efficient, effective, and therefore desirable -- but for our cause -- promoting and ensuring the future of Prescribed Fire in South Carolina -- partnerships are not an option, they're absolutely essential.

Before I talk about fire in the South, and more specifically, about fire in South Carolina, let's consider the unique natural phenomenon we call fire, and how it has shaped both the Earth's surface as well as human culture. Fire on the landscape is a **natural process** that's been around about **425 million years**, when fires ignited by lightning or volcanic action started sweeping the globe. Lightning-fires especially, have continued since that time to shape the Earth's surface. The Southeastern United States (SE) has one of the highest rates of lightning strikes of any part of North America.

Fire is also a **cultural** phenomenon -- an **ancient ritual** and **tradition**, and a key part of our **heritage**; it's **one of man's earliest tools -- the first process of the natural world that we learned to use to our advantage on a landscape level**. **Humans have used fire** for many purposes, to broadly mention a few -- for warmth and cooking, in ceremony, and of course, to alter the landscape to our advantage -- for at least **1.6 million years**.

Fire ecologist and historian Stephen Pyne noted in his classic book *Fire in America*, that the word fire is seldom used in a neutral manner – it usually has either positive or negative connotations. And if you think about it, that's true. Like all tools, fire can also be **mis**-used, and when unleashed carelessly or with bad intent, it can be a devastatingly destructive force. So the use of fire, which is inescapable on Earth, carries with it a huge responsibility of utmost care.

I saw a sign in a small airport once, which compared the perils of aviation with those of the sea. The sign read: Aviation in itself is not inherently dangerous. But to an even greater degree than the sea, it is terribly unforgiving of any mistakes, carelessness, incapacity or neglect. *Captain A. G. Lamplugh, British Pilot. Circa early 1930's.* Now it seems to me that aviation, the ocean, *and* fire are *all* inherently dangerous, but I certainly agree with the second sentence, and I think that it also applies very well to our use of fire.

The effect of fire on the landscape of the SE and its diverse ecosystems, and on the people who have lived here, is well-documented. By about 11,000 years ago, the PaleoIndians and their fires had traversed all of the New World from Alaska to the tip of South America. Henry Lewis compiled 70 different reasons that Indians burned the land, including, for hunting and driving game; for crop, pest and habitat management; for fireproofing for safety; for warfare and signaling; for improving visibility; for clearing areas for travel; and for felling trees for various purposes.

These first Americans, the Paleo-Indians, were hunter-gatherers, and so fire was for them likely mostly used to drive game, improve forage for themselves and the game they relied on for food and clothing, and for protection. At that time, the forests here along the 34th parallel of latitude were much different than they are today. At that time, glaciers covered much of our continent, and the forests here were much like the Canadian forests of today, with jack pine, spruce and similar boreal trees dominating the land. As the climate warmed and the glaciers receded, so also did Indian culture change. Studies of pollen buried in sediment at White Pond, near Elgin, SC show that about 12,800 years ago, the boreal forest migrated north and was replaced by oak-beech-hickory forest. These White Pond data also reveal that about 9,500 years ago, modern Southern pines joined with oaks to dominate the landscape, and contemporary species such as sweetgum and *Nyssa* showed up. Then, Southern pines dominated the area from about 7,000 years ago to the present. Fire suppression seems to be reversing this trend, by preventing longleaf pine regeneration and allowing hardwoods to take over many sites. Other pollen records, from Alabama, indicate that about 2,500 years ago pine and corn both increased remarkably in the SE, and fires set by Indians to clear land for agriculture seem the obvious primary cause for these changes.

As Indian culture progressed through the phases we now call the Archaic, Woodland and Mississippian periods, these people became less nomadic -- they became more sedentary and developed agriculture, as well as stratified societies. And their populations swelled; some researchers estimate that there may have been as many as 100 million Indians in North America in pre-Columbian times. As these societies grew and evolved, fire continued to be used as it was in the past, but it also took on new roles such as clearing travel corridors; clearing land and recycling nutrients for agriculture; controlling vermin such as rodents, ticks and chiggers near villages; and clearing brush around villages to improve visibility and prevent surprise attacks. In other words, the Indians became what we today would call “**land managers**,” and they seem to have been very good at it for thousands of years.

It's tragic and reprehensible that we destroyed the wealth of nature lore and oral history the Indians accumulated over their millennia-long reign here in the SE, but at that time most settlers foolishly thought that there was not much they could learn from the so-called "primitive" and "un-civilized" Indians. Who knows what ethnobotanical and other secrets we destroyed -- secrets that could immeasurably enrich our lives today?

As we move into historical times, we get a glimpse of pre-Columbian America through the accounts of early explorers, and one fact leaps out -- the oft-repeated notion that before Europeans arrived a squirrel could jump tree-to-tree from the Atlantic to the Mississippi without touching the ground **is simply not true**. Much of the landscape at that time was quite open, and fire was the primary natural process that kept it open.

Forest types can be broadly categorized into four classes based on the amount of tree canopy cover, which is reflected in how much sunlight reaches the ground. Forests tend to have at least 60% canopy cover; woodlands have less, say 30-60%, what we might call park-like conditions; savannas are mostly open, with 5-30% canopy cover, and prairies have very few trees; trees on prairies cover less than 5% of the ground. Many of the early historical accounts of the Carolinas describe prairies or savannas. Many of them also mention the widespread, frequent fires set by Indians.

In SC, we have 4 major physiographic regions: the Mountains, Piedmont, Sandhills, and Coastal Plain. Let's consider each, with respect to fire, from the mountains to the sea: Folks tend not to associate fire with Mountain ecosystems, but both history and remnant ecosystems belie that idea. William Bartram, who traveled the SE in the late 1700s, described meadow-like conditions in the valleys of the Blue Ridge in his classic book, *Travels of William Bartram*. He wrote: "[We] began to descend the hills of a ridge … and having gained its summit, enjoyed a most enchanting view; a vast expanse of green meadows and strawberry fields; a meandering river gliding through … flowers … flocks of turkeys strolling about … herds of deer prancing [and] bounding over the hills … companies of young, innocent Cherokee virgins … [lying] reclined under the shade of floriforous and fragrant bowers …" Bartram sure had a way with words. This sounds to me like a fire-maintained, park-like paradise.

The presence of fire-dependent species such as pitch and table mountain pines, coneflowers, and pitcher plants also underscore the role of fire in the Mountains. Many of these ecosystems are today imperiled because of fire suppression. Charles Hudson, in his classic book, *The Southeastern Indians,* describes how the Indians burned the woods to facilitate collection of chestnuts, which provided an unrivaled bounty each fall in the Southern Appalachians before the Eurasian blight we introduced wiped them out.

Much of the Carolina Piedmont -- which we often define today by its characteristic red clay -- was once dominated by grasslands punctuated by groves of mast-bearing oaks, all maintained by fire. Before King Cotton and the concomitant creek-bank-to-creek-bank plowing sent most of the Piedmont's topsoil into the Atlantic Ocean and Gulf of Mexico, the red clay was in places covered by a thick layer of dark, loamy soil in which grew a diverse variety of grasses and wildflowers. After Old World diseases wiped out about 90% of the Indians in the late 1500s, buffalo and elk moved eastward, and both species were common in the Carolina Piedmont just prior to and at the beginning of settlement. Neither seems to have been common in the SE before European contact. Spanish conquistador Hernando De Soto recorded no sightings of buffalo when he traversed the SE in 1539-1542, but he did mention seeing "cow" hide shields, and "horns of cattle." Since cattle had not yet been introduced to the area, these "cow" hides and horns were likely from buffalo -- perhaps obtained from trading with Plains Indians. But in the 1720s, the English naturalist Mark Catesby described the piedmont of the Carolinas as open savannah grazed morning and night by "droves" of buffalo, which sought refuge in creekside canebrakes during the hot part of the day. John Lawson mentioned that while traveling in the North Carolina piedmont around 1700, he went days without seeing a pine tree! Some of the species of bunch grasses grazed by buffalo on the Great Plains also grow here in the Carolinas. Anthropogenic fire was likely the primary factor in the establishment and maintenance of these grasses, and for the scarcity of trees. David Ramsey, a SC historian, wrote in 1858 that "in the year 1750, when the settlement of the upper country began, there were so many buffaloes, which have long since disappeared, that three or four men with dogs could kill from 10 to 20 in a day." And kill them we did. By 1775, buffalo were extirpated from the Carolinas.

The aptly named Sandhills -- often synonymous with the Fall Line -- run from the Carolinas to Alabama, separating the Piedmont from the Coastal Plain. We meet today here in Edgefield on the inland edge of the Sandhills. In the 1540s, De Soto's army of 600 men, 300 hogs, and a passel of horses, traveling from present-day North Augusta to Columbia, made more than 20 miles per day through these Sandhills. That would have been difficult or perhaps impossible unless the land was open, and the agent that kept it open was fire. Further evidence of the role of fire in the Sandhills is the fire-dependent, longleaf pine-bunch grass-scrub oak ecosystem that even today dominates the region. But whereas longleaf once dominated the canopy, and there was a diverse ground cover and sparse midstory -- today, because of fire suppression, the forest structure is quite different. With notable exceptions such as the Sandhills State Forest & Sandhills National Wildlife Refuge, Fort Jackson, and other sites -- vestigial mature longleaf now tower over thick midstories of scrub oaks (mostly turkey oak, with a scattering of bluejack oak and sand post oak), and the oaks shade out the groundcover. And longleaf regeneration is sparse, spindly or absent.

The diverse ecosystems of the Coastal Plain -- which in SC is about equal in area to the Mountains, Piedmont, and Sandhills combined -- are very much a product of frequent fire. Longleaf pine forests, woodlands and savannahs -- some dry and sandy, like on the rims of Carolina Bays and some riverbanks; some wet and fertile, like the seasonally-flooded flatwoods of Lee County -- were the dominant forest type of the Coastal Plain. As I mentioned before, longleaf is fire-dependent; its entire life cycle -- from the seed and seedlings which require mineral soil and low competition from other species, to its "grass" stage when the bud is protected by a thick sheath of needles and the taproot is burrowing deep into the soil, to the "bolting" or "rocket" stage when it shoots up quickly to get its bud aloft, to the mature tree with its thick, insulating bark -- its entire life cycle, its strategy -- is centered on fire -- **frequent** fire.

Conservation biologists define **ecosystem integrity as a function of "natural" processes, species composition, and structure**, and this model is especially clear and cogent for longleaf ecosystems. With fire as *a*, or *the*, primary process -- as long as the land burns frequently, the structure is intact (sparse midstory) and the species composition of the understory is diverse. Remove fire from the equation, and the mid-story encroaches, dominating and shading out the herbaceous groundcover. And these effects interplay with one another. As the herbaceous layer disappears and hardwood litter takes its place, fires don't carry as well, and so fire is even less likely to exert its "natural" stabilizing effect. Instead of these different components complementing one another in a positive loop, their "un-natural" counterparts begin to complement one another in an increasingly negative loop.

Fox squirrels, pine barrens tree frogs, red-cockaded woodpeckers, and bobwhite quail and other grassland birds are species associated with longleaf pine. Plant species diversity of intact longleaf forests rivals that of any ecosystem in the temperate world. And the aesthetic appeal of intact longleaf ecosystems is phenomenal. Bartram lyrically described this beauty, as follows: "We find ourselves on the entrance of a vast plain, generally level, which extends west 60 or 70 miles, rising gently. This plain is mostly a forest of the great longleaf pine, the earth covered with an infinite variety of herbaceous plants, embellished with extensive savannas, always green, sparkling with ponds of water."

Longleaf pine once was dominant or co-dominant on 60-90 million acres in the SE, but only about 3 million acres remain. Most of South Carolina's Coastal Plain and practically all of its Sandhills -- perhaps 5-6 million acres -- were dominated by longleaf just a few hundred years ago, but today, according to the US Forest Service, only 369,000 acres of longleaf remain.

Rhett Johnson of the Longleaf Alliance laments the sad irony that many of our children learn and are concerned about the tropical rainforest while the **Longleaf Pine Fireforest**, their heritage, disappears in their backyards. The Alliance is working to change that.

Many wetlands in SC are also a product of fire. Our native switchcane grows statewide. And the expansive streamside canebrakes described by early explorers -- Bartram mentions extensive canebrakes 24 times in his *Travels* -- once provided key habitat for birds such as passenger pigeons, black bear, Bachman's warbler, Swainson's warbler, and canecutter rabbits. In the Sandhills and Coastal Plain, seasonally-inundated, isolated wetlands -- including Carolina Bays of all types, whether peat-based with pocosin vegetation, clay-based with cypress/sedge forest, or treeless depression meadows -- are all shaped to some extent by fire, which along with hydroperiod (flood-drought cycles), determines their vegetation.

The term **pocosin** eminates from the Algonquian word for "Swamp on a Hill," which reflects the fact that much, but not all pocosin is found in isolated wetlands (no inlet or outlet). Pocosin (often colloquially known as titi) is evergreen and semi-evergreen shrub vegetation (such as swamp cyrilla [again, titi], gallberry, fetterbush, smilax, and the 3 "bays," sweetbay, red bay, and loblolly bay), which often grow atop peat. Pocosins don't burn as frequently as the uplands that surround them, but when they do burn, say every 5-25 years, they tend to burn intensively in stand-clearing fires.

The largest wildfire on record in South Carolina was the Buist Tract fire in Horry County near Myrtle Beach in 1976, which burned about 30,000 acres in 5 days. The magnitude of this fire -- much of which was in pocosin growing atop deep peat deposits -- is underscored by the fact that on average about 30,000 acres burn statewide **each year**. The Buist Tract fire burned that much in less than a week, with flaming material being thrown as much as a mile ahead of the flaming front. Today, 10,000 acres of the former Buist Tract is the SC DNR's Lewis Ocean Bay Heritage Preserve and Wildlife Management Area, which is now adjacent to the Carolina Bays Parkway and Conway Bypass -- both major thoroughfares. But despite the difficulties inherent in burning in such a "developed" area, with the help of the SC Forestry Commission and The Nature Conservancy, we regularly burn a couple of thousand acres a year there.

The rare and valuable Atlantic white-cedar bogs, also known as "juniper" swamps (as in the juniper whaleboats described in Melville's *Moby Dick*), are both fire- and wetland-dependent. We have an Atlantic white-cedar restoration site we are really proud of on our Aiken Gopher Tortoise Heritage Preserve and Wildlife Management Area not far from here, if anyone wishes to see it sometime.

Now that we've looked at aboriginal fire, and the primary fire-shaped ecosystems in SC, let's move forward to European settlement.

The first Europeans to settle permanently in the SE US were a diverse lot, but the ones that may have had the greatest impact on the fire-maintained landscape were the Scots-Irish. Lacking wealth, these people -- called "sandhillers," "rednecks," or "crackers" -- were for the most part pushed to marginal lands, which were unsuitable for row cropping, but well-suited for open-range grazing by livestock. The Scots-Irish were fiercely independent people who brought with them their native Celtic tradition of open-range grazing, and a key part of that tradition was frequently burning the land to encourage new growth of grasses and forbs. The extent of open-range grazing is evident in the fact that in the 1850s nearly 6 million head of cattle, sheep, horses and mules in the Carolinas and four other SE states were mainly supported by grazing on open range.

Africans also brought with them from their native continent the tradition of burning for range management, as well as to facilitate hunting and for other reasons, as the writings of Karamoja Bell, T. V. Bulpin and others attest. **So, the tradition, the ritual, and the heritage of Prescribed Burning in the SE -- begins with an ancient Native American foundation, which later meshed with European and African cultures. Prescribed**

Burning in South Carolina is truly an ancient, time-tested, and effective land management practice with multi-cultural roots, and it's certainly one worth preserving, for cultural as well as natural reasons.

Herbert L. Stoddard, often considered the Father of Bobwhite Quail Management, appreciated the benefits of frequently burning the land, especially as it related to benefiting quail. His pioneering, management-based research in the North Florida and South Georgia piney woods, starting in the 1920s, laid the technical and formal foundation for the modern prescribed burning we practice today. Stoddard's advocacy for prescribed fire -- and his research on large plantations, many of which had been kept intact only because of wealthy Northerner's interest in quail hunting -- later evolved into the Tall Timbers Research Station, the nucleus for research into the ecology, philosophy, and techniques of modern prescribed fire. Stoddard and his fellow researchers at Tall Timbers, especially brothers E.V. and Roy Komareck, successfully promoted acceptance of Prescribed Burning outside the Deep South. Tall Timbers could be called the mecca of **Prescribed Burning.**

Besides the large plantations that were acquired and managed for quail hunting and ended up conserving some of the most significant, fire-dependent longleaf and other threatened ecosystems in the nation, another situation developed that fortuitously protected large fire-dependent tracts of land -- that is, the military bases with their firing ranges and resulting unplanned, but highly beneficial and frequent fires. Much of the best fire-dependent land we now have is on military bases such as Fort Jackson, Fort Benning, Eglin Air Force Base, Shaw Air Force Base, and the former Fort McClellan in Alabama's Ridge and Valley, and Appalachian regions, part of which is now the Mountain Longleaf National Wildlife Refuge. While these ecosystems were preserved by chance, the Department of Defense now recognizes their value and purposely maintains these areas with prescribed fire and other management techniques.

Powerful forces and many taxpayer dollars have been used to proselytize a culturally-ignorant and condescending message of fire suppression in the South. Felix Salten's novel *Bambi* was translated into English in 1929; then Walt Disney got a-hold of it, and Disney switched the chief threat to Bambi and his companions from poachers to fire. Bambi was for a time used in a fire prevention poster.

In the 1920s, 30s and 40s -- our country's fire suppression movement became entrenched in government and forest policy. Starting in 1924, *federal funds were withheld from state forestry agencies if they even tolerated prescribed burning*. Then the American Forestry Association undertook a massive propaganda campaign, the Southern Forestry Education Project, from 1927-1930. Teams of proselytizers known as the Dixie Crusaders were sent into the rural South with trucks equipped with generators, movie projectors, films, radio broadcasts, posters, and pamphlets. They traveled 300,000 miles and passed out 2 million pieces of literature along the way. They presented more than 5,200 motion picture programs and lectures to 3 million people. One of the main themes of this mis-information campaign was fire's purported destructive effect on wildlife.

The US Forest Service, starting in the 1930s, employed sociologists and psychologists to study what it deemed to be the psychopathology of woods-burners, and continued to fund this work for 40 years. Then in 1945, Smokey the Bear came along. His slogan, "**Remember, Only You Can Prevent Forest Fires**" was the theme of one of the most successful advertising campaigns ever. In ways, the advent of Smokey was a death blow to ecosystem integrity on many wildlands in the SE. Of course, Smokey has done some good, and the part of his message about not being careless with fire will always be on-the-mark, but one might persuasively argue that Smokey has done more harm than good in the SE by disintegrating fire-dependent ecosystems and fostering fuel build-ups that eventually resulted in catastrophic wildfires. Smokey and his cohorts could also be labeled culturally-insensitive -- to use a euphemism -- since in the SE at least -- Smokey, the Dixie Crusaders and others ignored not just the ecological, but also the cultural value of woods burning, which was such an integral part of Southern life.

It is only fair to note that the fire hazard situation in our nation was quite complex when Smokey arrived on the scene, with factors like huge accumulations of tinder-like logging slash, and spark-spewing steam locomotives making matters quite volatile. But even today, when the US Forest Service is one of the main proponents and practitioners of prescribed burning, the mis-information campaign persists. I recently saw a prominent "Smokey" sign on the Talladega National Forest in Alabama that read: **Fire Destroys Watersheds.** That doesn't help our cause any. We need to get a drip torch in Smokey's hand.

Conditions in SC today are much different than in the past. Our state is changing at what seems to me an alarming rate. We call this change "progress" and "development," but I wonder if we need to redefine those terms. Both the land and the people of the state are now less rural, and with these demographic and landscape changes arise new challenges to maintaining prescribed fire as a traditional tool for natural resource management. Much of the increase in population that we're experiencing is from folks migrating Down South from Up North, many from northern cities. And while it may be tempting to blame the increasing hassles associated with land management practices on these immigrants, we should remember that many of these folks come from a region with a fire history much different than that of the South. The attitudes of people from the Lake States and the Northeast may be rationally and understandably influenced by passed-down accounts of conflagrations and tragedies like the Peshtigo Fire in Wisconsin, which killed 1,500 people and destroyed more than 1 million acres of timber. In just 8 hours, this fire devastated 1,000 square miles of pine forest. It burned on the same day as the Great Chicago Fire, in the fall of 1871, but killed 5 times as many people. Stephen Pyne makes a good point about what may be the chief reason for differing attitudes on fire, that is, "In the South, mass fires appeared as threats only with the advent of fire protection; in the Lake States, fire protection tended to eliminate the mass fire."

Bruce Matthews coined the term "**rurbanization**" "to define the invasion of affluent urban and suburban-oriented people into rural areas, looking for a self-defined 'country' lifestyle, while importing urban attitudes and values, and expecting urban amenities." Matthews maintains that, "the resulting conflict tears apart the fabric of rural communities, and often destroys the very nature of the 'country' experience originally sought, though few **rurbanites** realize it." Certainly rurbanization is a large part of the problem we face in maintaining prescribed fire in SC. A recent SC DNR study of Charleston & Dorchester counties showed not only that the population is growing (no surprise there), but that associated urban sprawl is growing at 4 times the rate of population growth.

A new term has arisen to describe these places where forestland meets suburbia -- the **Wildland-Urban Interface** -- and the SC Forestry Commission's excellent ***Firewise*** and ***Living on the Edge*** programs are working to educate folks who live there about how to make their homes safer from the threat of wildfire, so that theirs will not be one of the 60 homes damaged or destroyed by wildfire each year in SC. Memories of the Florida wildfires of 1998 are making this program quite relevant in certain parts of SC.

At any rate, I believe we need to constantly remind ourselves of the context and rationale -- sometimes justified and sometimes not -- behind perspectives that differ from our own on the issue of fire. Understanding root causes for these perspectives can help us understand how to change them, if need be.

We have a great challenge before us, but we have great and unique advantages in our favor. I believe we have all we need to ensure the future of Prescribed Fire in SC. Many of our most important elected state officials understand the need for Prescribed Fire. Our legislature specifically provided for Prescribed Fire in the Heritage Trust Act of 1976. This Act was the first law of its kind in the nation and has since been copied nationwide. Our legislature also wisely passed the **SC Prescribed Fire Act** of 1994, which legally defines Prescribed Fire thus:

"'Prescribed fire' means a controlled fire applied to forest, brush, or grassland vegetative fuels under specified environmental conditions and precautions which cause the fire to be confined to a predetermined area and allow accomplishment of the planned land management objectives. It also is known as a 'controlled burn'."

The Prescribed Fire Act also led to the **Certified Prescribed Fire Manager** program run by the SC Forestry Commission, and the law provides legal protection for those implementing Prescribed Fire. And we are lucky that current **South Carolina Governor Mark Sanford** understands land management; he owns land himself and is personally impacted by wildland fire issues.

Quail managers in SC have been carrying out and advocating Prescribed Fire since Stoddard's time. Today, the Northern Bobwhite Conservation Initiative has a goal of applying fire to 29.6 million acres of pinelands in the SE Coastal Plain. And federal initiatives such as the Landowner Incentives Program and Wildlife Habitat Incentives Program are providing support to private landowners to practice prescribed burning on their lands.

Now to the council itself: The **South Carolina Prescribed Fire Council** was formed in the summer of 2003, and our **mission is to foster cooperation among all parties in South Carolina with an interest or stake in prescribed fire, to optimize burning opportunities by encouraging the exchange of information, techniques, and experiences among practitioners of prescribed fire in South Carolina, and by promoting public understanding of the importance and benefits of prescribed fire**. And we have a slogan: **Keep SC Safe: Promote Rx Fire**

We plan to propose that the Governor declare a ***Prescribed Fire Awareness Month*** this winter, which will include regional media academies, in which we'll conduct demonstration prescribed burns (weather permitting), hand out fact sheets about prescribed burning, and answer questions. [note: in 2005, **South Carolina Governor Mark Sanford** proclaimed March as *Prescribed Fire Awareness Month*] We are also compiling a list of sites where the public can visit land that's regularly burned, to see what it looks like before, during, and immediately after burns -- and the best part -- to see what it looks like after re-growth. According to the SC Forestry Commission, over the past 10 years prescribed fire has burned an average of about 500,000 acres per year statewide. We think that acreage can and should be doubled.

The South is the origin of modern prescribed burning in the US. When the rest of the country "caught on" to the utility of prescribed burning, it came to the South to learn the principles and techniques. The art and science of woods-burning in SC is a deeply-rooted, traditional tool in Native American, African, and European culture and heritage -- and it is a unique and essential element of our Southern character, as well as being quintessentially natural.

We must succeed. The welfare of many species of wildlife and many ecosystems, and the safety of millions of citizens are responsibilities we must embrace. We have the time-tested knowledge that frequent woods-burning prevents fuel build-up, and that in many ecosystems it is not a matter of **if**, but **when**, fires will burn, and that it's always best to **choose** the "**when**." We have the beauty of fire-maintained ecosystems to inspire us. And we have the expertise. We have the legacy of Herbert L. Stoddard, the backing of several branches of government, including the SC Department of Natural Resources and SC Forestry Commission, as well as the US Forest Service, Fish and Wildlife Service, and Natural Resources Conservation Service -- and the support of organizations like the Longleaf Alliance, the Nature Conservancy, and Tall Timbers. We have the scholarship of fire researchers like Clemson University's David Van Lear and Tom Waldrop. And we now have this Council, which aims to pull all those with an interest in Prescribed Fire together toward our common goal. It is a worthy goal, and I look forward to us progressing together. Together we can ensure that Prescribed Fire will continue to keep South Carolina safe and natural, as it has for thousands of years.

Let me leave you with this proverb from the Tuareg people of North Africa:

The hand that holds the brand will never be burned by the fire.

Fire and Native Grasslands of the Mid-Atlantic States Before European Settlement

Cecil Frost, Landscape Fire Ecologist

What are eastern native grasslands? We have been vague about use of that term, focusing on the grass species rather than the communities. Examples from maps of presettlement vegetation and fire frequency for 14 large sites, from tidewater regions to the Southern Appalachians, make it apparent that, *with few exceptions, all upland communities of the region once had grass layers*. The exceptions include naturally fire-sheltered cove hardwood forests in the mountains and beech forests of the Piedmont and Coastal Plain. Our traditional pigeonholes for vegetation structure are prairie, savanna, woodland and forest, according to the amount of cover of woody canopy. Both prairie and savanna can be said to be dominated by grasses and we think of prairie as essentially treeless grassland, while definitions for savanna in the Southeast have allowed for up to 50% tree cover if there is a continuous herb layer. The amount of grass in the herb layer has not been much considered in relation to woodland or forest, yet the frequency of fire in presettlement forests dictates that their understories were much more open and grassy than the multistoried woody vegetation of fire suppressed forests today. The greatest amount of species diversity in fire-maintained upland communities of the region is always in the herb layer.

With the exceptions mentioned above there are no native communities of uplands of the mid-Atlantic states that do not require fire to maintain their species diversity. The amount of grass and forbs in a wooded community is proportional to the degree of sunlight in combination with the frequency of fire. The accumulation of litter and formation of a duff layer is lethal to pyrophytic grasses. Disregarding the naturally fire sheltered portions of the upland landscape, all uplands of the southeastern U.S. experienced fire on intervals from 1 to 12 years. Over this vast landscape most lands passed through a fire frequency bottleneck during the era of total fire suppression, with the consequence that most remnant examples of natural vegetation have lost 70-100% of the original plant species of the ground layer. Within longleaf pine grasslands, extrapolating from 785 stands I looked at from Virginia through Georgia, these communities have been extirpated from all but around 2.2% of their original range (excluding recent plantations), or about 1,050,000 ha. Of that fraction, only about 19% or 193,000 ha is currently being maintained with fire, and only 9% of what is left has escaped significant loss of species diversity resulting from past fire exclusion. That means that less than 96,572 hectares, or less than 0.2% of the original extent of the longleaf pine ecosystem remains in condition good enough to support all of its native plants and animals. Beyond the range of wiregrass and of longleaf, the picture is less complete but the small remnants of natural communities maintained with fire often have surface layers dominated by little bluestem (*Schizachyrium scoparium*), poverty grasses (*Danthonia sericea* and), Andropogons and others depending on fire frequency and soils. From here on, the first restoration questions we must ask ourselves involve what was the original fire frequency, how open would that have kept the understory and what species composition in the grassy layer did that support?

Effect of Eastern Gamagrass, Bermudagrass, Kudzu Hay and Sweet Potato silage on Performance of Boer Cross Male Goats

J. R. Bartlett[1], E. G. Rhoden[2], V. A. Khan[2] and O. S. Aribisala[1]

The meat goat industry is one of the fastest growing in the United States. The demand for goat meat is on the rise, with a 35% increase in imports annually. This has led to an increased interest in goat production by small-scale limited resource farmers to help reduce the dependency on imports. This has led researchers and extension agents to try and find alternative feed sources to help reduce the cost of production. Therefore, the objective of this study was to determine the effect of feeding sweet potato silage compared with different types of hay on the performance of Boer cross meat goats.

There were four treatments consisting of eastern gamagrass hay (EGG), Bermudagrass hay (BGH), kudzu hay (KZH) and sweet potato silage (SPS). The study utilized twenty-four goats for seven weeks. Goats were randomly assigned to individual pens and offered one of four treatments at 5% BW. Water and mineral blocks were offered *ad libitum*. Refusals were collected daily to determine feed intake, and goats were weighed weekly to monitor body weight gain. At the end of seven weeks, goats were slaughtered and carcass characteristics evaluated.

Results showed that the average intake for the SPS group was 35.7 lbs which was significantly higher than all three hay groups with 12.71, 11.0 and 9.57 lbs for EGG, BGH and KZH, respectively. However, the SPS was adjusted for dry matter (DM) content to be on par with the DM content of the other treatments. This resulted in the higher intakes reported. There were no significant differences in weight gain among the treatments, however, animals in all the hay groups tended to gain more (3.71, 3.57 and 3.14 lbs for KZH, EGG and BGH, respectively) than the SPS group (2.86 lbs). There were no significant differences among the diets for hot and cold carcass weights. The average dressing percentages for SPS, EGG, BGH and KZH were 46, 46, 44 and 44%, respectively. These results indicate that SPS compares well with the hay groups in goat performance.

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How Bessie Saved the World: a New Paradigm for Grasslands Conservation in the Southeast

Patrick D. Keyser[1], Gary E. Bates[2], Craig A. Harper[3]

Introduction Aldo Leopold's succinct observation about habitat management tools: "the ax, the plow, fire and the cow", seems to be well accepted among conservationists in the Southeast with the exception of the latter option. Herein we present a case that grazing is an overlooked and powerful tool for improving grassland habitats in the region.

Conservation at a Large Scale Grazing is the dominant land use on agricultural lands in the Southeast, a region dominated by private ownerships where economics are a critical consideration. If a business case can be made for incorporating native grasses into regional forage systems (e.g., low-input, high yield, warm-season perennials with high drought tolerance, good animal performance, and a potentially large secondary market in the form of biofuels feedstocks), then market-based approaches for large-scale deployment of native grasses within the region may be possible. The 40 million acre Rolling Red Plains Physiographic region is an excellent example of how market-based grazing can sustain high grassland bird numbers, as exemplified by 40-year trends in Northern Bobwhite (*Colinus virginianus*) populations demonstrate.

Why Aldo Was Right Studies on western rangelands have shown grassland birds respond positively to disturbance associated with grazing. Some wildlife managers have implemented low- moderate-intensity grazing as a tool to enhance habitat for high conservation concern species such as Greater Prairie Chicken (*Tympanuchus cupido*) on relict tall grass prairies. By contrast, ungrazed native grasses, such as those in CRP plantings, do not provide good habitat for nesting grassland birds. Indeed, historically some form of large animal herbivory was a key component of disturbance regimes in most eastern grassland communities. Grazing may also prove to be a valuable tool for incentivising restoration of oak savannahs, a community that may hold the best promise of restoring nearly complete native grass communities in the region.

Looking Forward The Center for Native Grasslands Management, along with a number of partners, is working toward identifying grazing systems that can provide some benefits of properly managed native grass communities as well as practical and economically viable forages. Current research includes integrating biofuels feedstock and forage production, incorporating legumes in native grass production systems, and evaluating use of winter annuals in warm-season grass systems. In addition, efforts are being made to develop studies examining the role of cattle grazing in oak savannah development and patch-burn grazing in switchgrass grazing systems.

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Effect of Eastern Gamagrass, Bermudagrass Hay and Two Silages on Performance of Meat Goats

Victor A. Khan[2], Jannette R. Bartlett[1], Errol G. Rhoden[2] and O. S. Aribisala[1]

Currently, the United States consumes more than 48 million pounds of goat meat and more than 22.4 million pounds are imported. As this industry grows, more limited resource farmers are getting involved in goat production. This requires an investment in feed material which can be expensive. It is therefore important to find economic means of production, and at the same time, produce the best quality meat. With this in mind, the objective of this study was to compare the effect of feeding different types of hay and different silages on the performance of Boer cross meat goats.

There were four treatments consisting of eastern gamagrass hay (EGG), Bermudagrass hay (BGH) as the control treatment, sweet potato (SPS) and kudzu silages (KZS). The study utilized twenty-four goats for five weeks. Goats were randomly assigned to individual pens and offered one of the four treatments. They were fed at 5% of their body weight. Water and mineral blocks were offered ad libitum. Body weights were recorded weekly. Refusals were collected daily to determine intake. The silage treatments were adjusted for dry matter (DM) content.

Results showed that the average weekly intake for the silage groups was 25.8 and 20. 6 lbs, for SPS and KZS, respectively. This was significantly higher than both hay treatments with an average of 10.4 and 7.2 lbs for EGG and BGH, respectively. Average weekly gain was highest for EGG with 2.36 lbs, 1.86 lbs (BGH), 1.76 lbs (SPS), and 1.96 lbs (KZS). At the end of the study, goats receiving EGG out-performed all other groups.

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Ecological compatibility of native, salt-tolerant graminoids and forbs: relationships between trait combinations, relative yield, and resource use

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The Solvay Settling Basins are a 600 ha complex of saline landfills near Syracuse, NY that generate leachate with electrical conductivities in excess of 100 dS/m. The overall site goal is the reduction and containment of this highly saline leachate. We have been examining the extent to which native, salt-tolerant graminoids and forbs can be used to assist in meeting this site goal while also restoring a globally imperiled plant community (inland salt marsh).

In 2006, we planted monocultures and all possible bi-cultures of seven species along a soil electrical conductivity gradient (initially 0.8 to 80 dS/m) and assessed biomass production, relative yield and community level transpiration in 2007.

Differences in plant traits (e.g. photosynthetic pathway, specific leaf area, and canopy architecture) between species in bi-cultures were related to the production, yield and transpiration data with respect to soil salinity. Across all plots, total (above plus belowground) biomass production ranged from zero to 1000 g m^{-2}, and significant over-yielding of total biomass production was not observed. Over-yielding of leaf biomass was observed in non-saline (less than 4 dS/m) settings; however this did not appear to have a significant impact on community level transpiration. Biotic factors driving community level transpiration were belowground biomass, whether or not the bi-culture was a C3/C4 combination (which generally increased community level transpiration), and the presence of the highly salt tolerant *Distichlis spicata* in bi-culture. Current analyses are further investigating the mechanisms behind over-yielding of leaf biomass and the extent to which canopy architecture affected community level transpiration. Overall, these analyses improve understanding of the autecology and synecology of salt-tolerant plants and have relevance to restoring inland salt marshes and understanding the zonation of saline plant communities.

Plant Community and Geomorphological Structure of a Piedmont Wet Prairie along Soil Gradients

Lee Roy Lehman[1] and Larry Barden[1]

Introduction: Tallgrass prairies of the American Midwest and Southeast have virtually disappeared since the mid-1800s due to colonization by European-Americans. Efforts to restore and re-create what were once extremely diverse prairie ecosystems in the piedmont of Southeastern US are particularly limited by lack of sites where the relationships between native vegetation communities, soils and geomorphology can be observed. In 1996, a rare remnant stand of a mesic Piedmont prairie was located in Cabarrus County, NC. This site has been used strictly for the production of native-grass hay by the Suther/Bell family since they settled the area about 1740. It is the purpose of this study to describe in detail baseline relationships between soils, geomorphology and ecology of this rare site.

Methods The surficial geology of Suther Prairie was mapped and soil pits were excavated on each geomorphic unit. The 7-acre site was surveyed at a 5 meter resolution with a laser theodolite and a 10x10m grid was established. Soil samples were collected from 0-15cm and 16-30cm depth at each grid point. These samples were analyzed for moisture, pH, texture, and carbon. In the spring and fall of 2006, the abundance of dominant plant species (>1% coverage) was collected by the pin-drop method at 69 sites within the grid. All data were inputted into ARC/GIS, and the vegetation and soil data were additionally analyzed using PC-ORD.

Results and Discussion Suther Prairie consists of four primary geomorphic units: floodplain, tributary alluvial fan, hillslope underlain by typical piedmont saprolite, and an anthropogenic ridge which dissects the western margin of the floodplain. Plant communities are statistically differentiable in both spring and fall and correlate well with geomorphic units and soil moisture. *Andropogon gerardii* (Big Bluestem) and *Tripsacum dactyloides* (eastern gamagrass) dominate the alluvial fan and upland hillslope of the prairie. The floodplain of the prairie consists primarily of *Carex stricta* (Tussock Sedge) and *Cephalanthus occidentalis* (Button Bush). Overall drier sites are dominated by Big Bluestem and Gamagrass, while wetter areas consist of Tussock Sedge and Button Bush. The soils and geomorphology of the Suther Prairie site are typical of many Piedmont floodplains. We therefore conclude that similar sites could be found and restored with native prairie ecosystems.

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Suther Prairie: Vascular Flora, Species Diversity and Edaphic Factors

Robert D. Tompkins[1]*,William C. Stringer[2], Catherine M. Luckenbaugh[3], Keith H. Richardson, Elena A. Mikhailova[4] and William C. Bridges Jr. [5]

Introduction Piedmont prairie communities were common prior to European settlement. These areas were maintained by periodic natural and man-made fires, as well as animal activity. Today, Piedmont prairies have been reduced to relict populations along roadsides and utility rights-of-way. Suther Prairie (3.2 ha) in Cabarrus County, North Carolina is among the best-known extant examples of such an ecosystem. It is unique for its mesic to hydric conditions and for not having been tilled. This study provides a complete floristic list for the site for the 2006-07 growing seasons, including frequency of species occurrence, as well as soil chemical status.

Methods The site was surveyed across the 2006-07 growing seasons and voucher specimens were collected. Transects were established and 90 random 1m² quadrats were sampled for species frequency. Six random quadrats were soil-sampled at depths of 0 to 10cm, 11 to 20cm, and 21 to 30cm, and soil pH, organic C, total N, extractable P, Ca, Mg, Zn, Mn, Cu, B, and Na were determined.

Results and Discussion A total of 139 species were identified in the 2006-07 growing seasons. In addition, 92 species identified in prior vegetative surveys and not collected in this study were included in the species list for the site for a total of 231 species. Ninety-five of which were prairie indicator plants. A total of 73 species were graminoids; 42 were grass species; and 31 were sedges and rushes. Wetland-obligate or facultative wetland species comprised 28% of the list. A total of 13 species were rare or uncommon for North Carolina. Big bluestem (*Andropogon gerardii*) and Eastern gammagrass (*Tripsacum dactyloides* var. *dactyloides*) had the highest frequency of occurrence at the site. There was significant variation in soil C, N, P and Zn levels among the sampled depths. Levels of Ca and Mg were considerably higher than normal for Piedmont soils.

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Invasion of cool-season plants into native, warm-season grass pastures

Benjamin F. Tracy[1]

Introduction. Agricultural grasslands in much of the eastern United States are dominated by cool-season forage species (e.g., tall fescue, Kentucky bluegrass). Native, warm-season grasses (NWG) have great potential to diversify cool-season grazing systems. Warm-season species possess a different photosynthetic system (C4 vs C3) and are most productive during summer when cool-season species are largely dormant. This characteristic of NWG can help increase grazing system productivity since their growth complements that of cool-season forages, which grow best in spring and fall (Belesky and Fedders, 1995; Moore et al., 2004). An additional benefit afforded from C4 photosynthesis makes NWG more nitrogen and water use efficient than most cool-season species so NWG require fewer inputs to attain high yield (Brown, 1978).

Use of NWG in cool-season forage-livestock systems has some drawbacks. Native, warm-season grasses are often slow to establish and have comparatively low forage nutritive value relative to cool-season species (Nelson and Moser, 1994). Because of their complementary growth patterns, cool-season species begin growth much earlier in the spring compared with NWG. The earlier growth of cool-season species may allow them to invade plantings of NWG.

In 2004 and 2005, two sites in Illinois were planted with mixtures of NWG with a goal of integrating these species into cool-season grazing systems. The objective of this particular study was to monitor the abundance of cool-season species in newly established NWG plantings to detect trends in invasiveness. Although many cool-season species can invade NWG stands, we were especially interested in two species – tall fescue and kura clover. Tall fescue can be invasive (Clay and Holah, 1999) was growing abundantly in pastures near NWG stands. Kura clover was purposely sown with NWG plantings to improve forage nutritive value and soil fertility. Although slow to establish, kura clover eventually becomes an aggressive (Seguin, 2007). We were concerned it could become invasive in these stands.

Materials and Methods. Sites used for this study were located at the University of Illinois Orr Center Beef Unit located in Baylis, IL and the Dudley Smith Research Farm near Pana, IL. The Orr Center grasslands were established in 2004 to a 4.6 ha area. The Orr Center was located on rolling deep-loess soils (primarily Hapludalfs, Ochraqualfs and Albaqualfs). The area had been planted to corn for one growing season (2003) and alfalfa previous to that. Prior to planting, soils were tested and adjusted for fertility. In spring of 2004, soils were tilled to prepare a clean seed bed. Three warm season perennial grasses (Eastern gamagrass, big bluestem and little bluestem) were drilled into the pasture in early May.

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Seeding rates were 5.6 kg/ha pure live seed (PLS) for each species. Kura clover was also sown with the mixture (2.2 kg/ha) to improve forage quality and add nitrogen to soils. The pasture was treated with one application of 2,4D herbicide to reduce broadleaf weeds in April 2005. In May 2005, the sown area was separated into three equal sized paddocks for grazing.

The Dudley Smith site was established in early June 2003. The area and establishment methods were similar to Orr Center except this site was previously used for corn-soybean production. Soils at the farm consist of silty, clay loams, classified as fine, smectic, mesic vertic arquioquolls, and are of the Virden series.

The two sites were grazed by cow-calf groups during the growing season. At each site, three cow-calf groups grazed the three NWG pastures at a stocking rate of 2.5AU/ ha. From April to July, cow-calf groups grazed adjacent cool-season pastures (mainly tall fescue/bluegrass mixtures). In summer, as forage growth slowed in cool-season pastures, cattle groups were moved to NWG pastures. This rotation gave cool-season pastures rest and allowed them accumulate forage. Once NWG had been grazed to a designated canopy height, cattle were moved back to cool-season pastures. When canopy of ~80% NWG cover had been grazed to 12 cm stubble height, we moved cattle back to cool-season pastures. At the Orr Center, NWG pastures were grazed in mid-July and mid-August each for approximately 10 days. We had less managerial control at Dudley Smith farm. Those NWG pastures were grazed more frequently starting in May and ending in August. Warm-season grass pastures were grazed 5-6 times during this period. Grazing residency lasted from 1-5 days depending on time of season.

Species composition at the sites was taken in mid-August, which corresponded to peak biomass of NWG. The Dudley Smith site was sampled from 2004-2006 and Orr 2005-2006. Species composition was not measured during the year of establishment. In each of the three NWG pastures we established three, 50m, permanent transects to evaluate species composition. Transects were run from the pasture border (fence line) to plot center. At every 5m along the transect, species composition was measured within a 0.5m x 2m quadrat. The percent ground cover occupied by each species and bare ground was recorded.

Several variables were calculated from the species composition data – relative ground cover, relative frequency and percent importance value (IV). Percent importance value was calculated by averaging relative cover and frequency values for each species. This variable gives an index of the relative importance of a species in the community as it encompasses both frequency of occurrence and the amount of space occupied by the species. Species richness was used as an index of diversity. It is the mean number of species that occur per unit area. This study was largely descriptive with two to three years of data was collected per site. As such, trends with time should be taken with caution. To test for differences in species abundance with time, we used a two factor ANOVA using year and site as independent variables and respective species abundance (IV or percent ground cover) as a dependent variable. A non-significant year x site interaction would allow us to test for differences between years.

Results and Discussion. The objective of this study was to monitor the abundance of cool-season species in newly established NWG plantings to detect trends in invasiveness. Particular interest was focused on two species – tall fescue and kura clover. Of the three NWG sown at sites, eastern gamagrass was, by far, the most dominant species (Table 1). Big and little bluestem established better at Orr compared with Dudley Smith. The more frequent grazing at Dudley Smith may partially explain why these two species were not more abundant. Three years after establishment, tall fescue had increased in importance at both sites (Table 1). The percent importance value (IV) of tall fescue increased about 2% each year and was statistically significant ($P=0.002$). Kura clover (KC) was sown with NWGs to improve forage nutritive value and soil fertility. It increased in importance at Dudley Smith site from 14 to 24% ($P=0.001$) over three years. This species showed no change at Orr (Table 1). Because of the aggressive growth of kura clover in spring, the NWG stands were grazed in May - much earlier than desired July timeframe. The earlier and more frequent grazing at Dudley Smith may have harmed NWG. Interestingly, the trend in increasing tall fescue and kura clover importance at Dudley Smith site was associated with a general decline in the three NWG species over time (Table 1). Where KC was less abundant at Orr, we saw a significant increase in eastern gamagrass ($P < 0.05$) and relatively stable abundance of bigbluestem and little bluestem.

Other cool-season species and weedy plants showed no consistent trends over time. Importance values for grass and broadleaf weeds averaged about 5% at both sites. The Orr site had significantly more plant species ($P <0.05$) compared with Dudley Smith (Table 2). These were mostly weedy species that were likely brought in from adjacent pastures, cropland and forest borders. The NWG stands at Dudley Smith were more isolated occurring essentially in the middle of corn-and soybean fields where weeds were actively controlled. The spatial isolation of the NWG stands at Dudley Smith may partially explain why fewer weedy plant species were found there.

Table 1. Percent importance value in grassland community of planted and non-planted species and bareground in two study sites.

		Importance Value (%)		
Site	Species*	2004	2005	2006
Dudley Smith	EGG	29.5 (1.6)	24.8 (0.6)	22.6 (0.4)
	BB	6.2 (0.5)	3.9 (1.6)	2.8 (0.7)
	LB	6.0 (1.7)	2.2 (1.1)	4.6 (1.1)
	KC	14.5 (1.9)	25.4 (1.2)	24.2 (1.2)
	TF	5.6 (0.7)	7.5 (0.6)	9.6 (1.2)
	GW	2.3 (0.5)	2.1 (0.5)	2.0 (0.6)
	BLW	2.5 (0.7)	2.9 (0.5)	3.0 (0.5)
	BARE	24.7 (2.1)	11.0 (1.3)	17.1 (0.6)
Orr	EGG		20.5 (0.4)	37.6 (3.8)
	BB		7.6 (1.0)	5.5 (1.4)
	LB		11.9 (1.3)	12.0 (2.1)
	KC		9.8 (2.4)	5.3 (2.6)
	TF		2.7 (0.3)	4.8 (0.5)
	GW		3.5 (0.5)	3.6 (1.3)
	BLW		1.8 (0.4)	1.4 (0.1)
	WP		1.7 (0.4)	2.9 (0.6)
	BARE		20.2 (1.0)	16.4 (1.3)

*Abbreviations are EGG – eastern gamagrass, BB – big bluestem, LB – little bluestem, KC – kura clover, TF – tall fescue, GW – grassy weeds, BLW – broadleaf weeds, BARE – bareground. Numbers in parentheses are 1 SE.

Table 2. Species diversity, expressed as mean species richness, of NWG stands at the two sites.

Site	Year	Species Richness
Dudley Smith	2004	10.6 (1.7)
	2005	14.6 (1.1)
	2006	12.8 (0.9)
Orr	2005	17.6 (0.7)
	2006	15.2 (1.2)

We also evaluated percent ground cover of species along the permanent transects. Transects were run from fence line to center of plots. The orientation of the transect was done to document potential spread of cool-season species from adjacent pastures into NWG stands. At both sites, tall fescue dominated pastures that abutted NWG stands. Analysis of the transect data showed no real trend in kura clover cover from fence line to plot center (Table 3). As expected, tall fescue cover was greater at the fence line near other fescue pastures. Over time there appears to be a trend in tall fescue presence deeper into the plots especially at Dudley Smith (Table 3). This might suggest that cattle might be depositing fescue seed into NWG stands – possibly in manure or from seeds trapped in fur.

Conclusions. This study focused on potential invasiveness of two cool-season species (kura clover and tall fescue) in young NWG stands. Kura clover was purposely sown with NWG plantings to increase forage nutritive value and soil fertility. At one site of the two sites, KC became invasive. We attempted to control KC by grazing, but the extra grazing may have reduced NWG abundance. Although KC is highly persistent and may benefit forage nutritive value in temperate grasslands (Mourino et al., 2003), it can be invasive in NWG stands. Using aggressive clover species, like kura, with NWG plantings is not recommended and probably unnecessary nutritionally for most types of livestock. Tall fescue abundance increased significantly over the three years of this study. The speed at which fescue established was surprising given it was not abundant in plots before planting with NWG. These results are testament to the competitive ability of tall fescue in grazing systems. Tall fescue is among the most abundant cool-season forage grasses in the eastern US, and its control will be necessary maintain species integrity of NWG stands planted in this region.

Table 3. Percent ground cover of dominant perennial warm-season grass (Eastern gamagrass) and two cool-season species (kura clover and tall fescue) along 50m transects. Transect started (0 m) at border of tall fescue pasture and NWG stands.

			Meters along transect										
Site	SPP	Year	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
Dudley Smith	EGG	2004	2.8	36.7	41.7	43.3	55.0	45.0	48.3	45.0	46.7	55.0	53.3
	EGG	2005	5.0	33.3	40.0	45.0	53.3	60.0	40.0	48.3	51.7	51.7	45.0
	EGG	2006	7.5	38.3	27.5	31.7	38.3	41.7	31.7	35.0	40.0	40.0	38.3
	KC	2004	.	11.2	14.2	13.7	17.0	19.2	25.0	10.0	25.0	23.8	21.3
	KC	2005	48.0	35.0	56.7	36.7	40.0	35.0	53.3	35.0	41.7	41.7	40.0
	KC	2006	24.0	36.7	55.0	41.7	35.0	33.3	48.3	36.7	33.3	42.0	24.2
	TF	2004	48.3	23.3	10.0	2.0	.	.	.	.	23.3	.	30.0
	TF	2005	65.0	33.3	20.0	30.0	.	20.0	17.5	7.5	7.5	10.0	5.0
	TF	2006	75.0	17.5	20.3	7.3	10.0	12.5	16.7	10.0	10.0	7.5	18.3
Orr	EGG	2005	.	50.0	40.0	31.7	31.7	43.3	28.3	41.7	35.0	38.0	41.7
	EGG	2006	.	66.7	82.5	80.0	62.5	54.2	55.0	60.0	60.0	72.5	65.0
	KC	2005	.	5.4	5.8	6.3	6.3	4.8	6.4	9.0	7.5	10.3	5.7
	KC	2006	.	5.7	1.5	30.0	20.5	20.0	6.3	4.0	4.0	1.5	6.0
	TF	2005	50.0	10.0	.	.	.	3.5	5.0	.	20.0	.	.
	TF	2006	56.7	2.0	1.0	2.0	.	5.0	.	2.0	5.0	5.0	.

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Fuel from Biomass: Alternatives, Current State of Development

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Since the 1973 oil embargo, the U.S. has been aware of the need to break its addiction to petroleum. Developing economies of India and China, coupled with the increased U.S. domestic consumption of oil has exacerbated fuel issues. Roughly 60% of all oil imported into the U.S. is used for the production of gasoline, diesel, and jet fuel. Biomass has the potential to produce a number of fuels, from syngas to bio-oil, but ethanol has been the primary focus of the U.S. Department of Energy.

Production of ethanol is not a new technology, mankind has been deliberately producing ethanol for thousands of years. It has only been since World War II, that technologies to produce ethanol from cellulosic material have been used. With the beginning of the new millennium, additional technologies have been developed that can greatly enhance ethanol yields from biomass. Until recently, acid hydrolysis of cellulose followed by fermentation of the resulting sugars (simultaneous saccharification and fermentation; SSF) has been the primary focus, but as research continues alternatives to this process are coming to light. Newer methods using cheaply produced cellulase enzymes to replace the acid hydrolysis are very attractive. Pyrolysis of biomass to produce syn-gas followed by fermentation of that gas to ethanol is also being investigated. Currently 25% of the U.S. corn crop goes into the production of 6.5 billion gallons of ethanol.

However, corn and other grains can only serve as a bridge to other feedstocks for ethanol production. Diversion of grain to fuel production, coupled with crop failures has caused the price of food to increase dramatically. While any number of plant species and waste streams can supply the raw material for the production of ethanol from cellulose, grasses, especially warm-season grasses, have a distinct advantage. Biomass yields from grasses greatly exceed that of even the fastest growing tree species, the material is relatively low in non-fermentable lignin and high in cellulose and hemicellulose. Perennial grasses naturally scavenge nutrients from their above-ground biomass back into the crown with the approach of winter, making supplemental nutrient application less of an issue. Of the perennial grasses, switchgrass (*Panicum virgatum*) has surfaced as one of the prime candidates to act as a major source of cellulose. As a North American native species, populations of switchgrass are already adapted to many areas of the U.S. Its growth habit lends switchgrass to low input, sustainable production. Yet improvements can be made. Given populations need to be tailored to given locations to maximize yield. Development of lower silica and lower lignin cultivars would aid in processing. Such developments will increase the energy balance for the production of cellulosic ethanol and other fuels, such as bio-oil.

Portraying the presettlement Southeast through oil paintings of remnant grassland communities

Philip Juras

Rather than an unbroken forest, the presettlement Southeast could have been described as a patchwork of adjacent, dissimilar communities transitioning into one another. From the mountains to the sea much of this patchwork would have exhibited grassland characteristics. This would be particularly true of the vast pine savannas of the coastal plain but would also be exhibited in upland piedmont openings and on the balds in the higher mountains. While there are early accounts describing some of these landscapes, visual records from the time of settlement do not exist, and the landscape itself, particularly the grasslands, has been all but forgotten. There are however, scattered grassland remnant communities that offer an aesthetically rich view into the presettlement landscape. I interpret that view with landscape painting inspired by grassland ecology and natural history.

To create images of these remnant grassland landscapes, I have painted field studies in oil on travels to a variety of remnant sites as well as images painted in the studio. Because my artistic intention is to convey as much as possible the experience of being in these places, I have primarily chosen sites that exhibit their characteristics over a large area, preferably to the limits of sight. Examples include the savannas of the Apalachicola National Forest, the salt marshes of the coastal plain, flat rock outcrops in the Georgia piedmont, and balds of the North Carolina mountains.

The existence of these remnant grassland communities can be traced to a more or less uninterrupted regime of disturbances such as fire, flood, drought, and even grazing. Due to these stresses, features that would normally be obscured by vegetation are clearly legible. The visual compositions of the unique vegetation, the abundant light, and the atmospheric effects lend themselves readily, in my view, to portrayal in oil on canvas, particularly when the sun is at a low angle. Highlighting these elements along with the natural and historical significance of the subject bears a resemblance to 19th century American painting, which also dealt with themes of grand nature.

The choice of these landscapes as subject matter is additionally significant when considering that they have exhibited more or less the same function and form for hundreds of years or more and thus provide a rare landscape size window through which to glimpse the vast presettlement wilderness. By taking such a glimpse one can better imagine the scenes described by early southeastern explorers, bringing into focus such descriptions as this one by William Bartram in the vicinity of the fall line in central Georgia: "...sublime forests, contrasted by expansive illumined green fields, native meadows and Cane breaks..."

The Return of the Natives to Mepkin Abbey

Guerric Heckel, Judith Kramer and John Martin

Mepkin Abbey is a place and a community of Trappist monks living on the site of an historic rice plantation in the South Carolina Lowcountry, near Charleston. The history of the land and its' people from the Native Americans to the monks is reviewed and related to current ecological conditions. The results of an ecological characterization of the property's 3100 acres by Dr. Richard Porcher are briefly summarized. The Abbey's native plant gardens are illustrated and described as forest, shrub and meadow reclamation gardens, woodland, wetland, and historical gardens. Reclamation and cultural practices are noted. The concept and importance of matrix spaces framing, buffering and connecting garden spaces is introduced. The conservation, use and promotion of native plants are fundamental to the environmental stewardship mission of the Abbey. The native plant gardens are open to the public for their enjoyment, education, inspiration and contemplative use and are designed and enhanced for these purposes. Elements of such design are illustrated. A key objective is to motivate visitors to use natives in landscaping and to provide conceptual tools and information for success. To further advance this objective, propagation capabilities are under development to meet the need for quality plant and seeds of known origin. Propagation facilities and fields are illustrated.

The Role of Ritual and Ceremony as a Means to Conserve Grasslands and other Fire-Maintained Biomes - and to Bind People to Place and Practice, and Develop and Preserve Community Bonds

Johnny Stowe, SC DNR

Throughout the long-past millennia, ritual and ceremony were vital to human survival. But today we often think of them as quaint luxuries, rather than as necessities. The rate of "civilization" appears in many cases to be negatively correlated with the importance of certain rituals and ceremonies, with more "civilized" and scientific societies attaching less importance to these ancient cultural practices. Considering the various detrimental effects of so-called "developed" societies on the natural world, I propose that we review and in some cases renew certain of the rituals and ceremonies that once bound us to the Earth, and to one another. I draw on the work of human ecologists and other thinkers to show how these practices help us maintain reverence for, and to conserve, landscapes, as well as to hold communities of people with shared vision and values together. One practice I cover in detail -- with both text and photos -- is that of the "First Fire" of the prescribed burning season.

Switchgrass and Biofuels: Challenges and Opportunities

Patrick D. Keyser[1], Craig A. Harper[2], and Gary E. Bates[3]

Introduction Dedicated perennial herbaceous crops for cellulosic ethanol are forecast to produce 377 million dry tons annually by 2030 requiring establishment of up to 55 million acres of perennial grasses, principally switchgrass (*Panicum virgatum*). Economic models suggest that a disproportionate share of this grass will be planted in the Southeastern US due to longer growing seasons, higher rainfall, and a higher proportion of marginal cropland. If the 55 million acre level is reached, this will by far exceed the acreage currently in pine (*Pinus* spp.) plantations in the SE (ca. 32 million acres) or CRP (ca. 35 million acres). Those two are concentrated in the Coastal Plain and Great Plains, respectively. Biofuel crops will be concentrated more in the "Fescue Belt". The implications for wildlife habitat and biodiversity conservation from such a substantial land use shift are profound.

Challenges Any cropping system, whether based on native grasses or not, that relies on a single species may have poor biodiversity values. In the case of switchgrass, current paradigms for management include relatively high density stands of lowland cultivars that will be harvested once annually, post-dormancy. Pressures for optimum yields and feedstock quality mandate use of inorganic fertilizers, mostly nitrogen, and herbicides to minimize "weeds" within the stand. Current tendencies to maximize field size for operational efficiencies are likely to continue. Such intensive, monotypic cropping systems suggest that wildlife habitat quality may be poor and other contributions to biodiversity may be limited.

Opportunities Switchgrass stands will be largely replacing non-native grasses or row crops, both of which have low biodiversity and are poor habitat for many wildlife species and require much higher inputs of pesticides and fertilizer. Traditional recommendations to break up larger crop fields and retain edges and fencerows certainly have merit with switchgrass as well. In addition, it may be possible to defer November harvests of switchgrass until later in the winter with minimal yield loss and with substantial gain in cover. Introducing disturbances to switchgrass stands early in the growing season through integrated forage production may also improve wildlife habitat quality through improved structure, invertebrate populations, and plant diversity. Introduction of legumes into switchgrass systems may also provide substantial benefits in these same areas. Finally, given the anticipated scale of biofuels production, the public's demonstrated interest in sustainability could translate into a willingness by growers to implement pro-active approaches that enhance sustainability.

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Biofeedstock Yield, Quality and Cell Wall Components of Tetraploid 'Meadowcrest' Eastern Gamagrass Grown Under Varying Nitrogen Rates

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Eastern gamagrass, *Tripsacum dactyloides* (L.) is a warm season grass which has potential for high biomass. Previous forage quality studies have indicated low lignin levels and higher digestibility and higher potential ethanol production compared to other warm season grasses.

A study was conducted at the USDA-NRCS Big Flats Plant Materials Center in Corning NY on a Unadilla silt loam soil. The gamagrass had been managed for seed production for 10 years and was planted in 3.5 foot row spacing. The treatments consisted of varying rates of nitrogen (0, 50, 100, 150, and 200 lb/ac) supplied as calcium ammonium nitrate. The stand was cut on 7/2/07 and 9/17/07 and dry matter yields were taken.

The eastern gamagrass showed a yield response to the nitrogen fertilizer with yields of 1.8, 2.9, 3.8, 4.5, and 4.6 tons/ac corresponding to the increasing rates of nitrogen fertilizer. There were significant differences due to nitrogen treatment with the maximum yield resulting from 150 lb/ac nitrogen. The yield and quality will be reported for both cuttings. The quality will be measured by percent CP, ADF, NDF and lignin through standard methods from a commercial lab. There were only significant differences in % CP at the 224 kg ha^{-1} rate with 11.9 percent CP for both cuttings. There were no significant differences for the fiber components for the first cutting with lignin levels being an average of 3.4% for all treatments. There were significantly lower fiber levels for the 0 nitrogen treatment for the second cutting. The second cutting levels were higher than for the first cutting. Additional methods will be used to assay neutral sugar content and ratios to determine hemicellulose and non-crystalline cellulose, insoluble cellulose and to evaluate the polysaccharide structure and degree of polymerization.

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Switchgrass Production Potential on Reclaimed Surface Mines in West Virginia

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The high cost of petroleum based transportation fuels has caused an increased interest in the development of renewable biofuels to supplement our energy needs. One energy crop that is well suited for conversion to biofuels is switchgrass because of its high biomass production on marginal lands with moderate fertility needs. West Virginia has the potential to become a center of biofuel production with its large expanses of reclaimed mine lands that are central to the U.S. energy market. Switchgrass production on surface mine land offers the unique opportunity to increase the land resources devoted to energy crops without decreasing the land resources devoted to food and livestock feed production. Our intention with this study is to identify the best varieties of switchgrass for mined lands in West Virginia, their planting and management requirements, yields, biofuel feedstock potential, capacity for carbon capture and sequestration and other revenue streams.

Two sites in the southern and one in the northern part of the state were selected for this experiment. Three varieties of switchgrass were randomly assigned and planted into one-acre plots, which were replicated three times for a total of nine plots at each site. The varieties of Carthage, Cave-in-Rock and Shawnee were chosen for their favorable growing characteristics and adaptation to West Virginia's climate. All three sites are reclaimed surface mines and have had topsoil rolled out above the overburden material. The Coal-Mac mine site in Logan County was prepared with a disk harrow and then hydroseeded with seed and mulch. The Hobet 21 mine site in Boone County was prepared with a disk harrow and then hand broadcast with a spinner spreader and then hydromulched. The Hampshire Hill site in Mineral County had been amended several years previously with bio solids from a municipal waste treatment facility, and the soil was disked, harrowed and then switchgrass was broadcasted by hand with a spinner spreader, and not hydromulched. Switchgrass seed of each variety was planted at a rate of 10 to 12 pounds pure live seed per plot at all sites. Germination success, percent cover, soil carbon levels and biomass yield were determined 2 months after seeding (July 2008) and 4 months after seeding (September 2008). Results will be discussed at the meeting in October 2008.

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Development of Fort Cooper source-identified germplasm of *Andropogon ternarius* for rangeland restoration in Florida

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At the time of European settlement, 24 million acres or about 70 percent of the total land area of Florida was rangelands. Now only about 4 million acres of rangeland remains. Concerns about habitat loss, water availability and quality, and the need to enhance sustainability of grazing enterprises are causing a reversal of the historic trend in rangeland conversion. Another source of localized pressure on Florida rangelands is presented by the phosphate mining industry. The rich phosphate deposits located 15 to 50 feet below the soil surface in central Florida's Bone Valley provide American farmers with 75 percent of their phosphate fertilizer requirements and a quarter of the World's needs. Mining companies are required by state and local environmental regulations to restore land that has been mined on an acre by acre basis to its pre-mined functional status (i.e., rangeland to rangeland, wetland to wetland, etc.). Direct seeding remains the most economical method for rangeland and mineland restoration.

In a 10-yr project, USDA, NRCS Brooksville Plant Materials Center (PMC) worked to identify and evaluate native upland species with suitable characteristics for restoration use (i.e., stand persistence; erosion control; livestock forage production; wildlife food and habitat, etc.) and to develop cultural methods to produce and establish these species. One of the species that showed excellent potential was splitbeard bluestem (*Andropogon ternarius*). Splitbeard bluestem is a clump-forming native grass that is found on dry upland sites in the Coastal Plain. The plants produce slender culms that are up to 1 m tall. The racemes are generally paired and the spikelets are white and villous. A key distinguishing characteristic is a fringe of white hairs that remains at the base of the raceme following seed dispersal. PMC staff used a Woodward flail-vac seed stripper to collect seed from a population of splitbeard bluestem growing in the northern section of Ft. Cooper State Park in Citrus County, FL in 1995 (NRCS accession number 9060084). Germination of seed produced in non-irrigated fields at the PMC was 36% and estimated yields were 86 pounds per acre. Germination increased to 92% when seed was dehulled to the bare caryopsis using a hammermill; however, sufficient research has not been conducted to determine if this treatment may cause damage to the seed coat that will reduce storage ability. In testing on reclaimed minelands near Ft. Meade, FL conducted from 1997 to 2001, 9060084 consistently germinated and established better on sand tailings than any of the other 34 accessions of grasses and forbs that were direct-seeded on the plots. Growth of 9060084 was reduced on plots located on overburden, which is likely due to the higher clay content of these substrates. In 2008, this accession was released as a source-identified material and given the name Ft. Cooper Germplasm. Splitbeard bluestem provides forage for livestock in the spring and provides excellent cover for many wildlife species; it has been found to be a preferred nesting site for Northern Bobwhite Quail (*Colinus virginianus*). However, the greatest potential use for Ft. Cooper is as a nurse crop to protect slower establishing native grasses.

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How Native Grass Morphology Affects Seed Harvestability

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Abstract The scarcity of seed of many native grasses is often the result of low harvest efficiency and difficulty in gleaning and conditioning the seed using standard harvest and cleaning equipment. Arbuckle Ranch Inc. with support from the Montana Board of Research and Commercialization Technology undertook an independent study to examine the key morphological characteristics of plants, inflorescences and seed and how they influence seed harvestability, which consequently affects their market availability and price. A dichotomous key was developed to categorize 999 native species and subspecies (continental US) based on plant height, inflorescence type, point of seed disarticulation, awn length, seed size, seed shape and seed hairiness. A detailed database was created of 197 native grass species with commercial importance, exhibiting morphological characteristics, ecological profiles, and seed availability.

Microsoft Access was used to query the database of 197 commercially important grasses finding that 86.8% had panicle inflorescences, while the remaining 13.2% had spikes or racemes. In 69.5% of the grasses the seed unit disarticulated above the glumes, while 30.5% disarticulated below the glumes. Other characteristics that affect harvestability are medium and long awns (25.3%), hairy seed or appendages (45.6%) and small or very small seed (56.8%). Indeterminacy and seed shatter also impact harvest efficiency, but are morphological characteristics that are understood primarily through practical experience of seed growers and researchers.

The Arbuckle Native Seedster is designed for harvest of difficult-to-harvest grasses, forbs and shrubs. The innovative design utilizes a combination of a counter-rotating comb and a brush to pluck the seed from the inflorescence. Grasses with paniculate inflorescences and/or with divergent or twisted awns, and hairy lemmas or appendages are generally difficult to harvest with the standard combine. Rather than a hindrance to harvesting, the awns and hairy appendages actually contribute to the effectiveness of the Native Seedster harvester. The results of this study can be used by the seed industry to predetermine the relative harvestability of a crop and its potential for harvest with a Native Seedster.

Introduction One of the principal means of restoring native plant communities is planting of adapted native grass, forb, and shrub species. Major barriers to this effort are the high costs of seeds adapted to specific planting sites and limited availability of many desirable species. The high market value of some native seed is a result of one or more of the following factors; scarcity of the plant (either small component of native communities or relatively few commercial production acres), low inherent productivity of individual species, low seed harvest efficiency, and difficulty in harvesting and conditioning. The demand for native seed often exceeds available supply. Consequently the use of many native species has been limited for government agencies involved in conservation, as well as, for private organizations and individuals interested in restoration and/or agricultural production. Improved seed harvesting methods are needed to expand the number of species used in restoration of native plant communities and to lower the cost of seed through increased harvest volumes (Lochner 1997).

Seed of commercially produced or wildland harvested native grass species come in a wide variety of sizes and shapes and have a variety of appendages and surface features (attached sterile or staminate florets, attached rachis, awns on lemmas and paleas, hairs/wool/bristles on lemma surface and calluses) that influence harvest efficiency. The unique morphology of a seed unit [naked caryopsis, caryopsis enclosed in palea and lemma (floret) or the caryopsis enclosed in the lemma and palea as well as the glumes (spikelet)] and the circumstances of their attachment to the parent plant have long posed problems and obstacles in efficient seed harvest. Both commercially produced and wildland seed is harvested using some version of the following harvesting equipment:

- Combine utilizing various sieves and screens
  - Combine from cured windrow
  - Direct combining
    - standard sickle and reel header
    - Shelbourne Reynolds Inc.™ header—England and KS
- Seed Stripper/Plucker
  - Single-brush stripper
    - Woodward Flailvac™ (front-mount)--OK
    - Prairie Habitat,Inc.™ (pull-type and front mount models)—Manitoba, Canada
  - Counter-rotating brushes (pull-type)-Genesis Grassland Harvester™--KY
  - Counter-rotating brush and comb drum (front-mount) Native Seedster Inc.™ MT
- Seedhead harvest with ‘diapered’ swather
- Hand Harvest

Certain seed and plant morphological characteristics can influence harvest efficiency with standard combining equipment while actually contributing to the harvest effectiveness of stripper/plucker mechanisms.

In the grass family (*Poaceae*) the inflorescence is made up of spikelets and their arrangement is classified as a spike (unbranched with spikelets directly attached to rachis), panicle (has main axis with spikelets on subdivided branches) or raceme (spikelets are on pedicels branching from a main rachis). These spikelets, for the majority of grasses, consist of two glumes (bract-like structures) that enclose one or more florets. The floret consists of a lemma and a palea, which cover or enclose the caryopsis. The hairs, awns, sharp calluses, and bristles usually occur as attachments to the lemma and/or glumes and are not attached to the actual seed (caryopsis). In some grass species the caryopsis will drop out of the floret when it matures, however there are species (e.g. *Paniceae* tribe) where the seed remains tightly enclosed within the floret. Throughout this report, the term 'seed' is used to describe the harvested 'seed unit' which may consist of only the naked caryopsis, the caryopsis enclosed in the lemma and palea (floret), or the seed enclosed in the lemma/paleas, as well as the glumes (spikelet).

Materials and Methods To characterize difficult-to-harvest native grass seeds the physical characteristics of both the seed and the parent plant were considered. These characteristics can be identified as follow (bolded ones were used for development of a dichotomous key):

- **Plant** characteristics:
    - size
    - **height**
    - shape
    - form (upright, decumbent, spreading)

- **Inflorescence** characteristics:
    - **type, (panicle, spike, raceme)**
    - size
    - shape
    - position in relation to foliage
    - location of seed within the inflorescence (e.g. inside sheath, exposed)

- **Seed attachment** characteristics:
    - **location of seed or spikelet disarticulation, (above or below the glumes)**
    - strength of attachment (shattering)
    - indeterminacy (ripens progressively)

- **Seed** characteristics (i.e. morphology):
    - **size (e.g. number per unit of weight)**
    - density
    - **shape (irregular, elongate, round)**
    - **lemma awn length**
    - **floret pubescence, hairs, appendages**

The morphological component of the seed key and database was created to:

- Identify and categorize morphological characteristics of native grasses and their seed that affect harvestability.
- Construct an extensive dichotomous grass seed/harvestability key based on these key morphologies.
- Describe the morphology, ecology, and availability of perennial native grasses that have current commercial value.
- Identify species that have difficult-to-harvest seed, and why?
- Determine the amount and distribution of difficult-to-harvest native grass species in the continental U.S.?

With the use of the USDA-NRCS PLANTS Database (http://plants.usda.gov) (Plant Guides, Plant Fact Sheets, and Release Brochures), Flora of North America (Vol. 24 & 25) (http://herbarium.usu.edu/webmanual/) (Intermountain Herbarium 2006), State Keys & Floras, private sector websites, Technical Reports, Journal Articles, and University Herbariums, a list of perennial native grasses occurring in the continental United Sates was created (999 species, subspecies and varieties) (Sindelar et al., 2008). Plant and seed morphological characteristics, features, and innovations were studied and grouped (using Microsoft Access™) to develop a dichotomous key based on grass plant, inflorescence and seed morphology with relevance to harvestability.

These seven morphological characteristics used were those for which data was commonly found in the reference material.

- Plant height (short-<18”, medium 18’-42”, tall >42”)
- Inflorescence (panicle or spike/raceme)
- Disarticulation (above or below the glumes)
- Awn length (awnless/awn tipped, <10mm, 10-30mm, >30mm)
- Seed size (>1,000,000/lb, 250,000 to 1,000,000, 100,000 to 250,000, <100,000)
- Seed shape (elongate, ovoid, or irregular)
- Seed hairs (present or absent)

In the dichotomous key plant height, type of inflorescence, and point of disarticulation were used to create 12 primary groups. Because of limited taxonomic information on some species, they could only be classified within one of these twelve groups. The other species for which detailed taxonomic information was available were further categorized using awn length, seed size, seed shape, and floret hairiness. Combinations of all the subdivisions of each of the 7 primary morphological characteristics resulted in the potential of 1152 groups in which these native grasses can be classified within.

Also an extensive database consists of only native grasses having current economic value. Morphological and ecological profiles were created for 197 native grasses using a variety of information sources. Information included plant and seed morphology (7 primary characteristics), ecological setting, associated plant communities, uses, seed availability and harvest notes. This data base is posted on the Native Seedsters website (www.Native Seedsters.com) as a read-only file.

Information on plant characteristics such as uniformity of ripening (indeterminacy) and tendency to shatter can only be acquired through practical experience of growers and researchers. It was not in the capabilities of this study to get such detailed information on all of the 197 commercially important species. As additional data is obtained, it will be added to the existing database.

Personnel conducting the study included former Montana State University (MSU) Range Science professor-Dr. Brian Sindelar, recent University of Wyoming graduate-Drew King (Botanist), MSU Herbarium curator-Matt Lavin, MSU student-Leslie Eddington, Texas A & M agrostologist-Dr. Stephan Hatch, Plant Materials Specialist-Mark Majerus and Native Seedsters Project Director-Lee Arbuckle.

Results While 999 native perennial grasses were included in the dichotomous plant/seed morphology key, the comprehensive database concentrated on 197 commercially significant species. It was found that 86.8% of the native perennial grasses of commercial importance in the continental United States have panicle inflorescences while the remaining 13.2% had spike or raceme inflorescences (Table 1). Nearly half of these species had paniculate inflorescences and were of medium height. Although relatively few commercially important species have a spike inflorescence, many of these species are produced in large quantities, as they are commonly harvestable with standard combines. Short species (7.6%) are difficult to harvest with any type of equipment and are often expensive and in limited supply. Tall species (38.1%) are common in the commercial seed production industry and pose problems in harvest because of the combined influence of the tall stature and abundant biomass.

Table 1: Plant heights and inflorescence types of native grasses of economic importance in the continental U.S.

Height	Spike/Raceme Inflorescence Species	Panicle Inflorescence Species	Total
Short	3	12	15
Medium	13	94	107
Tall	10	65	75
Total	**26 (13.2%)**	**171 (86.8%)**	197 (100%)

Using plant height, inflorescence type, and point of disarticulation all 999 native U.S. grasses were grouped into 12 major groups (Sindelar, et al. 2008). Of the 197 commercially important species queried, 137 (69.5%) species exhibited disarticulation above the glumes and 121 (61.4%) had a combination of paniculate inflorescence and disarticulation above the glumes (Table 2). Although not the case in all species, it is generally accepted that seed units disarticulating above the glumes tend to shatter more readily than those disarticulating below the glumes. Many of the small seeded species not only disarticulate above the glume, but are also loosely enclosed in the lemma and palea and readily shatter as a naked caryopsis.

Table 2: Morphological classification of perennial native grasses of economic importance into 12 groups based on height, type of inflorescence, and point of disarticulation.

Group	Plant Height	Inflorescence Type	Disarticulation Location re. Glumes	Number of Species
I	Short	Spike/Raceme	Above	0
II	Short	Spike/Raceme	Below	3
III	Short	Panicle	Above	9
IV	Short	Panicle	Below	3
V	Medium	Spike/Raceme	Above	9
VI	Medium	Spike/Raceme	Below	4
VII	Medium	Panicle	Above	73
VIII	Medium	Panicle	Below	21
IX	Tall	Spike/Raceme	Above	7
X	Tall	Spike/Raceme	Below	3
XI	Tall	Panicle	Above	39
XII	Tall	Panicle	Below	26

While conventional harvesters can effectively harvest some panicle type species, many of these species fall into the difficult-to-harvest category. Several seed morphological characteristics contribute to poor gleaning of seed through the sieves or screens of a standard combine and influence the flow of harvested seed through the combine and the unloading of ‘in-the-dirt’ seed from the hopper. Awns can cause seed to adhere to straw and chaff, preventing them from being efficiently screened through the sieves. Long awns, particularly those that are curved and/or twisted can be problematic. Also the hairiness of the lemma, attached rachis, attached sterile florets and the callus can also contribute to poor gleaning and poor seed flow. Seed stripper/plucker machines are capable of harvesting this type of seed with minimal amount of trash intake (leaves, stems, chaff). Rather than a hindrance to harvesting, the awns, appendages and hairs actually contribute to the harvest effectiveness of a stripping/plucking machine regardless of whether it is a spike, panicle, or raceme. Small seed can also be hard to harvest and convey through standard equipment. Again, machines which strip or pluck the seed are designed to handle all sizes of seed, with limited loss or leakage from the system. Microsoft Access was used to query the database to find out how many species have long and medium length awns (50) (25.3%), hairy seeds or appendages (90) (45.6%), or small or very small seeds (112) (56.8%) (Table 3). This information can be especially useful in targeting high value species for harvest while anticipating which morphological characteristics typically limit harvest success with standard harvesting equipment.

Table 3. Comparison of panicle and spike/raceme grass traits which can make standard seed harvest difficult.

Inflorescence Type	Spike and spike-like	Panicle and raceme
Total number of current economically important species for each inflorescence type	26	171
Grass with seed that disarticulates above the glume	16	121
Seeds or florets with hairs	11	79
Seeds or florets with medium to long[1] awns	16	34
Small or extra small seed size[2]	5	107

1. Awns greater than 10 millimeters
2. 250,000 or more seeds per pound

The following is a list of plant groups (genera) that have morphological characteristics that in some way influence harvest efficiency when harvested using standard direct combining or combining from a cured windrows.

Achnatherum/Nassella/Hesperostipa--hairy florets, medium-long awns, twisted and /or geniculate awns
Andropogon/Schizachyrium--hairy florets, hairy rachis, attached sterile floret, medium to long awns
Aristida--medium to long triple awns, sharp callus
Bouteloua--attached sterile floret, hairy florets
Calamogrostis--hairy florets
Calamovilfa--hairy florets
Danthonia--devergent awns, some floret hairiness
Elymus--species with medium to long awns, disarticulating rachis, floret pubescence
Hilaria--hairy florets
Poa--species with wooly lemma base

Pseudoroegneria--medium length divergent awns
Seteria--long bristles below glumes
Sorghastrum--hairy florets, attached sterile floret, medium to long awns
Trisetum--divergent awns

Summary and Discussion The native grass seed industry in the United States is expanding because of increased reclamation, forage and energy demands. State and federal laws require the use of native species for reclamation, government agencies have an increased emphasis on natives for use in Farm Bill related activities, agency and private organization are utilizing natives in the re-establishment of wildlife habitat, and the bio-fuel and energy industries has discovered the attributes of native perennial grasses.

The availability and market value of native grass seed is often directly correlated to how easy a species is to grow and how efficiently it can be harvested and conditioned. A Plant/Seed Morphology Study, jointly sponsored by the Montana Board of Research and Commercialization Technology and Arbuckle Ranch, Inc. was initiated in 2006 to evaluate morphological characteristics of native grasses that affected seed harvest efficiency of standard combines and how these characteristics may actually contribute to the effectiveness of the Native Seedster™ harvester. Grass species that have seed with fluffy or bulky appendages, e.g., attached sterile florets, hairy rachilla, long and/or twisted awns, hairy lemma or callus, sharp callus, or attached bristles, are not easily gleaned through combine sieves or screens and are difficult to convey through the combine and unload from the bulk seed hopper. Also species that have indeterminant ripening and are prone to premature shattering are not efficiently harvested with standard harvesting equipment. This study was designed to identify 'difficult-to-harvest' in all major seed production areas of the continental United States.

The Native Seedster design utilizes a counter-rotating 24" diameter brush (clockwise rotation) and a 6" diameter comb drum (counter clockwise rotation) creating a 'pinch point' where seed are plucked from the inflorescence. The lower comb drum lifts and firmly holds the inflorescence while the brush dislodges the seed from the inflorescence. The Seedster is also equipped with a small 4" diameter brush that sweeps the comb drum clean, reducing seed carry-over and stem wrap-around. This small brush also assists in the air-flow pattern created by the 24" brush. The rotation of the large brush creates a vacuum affect at the pinch point and produces airflow from the pinch point to the seed collection hopper. Seed with attached appendages (awns, sterile florets, rachilla) and hairs or wool on the lemma are more readily engaged by the brush and pulled from the inflorescence. The Native Seedster can be used on grasses that do not have uniform ripening, harvesting the mature seed on the first pass, leaving immature seed intact to be harvested at a later date. Speeds of the hydraulically powered brush and combing drum and their position and spacing are independently controlled for optimum harvest efficiency. Brush filaments and comb shapes can be selected for specific applications.

'Single-brush' seed strippers brush the inflorescence forward with only the adjacent plants to hold it in place while being engaged by the brush, often resulting in incomplete harvesting of the inflorescence. Forward rotating brushes can also prematurely dislodge seed, resulting in shatter loss and low harvest efficiency.

Field testing has identified groups of grass species that have unique morphological characteristics which contribute to harvest efficiency of the Native Seedster. The most successfully harvested genera/species include:

- indeterminant ripening/divergent awns--green needlegrass (*Nassella viridula*) blue wildrye (*Elymus glaucus)*
- long twisted awns/sharp callus--needlegrasses (*Hesperostipa, Nassella, Achnatherum*)
- attached sterile florets/hairy rachilla--bluestems (*Andropogon, Schizachyrium)* Indiangrass (*Sorghastrum)*
- disarticulating rachis--bottlebrush squirreltail (*Elymus elymoides*)
- attached sterile floret/diffuse panicle--switchgrass (*Panicum virgatum)*

A wide variety of species can be effectively harvested with the Native Seedster if brush speeds, comb speeds, and comb shapes are configured or calibrated for the species' particular morphology.

This grass plant/seed morphology study did not completely address the species that readily shatter or have indeterminacy problems. Future contact with researchers and seed producers will help to identify those species with these particular shortcomings that affect harvest efficiency. Additional studies are planned that will address plant, inflorescence, and seed morphological characteristics of wildflowers and dry vegetables that influence seed harvestability using standard harvesting equipment and how these characteristic may actually contribute to the effective harvest with the Native Seedster.

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The Long Island Native Grass Initiative….Bridging the Gap.

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Long Island is a diverse mosaic of maritime grasslands, pitch pine, oak and beech forests, rivers, streams, tidal marshes, bluffs, and beaches that are fragmented by towns, roads, and development. As is the trend across the country, a decline in biodiversity continues to be witnessed as these natural habitats are further encroached upon by agriculture, development, and invasive species. In the fields of Restoration Ecology and Conservation Biology, conserving such biodiversity has long been focused at the habitat, population, and species levels. Recently, the importance of protecting biodiversity at a genetic level has gained recognition and momentum as the implications of the loss of biodiversity within native plant populations and communities are understood.

The use of local, genetically native "ecotyped" plant material in landscaping and restoration activities is now being encouraged in order to help preserve the genetic heritage of native plant species and thereby, biodiversity on a molecular level. Environmental organizations, nurseries, and governmental agencies have responded to this shift in focus by increasing the demand for such plant material. Unfortunately the momentum has been stifled and is attributed to a lack of native plant source material needed to create a commercially available product.

The Long Island Native Grass Initiative (LINGI) is a cooperative effort of 30 non-profits, governmental agencies, and nursery professionals whose goal is to provide a source of native grass seed to seed producers, nursery growers, and restorations in order to bridge the gap between supply and demand, ultimately providing the option of using native genotype plants along with cultivars and hybrid plants. Indiangrass (*Sorghastrum nutans),* Little Bluestem (*Schizachyrium scoparium),* Big Bluestem *(Andropogon gerardii),* and Switchgrass (*Panicum virgatum*) are the four grass species selected for propagation by LINGI.

Through the combined resources of LINGI members, the program has focused in two directions. The first is the creation of "Source Identified" certified seed through standard seed propagation techniques. This seed would be provided to seed producers, nursery and landscapers for plant or seed production. The second direction involves seed banking, which involves increasing seed quantity through annual seed collections. This seed would be provided to sensitive and direct seeding restoration activities.

Many milestones have been witnessed since LINGI's inception including the identification of target species and suitable sites, development of collection methods to preserve genetic variability, delineation of a Long Island Ecotype boundary, seed collection from 20 sites, establishment of a founder block, and the creation of a grassland inventory map. However, due to the time involved in scientifically harvesting and reproducing the seed, an available seed source for market opportunities is at least 5 years off. But with subsequent seed collections and an expected increase in the demand for native genotyped seed, it is the hope that this program will continue to go to seed!

Genetic control of grassland assembly rules: preliminary results

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There is a long running debate between the appropriateness of using grass cultivars that have been developed as forage / soil erosion control crops when restoring or augmenting native grasslands. A field study was established in March 2006 to test whether differences within multiple dominant species widely used in community re-assembly acts as a filter on community assembly and scales to affect ecosystem function. This experimental design is unique as it provides replicated experimental community assemblages that differ in source (cultivar vs. wild collected) of the dominant grasses. We are using this experiment to determine how population source of the dominant grasses affects the genetic structure of the subordinate species. The Citadel Plant Ecology Laboratory (CPEL) is using inter-simple sequence repeats (ISSR) DNA markers to characterize differences in population genetic structure of one of the dominant planted grasses (*Sorghastrum nutans*) in this experiment and two subordinate forbs (*Chamaecrista fasciculata*, *Silphium laciniatum*) growing in the matrix of wild collected and cultivar dominant grass.

Preliminary analysis indicate significant differences (T=-3.131, A-0.053, P =0.011) between *Chamaecrista fasciculata* growing in two plots planted with cultivar grasses versus this same species growing in two plots planted with native collected grasses. UPGMA cluster analysis based on Jaccard's similarity also showed that *Chamaecrista fasciculata* growing in the native grass communities were more genetically similar to each other than they were to *Chamaecrista fasciculata* growing in the cultivar grass communities.

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Native Species and Genetic Diversity

John Lloyd-Reilley[1], Valerie Hipkins[2], & Shelly D. Maher[1]

There is growing interest in using native plant species for rangeland, restoration, and wildlife habitat. Some ecologists are concerned that the current selection and breeding program used in cultivar development and release of native species reduces or eliminates genetic diversity and debases the whole "adapted" concept for using native species. Ecotype selection programs must carefully maintain genetic diversity and integrity without becoming so burdensome as to be commercially unviable. The USDA-NRCS E. "Kika" de la Garza Plant Materials Center in Kingsville, Texas, in partnership with the U.S. Forest Service-National Forest Genetics Laboratory in Placerville, CA, will report on their efforts to genetically screen plant material.

Twenty-six collections of multiflower false Rhodes grass representing 16 of the known 25 counties from which this species is known to inhabit are under evaluation. There were no differences among the 26 collections in ploidy levels. Isozyme analyses revealed that 21 of the 26 collections had the same genotype. Five collections contained low levels of genetic variation with only one of these revealing a fixed allelic difference. This genetic screening along with our ecotype selection program improves our efforts to release commercial seed that is adapted, diverse, and appropriate for the landowners of south Texas.

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Salt Tolerance of Native Grasses with Potential for Use on Roadsides in New England

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Interest in using native species to vegetate roadsides in New England has increased since President Clinton and the National Highway Authority mandated the inclusion of native species in all federally-funded highway projects (Clinton 1999). However, the use of native species along high speed roadways in New England is still limited compared to many other regions. Grasses are the dominant vegetation of much of the roadside, particularly along the interstates. Historically roadside grasslands were seeded with colonial bentgrass (*Agrostis capillaris*); currently a mixture of creeping red fescue (*Festuca rubra*), Kentucky bluegrass (*Poa pratensis*), and perennial ryegrass (*Lolium perenne*) is used on most sites (RIDOT 2004). Efforts to replace these introduced species with native grasses are hindered in part by a scarcity of native species; only 43% of the naturally-occurring grass species in New England are unquestionably native (Angelo and Boufford 1998) and few of these are commercially available as New England ecotypes. In addition, roadside grasslands are a distinct environment, different from any of the naturally-occurring grasslands in New England. As a result, we cannot use natural grassland communities as a model for selecting among the native species. Instead, we must test species and ecotypes to determine their potential to thrive in the roadside environment. The research reported here is part of a larger study evaluating the tolerance of native and low-input grasses to stresses characterizing the roadside grasslands of southern New England.

In Rhode Island, the majority of the area vegetated and maintained by the Department of Transportation consists of the clear zone. The clear zone is defined as the zone closest to the pavement which serves as an escape route for vehicles needing to leave the roadway (Harper-Lore 1999). The clear zone must be kept clear of all woody vegetation greater than 4 inches in diameter, and it is mowed 2-4 times during the summer to prevent the buildup of brush and tall grasses. Tall vegetation is undesirable because it hides deer and other wildlife approaching the road, interferes with litter cleanup, increases the risk of fire, and looks weedy to an urban/suburban public accustomed to lawns. In addition to mowing, environmental constraints characterizing the clear zone in Rhode Island include thin, well-drained acidic soil, very low fertility, and large seasonal fluctuations in sodium chloride levels. During the winter and spring sodium levels in the rootzone can reach 55 dS/m, which is similar to seawater. However, during the summer and fall the sodium levels drop so low as to be undetectable (Gorres and Brown, unpublished data). The high salt levels in the winter are sufficient to kill all but the most tolerant species. Alkaligrass (*Puccinellia distans*) has been shown to tolerate salt levels of 30 dS/m in multiple studies (Hughes et al. 1975, Greub et al. 1983) and is often included in grass mixes for salt-impacted roadsides. Biesboer and Jacobsen (1994) examined the salt tolerance of six warm-season grasses native to the prairies of Minnesota. They found high levels of salt tolerance in buffalo grass and blue grama. Salt-tolerant cultivars of perennial ryegrass, tall fescue (*Festuca arundinaceae*) and red fescue (*Festuca rubra*) have also been developed. Greub et al. (1983) showed that quackgrass (*Elymus repens*) was as tolerant as tall fescue, and it is commonly found as a volunteer species along roadsides. However, each of these species has problems which preclude or complicate use on roadsides in southern New England. To begin with, none are native to southern New England except blue grama and possibly red fescue. Alkaligrass, buffalograss and perennial ryegrass do not survive the summer conditions on the roadside. Tall fescue and quackgrass require frequent mowing, and are classified as weeds or undesirable species. Red fescue is very well adapted to New England, but seed of salt-tolerant cultivars is much more expensive than seed of the salt-sensitive common type, and is often in short supply. As a result, most of the red fescue planted on roadsides is the common type. This is the first study to report on the salt tolerance of several grass species and ecotypes native to southern New England.

Materials and Methods: Salt tolerance screening was conducted in the greenhouse at the University of Rhode Island from January through May of 2007 and 2008. The 2007 experiment included 48 accessions from 21 species; 56 accessions representing 20 species were screened in 2008. Most of the species were screened both years, but only 15 accessions were repeated. The accessions and seed sources are listed in tables 1 and 2. Eastern ecotypes and PI accessions were used when they were available. *Puccinellia distans* and *Festuca rubra* were included as standards for comparison. *F. rubra* was represented by both the common type and the salt-tolerant cultivar Seabreeze GT. The NRCS PLANTS database was used to determine which species were native to southern New England (USDA-NRCS 2006).

Seed was germinated on filter paper in petri dishes in a growth chamber maintained at 70°F; daylength was 16 hours with low light intensity. Pre-chilling, 2% KNO_3 and sodium nitroprusside were used to break dormancy and increase germination as recommended by Sarath et al. 2006 and CFIA 2008. Germinated seedlings were transplanted into 3-inch square pots filled with sand, with 10 seedlings per pot and six pots per accession. Pots were placed in an ebb-and-flow hydroponics system in a cool greenhouse. Hoaglands solution was used to provide complete nutrients. In 2007 plants were grown under natural daylight, with light intensity and daylength increasing throughout the experiment. In 2008 high intensity lights were used to maintain a minimum daylength of 14 hours from January through April to improve the growth of warm-season species. Four pots of each accession were treated with salt; the remaining two pots served as a control. Pots were fully randomized within the hydroponics bays. Plants were clipped weekly to a height of 5 inches to prevent shading.

Once plants were established and had begun tillering NaCl was added to the hydroponics solution to increase the salt level by 2500 ppm (4 dS/m) every two weeks. Solution was cycled through the system so that the sand remained at field capacity and the salt level in the root zone was the same as in the hydroponics solution. All plants were photographed at the end of each two-week period using a digital camera positioned directly over the pots. Leaf firing was used as a measure of salt damage. Damage was visually rated on a 1-9 scale with 1 indicating a dead plant and 9 indicating no visible damage. Ratings were confirmed using the photographs to compare plants over time and across the trial. Control plants were monitored to detect any stresses environmental stresses other than salt which might cause leaf firing or plant death. Data was analyzed using ANOVA and Fisher's Least Significant Difference to determine differences among accessions and among species.

Results: Salt tolerance varied greatly among species. There was also significant variation between accessions for several species, indicating that tolerance could be improved by breeding or careful selection of ecotypes. As expected, *Puccinellia distans* was the most tolerant species, exhibiting only minimal damage at 20,000 ppm NaCl. *Bromus ciliatus* was killed by 10,000 ppm NaCl both years, making it the most sensitive species. *Eragrostis spectabilis* and *Panicum virgatum* were the most tolerant of the warm-season grasses; *Schizachyrum scoparium* and *Sorghastrum nutans* were the least salt tolerant.

2007 Results: Salt tolerance data is presented in table 3. At 5,000 ppm NaCl 15 of the 19 species showed little or no damage. *B. ciliatus*, *S. nutans*, *S. scoparium* and *M. schreberi* showed moderate damage. The results were similar at 7,500 ppm except that the *S. nutans* accession showed severe damage. By 10,000 ppm *B. ciliatus*, *S. scoparium* and one *Elymus hystrix* accession showed severe damage. Twenty-one accessions had moderate damage and 25 accessions from nine species had no significant damage. Damage increased markedly after two weeks at 12,500 ppm NaCl. Only nine accessions from four species continued to show little damage. Species in this group included *P. distans* (3 accessions), *Agrostis stolonifera* var. *palustris* (4 accessions), *A. perennans*, and *Bromus inermis*. Twenty-three accessions showed moderate damage, and 16 were severely damaged or dead. Species added to this last group included *Elymus canadensis*, *E. hystrix*, *E. virginicus*, *Muhlenbergia schreberi*, *Andropogon virginicum*, *Koeleria macrantha*, and *Bromus inermis* subsp. *pumpellianus*. After two weeks at 15,000 ppm NaCl only the three *P. distans* accessions were undamaged. The *A. stolonifera* var. *palustris* accessions, the salt-tolerant *F. rubra*, *Panicum amarum*, *P. virgatum*, and two *B. inermis* accessions showed only moderate damage, with substantial green tissue remaining. All other accessions were either dead or dormant, with no significant green tissue. Shortly after the NaCl concentration was increased to 17,500 ppm a prolonged power outage caused temperatures in the greenhouse to exceed 100°F, killing many of the control plants and terminating the experiment.

2008 Results: Salt tolerance data is presented in table 4. The biggest difference between 2007 and 2008 is that more warm-season grass species and accessions were included. Additional *D. cespitosa* accessions were added, and *A. stolonifera* var *palustris* and *E. hystrix* were removed from the trial. Results were similar to 2007 up through 12,500 ppm. *S. nutans* 'NE 54' died at 7,500 ppm NaCl as in 2007, but several other *S. nutans* accessions tolerated 10,000 ppm. *S. scoparium* did quite well up to 7500 ppm, but declined rapidly at 10,000 ppm as before. At 10,000 ppm NaCl 29 accessions from 12 species showed little damage. All nine accessions of *D. cespitosa* were in this group. Nine accessions from six species were severely damaged or dead; the remaining accessions showed moderate damage. As in 2007 damaged increased dramatically after two weeks at 12,500 ppm NaCl. Only 11 accessions showed little damage, and all showed more damage than they had at 10,000 ppm. Species represented in this group included *P. distans*, *F. rubra*, *D. cespitosa*, *Elymus trachycaulus*, *P. virgatum*, and

Festuca longifolia. Sixteen accessions were severely damaged, and the rest developed moderate damage. *Eragrostis spectabilis* and *P. virgatum* were the only warm-season grasses still doing well.

A number of accessions which had been severely damaged at 15,000 ppm in 2007 retained significant amounts of green tissue at 15,000 ppm in 2008. The difference between the two years is likely due to better temperature control in the greenhouse in 2008. Ten accessions continued to show little damage, including *P. distans*, *E. spectabilis*, the salt-tolerant *F. rubra*, and some accessions of *D. cespitosa*, *P. virgatum*, and *B. inermis*. Only 22 accessions were severely damaged or dead, and 25 exhibited moderate damage. At 17,500 ppm the three *P. distans* accessions and the salt-tolerant *F. rubra* retained the most green tissue. A second group of 12 accessions suffered slightly more damage. Forty-one accessions, representing all species except *P. distans*, *E. spectabilis*, *E. trachycaulus* and *F. longifolia*, retained little or no green tissue. Increasing the salt level to 20,000 ppm resulted in significant damage even to *P. distans*, which remained the most salt tolerant. The salt-tolerant *F. rubra*, *E. spectabilis*, *D. cespitosa* and the two most tolerant *B. inermis* accessions were only slightly less tolerant than *P. distans*. The remaining 46 accessions were severely damaged; most appeared dead. After two weeks at 20,000 ppm NaCl the hydroponics system was refilled with fresh Hoaglands solution without added NaCl and the plants were permitted to recover for six weeks. All of the accessions in the two most tolerant groups recovered, as was expected. However, a number of the accessions which had been heavily damaged also recovered. In particular, six *Bromus inermis* accessions and three *D. cespitosa* accessions recovered, suggesting that they had gone dormant in response to the salt stress rather than dying.

Application of these Results: *P. distans* was clearly the most salt tolerant species examined. This agrees with the results of several other studies (Greub et al. 1983, Hughes et al. 1975). However, *P. distans* has shown poor survival in trial plots on the roadside and at our research farm, indicating that the accessions we have tested are not well adapted.

In 2007 *Agrostis perennans*, *A. stolonifera* var. *palustris*, and *B. inermis* accessions performed nearly as well as *P. distans* up to 12,500 ppm. *A. perennans* and *B. inermis* retained acceptable green tissue to 15,000 ppm in 2008, and many of the *B. inermis* accessions recovered from exposure to 20,000 ppm. All of these species perform well under field conditions, are easy to establish, and tolerate mowing. *A. perennans* appears to be a good choice for moderately salt-impacted roadsides. It is unquestionably native to New England and the commercially available accession is well adapted. *Agrostis stolonifera* var *palustris* and *Bromus inermis* are more problematic. *A. stolonifera* is the creeping bentgrass used world-wide on golf courses. It is native to Eurasia, and is highly variable. Variety *palustris* has at various times been considered to be a separate species (Hitchcock, 1950). It is a salt-tolerant type native to the upper reaches of salt marshes; some authorities consider it to be native to New England as well as in Europe (Harvey 2007). However, the salt-tolerant type has been extensively intercrossed with true *A. stolonifera* to improve the salt tolerance of cultivars for golf course use, and the 2008 revision of the PLANTS database no longer recognizes *palustris* as a separate variety

(USDA-NRCS 2008). In addition, most commercially available *A. stolonifera* has been bred for performance under the extremely high maintenance of the golf course, and is unsuited to roadside use. Development of *A. stolonifera* var. *palustris* for roadside use would require the collection of naturally occurring ecotypes from roadsides and salt marshes of New England and development of commercial selections specifically for low-maintenance use. The naturally low growth and sod-forming habit of *A. stolonifera* var. *palustris* could be very useful for protecting sandy roadside soils from erosion while minimizing the need for mowing.

Bromus inermis is even more problematic than *A. stolonifera* from a native grasses perspective. There are two recognized subspecies of *B. inermis*. Subspecies *inermis* is the smooth brome used as a forage grass. It is native to Eurasia and is considered an invasive grass in tall grass prairies. Subspecies *pumpellianus* is native to North America, specifically Canada, the Pacific Northwest, the Rocky Mountains, and the Northeast. In the Northeast it is generally found in sandy habitats such as lakeshores, which suggests that it could be well-suited to roadside use. However, the two species are fully cross-compatible, and can be difficult to distinguish (Elliot 1949). The commercial seed is all subspecies *inermis*, and the eastern ecotype of subspecies *pumpellianus* is not available in the USDA germplasm system. The western ecotypes grew 4-6 feet tall in plots at the research farm, suggesting that they would require too much mowing to be useful on the roadside. However, the species has good potential for salt tolerance, and an effort should be made to collect seed of eastern ecotypes and evaluate them for roadside use.

In 2008 *Eragrostis spectabilis* performed as well as *P. distans*, suggesting that it may be quite salt tolerant. However, these results must be considered preliminary, as we had only a single accession, and difficulties in seedling establishment left us with only a single pot for salt screening. Purple lovegrass is native to southern New England and is commonly found along high-speed roads. It is low growing, with a prostrate habit which allows it to mature seed even when mowed. Unfortunately, little commercial seed is available.

Certain accessions of *F. rubra* and *D. cespitosa* showed good salt tolerance to 10,000 ppm in 2007 and to 17,500 ppm in 2008. They were also able to recover from exposure to 20,000 ppm NaCl. Both are very diverse species which are well adapted for use as low maintenance turf in the Northeast and are commercially available. *D. cespitosa* is native both to North America and Eurasia. Much of the seed currently on the market is derived from European ecotypes, but researchers are actively working on commercializing populations derived from North American ecotypes. *Festuca rubra* has numerous subspecies, some of which are native and others of which are introduced. In addition, the taxonomy of the fine-leaf fescues, including *F. rubra*, is extremely complex and changes frequently, complicating interpretation of historical records and the species identification of commercial seed. Many commercial cultivars are available, some of which have even greater levels of salt tolerance than the Seabreeze GT used in this study (R. Brown, unpublished data).

Other species which showed acceptable salt tolerance at 17,500 ppm in 2008 were *P. virgatum* and *E. trachycaulus*. Both are commercially available, and are widely used as forage and conservation grasses in the western United States. *P. virgatum* in particular has received considerable attention as a biofuel. It is well adapted to roadside conditions but does not tolerate regular mowing. The Rhode Island Department of Transportation has had success in vegetating the guardrails of narrow medians with High Tide switchgrass established from transplants. Cultivars developed for use as forage or biofuels are likely to be too tall for roadside use, but the development of dwarf types could make switchgrass an excellent roadside grass.

Conclusions: In general the cool-season grasses showed more salt tolerance than the warm-season grasses. *S. scoparium* and *A. virginicus* are the most common warm-season native grasses on dry, infertile sites in New England. However, they have little salt tolerance so are probably best suited to planting more than 10 feet from the pavement on high-speed roads. The wildryes (*Elymus* species) are often recommended as a native cool-season replacement for *Lolium perenne*. However, they are much less tolerant of both salt and mowing than commercial cultivars of *L. perenne*, with some accessions tolerating only 10,000 ppm NaCl and most tolerating only 12,500 ppm. Thus they are best suited for use with *S. scoparium*, *S. nutans* and *A. virginicus* beyond the high salt zone. Of the grasses included in this study, *F. rubra*, *D. cespitosa*, *A. stolonifera* var *palustris*, *E. spectabilis* and *A. perennans* show the best potential for use in the high salt zone up to 15 feet from the pavement. However, there is need for careful specification of cultivars and ecotypes to ensure salt tolerance. In particular the common-type *F. rubra* currently used on roadsides in the Northeast has poor salt tolerance. Collection and commercialization of seed from ecotypes found along roadsides and in dry natural grasslands in the Northeast would be beneficial in increasing the use of native grasses for vegetating high-speed roadsides.

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Table 1. Accessions screened in 2007.

Species	Accession	Seed Source[a]
Agrostis perennans	Autumn Bent	Ernst Seeds
Agrostis stolonifera var. palustris	PI 578529	USDA W-6
Agrostis stolonifera var. palustris	PI 251945	USDA W-6
Agrostis stolonifera var. palustris	PI 235541	USDA W-6
Agrostis stolonifera var. palustris	PI 235440	USDA W-6
Agrostis stolonifera var. palustris	PI 221906	USDA W-6
Agrostis stolonifera var. palustris	PI 204390	USDA W-6
Andropogon virginicus	Broomsedge	Ernst Seeds
Bromus ciliatus	PI 232214	USDA W-6
Bromus inermis	PI 24201	USDA W-6
Bromus inermis	PI 24274	USDA W-6
Bromus inermis	PI 578542	USDA W6
Bromus inermis subsp.pumpellianus	PI 562648	USDA W-6
Bromus inermis subsp.pumpellianus	PI 232241	USDA W-6
Bromus inermis subsp.pumpellianus	PI 232242	USDA W-6
Bromus inermis subsp.pumpellianus	PI 236764	USDA W-6
Bromus inermis subsp.pumpellianus	PI 371709	USDA W-6
Bromus inermis subsp.pumpellianus	PI 372670	USDA W-6
Deschampsia cespitosa	PI 584479	USDA W-6

Table 1. Accessions screened in 2007. (cont.)

Deschampsia cespitosa	PI 241051	USDA W-6
Elymus canadensis		Big Flats PMC
Elymus canadensis	PI 531568	USDA W-6
Elymus canadensis	PI 578676	USDA W-6
Elymus canadensis	PI 436919	USDA W-6
Elymus hystrix	PI 531616	USDA W-6
Elymus hystrix	Bottlebrush grass	Ernst Seeds
Elymus virginicus		Big Flats PMC
Elymus virginicus	PI 531707	USDA W-6
Elymus virginicus	PI 531706	USDA W-6
Elymus virginicus	PA Ecotype	Ernst Seeds
Festuca longifolia	Durar	USDA W-6
Festuca rubra	common type	Allens Seed Store
Festuca rubra	Seabreeze GT	Turf Seed, Inc
Koelaria macrantha	PI 477978	USDA W-6
Koeleria macrantha	PI 639190	USDA W-6
Koeleria macrantha	PI 387927	USDA W-6
Koeleria macrantha	June grass	Ernst Seeds
Muhlenbergia schreberi	Nimblewill	Ernst Seeds
Panicum amarum	Atlantic	Ernst Seeds
Panicum virgatum	9081253	Big Flats PMC
Puccinellia distans	PI 578856	USDA W-6
Puccinellia distans	PI 443386	USDA W-6
Puccinellia distans	Fults	Jacklin Seeds
Schizachyrium scoparium	CT Ecotype	Ernst Seeds
Sorghastrum nutans	PA Ecotype	Ernst Seeds

[a] USDA W-6 is the Western Region Plant Introduction Station in Pullman, WA.

Table 2. Accessions screened in 2008.

Species	**Accession**	**Seed Source**[a]
Agrostis perennans	Autumn Bent	Ernst Seeds
Andropogon gerardii	Niagara	Ernst Seeds
Bouteloua curtipendula	Eastern ecotype	Ernst Seeds
Bromus ciliatus	Fringed brome	Ernst Seeds
Bromus inermis	PI 24274	USDA W6
Bromus inermis	PI 24201	USDA W6
Bromus inermis	PI 372671	USDA W6
Bromus inermis	PI 584449	USDA W6
Bromus inermis	PI 578542	USDA W6
Bromus inermis subsp.pumpellianus	mixture	USDA W6
Bromus inermis subsp.pumpellianus	PI 196321	USDA W6
Bromus inermis subsp.pumpellianus	PI 372620	USDA W6
Bromus inermis subsp.pumpellianus	PI 371709	USDA W6

Table 2. Accessions screened in 2008 (cont.)

Bromus inermis subsp.pumpellianus	PI 562648	USDA W6
Bromus inermis subsp.pumpellianus	PI 19743	USDA W6
Bromus inermis subsp.pumpellianus	PI 236764	USDA W6
Deschampsia cespitosa	PI 387916	USDA W6
Deschampsia cespitosa	Barcampsia	Barenbrug Seeds
Deschampsia cespitosa	PI 371726	USDA W6
Deschampsia cespitosa	PI 371725	USDA W6
Deschampsia cespitosa	PI 372692	USDA W6
Deschampsia cespitosa	Tufted Hairgrass	Ernst Seeds
Deschampsia cespitosa	PI 371724	USDA W6
Deschampsia cespitosa	PI 349189	USDA W6
Deschampsia cespitosa	mixture	USDA W6
Elymus canadensis		Big Flats PMC
Elymus canadensis	PA ecotype	Ernst Seeds
Elymus trachycaulus	slender wheatgrass	Ernst Seeds
Elymus virginicus	PA ecotype	Ernst Seeds
Elymus virginicus	PI 531706	USDA W6
Elymus virginicus		Big Flats PMC
Elymus virginicus	Commercial type	Ernst Seed
Elymus virginicus	PI 531707	USDA W6
Elymus virginicus		
Eragrostis spectabilis	FL ecotype	Ernst Seeds
Festuca longifolia	Durar	USDA W6
Festuca rubra	Seabreeze GT	Turf-Seed Inc.
Festuca rubra	common type	Allens Seed Store
Koeleria macrantha	Barleria	Barenbrug Seeds
Koeleria macrantha	June Grass	Ernst Seeds
Muhlenbergia schreberi	nimblewill	Ernst Seeds
Panicum amarum	Atlantic	Ernst Seeds
Panicum virgatum	PI 598136	USDA PGRCU
Panicum virgatum	9081253	Big Flats PMC
Puccinellia distans	alkaligrass	Ernst Seeds
Puccinellia distans	PI 578856	USDA W6
Puccinellia distans	Fults	Jacklin Seeds
Schizachyrium scoparium	Aldous	Ernst Seeds
Schizachyrium scoparium	PI 421533	USDA PGRCU
Schizachyrium scoparium		Big Flats PMC
Schizachyrium scoparium	PI 635106	USDA PGRCU
Sorghastrum nutans	PI 476999	USDA PGRCU
Sorghastrum nutans		Big Flats PMC
Sorghastrum nutans	NE 54	Ernst Seeds

[a] USDA W-6 is the Western Region Plant Introduction Station in Pullman, WA. USDA PGRCU is the Plant Genetic Resources Conservation Unit in Tifton, GA.

Table 3. Salt tolerance ratings from 2007. Leaf firing was used as a symptom of salt stress. The rating scale is 1-9 with 1 indicating a completely brown plant and 9 indicating no damage. Each value is the grand mean across all accessions for the species. Each accession was replicated four times. Ratings were conducted on individual pots, with each pot containing 10 plants.

		5,000 ppm		7,500 ppm		10,000 ppm		12,500 ppm		15,000 ppm	
Species[b]	Accessions	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
P. distans	3	8.1	8.0-8.3	8.3	7.8-8.8	8.3	7.8-8.8	7.8	7.3-8.5	7.3	7.0-7.5
A. perennans	1	9.0	--	9.0	--	8.8	--	7.0	--	2.5	--
A. stolonifera palustris	6	8.9	8.8-9.0	8.1	7.5-9.0	8.0	7.3-9.0	6.8	4.8-8.3	3.5	1.3-5.0
B. inermis	4	8.3	8.0-8.8	7.8	7.3-8.5	7.6	7.0-8.3	6.4	5.3-7.5	3.6	2.8-4.0
F. rubra	2	8.3	8.3	8.3	8.3	7.9	7.5-8.3	5.6	4.8-6.5	2.6	1.8-3.5
P. amarum	1	6.8	--	6.3	--	5.8	--	5.3	--	3.8	--
F. longifolia	1	8.5	--	8.8	--	7.8	--	4.5	--	1.3	--
P. virgatum	1	8.3	--	6.8	--	5.5	--	4.0	--	3.3	--
B. inermis pumpellianus	6	8.2	7.0-8.8	7.6	6.5-8.8	6.8	5.5-8.5	3.7	1.0-6.3	1.6	1.0-2.8
D. cespitosa	2	8.2	8.0-8.3	7.0	7	6.4	6.3-6.5	3.6	3.5-3.8	1.5	1.3-1.8
E. canadensis	4	7.2	6.3-7.8	6.4	5.5-7.0	5.6	4.3-6.3	3.3	1.8-4.8	1.3	1.0-2.0
K. macrantha	4	8.7	8.5-9.0	8.0	7.5-8.5	6.9	5.8-7.3	3.3	2.5-4.3	1.1	1.0-1.3
E. hystrix	2	7.9	7.8-8.0	6.2	5.5-6.8	4.6	2.3-6.8	2.6	1.3-4.0	1.6	1.0-2.3
E. virginicus	4	7.8	7.5-8.0	7.4	6.3-8.3	5.8	5.0-6.8	2.3	2.0-2.5	1.1	1.0-1.3
A. virginicus	1	9.0	--	7.5	--	4.8	--	1.8	--	1.0	--
M. screberi	1	5.3	--	5.5	--	4.8	--	1.3	--	1.0	--
S. nutans	1	5.5	--	1.5	--	1.5	--	1.0	--	1.0	--
S. scoparium	1	5.5	--	3.5	--	1.0	--	1.0	--	1.0	--
B. ciliatus	1	5.3	--	4.3	--	1.8	--	1.0	--	1.0	--
Fisher's LSD[a]		0.6		0.9		1.3		1.8		1.1	

[a] Means within a column which differ by more than the Fisher's LSD value for the column are significantly different.
[b] Species are arranged in descending order by salt tolerance at 12,500 ppm.

Table 4. Salt tolerance data from 2008. Methods were the same as in table 3 above, except that salt stress was continued to 20,000 ppm NaCl. All means are grand means across all accessions of a species. Each accession was replicated four times except where noted.

		5,000 ppm		7,500 ppm		10,000 ppm		12,500 ppm		15,000 ppm		17,500 ppm		20,000 ppm	
Species[a]	Accessions	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
P. distans	3	8.7	8.3-9.0	8.5	8.0-8.8	7.8	7.0-8.5	7.2	6.5-7.8	6.8	6.5-7.3	6.5	5.8-7.3	6.0	5.3-6.5
E. spectabilis[b]	1	9.0	--	9.0	--	7.0	--	nd[c]	nd	6.0	--	5.0	--	5.0	--
P. virgatum	2	7.6	7.5-7.8	7.3	6.8-7.8	6.6	6.0-7.3	6.7	6.3-7.0	5.5	5.0-6.0	3.8	3.8	1.5	1.5
E. trachycaulus	1	7.0	--	7.3	--	6.8	--	6.3	--	5.3	--	4.5	--	2.8	--
D. cespitosa	9	8.3	7.8-8.8	7.9	7.0-8.3	7.2	6.8-7.5	6.0	5.3-6.8	5.0	4.0-6.8	3.6	1.8-5.3	2.6	1.0-4.5
F. longifolia	1	8.0	--	7.8	--	7.3	--	6.3	--	5.0	--	4.0	--	2.3	--
F. rubra	2	8.9	8.8-9.0	8.5	8.3-8.8	7.5	6.8-6.3	5.5	3.8-7.3	4.6	2.3-7.0	3.8	1.3-6.3	2.9	1.0-4.8
A. perennans	1	7.5	--	7.8	--	6.5	--	5.3	--	4.5	--	2.8	--	2.0	--
B. inermis	6	8.2	8.0-8.5	7.4	6.0-8.5	6.5	5.0-7.8	4.9	3.8-6.0	4.2	2.0-5.8	3.6	2.0-5.0	2.7	2.0-4.3
K. macrantha	2	8.3	8.0-8.5	7.6	7.5-7.8	6.9	6.8-7.0	5.6	5.3-6.0	3.9	3.5-4.3	2.6	2.0-3.3	2.0	1.3-2.8
E. canadensis	3	7.1	6.8-7.3	6.3	5.5-7.0	5.9	5.0-6.5	4.6	4.0-5.0	3.9	3.3-4.8	3.4	2.8-4.0	2.1	1.8-2.5
B. inermis pumpellianus	8	8.1	6.3-8.8	6.5	4.0-8.0	5.1	2.3-7.0	3.8	1.0-5.0	3.1	1.0-4.3	2.3	1.0-3.3	1.5	1.0-2.3
B. curtipendula	1	7.5	--	7.0	--	5.0	--	2.8	--	2.0	--	1.8	--	1.3	--
E. virginicus	6	7.3	6.0-8.5	5.6	4.5-7.3	3.1	2.0-4.8	2.1	1.0-4.0	1.5	1.0-3.0	1.1	1.0-1.5	1.0	1.0
A. gerardii	1	8.5	--	6.3	--	4.0	--	2.0	--	1.5	--	1.0	--	1.0	--
M. schreberi	1	6.7	--	4.7	--	2.7	--	2.0	--	1.3	--	1.0	--	1.0	--
P. amarum	1	7.3	--	6.0	--	4.8	--	2.8	--	1.3	--	1.0	--	1.0	--
S. scoparium	4	7.2	4.8-8.8	5.8	2.8-7.3	3.1	1.3-4.3	1.6	1.0-2.0	1.1	1.0-1.3	1.0	1.0	1.0	1.0
S. nutans	3	6.0	2.7-7.7	4.8	1.3-6.7	3.3	1.0-5.0	1.5	1.0-2.3	1.1	1.0-1.3	1.0	1.0	1.0	1.0
B. ciliatus	1	2.3	--	1.0	--	1.0	--	1.0	--	1.0	--	1.0	--	1.0	--
Fisher's LSD[d]		1.1		1.4		1.3		1.1		1.2		1.2		1	

[a] Species are arranged in descending order of salt tolerance at 15,000 ppm NaCl.
[b] Eragrostis spectabilis was not replicated due to poor seedling survival [c] the data for E. spectabilis at 12,500 ppm was lost
[d] Means within a column which differ by more than the Fisher's LSD value for the column are significantly different.

Ten years of canebrake restoration in the Georgia Piedmont

Nathan Klaus
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The Swainson's warbler is a rare inhabitant of bottomland hardwoods of the Georgia Piedmont. It is uncommon because it requires a thick understory in which to nest and forage, usually in wide bottomland hardwoods (generally at least 100m) with high regional forest cover. Once, thick stands of cane (*Arundinaria* spp.) provided habitat for this species. These canebrakes are much less common today than indicated by historic accounts. Canebrakes were used by settlers as forage for cattle and were likely overgrazed, then plowed and planted to other crops. Canebrakes were probably one of the first habitat types in Georgia to fall to the plow since associated soils were fertile, near water, and required comparatively little labor to clear after grazing.

Some research suggests cane may require occasional fire to survive. In addition clearing of land for agriculture and timber early in the 1900s has resulted in an unnaturally homogenous and vigorous forest throughout the Piedmont, with lower levels of tree mortality and associated canopy gaps, and beaver populations have been suppressed in Georgia for decades. This has resulted in forests with low structural diversity and fewer canopy gaps. I will review 10 years of restoration activity on 40 study plots across Georgia's Piedmont. I investigated the effects of fire and increased canopy openness on cane regeneration and Swainson's Warbler occupancy. Through the development and promotion of management techniques I hope to restore this once common habitat type to degraded sites throughout the Georgia Piedmont. Short term (<10 years) fire effects were negative for cane, but longer-term effects may be to control hardwood competition. Increased light levels caused substantial increases in cane height and density. Swainson's Warblers have not responded to treatments, possibly due invasion from the exotic grass *Microstegium vimenium.*

Techniques for the successful restoration of canebrakes in central Georgia.

Joyce Marie Klaus[1] and Nathan Klaus[2]

Canebrakes once covered a considerable portion of alluvial floodplains of the southeastern U.S. and were important habitat for many wildlife species including bear, elk, panther, Bachman's Warbler and Swainson's warbler. As canebrakes disappeared to make way for agriculture, associated species became rare or were extirpated. Cane remains widespread throughout its former range as a minor component of the understory and although considerable interest has emerged in the restoration of canebrakes, techniques remain enigmatic. Seed collection is problematic, competition from woody hardwoods is difficult to control and establishment of new canebrakes depends of the successful transplant of adult culms.

Our study examined the tolerance of cane to four herbicides that effectively control woody species in bottomland forests, and investigated factors affecting transplant success of cane. We compared four different herbicide treatments with controls to determine the best chemical for controlling woody competition with minimal impact to cane. In a separate but related experiment we transplanted 66 cane culms from an existing cane stand and used model selection to elucidate the factors most important for transplant success. The results will give managers and technicians the information they need to select the most appropriate time and technique for transplanting cane. These experiments provide information that can be used to improve existing cane stands or to create new ones on suitable sites.

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Raising Cane

Johnny Stowe, SC Dept of Natural Resources

Cane pole slung over his shoulder, a barefoot boy heads to the creek. Few images are as quintessentially Southern and timeless. Once the primary fishing tool in South Carolina, cane poles have been replaced by rods and reels. But many of us who learned to fish with cane poles still enjoy using one now and then, especially when teaching a small child to fish. Like many other things in life, sometimes simpler fishing is better.

Endemic to the South, and common but scattered in South Carolina today, cane was once the keystone of an important ecosystem—the famed Southern canebrakes. Almost every early account of the region's landscape prominently mentions canebrakes.

William Bartram noted them at least twenty-four times in his classic book Travels, which documented his ramblings through the South in the late 18th century. He described them in terms such as "vast cane swamps . . . and meadows . . . of immense extent, [where] canes grow . . . thirty or forty feet high, and . . . three or four inches in diameter."

Place-names like the ubiquitous "Cane Creek" in this and other parts of the South attest to the prominence of cane in the past. The Toxaway drainage of Lake Jocassee is known as The Canebrake, and S.C. Department of Natural Resources wildlife biologist Jamie Dozier says a quick search of the term "cane" using the federal Geographic Names Information System yields ninety-two locales in South Carolina alone!

Cane's lightweight strength and flexibility make it an excellent raw material for tools and construction. Besides their use in fishing, cane stalks make sturdy stakes for "beanpoles," trellises and other uses. Cane was one of the most important of all raw materials for southeastern Indians, according to DNR archaeologist Chris Judge. "Cane was used for many purposes," Judge says, "including houses and other structures, drills, knives, arrow and spear shafts, blowgun and medicine tubes, shields, baskets, mats, fish creels and traps, beds, cradles, torches, sieves, fanners, containers, rafts, litters and flutes, and to hold hair braids. Cane was ideal for granaries to store food, since it was difficult for rats to chew through. Indians also ate the seeds and tender shoots of cane."

Canebrakes and savannas are prime wildlife habitat. Six species of butterflies—five of them rare—are canebrake specialists. The larvae of the Creole pearly eye, Southern pearly eye, Southern swamp skipper, cobweb little skipper, cane little skipper and yellow little skipper all feed on cane foliage. Deer seek cover in cane and feed on its tender new growth, and in the 18th century, large herds of elk and buffalo were documented on canelands as far east as the Charlotte area. Most records of buffalo east of the Mississippi River were associated with canelands.

Cane lends its name to local critters such as the canecutter, or "buck" rabbit of the Upstate, and the canebrake rattlesnake. Black bears are fond of canebrakes for cover. Wild turkeys and canebrakes are mentioned in many historic accounts, and Audubon's famous wild turkey painting includes cane. Bachman's warbler, now feared extinct, may have been a cane-dependent species, and both Swainson's and hooded warblers nest in canebrakes. The demise of the passenger pigeon and Carolina parakeet may have been in part related to the loss of canebrakes.

Cane is a member of the grass family, and its taxonomy is "currently unsettled," says Patrick McMillan, Clemson University Herbarium curator. The cane most people know is "river" or "giant" cane, the fishing or beanpole cane that grows in bottomlands and along the margins of streams. This type grows largest and is evergreen. While a few individual stalks may flower each year, it generally flowers infrequently and en masse, with all the colonies in a widespread area blooming, setting seed in clusters like oats, and dying simultaneously. These events can leave wildlife and other animals fat from eating the cane seeds, which contain more nutrients than either rice or wheat.

The other cane associated with wet areas is the "switch" cane that grows in pocosins and savannas. It is short and evergreen or tardily deciduous. It flowers frequently, even annually in some populations, and profusely in response to fire.

The upland cane that grows on ridges in the Upstate is short and deciduous. McMillan says this type is now being described taxonomically. He has never seen it flower! It grows alongside table mountain pine and smooth coneflower on the fire-maintained ridges of Buzzard's Roost Heritage Preserve and Wildlife Management Area in Oconee County.

Cane ecosystems are classified as critically endangered—98 percent of the canebrakes are gone as a result of overgrazing by cattle, land clearing, lack of fire and inundation and flood control. Scattered stems of cane are still extremely common across the South, but the expansive thickets are all but gone. Many former cane sites now are either in pastures, row crops and pine plantations or have been invaded by invasive exotic plants like Oriental privet.

Managing for cane is not a popular or well-understood practice. Like longleaf pine or Atlantic white cedar, cane as a species is not imperiled, but the unique ecosystems centered on these species are in danger of disappearing. Indians managed cane by burning canebrakes to drive game, regenerate the plants, and clear riparian areas for various reasons. When burned, the airtight internodes on canes explode loudly—that's several explosions per stem, multiplied by many thousands of stems per acre.

The historical canebrakes were prime hunting grounds. Canebrakes and bottomland hardwood forests managed by Creek Indians were known as nokose-em-ekanas, or "beloved bear grounds." The settlers recognized the unique nature of canebrakes as hunting "honey holes." Frontier naturalist Gideon Lincecum described canebrakes as the "great sanctum sanctorum; the inner chamber of the hunting ground." The epic bear hunts of the Mississippi Valley so masterfully described by William Faulkner centered on canebrakes, as did the exploits of great bear hunters like famous South Carolinian Wade Hampton III.

Bobwhite quail are fond of the short cane that grows in frequently burned, poorly drained longleaf and pond pine flatwoods. Jimmy Bland of Mayesville, a dedicated and life-long quail hunter who remembers the glory days of "bird hunting" in Lee and Sumter counties, is interested in restoring cane to his land. "We used to find a heap of quail in those short canes," he says. "I reckon they used it for cover." Matt Nespeca of The Nature Conservancy and Pee Dee DNR staff are putting in experimental herbicide plots on land where Bland recently harvested timber, with the aim of getting cane back.

Another benefit of canebrakes is their ability to stabilize streambanks and streamflow by holding soil in place and mitigating against floods and droughts, and to enhance water quality. The U.S. Forest Service is restoring river cane on the Sumter National Forest, and switch cane is rebounding on state DNR lands where fire is the paramount land management tool.

Small-scale restoration can be as simple as transplanting clumps of stems and rhizomes, but make sure you are working with native cane, not one of the many Asian varieties, which can be highly invasive and disrupt ecosystem integrity. Ongoing research projects aimed at "raising cane" promise to yield new restoration techniques and improve old ones. One day, perhaps, we will see a resurgence of this uniquely Southern grass, along with the cultural and natural history that accompanies it.

Providing Native Grassland Habitat for Wildlife through the Conservation Reserve Program in Kentucky and Pennsylvania

B. Isaacs[1], M. T. Pruss[2], D. Figert[3], D. Hughes[4], and M. J. Howell[5]

The Conservation Reserve Program (CRP) and Conservation Reserve Enhancement Program (CREP) have provided the opportunity to significantly increase the acreages of native grasses throughout the United Sates. In the Eastern United States these programs have been particularly significant in introducing thousands of land owners and operators to native grasses. Agencies and organizations in Kentucky and Pennsylvania have taken advantage of this opportunity even though field size and acreages owned or managed are small compared to the Great Plains and Corn Belt states. Kentucky currently has over 135,000 acres of native grasses enrolled out of 375,800 acres of CRP/CREP combined (36 percent), and Pennsylvania has 39,400 acres of 227,300 acres (17 percent). Objectives of the CRP and CREP programs include improving water quality, reducing soil erosion, and providing secure nesting cover for grassland nesting birds. Most grassland nesting bird populations in Eastern United States have declined by over 80% in the past 40 years due to loss of habitat to development and increasingly intensive farming practices. To encourage landowners to enroll in CRP/CREP and plant native grasses, the United States Department of Agriculture (USDA), state agencies, and national and local organizations provide 10-15 year contracts with annual rental and increased reimbursement (> 50%) of costs for establishing native grasses. To ensure that equipment is available to plant the native grass, state agencies and national and local organizations arrange for native grass drills to lend or rent to land owners or operators. Beginning in 2003 Mid-Contract Management became part of the CRP and CREP programs. The different management options this provides can further improve habitat for grassland nesting birds. The CRP and CREP programs have significantly improved habitat for grassland birds and allowed natural resource professionals and land owners and operators to improve native grass establishment and management techniques.

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[1]USDA-NRCS, [2]Pennsylvania Game Commission, [3, 4]Kentucky Department of Fish & Wildlife Resources, [5]USDA-NRCS.

Managing for Woodland-Savannah Birds on the Sumter National Forest

Jeffrey M. Magniez, U.S. Forest Service, Sumter National Forest, South Carolina

The Enoree Ranger District (RD) of the Sumter National Forest encompasses about 170,000 acres of National Forest land in the piedmont of South Carolina. Approximately 7,800 acres have been designated to be managed as woodland-savannah habitat. This plant community is characterized by open, park-like forests with relatively low tree densities of 25 to 60 percent forest cover and an understory dominated by native warm-season grasses and forbs.

Landscape-scale restoration of woodland-savannah plant communities began on the Enoree RD in 2004. Treatments call for the basal area of existing forest cover, dominated by loblolly pine (*Pinus taeda*), to be reduced from 150 ft^2/acre to 30-70 ft^2/acre. Existing shortleaf pine (*P. echinata*) and xeric hardwoods are retained. Native warm-season grasses, such as little bluestem (*Schizachyrium scoparium*) and indiangrass (*Sorghastrum nutans*), and a variety of native forbs are regenerated in the understory. These plant communities are maintained with prescribed fire every 2 years.

In North America, birds that use grasslands and shrublands are declining at a greater rate than other bird groups. The restoration and management of woodland-savannah plant communities results in ideal habitat for bird species which use open, grass-dominated landscapes. Four avian species are expected to benefit from habitat restoration work on the Enoree RD: field sparrow (*Spizella pusilla*), northern bobwhite (*Colinus virginianus*), Bachman's sparrow (*Aimophila aestivalis*), and loggerhead shrike (*Lanius ludovicianus*).

Using point count data collected from 1992-2004, the U.S. Forest Service summarized population trends and habitat occurrence for bird species on the Sumter National Forest. Of those species that use woodland-savannah habitats, the field sparrow exhibited the greatest population decline at 19.1%. This species was associated most frequently with glade-shrub-savannah habitats and the grass/forb stage of hardwood-pine and loblolly-shortleaf pine forests. Trend estimates for northern bobwhite suggest a 10.0% decrease. Northern bobwhite was associated most frequently with grass/forb stages of pine and hardwood-pine forests. Bachman's sparrow was associated with grass/forb stages of loblolly-shortleaf pine forest and with glade-shrub-savannah habitats. It experienced a 6.3% decline in population. The loggerhead shrike was not included in this analysis because it was not detected using point counts. This species does occur on the Enoree RD and is expected to benefit from woodland-savannah management. Trend estimates derived from the Breeding Bird Survey and Christmas Bird Count suggest that over the last 40 years this species has experienced a 70% decline across its entire range.

By managing for woodland-savannah plant communities, the Sumter National Forest hopes to provide habitat for these declining bird species. Point counts will continue to be used to monitor the effectiveness of woodland-savannah management on bird populations.

Observations on Establishment and Maintenance of Native Warm-Season Grasses for Wildlife Conservation Practices on the South Carolina Inner Coastal Plain

Anthony J. Savereno[1], Laura A. Knipp[2], and Gregory Yarrow[2]

Introduction Native warm-season grasses (NWSG) are widely promoted and used in wildlife habitat conservation practices. Successful methods of planting, weed suppression, and controlling ecological succession vary with soil type, climate, and composition of local flora. This poster discusses these factors and how we dealt with them on the Inner Coastal Plain of South Carolina. Study sites will be highlighted during the field tour to Clemson University's Pee Dee Research and Education Center.

Methods In 2003-2004, we established select USDA Farm Bill Wildlife Habitat Incentives (WHIP) Program practices following NRCS guidelines. Three of those practices incorporated NWSG as wildlife habitat: field borders, filter strips, and establishment of NWSG plots. We established 6 field borders with an average width of 45 ft at the edges of agricultural fields and planted various mixtures of NWSG, including switchgrass (*Panicum virgatum*), coastal panic grass (*Panicum amarum*), little bluestem (*Schizachyrium scoparium*), yellow Indiangrass (*Sorghastrum nutans*), eastern gama grass (*Tripsacum dactyloides*), and big bluestem (*Andropogon gerardii*). We planted 2 filter strips at field edges in the same manner as described for field borders. We established 4 plots of NWSG, ranging in size from 0.9 to 2.6 acres. We planted 3 of these plots in mixtures of the grasses described above. We planted the fourth plot half in a pure stand of eastern gamma grass and half in switchgrass.

Results and Discussion By the third growing season, planted NWSG were successfully established in all field borders, filter strips, and NWSG plots. Among our findings and observations:

- NWSG can be successfully planted with a cyclone spreader. Calibration is critical, especially when planting seed mixtures. We have found in subsequent work that mixing seed with ground clay cat litter improves the evenness of distribution, especially when dealing with small quantities of seed.
- In our cultivated fields, pigweeds (*Amaranthus* spp.) and sicklepod (*Senna obtusifolia*) were the most serious competitors during the first growing season, followed by horseweeds (*Conyza* spp.) in the second year. However, our only method of control was mowing in late winter followed by a prescribed burn to remove biomass. No post-establishment herbicides were used.
- Bahia grass (*Paspalum notatum*) and Bermuda grass (*Cynodon dactylon*) are our most persistent weeds, although maintenance disking and burning seem to be resulting in their gradual replacement by volunteer broomsedge (*Andropogon virginicus*). If bahia and/or Bermuda grass are present, aggressive pretreatment with herbicides should be employed prior to planting.
- Vigilant patience is a must. Don't give up at the end of the first growing season.

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Forest Service / SC Native Plant Society Collaborative Native Seed Source Program in South Carolina

William C. Stringer and Dennis Law
SC Native Plant Society and US Forest Service

Once upon a time, a South Carolina Naïve Plant Society (SCNPS) member and a USFS soil scientist were bumping down a Forest Service Road in the Sumter National Forest Service, the SCNPS guy grumping about all the sericea lespedeza and bahiagrass lining the roadside. They started talking about why it had to be that way, and concluded that a collaborative project could be a solution to the problem. From that discussion, a series of meetings was organized, and a few weeks later, SCNPS, USFS, NRCS, USDA-PMC, SC DNR and Tall Timbers people were sitting around a table discussing ideas as to how USFS could obtain an adequate supply of native grass seeds to begin replacing invasive exotics with native grasses on disturbed sites in the Forests.

The first idea tossed out for consideration was to spend the extra money to buy native grass seeds from the commercial market, which at that time meant bringing in seed from mid-western producers. While this was deemed less than desirable, in light of the fact that small areas of all the appropriate native grass species could be found along the roadside, the feasibility of getting enough local seed was very questionable. Until the idea of training and using volunteers to go out on beautiful October afternoons to scour roadsides in the area for local seeds came up. SCNPS made a bet that they could collect significant quantities of local natives, and USFS put up some money and told them to prove it. From that first fall season, rented vans of SCNPS-trained volunteers, USFS people on their own time, school and college students, Scouts and others have gone out every fall. The result is a program run by USFS in the Sumter National Forest that supplies seed for FS needs throughout the Piedmont. Along the way, we added early summer collection dates to collect cool-season seed, and added a long list of forbs to our list of target species.

Those first little bags of seed were cleaned and tested by the Americus PMC, and used by USFS folks at the Seed Orchard in the Francis Marion NF to generate thousands of seedling plugs. Those plugs were transplanted back into the Forest districts on logging deck areas, and now you can go into some of those areas and harvest more seed in an hour than a van load of people can collect in a day long trip. We have recently begun expanding the effort into the Francis Marion NF on the Coastal Plain.

USFS has invested many thousands of dollars into funding collection trips, plug production and transplanting, The seed production in the Forests has grown to the point that a Flail-Vac harvestor is used, and a no-till drill is used to seed restoration sites on the Forests.

So, thanks to a bumpy ride and the questions raised that day has come a program so successful that USFS in SC is practically free of the need to buy bags of invasive exotic seeds, and can be proud of the fact that disturbed land restoration in the Forests is compatible with 20,000 years of plant community evolution in the South Carolina piedmont. Thanks to the power of a good idea and some willing hands to give it a try.

Optimal Harvest Regime and Nutritional Quality of Mixed Native Grasses

D. Scott Horton, J. Brett Rushing, Brian Rude, Brian Baldwin
Department of Plant and Soil Sciences, Mississippi State Univ

Interest in native warm season grasses for dual use in pastures and wildlife habitat has increased. Sustainability of a native grasses under intense grazing is one factor that must be understood if a conversion from current forages to native warm season forages is desired. Little is known of the fundamental practices needed to utilize and sustain a native warm season perennial grassland that's primary function is intense cattle grazing as opposed to ungrazed prairie.

A study was initiated near West Point, MS in 2007 to determine the persistence and quality of the grasses and find an optimal simulated grazing regime of this native grass sward. Little bluestem (*Schizachyrium scoparium*) and indiangrass (*Sorghastrium nutans*) were the predominant species in the test plots. The simulated grazing consisted of four treatments with regimes of 1 harvest at the end of the season, 2, 3, and 4 harvests spaced equally during the growing season. The season began on 15 May and ended 15 September. Forage quality estimates were taken from samples of all harvest dates, and a cumulative yield was also recorded.

It was observed that as the season progressed each harvest regime increased in dry matter production. The three- and four- cut treatment annually produced the most dry matter (4243 and 4294 lbs/A, respectively) while the one- and two- cut system were significantly lower(2249 and 3258 lbs/A, respectively). The data for forage quality showed that percent organic matter peaked in mid August, while percent crude protein ranged from 3.5-8%. Neutral and acid detergent fiber were lowest under a four cut system. Indiangrass had the highest organic matter, neutral detergent fiber, and acid detergent fiber. The project is currently being repeated to determine sustainability of the most intensive harvest regimes.

Nutritive Evaluation of American Wildrye (*Elymus spp.*) as a Potential Forage for the Southeast USA

[1]J. Brett Rushing, D. Scott Horton, Brian Baldwin

Introduced species account for a majority of forage grasses grown for livestock in North America. Cool-season non-native species include: tall fescue (*Festuca arundinacea*), annual and perennial ryegrass (*Lolium spp.*), bluegrass (*Poa spp.*), and orchardgrass (*Dactylis glomerata*). Wildrye (*Elymus virginianus* and *E. canadensis*) is a native cool-season perennial grass with forage potential. It also has potential for prairie restoration and conservation projects.

Seed of both species were collected from several locations in Arkansas, Tennessee, northern and eastern Mississippi and western Alabama. Bulked seed were planted in ten 9-m rows for an initial screening, selection, and increase. Preliminary forage analysis was conducted on four species including: wildrye, tall fescue, little barley (*Hordeum pusillum*), and annual ryegrass from April to June. Plant samples were collected bi-monthly and subjected to Van Soest analysis.

Wildrye had the highest protein and lowest fiber. Observations on growth habit indicate while the other species had jointed by the first week of May, wildrye was still vegetative. In addition to the forage value, inclusion of wildrye in a NWSG pasture could offer assistance in suppressing bermudagrass.

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NCSG's (Native Cool-season Grasses) Need Love Too!

William C. Stringer, Clemson University

It seems to me that cool-season grasses are the "invisible man" in the room where native grasses are discussed. In fact, many people use the term "native warm season grasses" or "NWSG's" to mean the same thing as native grasses. I "Googled" for native warm season grasses and native cool season grasses, and found more than 10X as many warm season than cool season hits. I suggest that NCSG's may be under-appreciated in relation to their ecological contribution.

I searched the USDA Plants database http://plants.usda.gov , for native Poaceae found in SC. Then I separated them into cool-season and warm season species, using several sources that listed characteristics of the species. Is some instances, I separated them on presence of Kranz leaf morphology and/or the PEP carboxylase enzyme, both indicating warm-season species.

South Carolina is home to 339 species of native grasses, in 68 genera. Cool-season grasses comprise 111 species in 24 genera, with two genera (*Sporobolus* and *Leptochloa)* containing both cool-season and warm-season species. The large genus *Panicum* was recently subdivided into *Panicum* and *Dichanthelium*, with cool-season species being placed in *Dicanthelium.*

Cool-season grasses are an important part of native grass communities for many reasons. Several cool-season species are adapted to seriously degraded sites. *Danthonia* species are adapted to very acid, highly eroded soils, especially *D. spicata*, poverty oatgrass. Several cool-season annual and perennial species are adapted to sharing the 12-month cycle with warm-season grasses. *Vulpia* species (annuals) are very good at occupying disturbed sites in the spring season. Poverty oatgrass (*Danthonia spicata*) and Silky oatgrass (*D. sericea*) will dominate canopies in full sun areas in spring, whereas the same canopies will contain predominately purpletop (*Tridens flavus*) and *Andropogon* species by late summer. In more shaded areas, speargrass (*Piptochaetium avenaceum*) in spring will give over to little bluestem (*Schizachyrium scoparium*) in the late season. You can see this happening, as the blond stems and empty seedheads of *Danthonia* suddenly crumple to the ground in July, just about the time the purpletop begins to elongate.

The presence of green growth of cool season grasses in winter is vital to grazing wildlife like rabbits. *Danthonia* spp. and *Dicanthelium* spp. (rosette grasses) provide new growth in all but the coldest parts of winter. The rosette grasses also produce seeds from early spring to mid-summer, thus providing vital a vital food source for over-wintering and early arriving birds (quail and songbirds).

Another vital role played by CSG's is the capture of nutrients weathering out of dead WSG herbage in winter. Without some active growth and nutrient uptake in our wet winters, significant amounts of nutrients might be lost in percolation and runoff flows. Thus a balance of cool season and warm season grasses is vital to long-term stability of natural, un-amended ecosystems. I will present information on characteristics of a number of cool-season native grasses found in South Carolina.

We members of the genus *Homo* tend to believe (still) that we are quite capable of managing and restoring naturally functioning ecosystems. We seem to forget that we got here very late in the game, and that things functioned very well before we arrived. We might be wiser to do more observing and less managing of our native grasslands. If in doubt, we might ask (in the format of the recently popular question), "WWED – What Would the Ecosystem Do?"

Sources:

USDA Plants Database website. http://plants.usda.gov/

Table 1. South Carolina genera comprising some or all CSG's

Genus	General common name
Agrostis spp.	bentgrasses
Alopecurus	carolina foxtail
Ammophila	American beachgrass
Amphicarpum	maidencanes
Bromus spp.	hairy woodland brome
Calamagrostis	arctic reedgrass
Chasmanthium spp.	woodoats
Cinna	woodreeds
Danthonia spp.	oatgrasses
Deschampsia	hairgrasses
Dichanthelium spp.	rosette grasses, panicgrasses
Elymus spp.	wildryes, bottlebrush
Festuca spp.	fescues
Glyceria	mannagrasses
Hordeum	barleys
Leersia spp.	cutgrasses
Melica	melicgrass
Nassella	needlegrasses
Piptochaetium	speargrass
Phalaris	canarygrasses
Poa spp.	bluegrasses
Sporobolus spp.	dropseeds
Torreyochloa	false mannagrasses
Vulpia spp.	annual fescues

Building the Ecological Site Concept
Linking Soils, Landscapes & Vegetation

Homer Sanchez[1]

Introduction Various recognized processes are utilized nationally to describe ecosystems. Many partnerships have been forged in efforts to catalogue existing vegetation dynamics and good progress has been made towards recognizing ecosystems at the regional and landscape level. Some efforts focus on describing ecosystems through the ecological classification system (ECS), a classification process that utilizes a national hierarchical framework for classifying vegetation.

Purpose This presentation will focus on describing ecosystems through a land classification and interpretation process based on the "ecological site" and state-and-transition modeling (STM) concepts adopted by The USDA-Natural Resources Conservation Service (NRCS). NRCS defines an "ecological site" as "a distinctive kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation. Unlike many classification systems which are based on existing vegetation, ecological sites are based on the relationships of vegetation to soil, geomorphic characteristics, and climate.

Vegetation and soil change are represented by STMs associated with each ecological site. The STMs describe alternative ecosystem states and the mechanisms of transition or restoration between states. Ecological sites and their associated STMs are designed to help users interpret and predict ecosystem potential, function, and change at the scale where land management decisions are made. For this reason, ecological sites are a logical basis for stratification of management, assessment, and monitoring activities. Ecological sites have been developed primarily for rangelands, but their potential utility spans nearly all managed and natural systems.

NRCS is currently developing ecological site descriptions through a process that digitally links soil and vegetation at the map unit level. This functionality allows the display of a wealth of geospatial information worldwide that can be used to map ecological sites directly. By connecting soil and climate maps to ecological site classifications one can provide spatially-explicit information on the possible states, the conditions promoting resilience, and restoration opportunities.

This presentation focuses on concepts utilized to develop ecological sites through processes that utilize partners and available natural resources professionals and scientists. Successful ecological sites are development when expertise in GIS, remote-sensing, soil science, and vegetation ecology, are utilized.

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Managing Forest and Grasslands through Ecological Site Descriptions

George Peacock Jr. and Arnold Norman[1]

Managing forest and rangeland communities requires a sound understanding of ecological processes. When studying landscapes, it is not difficult to recognize that some parts are different from other parts and because of these differences, each type of landscape will produce different kinds and amounts of vegetation. The question is, "How are they different and how do they respond to management?"

To conceptualize and understand variation across the landscape, these different parts are classified into units called **ecological sites**. These site delineations are utilized as the basic subdivision for the inventory and analysis of landscapes. The interpretation of these sites is the written Ecological Site Description.

Ecological sites are defined as: "a distinctive kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation". Each ecological site is a product of all the environmental factors responsible for its development, such as soils, relief or topography, climate, and natural disturbances (fire, herbivory, drought, etc.). Unique associations of plants replicate under specific environmental factors. The plant communities on an ecological site are somewhat predictable and are recognizable. The resiliency of these communities and the drivers of change are thoroughly described for each ecological site.

Each Ecological Site Description contains information about physiographic features, climatic features, soils, associated hydrologic features, and plant communities that occur on the site. Plant community dynamics, annual production estimates, growth curves, associated wildlife communities, and interpretations for use and management of the site are also part of each site description.

One of the major components of the Ecological Site Description is the state and transition model. It is a diagram that describes vegetation dynamics of each ecological site. The state and transition model provides a visual picture to communicate complex information about vegetation responses to disturbances and management. Once developed, the state and transition model will assist land managers in making timely, well informed management decisions.

Today, land managers are challenged with synthesizing an overwhelming amount of scientific information concerning soils, hydrology, ecology, management, etc. Ecological Site Descriptions put the ecological reference into an applied context. Not only do they capture the knowledge of experienced individuals, but they remain as guidance documents for landowners, agencies, organizations and university teaching.

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Accessing Ecological Site Information through NRCS Web-based Systems

[1]Michael Hall and [2]Dennis Chessman

Introduction The Natural Resources Conservation Service (NRCS) often receives questions from landowners and other agencies about ecological sites. For example: Where can you go to find information on each individual ecological site? Where can you find information on native plants adapted to each ecological site? Where would you go to find information about how different plant communities on an ecological site respond to different disturbances? What about information on hydrology and erosion potentials as plant communities change? A complete ecological site description document can provide information to answer these types of questions.

Purpose This presentation will focus on showing the audience how to access ecological site information from various USDA-Natural Resources Conservation Service (NRCS) http://www.nrcs.usda.gov/ web sites. NRCS has linked various web services in an effort to facilitate technology transfer internally, as well as with customers and partners. The ESIS database is linked to the National Soil InformationSystem (NASIS), the Web Soil Survey (WSS) http://websoilsurvey.nrcs.usda.gov/app/ , the electronic Field Office Technical Guide (eFOTG) http://www.nrcs.usda.gov/technical/efotg/, and the National Plants Data Center (NPDC) http://plants.usda.gov/ . The demonstration will include an overview of the Ecological Site Information System (ESIS) http://esis.sc.egov.usda.gov/ web site. Demonstrations of how a user can access ecological site and soil information from one or more of these databases will be conducted.

A draft version of an ecological site State and Transition Model (STM) for the Piedmont Region of South Carolina will be presented for comment and discussion. Triggers of change and Feedback mechanism discussion relative to states, communities and threshold activity will be presented. Once developed, ecological sites and State and Transition Models will assist land managers in making timely, well informed management decisions. Development of ecological sites requires a joint effort among all organizations, agencies, universities, and others that have interest in, or knowledge of the ecological dynamics.

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Response of Native Forbs to Pre-Emergent Treatment of Imazapic Herbicide

Matt A. Bahm[1] and Thomas G. Barnes[2]

Grassland restoration involves attempting to restore and/or re-create biologically diverse native plant communities. Herbicides are an important tool for removing competition from exotic species. Subsequent plantings are often necessary to increase native plant diversity, increasing management inputs and costs. Imazapic herbicide is widely used in grassland restoration projects. In spring 2006, we initiated a study testing response of 22 native forbs to 2 and 4-oz/ac pre-emergent treatments of imazapic. Sites were established in KY and IN to provide broad applicability of results. Seedling establishment and weed cover were monitored at 30 60, 180 days and 15 months after treatment. Information will provide managers a more encompassing list of species to include in initial plantings, increasing diversity and reducing costs of restoration projects.

Introduction

Grasslands are among the most threatened terrestrial ecosystems on the globe. Less than 4% of the original 80 million ha of tallgrass prairie remains (Steinauer and Collins 1996). Managers have been re-creating or restoring grasslands using a variety of management techniques including seeding, burning, grazing, and most recently using herbicides (Barnes 2007). Some of the restorations are more successful than others and success or failure often depends on how well weed competition is suppressed, (Martin et al. 1982, Masters et al. 1996) typically through the use of herbicides (Masters et al. 1996, Beran et al. 1999*a*, Barnes 2004). The imidazolinone herbicides have shown to reduce weed competition and enhance native species stand establishment (Masters et al. 1996, Beran et al. 1999*a*, Beran et al. 1999*b*, Beran et al. 2000, Washburn and Barnes 2000). This family of herbicides controls a wide range of grassy and broadleaf weeds (Little and Shaner 1991; Shaner and Mallipudi 1991), with imazapic being widely used in restoration plantings (Barnes 2004; Barnes 2007).

By identifying native grass and forb species that respond favorable to pre-emergent herbicide application, more species could be included in initial restoration plantings potentially saving managers time and money and may allow the community to better adapt to environmental change (Brown 2004). *Rudbeckia triloba*, *Echinacea purpurea*, *Liatris spicata*, *Gaillardia aristata*, and *Ratibida columnifera* are commonly used in restoration plantings and have shown pre- and/or post-emergent resistance to a 4 oz/ac treatment of imazapic (Beran et al. 1999*a*, Anonymous 2002). Several native legumes have shown resistance to imazapic. *Baptisia australis*, *Chamaecrista fasciculata*, *Dalea candidum*, *Dalea purpurea*, *Desmanthus illinoensis*, and *Desmodium canadense* have all shown resistance to imazapic treatment (Beran et al. 1999*b*, Washburn and Barnes 2000, Anonymous 2002). The goal of this study was to determine the influence of pre-emergent treatments of imazapic on establishment of 22 native forbs that occur in eastern grasslands.

Materials and Methods

In Spring 2006, we initiated a native forb study in Kentucky and Indiana to determine response of species to pre-emergent treatments of imazapic herbicide.

Experiments were conducted at Griffith Woods, Harrison County, KY and Purdue Wildlife Research Area, Tippecanoe County, IN. The soil at Griffith Woods was a Loradale silt loam with 19.5% clay, 26.7% sand, 53.8% silt, and 3% organic matter. The soil at Purdue Wildlife Research Area was a Rainville silt loam with 19% clay, 15% sand, 66% silt, and 2% organic matter. All soil data were obtained through the NRCS's Web Soil Survey (http://websoilsurvey.nrcs.usda.gov). The Griffith Woods area was dominated by tall fescue (*Festuca arundinacea* Schreb.), sprayed with glyphosate, and tilled, using conventional methods, 6 weeks prior to initiation of the research. The Purdue Wildlife Research Area had been used as native habitat research plots and were tilled, using conventional methods, 4 weeks prior to planting.

Two imazapic rates (0.035 and 0.07 kg ai/ha) and an untreated control were randomly assigned and applied to an area approximately 3 m x 20 m (10 ft x 65 ft). Within each treatment, 22 1 m^2 subplots were established and each of the species was randomly assigned to 1 subplot/treatment. Plots were sprayed in April (Kentucky) and May (Indiana) with a 0.035 kg ai/ha imazapic (2-oz/ac) and 0.07 kg ai/ha imazapic (4-oz/ac) rate of imazapic. Herbicides were mixed with water and methylated soybean oil (a surfactant) at 2.34 l/ha (1 qt/ac) and sprayed using an ATV-mounted sprayer delivering a rate of 187 l/ha (20 gal/ac) at 241 kPa (35 psi). Plots were then hand-broadcast with native forb seeds, within 2 hours following spraying, at a rate equivalent to 11.2 kg/ha (10 lbs/ac). Prior to seeding, seeds were cold-moist stratified following methods presented in Packard and Mutel (1997).

Percent cover of non-planted (weed) species was visually estimated and the total number of plants emerged for each 1 m^2 plot was collected on 17-19 June, 15-19 July, 21-23 September 2006 and 15-17 July 2007. Numbers of planted species were ranked and analyzed using a Kruskal-Wallis One-Way Analysis of Variance (Daniel 1990). Each species forb was analyzed separately to test for differences in density due to herbicide effects for each time period. If a difference ($p < 0.05$) was detected, multiple comparisons were made using the procedure described by Dunn (1964) using an experimentwise error rate of $\alpha = 0.15$. Weed cover data were combined for each treatment and arcsine square root (Zar 1999) transformed values for non-planted species cover were analyzed using the MIXED procedure in SAS (2002). Mean comparisons were made using the PDIFF option in SAS (2002) at the 5% significance level (Little et al 1996).

Results and Discussion

In most comparisons there were no significant site interactions. Therefore, data were pooled across sites for treatment analysis. In situations with significant site by treatment interactions, data were analyzed separately for each site. Means for individual species at each site are given in Table 1.

Astragalus canadensis, *Baptisia australis*, *Eupatorium perfoliatum*, *Eryngium yuccifolium*, *Lespedeza capitata*, *Liatris aspera*, and *Liatris squarrosa* averaged fewer than 5 individuals in any treatment (Table 2). Low germination could potentially be linked to drought conditions at the study sites in the first season of the study.

Aster azureus, *Monarda fistulosa*, *Ratibida pinnata*, *Rudbeckia fulgida*, *Rudbeckia subtomentosa*, and *Rudbeckia triloba* had significantly higher numbers of plants in the control plots as compared to treated plots after 180 days (Table 2). *Monarda fistulosa*, *Ratibida pinnata*, *Rudbeckia fulgida*, *Rudbeckia subtomentosa*, and *Rudbeckia triloba* showed the same pattern after 15 months, while *Aster azureus* had similar densities in the control and 2 oz/ac treatments (Table 2). Weed competition may have reduced *Aster azureus* in control plots, in the 15 month sample (Washburn and Barnes 2000). Our results are similar to those reported by Beran et al. (1999*a*) for *Monarda fistulosa*, which had reduced establishment following herbicide application. We did not expect to see this pattern in members of the genera *Rudbeckia* and *Ratibida*, which have species known to exhibit resistance to these levels of imazapic (Beran et al. 1999*a*, Anonymous 2002).

Amorpha canescens, *Aster novae-angliae*, *Baptisia alba*, *Desmodium illinoense*, and *Solidago rigida* had similar numbers across treatments at 180 days and 15 months after treatment (Table 2). Herbicides did not appear to effect establishment of these 5 species. *Aster novae-angliae* is typically tolerant only to post-emergent treatment with imazapic (Anonymous 2002). Imazapic has been reported to negatively impact certain native legumes, such as *Amorpha canescens* and *Lespedeza capitata* (Beran et al. 1999*b*).

Aster laevis and *Heliopsis helianthoides* had significantly lower plants/m^2 in the 0.07 kg ai/ha imazapic treated plots (Table 2). Higher rates of imazapic could negatively affect establishment of *Aster laevis* and *Heliopsis helianthoides*. *Desmodium canadense* had significantly higher plant densities in the 2 oz/ac imazapic treated plots (Table 2). Reduced initial weed cover in the 2 oz/ac imazapic plots could have allowed greater establishment (Washburn and Barnes 2000). Beran et al. (1999*b*) reported significant injury to *Desmodium canadense* at rates of 4 oz/ac during the year of establishment, and could potentially be responsible for the lower numbers observed during our study.

Weed cover was significantly lower in herbicide treated plots throughout the first growing season (Table 3). After 180 days, all plots averaged >80% weed cover and >90% weed cover was recorded on all plots after 15 months.

Conclusions

This research has several potential implications for managers. *Aster azureus*, *Monarda fistulosa*, *Ratibida pinnata*, *Rudbeckia fulgida*, *Rudbeckia subtomentosa*, and *Rudbeckia triloba* must be used with caution when conditions are similar to those examined in our study. It is important to note that although *Rudbeckia hirta* and *Ratibida columnifera* have shown resistance to similar treatments of imazapic, members of the same genera in our study were negatively affected by imazapic application. *Amorpha canescens*, *Aster novae-angliae*, *Baptisia alba*, *Desmodium illinoense*, and *Solidago rigida* would appear to be appropriate for inclusion in seed mixes when using similar rates of imazapic. *Amorpha canescens* has been reported to be susceptible to injury in other research and therefore, should be judged on a site by site basis. *Aster laevis* and *Heliopsis helianthoides* should only be included in seed mixes when using imazapic rates less than 4 oz/ac. *Desmodium canadense*, *Baptisia alba*, and *Desmodium illinoense* could be a good addition to seed mixes, especially if inclusion of a legume species is important to management objectives. Perhaps most importantly, this research and the research cited within demonstrate the variability of imazapic herbicide between site and species interactions and should be strongly considered prior to development of seed mixes.

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Table 1. Average number of seedlings at 180 days and 15 months after pre-emergent treatment of imazapic at Griffith Woods, KY and Purdue Wildlife Research Area, IN. All averages are rounded to the nearest whole number.

	Treatment											
	2 oz/ac				Control				4 oz/ac			
	180D		15M		180D		15M		180D		15M	
Species	KY	IN	KY	IN	KY	IN	KY	IN	KY	IN	KY	IN
Amorpha canescens	4	1	4	1	5	0	4	0	9	2	5	1
Aster azureus	7	6	7	6	4	49	2	28	1	1	1	3
Aster laevis	20	8	11	7	117	25	46	17	7	3	6	3
Aster novae-angliae	27	27	27	22	11	64	11	58	33	95	19	2
Astragalus canadensis	1	0	1	1	0	0	0	0	5	0	5	0
Baptisia australis	1	2	1	2	0	1	0	1	0	3	0	3
Baptisia alba	3	9	3	8	0	10	0	10	8	3	6	3
Desmodium canadense	44	33	44	32	9	19	9	19	23	10	12	10
Desmodium illinoense	8	8	8	8	1	9	1	9	11	20	8	20
Eupatorium perfoliatum	0	0	0	0	0	0	0	0	0	0	0	0
Eryngium yuccifolium	0	0	0	0	0	0	2	0	0	0	0	0
Heliopsis helianthoides	39	23	39	22	10	35	10	25	10	5	6	5
Lespedeza capitata	1	0	0	0	0	0	0	8	1	2	0	2
Liatris aspera	0	0	1	0	0	8	0	7	0	0	1	0
Liatris spicata	0	0	0	0	0	0	0	11	0	0	0	0
Liatris squarosa	1	0	1	1	8	0	4	2	1	0	1	0
Monarda fistulosa	0	0	0	0	3	15	2	15	0	0	0	0
Ratibida pinnata	30	1	17	1	199	110	51	70	4	1	3	1
Rudbeckia fulgida	8	1	6	1	92	27	76	27	7	0	7	0
Rudbeckia subtomentosa	0	1	0	1	6	66	27	37	1	1	1	1
Rudbeckia triloba	4	0	4	0	48	21	17	21	0	0	0	0
Solidago rigida	2	12	2	12	7	30	7	27	30	3	24	3

Table 2. Number of forb seedlings, averaged across sites, 180 days and 15 months after pre-emergent treatment of imazapic. Means with different letters are significantly different (α = 0.05). Species with an (*) were analyzed by site due to significant interaction and individual means are presented when significant. All averages are rounded to the nearest whole number.

	Treatment					
	2 oz/ac	Control	4 oz/ac	2 oz/ac	Control	4 oz/ac
Species	180D			15M		
Amorpha canescens	3a	3a	6a	3a	2a	3a
Aster azureus	7a	27b	1a	7a	15a	2b
Aster laevis	14ab	71b	5a	14ab	32b	5a
*Aster novae-angliae**	27a	38a	64a	25a	35a	11a
Astragalus canadensis	1a	0a	3a	1a	0a	3a
*Baptisia australis**	2a	1a	2a	2a	1a	2a
Baptisia alba	6a	5a	6a	6a	5a	5a
Desmodium canadense	39a	14b	17b	38a	14b	11b
Desmodium illinoense	8a	5a	16a	8a	5a	14a
Eupatorium perfoliatum	0a	0a	0a	0a	0a	0a
Eryngium yuccifolium	0a	0a	0a	0a	1a	0a
Heliopsis helianthoides	31a	23a	8b	31a	18a	6b
*Lespedeza capitata**	1a	0a	2a	0a	4a	1a
Liatris aspera	0a	4a	0a	1a	4a	1a
Liatris spicata	0a	0a	0a	0a	6a	0a
Liatris squarosa	1a	4a	1a	1a	3a	1a
Monarda fistulosa	0a	9b	0a	0a	9b	0a
*Ratibida pinnata**	16a	155b	3a	9a	61b	2a
*Rudbeckia fulgida**						
Kentucky	8a	92b	7a	6a	76b	7a
Indiana	1a	27b	1a	1a	27b	1a
Rudbeckia subtomentosa	1a	36b	1a	1a	32b	1a
Rudbeckia triloba	2a	35b	0a	2a	19b	0a
Solidago rigida	7a	19a	17a	7a	17a	14a

Table 3. Percent weed cover of experimental plots after 30, 60 and 180 days and 15 months at Griffith Woods, KY and Purdue Wildlife Research Area, IN. Means with different letters are significantly different (α = 0.05).

	Treatment		
Time Since Treatment	2 oz/ac	Control	4 oz/ac
30 Days	4a	85b	2a
60 Days	12a	99b	3c
180 Days	91a	100c	81c
15 Months	98a	92ab	94b

Herbicide Application Selectivity in Native Grass Restoration Projects

Matt Nespeca[1]

When restoring native grasses, herbicides are a tool that can increase survival and growth of desirable native grasses and forbs, while reducing cover of ruderal or invasive plants. It is important to know what plants an herbicide is capable of controlling on a site, but it is even more important to understand what plants an herbicide will not control. On a restoration site, the idea of **herbicide application selectivity** (or the susceptibility or tolerance of a plant to an herbicide application), can be attained through herbicide spectrum, herbicide placement, or herbicide timing. Over the past several years, these methods have been used on native grass restoration projects throughout South Carolina, such as Mepkin Abbey, McAlhaney Preserve, and Rock Hill Black Jack Heritage Preserve.

In some native grass restoration projects, a manager can rely on **herbicide spectrum** to provide selectivity. When bahiagrass is out-competing an established stand of big bluestem and little bluestem, a manager can use a broadcast herbicide treatment of Escort XP Herbicide to reduce the bahiagrass competition and release the native grasses. If the same established stand of big bluestem and little bluestem is being infested by johsongrass, Plateau Herbicide provides selective control of johnsongrass, but is safe for the native grasses. A more obvious method of utilizing an herbicide spectrum in native grass restoration is with broadleaf specific products such as Garlon 4 Ultra, which control broadleaf species, while releasing grasses.

Herbicide placement, as it relates to native grass restoration, can be accomplished through directed foliar applications to undesirable plants while avoiding contact with desirable plants. For example, Roundup Pro will control many grasses during the growing season, but a skilled applicator can still treat patches of bermudagrass out of a restoration area with Roundup Pro, while avoiding contact with desirable nearby grasses.

Herbicide timing can be a very effective method to control cool-season grasses with non-selective herbicides such as Roundup Pro during seasons when warm-season grasses are still in dormancy. Herbicide timing is also effective for mid-winter applications when non-native evergreen shrubs such as Chinese privet are invading highly diverse grassland habitats, where safety for existing forbs and grasses is essential.

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Responses of wiregrass (*Aristida stricta*) and associated herbaceous species to herbicide and fire treatments

Allyson S. Read[1, 2], Sara H. Schweitzer[1], and Mike Murphy[1]

Introduction Because of our interest in restoring the longleaf pine-wiregrass (*Aristida stricta* Michx. and *A. beyrichiana* Trin. & Rupr.) ecosystem, we examined effects of the herbicides, hexazinone (Velpar L) and imazapyr (Chopper), with and without fire, on regeneration of wiregrass and associated herbaceous plant species typical of the understory of longleaf pine savannas. We expected that effects of treatments on groundcover vegetation would differ; specifically, that a combination of fire and herbicide would be best at controlling competition from hardwood species and promoting regeneration of wiregrass and associated herbaceous vegetation.

Methods On Yuchi Wildlife Management Area, Burke County, Georgia, 3 study sites were each divided into 18 plots, so each of 6 treatments was replicated 3 times per site. We recorded percentage of horizontal cover, height, structure, and species diversity of vegetation from October 2005 to October 2006. We used a nested ANOVA design, and repeated measures to evaluate time and treatment effects and interactions. The *a priori* level of significance was $P \leq 0.05$.

Results and Discussion In October 2006, horizontal cover, height, structure, and species diversity of vegetation were not different among treatments. Horizontal cover of grass species did not differ among treatments throughout the study; however, wiregrass was present in each treatment, each season. Wiregrass is usually released by herbicide-with-fire treatments, but we detected decreased frequency of occurrence of wiregrass. After application of fire in February 2006, the frequency of occurrence of wiregrass was lower in imazapyr-with-fire, fire-only, and hexazinone-with-fire than in the without-fire treatments for June, August, and October 2006, but because wiregrass may take up to 5 years to increase in occurrence after herbicide treatment, our results were not alarming. Plant species were ranked by significance on a scale developed with the Georgia Department of Natural Resources (-2 to +2). Species ranking from hexazinone-with-fire (0.97) and hexazinone-only (0.93) treatments were greater ($P = 0.002$) than those from imazapyr-with-fire (0.52) and imazapyr-only (0.42) treatments, indicating that plant species characteristic of the sandhill community were more numerous in these treatments. Like wiregrass, much of the associated herbaceous vegetation of this ecosystem is fire-dependent. Herbicides can mimic some ecological effects of fire, but they cannot clear litter and debris that may inhibit regeneration of some sandhill plant species. Based on our overall results, we rejected the hypothesis that plant treatments would differ in their effect on groundcover vegetation. We concluded that data collection and analyses conducted over a period of 2–5 years post-treatment are needed to understand the effects of the herbicides, hexazinone (Velpar-L) and imazapyr (Chopper), on the vegetation of this xeric sandhill scrub ecosystem.

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The Use of Volunteers for Invasive Weeds Survey

Stephen Compton[1] and George Kessler[2]

Introduction This presentation is to report on the use of volunteers from various environmental, educational groups and private individuals participating in a state-wide survey for cogongrass in May 2008. Using surveyors from multiple organizations can beeffective when funding and manpower are limited. This presentation will outline the challenges and successes of such a survey.

Methods During mid-May, a survey for the noxious weed cogongrass was conducted in South Carolina. This was a collaborative effort of the SC Cogongrass Task Force, which includes representatives from the Department of Plant Industry, Clemson University Department of Forestry and Natural Resources, SC Forestry Commission, USDA APHIS PPQ, and other agencies and organizations. The nearly 200 volunteers that participated in the survey came from the SC Exotic Pest Plant Council; the Nature Conservancy; SC Native Plant Society; the College of Charleston; Master Gardeners, and various educational and environmental groups. Public awareness brought volunteers from all sectors of South Carolina's concerned citizens because of the invasive nature and cost associated with this noxious grass.

Discussion The invasive grass species called cogongrass, *Imperata cylindrica*, is a growing threat across the Southeastern United States. Cogongrass has been confirmed in nine South Carolina counties and now occupies more acres than kudzu in the Southeastern United States. Cogongrass is a perennial grass that reproduces by seeds and rhizomes. Cogongrass produces about 3000 seeds per plant and new plants can begin when small pieces of the rhizome or seeds come in contact with soil. Cogongrass forms dense stands that that can produce over three tons of rhizomes per acre and excludes native flora and fauna. These factors make the spread of cogongrass by man, equipment, nursery stock, bark, wind, and movement of soil a real threat in our mobile world. The fact that cogongrass exists in South Carolina should cause great concern to those that wish to protect our state's natural ecosystems.

Results As a result of the survey and public awareness programs, Clemson University's Department of Plant Industry investigated nearly 100 reports of suspect cogongrass. Ten new sites were discovered, all of which have been treated and will be monitored for regrowth. The volunteer force reported 13,587 miles of travel, 1,060 hours of related work and observation of 1,383 sites, points, and roads. The survey was considered an immense success and future events to survey for this invasive grass are planed for 2009.

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Optimizing Germination of Rivercane (*Arundinaria gigantea*) Seed

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Rivercane is the only bamboo native to North America. The land area occupied by canebrakes has been reduced to about 2% of its original range over the last 70 years. Rivercane serves a number of purposes in the ecosystem. It provides extensive land stabilization, preventing erosion and enhancing water quality by holding the soil with its interlocking rhizomes and intercepting surface water with an extensive array of culms as it moves toward streams and rivers. Expansive stands of rivercane, called brakes, are no longer common place. Rivercane is one of only a few native evergreen grasses. It is reported to have been grazed by bison and eastern elk. Choctaw, Cherokee, and Chickasaw craftsmen and women use rivercane as a raw material for a small, but highly profitable industry. However, cane stands of significant size are declining. During the last two years we have observed rivercane flowering at many locations in the Southeast [Mississippi's western alluvial plain (The Delta), Miss. hill county, western Tennessee, western North Carolina, and central Alabama]. Due to extensive juvenility, gregarious flowering habit and the monocarpic nature of rivercane, the current flowering event allows us to conduct research that may not be possible again for another 40-60 years. Rivercane seed is currently available for experimentation to determine the environmental requirements for germination.

Seed lots from two locations (Kitawah and Cullowhee) in North Carolina were tested at six temperature regimes (15-40 at 5°C increments). Standard roll towel method was used in the first experiment. Questions of the effect of light on germination caused us to initiate a second experiment utilizing clear Lucite® boxes. In all cases, ungerminated seed were soaked with gibberellic acid (GA_4) to stimulate latent germination. Seed that still had not germinated were soaked in 2% tetrazolium solution soak to determine seed viability.

Maximum total germination was observed in the seed lot from Cullowhee, NC (57%). The temperature giving highest germination for both genotypes was 30/20°C (16/8 hrs). In every case, seed that did not germinate was not viable. Germination of seed in Lucite® boxes was substantially less that in the roll towels. Repeated testing of the seed seems to indicate that rivercane seed is recalcitrant in nature, with a 10 week limit on storability under our conditions (20°C at 60% RH). Such information can help researchers and conservationists establish new stands of rivercane, and offer information to enhance seed viability in storage.

Seed Production Comparison of Three Eastern Gamagrasses in East Texas

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Introduction:
Eastern gamagrass, *Tripsacum dactyloides*, is a native warm season perennial grass adapted throughout most of the eastern United States. It is typically used as livestock forage, and has potential for use in vegetative barriers and soil phyto-remediation. Low seed yields have limited its acceptance in the commercial seed industry. The objective of this study is to compare seed production potential of two cultivars and accession 9043629 currently produced by the USDA-Natural Resources Conservation Service East Texas Plant Materials Center (ETPMC).

Methods: Two cultivars of eastern gamagrass; 'Medina', 'Jackson', and accession 9043629 (Nacogdoches County, Texas.) were planted in a randomized complete block design with 3 replications at the ETPMC on an Attoyac fine sandy loam in 2006. Plots were 9x12 feet, and started from vegetative rootstock spaced on 3 foot centers with 4 foot allies between replications. Data was collected from the interior plants in each plot to minimize edge effects. A soil test was used to adjust pH to 6.0 and to bring P and K to a medium level. Nitrogen fertilizer was applied at a rate of 75 lb/acre using ammonium nitrate as the N source when spring regrowth reached 6 inches. Fertility was maintained at a medium level throughout the course of the study. The number of vegetative tillers, reproductive tillers, and axillary seed heads per reproductive tiller were recorded from 3 randomly selected plants in each plot. The axillary seed heads were hand harvested when approximately 75% of the staminate portion of the flowers had shed. Seed was allowed to air dry, cleaned with a South Dakota Seed Blower set at 70% open to eliminate any unfilled seeds, and yield and germination results were recorded. Four replicates of 100 seed were placed in germination boxes and germinated in a controlled chamber (20^o-30^o C, 8 hours light and 16 hours dark). Counts were made at 14, 21, 28, and 35 days.

Results and Discussion:
Vegetative data collected in 2007 and 2008 showed accession 9043629 had significantly more ($P<0.05$) reproductive tillers, axillary seed heads, and fewer vegetative tillers than 'Jackson' or 'Medina'. Germination tests performed on seed collected in 2007 did not show any significant differences ($P<0.05$) between the entries. There were also no significant differences ($P<0.05$) in yield between entries when compared on a pure live seed (PLS) basis. However, 9043629 had the highest pure live seed (PLS) yield in 2007. Harvest from production fields at the ETPMC support this trend with accession 9043629 producing twice the yield per acre as 'Medina'. Additional germination and PLS yield data are scheduled to be collected in the fall of 2008 and 2009. 'Medina' was heavily infected with the fungal pathogen, *Puccinia* spp. in 2007. Reduced yield and vegetative data were collected in 2008. This study is in its first of three years of data collection.

Andropogon ternarius and *Andropogon gyrans* Propagation Techniques

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Introduction: Splitbeard bluestem [*Andropogon ternarius* Michx.] and Elliot's bluestem [*Andropogon gyrans* Ashe] are widely distributed throughout the Eastern United States. These native grasses are frequently identified as attractive components of natural landscapes, but detailed information about their culture is lacking. Splitbeard and Elliot's bluestem are important floristic components of cedar glade communities at Stones River National Battlefield in Murfreesboro, Tennessee and the Natural Resources Staff there uses these and other native species extensively in landscape restoration to maintain and/or enhance the Park's circa 1863 floristic authenticity. Through a Cooperative Agreement with Stones River National Battlefield, the Appalachian Plant Materials Center has perfected a propagation technique and provided plugs of these species suitable for mechanical transplanting to the Park for landscape restoration for five years.

Materials and Methods: Splitbeard and Elliot's bluestem seed was hand harvested from existing populations within the battlefield. Seed of both species is perhaps best described as being conspicuously tufted or covered with silky white rather stiff racemes. Tufts are removed with a brush machine using a coarse shell mantle and medium stiff brushes at a brush speed of 10 – 12cycles/minute. De-tufted seed is planted into round cell, 38 cells per tray, greenhouse propagation trays filled with coarse processed bark and composted pine bark growing medium. Seed is surface sown at a rate of 3 -5 seeds per cell and lightly covered with starter sized, 1/16" – 1/8", granite poultry grit to combat damping off diseases. Prepared trays are lightly hand watered to slightly moisten the growing medium and cold stratified at 35 degrees Fahrenheit for a minimum of 21 days. Stratified seed is placed into a greenhouse maintained under natural lighting and at a minimum temperature of 70 degrees Fahrenheit. Germination typically occurs 7 – 10 days after placement in the greenhouse. Soil moisture is maintained during germination by an automatic overhead system set to cycle for 20 seconds every 30 minutes during daylight hours. After germination, watering is reduced to overhead hand watering once daily. Seedlings are maintained in a greenhouse environment typically 2 -4 months to promote development of a plug with 4 -6 inches of top growth and a dense, fibrous root system suitable for mechanical transplanting. Seedlings receive a water soluble complete fertilizer bi-weekly until acclimating to natural climatic conditions. Acclimation is typically accomplished through placement of seedlings outdoors in a protected location, e.g., a shade structure, for a 1 -2 week period prior to transplanting.

Results and Discussion: Using the technique described above, the Appalachian Plant Materials Center has successfully produced in excess of 30,000 propagules each of splitbeard and Elliot's bluestem from wild harvested seed of unknown quality. Typical cell fill rates have been greater than 85% and transplant survival has been greater than 80%. Cell fill percentages may improve by germination testing wild harvested seed.

Preliminary Results on the Development of Seed Conditioning and Germination Protocols for Grass Species in the Longleaf Pine Ecosystem

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Introduction: Longleaf pine (*Pinus palustris* Mill.) ecosystem restoration is currently a priority of many longleaf pine landowners and enthusiasts in conjunction with federal and state agencies mandate (Brockway et al., 2005). Reintroducing the herbaceous ground layer under mature longleaf pine stands is a critical component in ecosytem restoration. Much of the native plants' seed banks have not persisted over time, so seed reintroduction into the area is needed through direct seeding or planting (Coffey and Kirkman 2006).

Ground layer revegetation through seed introduction depends on a ready source of viable seed for many of these species. Unfortunately, cleaned, viable seeds are not yet available to propagate most of the species. One bottleneck is lack of basic information on seed cleaning, seed germination, long-term seed storage, and efficient procedures for nursery propagation (see Pfaff and Gonter 1996, Glitzenstein et al. 2001, Pfaff et al. 2002, Coffey and Kirkman 2006).

To answer some of these questions, an ongoing study is being conducted to determine how to condition native plants' seeds and develop germination protocols for laboratory and nursery propagation. All species in the study are found in the longleaf pine ecosytem. This paper presents information on native grass propagation only. Detailed notes on machine settings, screen sizes, and seed moisture were recorded during the conditioning process. Nursery propagation information is included for a few species, but at this time there is no outplanting data available. Seed storage germination data is not complete at this time, so these results are only preliminary. More conditioning, germination, and seed storage information will be presented in the future as it becomes available.

Methods: *Winter 2005-2007 collections*
Seeds from 13 grass species were collected by hand in 2005, 2006, and 2007 from 6 sites within Alabama, Georgia, and South Carolina. (Fort Benning, GA, Aiken Gopher Heritage Preserve, SC, three private landholdings in Russell County, AL, one private landholding in Stewart County, GA). The grass species were *Aristida condensata* Chapm., *Aristida lanosa* Muhl.ex Elliot, *Aristida purpurascens* Poir., *Aristida stricta* Michx., *Panicum anceps* Michx., *Saccharum alopecuroides*(L.)Nutt., *Saccharum brevibarbe* (Michx.)Pers., *Schizachyrium scoparium* (Michx.)Nash, *Sorghastrum elliottii* (C.Mohr)Nash, *Sorghastrum nutans* (l.)Nash, *Sorghastrum secundum* (Elliot)Nash, *Sporobolus junceus* (P.Beauv.)Kunth, and *Tridens flavus* (L.)Hitchc. Seeds were allowed

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to dry naturally in paper bags, then delivered to the USDA Forest Service National Seed Laboratory for cleaning in the spring of 2006, 2007, and 2008. Some collections were too small to clean with equipment, so these seeds were extracted by hand.

*Seed Conditioning***:** Generally, grass species are easier to clean with the Westrup brush machine than other herbaceous species. The brush machine is similar to a debearder and easily separates the inflorescences and removes awns; thereby, creating a flowable product for further conditioning.

Very small seeds pass through the mantle of the brush machine and fall out below the machine while larger seeds move through the mantle to the discharge end of the machine. X-ray analysis and magnification are used to examine the seeds before combining the two portions. In some cases the seed quality is quite different and each portion should be further cleaned separately.

Following separating seeds from their inflorescences, large linear size debris is removed with screens and/or indent cylinders. The most commonly used screens for grasses were sizes 6 x 20 and 6 x 21 which translates into 6 wires per square inch by 20 wires per square inch. *Sporobolus junceus* required screen 4 x 20 for large debris removal.

To remove very small debris, an aspirator is used. Aspirator fans create a vacuum and air filling the vacuum is used to separate seeds of different weight. Air lifts up the light weight material whose terminal velocity is equal to or less than the air stream, and discharges it while the heavier material just falls out at the bottom of the air column (Gregg et al. 1970). Sometimes the seeds are aspirated more than once.

A specific gravity table performs a similar function as an aspirator, but it is more sensitive to weight differences. Specific gravity tables can condition large quantities of seeds in less time making it more efficient than aspirators.

Blowers are used to remove more debris or poor quality seeds if the aspirator did not remove it all. Air blown up through the seeds, lifts the lighter weight seed up the column. The blowers available for this study were the South Dakota blower, the Stultz blower, and the General Blower. General Blower separates very small size seeds or very light weight debris from the seedlot. Seeds are poured in a cup that has a capacity of only a couple of teaspoons, so the machine only practical for small seed quantities.

Through the entire conditioning process, a water activity meter was used to check the seed moisture. Checks were made while the seeds were being cleaned, before germination testing, and before and after they were placed in cold storage. The meter measures the equilibrium relative humidity which when multiplied by 100 equals the relative humidity. A relative humidity of 30% equates to a moisture content of 8% or lower. Typically, orthodox seeds dried to a moisture content below 10% can be stored in freezing temperatures without killing the seeds.

Germination: Standard germination tests were conducted on seeds from each collection. Small germination dishes were utilized in 2006 and 2007. Kimpak was placed under the blue blotters as media to keep the blotters moist. The media received 47.5 ml of water.

Clear styrene jars (60oz-89mm) were substituted in 2008 for germination testing. Only moistened blue blotters were used as media. Circular blotters, 3 3/8 inch in diameter, fit into the jar lids which screwed on; thereby, trapping the moisture inside the jar.

Germination temperature used in 2006 was 20° C (68° F) with 16 hours of darkness and 30° C (86 ° F) with 8 hours of light. For *Schizachryium*, *Sorghastrum*, and *Saccharum* genera, the caryopsis and whole seeds were germinated separately to determine germination differences. In 2007, only 20° C (68° F) with 16 hours of darkness and 8 hours of light was used. It was postulated that if longleaf pine seeds germinated well at this temperature, then other native plants' seed may be adapted to this temperature too. In 2008, 3 temperatures (15°C (59° F), 20°C, and 20/30°C), each with 8 hours of light, were deployed to determine the optimum temperature for germination.

Various quantities were used for germination testing depending on the amount of seed and time available to perform the germination tests. In 2006 and 2008, 100 seeds were divided into 4 dishes of 25 seeds. In 2007, 200 seeds were divided into 4 dishes of 50 seeds. If seeds were limited, then 25 seeds or less per dish were used.

Seeds for some species were stratified in a cooler at 3° C (38 ° F) prior to germination testing. Seeds were placed in the cooler already planted in the germination dishes. After a specified period of 14, 21 or 28 days, the dishes were examined for germination and then tranferred into germination rooms at specified temperatures. Results were compared with unstratified germination tests to determine the degree of dormancy present.

Seeds in the dishes were counted weekly and those that germinated were discarded. Germination was recorded when the radicle appeared. Tests were run for 28 days unless maximum germination had not been achieved, and then they were extended.

Storage study: A storage study was initiated with the 2007 seed collections to determine if the seeds could survive in cold, dry storage. Two temperatures were used- one above freezing 3°C(38 °F) and the other below freezing -7°C(20 °F). Seeds, placed in plastic bags, were put in the above freezing temperature for a period of 3 months, 6 months, and 1 year while only the 6 month time period was used in the freezer. Some seedlots were placed in storage with cleaned and uncleaned seeds to examine the mechanical effect on seed longevity. The water activity meter was used to measure the equilibrium relative humidity before the seeds were placed in storage.

Nursery propagation: Seeds from 4 grass species (*Aristida condensata*, *Saccharum alopecuroides*, *Schizachyrium scoparium*, and *Sorghastrum nutans*), were hand planted in August 21-30, 2006 in hard plastic propagation trays at the American Tree Seedling Nursery in Bainbridge, Georgia. Germination for all species was checked on October 4, 2006. In 2008, seeds from 3 grass species (*Aristida condensata*, *Schizachyrium scoparium*, and *Sorghastrum nutans*) were sowed in trays in Jeff Glitzenstein's backyard until germination began and then were transported to American Tree Seedling Nursery to grow until outplanting. Nursery and laboratory germination for the winter 2005-2007 collections are listed in table 1. No grass species were planted in 2007. At this time there is no survival data on the outplanting of the nursery stock.

Results and Discussion:

Conditioning*: Schizachyrium scoparium* and *Saccharum alopecuroides* spikelets from the discharge end of the brush machine did not need further processing, so the spikelets from each opening were processed separately. In 2008, *Sorghastrum secundum* spikelets from the discharge end had 35% greater germination than spikelets that fell out the bottom of the brush machine. In contrast, *Sorghastrum elliottii* and *Sorghastrum nutans* seeds from the discharge end and bottom of the machine have similar germination, so they were combined. A cleaned, 2006 *Schizachyrium scoparium* seedlot had 38% better germination at 20°C; there was no difference in germination between 2007 cleaned and uncleaned seedlots, but not all the information is complete at this date.

The brush machine was used to remove awns from a 2008 *Aristida condensata* seedlot using a combination of mantles and brushes (Table 1). Florets were easily broken even with hand extraction, but the embryo was still intact and still germinated. Uncleaned floret germination was 62% and the cleaned floret germination ranged from 54% to 73%, averaging 64%. Florets from the best treatment (G) germinated 73% which was the coarsest mantle (number 10 square wire) and soft brushes. Florets from the harshest treatments (A,C,D, and H) - number 16 square wire mantle and medium stiff brushes plus the hand extracted treatment- began germinating at 14 days; while the softer treatments (E, F, and G) - soft wire mantle (number 40 wire) with medium brushes and the coarsest mantle with soft brushes - took 21 days before the radicle emerged. Most of the germination occurred after 28 days at 20°C. Radicle emergence from the 2005 *Aristida* seedlots occurred at the same time at alternating temperature (20/30°C) as it did at a constant 20°C.

Seed collections: In general, the seed quality and viability varied greatly between 2005, 2006, and 2007. A great deal of insect predation was present in the 2005 collection resulting in poor quality seeds. A severe summer drought in 2006 affected the production and quality of native plant seeds in the collection areas. Seed collections in 2007 were much improved as more became known concerning native habitats and seed maturation. *Sporobolus junceus* 2005 collection had almost no germination compared with 70% germination in 2007. Only 1 out of 4 *Sorghastrum nutans* collections in 2007 had good germination. *Schizachyrium scoparium* spikelets were fairly consistent over the 3 years in germination.

Germination response to conditioning: Higher germination was obtained for all seedlots when the caryopsis was separated from the spikelet in the *Saccharum alopecuroides*, *Schizachyrium scoparium*, and *Sorghastrum nutans* and *S. secundum* 2005 collections (Table 1). *Saccharum alopecuroides* spikelets had 15% germination compared with 53% germination for the caryopsis in a 2005 collection, but *Saccharum brevibarbe* had only 1% germination even though the seeds stained 42% viable with tetrazolium chloride testing. Uncleaned *Sorghastrum elliottii* spikelets in 2006 had higher germination than those of cleaned 2007 collections. Deawned, broken *Aristida condensata* florets germinated about the same awned florets.

Cleaning a *Sorghastrum secundum* 2007 seedlot increased the germination 7 to 42% over uncleaned inflorescences at 20°C. Spikelets that fell out the discharge end of the brush machine had 35% better germination than the spikelets that fell through the mantle. When a Stultz blower was added to the conditioning process, the spikelets, from the discharge end of the brush machine and from the bottom of the blower, had 36% better germination than the spikelets that blew up the column; the difference was only 9% better germination for spikelets that fell through the brush machine mantle and remained in the bottom of the blower from those that blew up the column.

Germination response to temperature: In general, grasses in this study preferred a warmer temperature for germination than the forbs species. Speed of germination was increased with increasing temperature and varied greatly at 15°C from 14 to 56 days depending on the species. Radicle emergence usually occurred within the first week of germination at 20/30°C and between the first and second week at 20°C. All species had lower germination at a constant 15°C.

Cumulative germination was relatively the same at 20°C and 20/30°C for some species, except for a 2007 *Schizachyrium scoparium* seedlot that had similar germination at 15°C and 20°C, but at 20/30°C had higher germiantion by 4 to 15 % with stratified, cleaned spikelets. S*porobolus junceus* florets responded similarly to 20°C and 20/30°C, but had a 18 to 22% lower response at 15°C. The pericarp of the floret is a loose sac that swells up and gelatinizes when wet, hindering the ability to see radicle emergence (Clark and Pohl, 1996).

Sorghastrum elliottii collections from 2006 had higher germination at 20°C than the 2007 seedlots But from within the 2007 collection year, unclean, spikelets' germination increased at 20/30°C by 3 to 35%, and for cleaned spikelets by 14 to 21% over germination at 20°C.

Germination response to stratification: Stratification for 28 days decreased the time of radicle emergence and increased the cumulative germination when compared with unstratified seed for some species. Radicles appeared within the first 7 days of germination, especially at the higher temperature. *Sporobolus junceus* radicles emerged at 20/30°C for stratified seeds the first week, second week for 20°C, and third week for 15C. A 2006 *Schizachyrium scoparium* seedlot had 18% better germination with stratification and the cleaned, stratified spikelets had 38% higher germination at 20°C. A 2007 *Sorghastrum elliottii* seedlot responded dramatically to 28 day stratification with a germination increase of 36% at 20°C and 43% at 20/30°C over unstratified spikelets, but at 15°C there was no increase in germination and radicle emergence was delayed at least 3 weeks and 8 weeks for stratified and unstratified spikelets.

Stratified grass seeds did not germinate in the cooler at 38° C in the dark for a month and up to 3 months with forb species, but when transferred to a warmer temperature and light, they germinated quickly. Coffey and Kirkman (2006) did not report any germination of their native grass seeds when they dug up the buried seeds in the ground after 1 and 2 years, and then planted the seeds them in the greenhouse. These herbaceous species are exhibiting nondeep physiological dormancy as described by Baskin and Baskin (2001).

Propagation in the nursery:
Seeds from the 2005 collections were hand planted in August 21-20, 2006 in hard plastic propagation trays (45 cells) at the American Tree Seedling Nursery in Bainbridge, Georgia and germination was checked on October 4, 2006. Ambient temperature in August of 2006 was too high to achieve maximum germination of most species' seeds. *Saccharum alopecuroides* and *Schizachyrium scoparium* 2005 collections had only 6 and 5% germination in the nursery even though the caryopsis germinated 53 and 54% in the laboratory (Table 1). Seeds from the 2007 collections of *Aristida condensata*, *Schizachyrium scoparium*, and *Sorghastrum nutans* were sowed into 45 cell plastic propagation trays in late spring and summer at Jeff Glitzenstein and Donna Streng's house and then transported to the American Tree Seedling Nursery. Seedling counts were made on July 22-23, 2008 and over 50% of the cells were filled for all three species. *Sorghastrum nutans* seedlot had higher germination in the nursery than the laboratory. Presently, no nursery data is available for the 2006 collections.

More is becoming known about nursery propagation of these species in containers: sowing dates, nutrient regime, growing habit, and preparation for out-planting. More experiments need to be conducted in the nursery to answer these questions. Nursery propagated plugs survive well in the field over the short term (Glitzenstein et al. 2001), but long-term survival and demography information is not available for most species.

Conclusion: The inflorescences and awns of the native grasses in this study were easily separated and appendages removed with the Westrup brush machine. Seed conditioning resulted in higher germination for *Schizachyrium scoparium*, and *S. secundum*. Broken florets of *Aristida condensata* germinated as well as awned florets. All the species' seeds preferred a warmer germination temperature greater than 15°C, with *Schizachyrium* and *Sorghastrum elliottii* preferring alternating temperature 20/30°C over a constant 20°C. Stratification reduced the time of radicle emergence and increased the cumulative germination. Grass seeds exhibited nondeep physiological dormancy. In general, germination was greater in the laboratory than the nursery.

All data collection is not yet complete, so this is only a preliminary report. But it does answer some important questions concerning cleaning seed, germination temperature, and pretreatment of seeds of some ground layer plants.

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Table 1. Germination data for the winter 2005-2007 seed collections.

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Table 1. Germination data for the winter 2005-2007 seed collections.

Species	**Nursery Germ %**	**Lab germ %**	**Comments**	**Comments**	**Seed/lb before cleaning**	**Seed/lb after cleaning**
Aristida condensata GA	12	20	355 dormant after test	2005 seed 20/30°		
Aristida condensata GA	72	62	No cleaning	2007 seed	667,059	
Aristida condensata GA		54	A :16 square mantle, med brush, speed 8, 6x21 screen, aspirate @ 0.02, bottom GB, > sieve no. 35	2007 seed		
Aristida condensata GA		37	C: Trash, 16 mantle, med brush, speed 8, 6x21 screen,	2007 seed		

Species	Nursery Germ %	Lab germ %	Comments	Comments	Seed/lb before cleaning	Seed/lb after cleaning
			aspirate @ 0.02, upper GB , < sieve no. 35			
Aristida condensata GA		64	D: 16 light square mantle, speed 3, med. Brush	2007 seed		
Aristida condensata GA		65	E: cut stem with scissors, 40 mantle, speed 1, med. Brush	2007 seed		
Aristida condensata GA		65	F: hand broken stems, 40 mantle, speed 1, med brush	2007 seed		
Aristida condensata GA		73	G: 10 mantle, soft brush, speed 1	2007 seed		
Aristida condensata GA		60	H: hand extracted on 6x21 screen	2007 seed		
Aristida lanosa SC		8	Unstrat	Echaw Rd. , South Carolina		
Aristida lanosa SC		71	Strat	Frances Marion NF SC		
Aristida purpurascens GA		4 2	32% dormant no dormant	20/30° 2005 seed		
Aristida stricta SC		38, 24	12/19/05 12/25/05	Collection dates	767,512 835,359	
Panicum anceps SC		0	Paired	Hand cleaned		
Saccharum alopecuroides AL	6	53 16	Caryopsis Whole seed	20/30° 42% TZ 2005 seed	180,501 caryopsis	247,463 whole
Saccharum brevibarbe GA		0 1 1	No prechill 20°C strat 20/30° strat	2007 seed 3 month storage	228,571	
Schizachyrium scoparium SC		3;21 59	Paired Strat	No clean Cleaned		
Schizachyrium scoparium GA	5	54 49	Caryopsis Whole seed	20/30° 2005 seed		

Schizachyrium scoparium GA		14	28 day strat	2007 seed	437,626	
Schizachyrium scoparium GA	53	56 56 71 67	20°C unstrat 20°C 20/30° 15°C	Unclean Paired-clean 28 day strat 28 day strat	474,229	
Schizachyrium scoparium GA		11 6.5	20°C;2007 20°C ;2006	28 day strat unstrat	483,582	
Sorghastrum elliottii GA		20	20°C unstrat	Clean		194,095
Sorghastrum elliottii AL		3; 39 17; 60 2; 3	20°C 20/30° 15°C	Cleaned: paired paired paired		215,589
Sorghastrum elliottii SC		89 75 80	unstrat unstrat unstrat	No clean Bottom brush Chute end		
Sorghastrum nutans GA	56	1;29 5;17 2;5	20°C 20/30° 15°C	paired paired paired	357,729	
Sorghastrum nutans AL		17; 3	caryopsis whole seed	20/30° 2005 seed	472,008 caryopsis	274,410 whole
Sorghastrum nutans AL		3; 1	caryopsis whole seed	20/30° 2005 seed	521,379 caryopsis	318,539 whole
Sorghastrum nutans AL	24	12 35	caryopsis strat	11% after cleaning	424,925 caryopsis	305,572 caryopsis
Sorghastrum secundum GA		18 2	caryopsis whole seed	20/30° 2005 seed	905,389 caryopsis	343,896 whole
Sorghastrum secundum GA		4; 11; 46	20°C unstrat 20°C unstrat 20°C unstrat	No clean Bottom brush Chute end	358,294 293,687	
Sporobolus junceus GA		0;1	20/30° 14 day strat	Paired; 2005 seed		
Sporobolus junceus GA		75;69 67;65 49;43	20°C 20/30° 15°C	Paired Paired Paired		783,758
Tridens flavus SC		41	20°C	14 days strat		

Native warm-season grasses and early successional wildlife habitat: Past lessons and a new vision

Craig A. Harper[2], Christopher E. Moorman[3], and Patrick D. Keyser[4]

Introduction - A historical perspective Land-use patterns have changed dramatically across the South in the past 50 years (Heard et al. 2000). The biggest change is human encroachment into rural areas (Southern Forest Resource Assessment 2002). Thousands of acres of potential wildlife habitat are lost each year to a growing suburbia. Moreover, land that isn't lost to urban development has changed greatly. The small family farms of yesteryear have disappeared along with small row-crop fields that were fallow during much of the year, weedy field borders and fencerows, and brushy creek banks. Today, remnant farmland is stressed to produce high yields on larger fields that are double- or triple-cropped annually and cleaned with herbicides, leaving no fallow growth for wildlife habitat. Many fields that were in row-crop production through the 1960's were planted to pasture or hay through the following decades, often just to keep the fields from "growing up," rather than for financial gain. Virtually *all* of these pastures and hayfields were planted to non-native perennial grasses, such as tall fescue and bermudagrass (*Cynodon dactylon*), which provide little wildlife benefit and displace potential quality early successional cover (Barnes et al. 1995). Many of these fields are not even used for haying or grazing, but simply mowed (that is, "bushhogged") one or more times through the growing season, often as a source of recreation by the landowner who enjoys working outside.

Through this period, many wildlife species dependent upon and/or associated with early successional plant cover experienced significant population declines (Peterjohn and Sauer 1999). These declines have been well documented for many species of birds, including northern bobwhite (*Colinus virginianus*), loggerhead shrike (*Lanius excubitor*), Henslow's sparrow (*Ammodramus henslowii*), field sparrow (*Spizella pusilla*), grasshopper sparrow (*Ammodramus savannarum*), and eastern meadowlark (*Sturnella magna*), and similar trends have been documented for eastern cottontail (*Sylvilagus floridanus*). Although there are few factors associated with these declines, the overriding cause is habitat loss and/or conversion to unsuitable cover (Dimmick et al. 2002). The loss of and conversion of desirable to undesirable plant cover types and the associated population decline for many early successional wildlife species occurred so slowly that it was not perceived by most landowners and wildlife managers until fairly recently.

Initially, many factors were blamed for population declines. For example, predation, disease, and inadequate food supply all were suspected and investigated to some degree as the cause for northern bobwhite declines. More recently, however, rigorous habitat investigations and population modeling have identified broad deficiencies in habitat quality on a landscape scale for most species strongly associated with early successional cover types (Burger 2002). Managers now realize the importance

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of habitat connectivity and landscape-scale conservation, and that many early successional species cannot be managed on a field-by-field basis (Guthery 1997). Nonetheless, habitat improvement begins at the individual field level and there is a strong push from the conservation community for landowners to improve habitat for wildlife dependent upon early successional cover. This effort includes a wide variety of programs that provide cost-share assistance and sign-up incentives designed to persuade landowners to change many current land-use habits (Heard et al. 2000)

Problems Associated With Past Habitat Improvement Efforts: Habitat improvement efforts have included eradication of non-native perennial grasses and establishment of native grasses, usually native warm-season grasses (nwsg). Switchgrass, big and little bluestem, and indiangrass have been the primary species recommended by state wildlife agencies, the Natural Resources Conservation Service (NRCS), and non-profit organizations. As private lands management initiatives have been developed, 5 main problems associated with these habitat improvement recommendations have become evident.

Lack of non-native grass control: Non-native perennial grasses, such as tall fescue and bermudagrass, lack desirable cover and provide poor structure for many birds and other small wildlife (Barnes et al. 1995, Bond et al. 2005). Thick growth at ground level makes travel through fields dominated by these non-native species difficult. Seed availability also is reduced by the sod and thatch produced. Forb coverage is limited because of the literal "carpet" of grass that blankets the seedbank and limits germination. Before any habitat improvements can be made, it is imperative that these grasses be eradicated.

Many fields have been planted to nwsg without first spraying and effectively killing the existing non-native grass cover with the appropriate herbicide. Burning and disking do not kill these undesirable grasses (Greenfield et al. 2001, Madison et al. 2001). Even if nwsg are established successfully, non-native grasses grow amongst the nwsg within 2 years if they are not eradicated beforehand. Thus, even though nwsg are growing on the site, field conditions for wildlife remain suboptimal. The ubiquitous field of tall fescue with scattered bunches of senescent broomsedge rising above comes to mind. Although desirable nesting cover for bobwhites is present at the base of broomsedge, mobility within the field and food availability is limited at best.

Nwsg planted in fields containing bermudagrass pose an especially unique problem. Although herbicide advancements in the last 10 years have made nwsg establishment much easier, there is no herbicide that will kill bermudagrass growing in association with nwsg. Thus, the planted native grass must be killed to eradicate bermudagrass growing underneath. Many planting efforts have been for naught because bermudagrass was not eradicated before the field was planted. Even more common is the field of bermudagrass that was sprayed once, with apparent success, but patience was not exercised, and as the bermudagrass returned (albeit with less coverage) it was able to spread once again throughout the field over the course of a few years. **Eradicating bermudagrass requires at least 2 years!** Residual seedlings from the seedbank and sprouts from stubborn rootstocks must be treated the year after the initial spraying. Native grasses and forbs should not be planted (for wildlife) until the seedbank has been evaluated. It is foolish to spend time and money planting if the seedbank holds problem plants that will render the effort useless or if desirable plants are present and await release.

Lack of establishment success: Early attempts (1980's through the mid-1990's) at habitat restoration with nwsg was set back severely because of establishment problems. Establishment success has improved dramatically with recent advancements in planting equipment (e.g., no-till drills specifically designed for nwsg seed with long awns) and herbicides (Harper et al. 2004). However, despite these advancements, difficulties establishing native grasses and forbs still occur. Most notably, planting seed too deep and too late in the growing season and competition with undesirable plants lead to many planting failures. As a result, many landowners and managers become discouraged and recommended against planting nwsg because the seed did not germinate quickly (if at all) and the seedlings did not grow quickly during the year of establishment and/or did not compete well with "weeds."

Improper species mixtures and high seeding rates: Prior to development of the appropriate drill attachments, it was difficult to sow the fluffy seed of bluestems and indiangrass. As a result, most managers planted switchgrass. The seed was small and smooth (much like millet) and it was easily top-sown or drilled. There were problems with plant competitors, especially with non-native warm-season grasses (such as crabgrasses and johnsongrass), but the patient manager could usually establish a stand of switchgrass within a couple of years. Thus, for many, establishing nwsg meant sowing a pure stand of switchgrass. Moreover, expectations as to what the field should look like undoubtedly were influenced by past experiences with non-native cool-season grasses. Managers planted thick stands of switchgrass, often using 8 – 10 pounds of pure live seed (PLS) per acre. As a result, wildlife response was mixed. It was recognized that a thick stand of switchgrass was not much different structurally than a thick stand of johnsongrass. Food availability was terribly low in these switchgrass monocultures because of a lack of desirable forb cover. Indeed, a pure stand of switchgrass was about as unnatural as a field of tall fescue.

As cost-share assistance programs began to enroll considerable acreage into nwsg and equipment improvements were made (late 1990's), more bluestems and indiangrass were planted. However, problems associated with field image continued. Mixed stands of nwsg were planted at 6 – 10 pounds PLS per acre, which resulted in a *thick mixed* stand with few forbs present in the field. Landowners began to think this was what "early successional habitat" should look like because that's what the biologists prescribed. Again, wildlife response was mixed, and it was common to see reduced wildlife activity in those fields with dense grass that were not burned or disked (Dykes 2005). Grass density generally became excessively dense 4 – 5 years after planting.

Lack of recognition of desirable early successional cover: Although relatively high seeding rates were commonly recommended, grass density in many fields was *apparently* sparse. Landowners and many managers were accustomed to planting non-native cool-season grasses and food plots where it was common and *expected* to see dense grass seedlings coming up all over the field. A stand of sparse native grass seedlings was viewed as a failure. This, coupled with a plethora of "weeds" (which were as often as not most desirable forbs) germinating from the seedbank, stimulated many landowners and managers to mow, spray, or disk the field! Often, the field was re-planted in non-native cool-season grasses because the native grass planting had "failed."

Recognizing quality early successional cover is terribly difficult for most landowners, even those with a primary interest in wildlife. Maintaining a "clean and even" landscape without "weeds" is firmly engrained with most landowners. Thick stands of grass limit forb coverage, and this reduces habitat quality for most wildlife species that use early successional cover. Forbs and brambles, such as pokeweed (*Phytolacca americana*), ragweed (*Ambrosia artemisiifolia*), blackberries (*Rubus* spp.), native lespedezas (*Lespedeza* spp.), beggar's-lice (*Desmodium* spp.), partridge pea (*Chamaecrista* spp.), and several asters (*Aster* spp.) and goldenrods (*Solidago* spp.), provide structural diversity, more openness at ground level, quality forage, and an important seed source (Gruchy 2007). Forbs also attract high numbers of pollinators and other invertebrates, which are an important food source for many birds. Shrubs represent yet another critical component for a number of wildlife species. Scattered shrubs provide additional cover and diverse structure needed by northern bobwhite and several "scrub-shrub" songbirds. Many shrubs, such as wild plum (*Prunus* spp.), sumac (*Rhus* spp.), elderberry (*Sambucus canadensis*), hawthorn (*Crataegus* spp.), and devil's walkingstick (*Aralia spinosa*), also provide soft mast for birds and mammals and are important components in early successional wildlife habitat.

Lack of management: Although a number of management options exist to maintain early successional cover (Harper 2007, Harper et al. 2007), most fields enrolled into conservation programs were not "set back" or managed until 2004 when mid-management practices were prescribed by the NRCS to invigorate fresh growth and improve the structure and composition of enrolled fields. Unfortunately, a "reluctance to burn" attitude prevented many landowners and some wildlife managers from using fire to manage fields, leaving only mowing, disking, and herbicide applications as viable management options. Unless heavy offset disk harrows were available, it was impossible to disk the thick, tall mixtures that were recommended and planted; thus, most landowners used mowing as a management practice (Dykes 2005). This only made field conditions worse. Mowing was (and still is) most often accomplished during the summer. Landowners commonly reported killing young wildlife (such as fawns and nestlings) and the cover necessary for reproductive success was destroyed during the time of year it was needed most. Mowing also accumulated thatch and other debris, reducing openness at ground level and limiting germination and growth from the seedbank (McCoy et al. 2001, Dykes 2005, Gruchy 2007).

A NEW VISION

Recent research has shown burning and/or disking are necessary to reduce grass density and improve the structure and composition of early successional wildlife habitat (Gruchy and Harper 2006, Gruchy et al. In press). Further, managers have begun to realize 3 – 4 pounds PLS per acre is plenty of grass seed when planting native grasses is necessary. When coverage of native grass does not exceed 60 – 70 percent, plenty of bare ground space is available to allow forbs from the seedbank to germinate. If desirable forbs are not present in the seedbank, they should be planted with the grasses. This is necessary to develop an *early successional community*, replete with a variety of forbs, grasses, and scattered shrubs, which is used by an array of wildlife species. **This composition and structure is absolutely crucial when trying to replicate the quality habitat with which our native wildlife evolved**.

Ideal early successional cover is often created simply by eradicating non-native cover and allowing the seedbank to respond. Indeed, seed from many native grasses and forbs remain viable in the seedbank for more than 100 years, as evident by their germination and growth following clearing and burning mature forest. Recent research has shown dramatic increases in wildlife populations when naturally occurring forbs and grasses are allowed to develop in place of non-native cover (Palmer et al. 2005).

Is there a need to plant? If quality early successional habitat can be created by stimulating the seedbank, is it necessary to plant? We don't think so. However, there are some considerations when direct planting is not used.

An obvious consideration is waiting to see what the seedbank contains. This requires patience and time. Evaluating the seedbank 1 – 2 years after spraying existing non-native cover is difficult for some landowners, especially those who want improved cover "now." Seedbanks vary greatly from site to site, but there are some generalities that hold true. Forested areas at least 60 – 70 years old usually contain extremely rich seedbanks with few if any non-native early successional species. Within 2 years after clearing, a diverse early successional community is usually established without planting. Old pastures, however, are always full of non-native grasses and forbs. Knowledge of selective herbicides and timing of spraying and burning is necessary to remove undesirable plant species and promote desirable species. Fields that have been in agricultural production for many years often have a severely depleted seedbank, especially fields with a history of continued herbicide use. Planting is generally necessary when establishing quality early successional cover on these sites.

The remaining major consideration when promoting quality early successional cover for wildlife is landowner perception. The specific plants often being promoted – "weeds" – are what landowners have fought against for years. Creating the structure desirable for many species of wildlife that depend upon early succession is not aesthetically pleasing to most people; these fields look unkempt. To most onlookers, it reflects laziness of the owner and an unwilling attitude to "tend their property properly." Concern over what others might think is a real issue in persuading people to more appropriately manage for quality early successional plant communities. An aggressive educational campaign from natural resources professionals will be necessary to overcome this stigma and help the public see these fields not as weedy wastelands, but as native plant communities harboring abundant wildlife. As we see it, this is the next step in helping landowners enhance habitat so wildlife species dependent upon native early succession can rebound from precipitous population declines.

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The Use of Native Grasses at the Palmerton Superfund Site

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Introduction More than 2,000 acres of the Kittatinny Ridge (Blue Mountain) near Palmerton, Pennsylvania were deforested and contaminated as a result of zinc smelter operations during the period between 1898 and 1980. From 1918 to 1962 sulfur dioxide emissions from two plants have been estimated at between 1500 and 1630 kg per hr and the resulting acid deposition was largely responsible for the initial deforestation of the Kittatinny. Heavy metal concentrations in the soils in the region are as high as 80,000 ppm Zn, 6400 ppm Pb and 1500 ppm Cd (Jordan 1975). In 1983, the site was added to the National Priorities List under the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA), commonly referred to as the Superfund law. The Palmerton Superfund site included several thousand acres of land on the Kittatinny plus other lands on an adjacent ridge called Stoney Ridge. The area was mostly devoid of vegetation, and, in many places, the A and B soil horizons had eroded from the mountainside.

Removal of the contaminated soil over this extensive area was not feasible (economically or technically) so the U.S. EPA Record of Decision included three goals for the barren sites: 1) revegetate the barren slopes with native vegetation, 2) stop the erosion of metal contaminated soil down slope and into waterways, and 3) sequester the metals in the soil by avoiding plant uptake and mobilization of the metals into the food chain. From 1991-95, the responsible parties and EPA utilized a revegetation method for about 900 acres on the east side of the Lehigh Gap that included bulldozing nearly 60 miles of dirt roads on the mountainside and trucking in millions of tons of sewage sludge and fly ash to create an organic layer (Oyler 1988). Various grasses and tree seedlings were planted in the mixture. Today the acreage thus treated is mostly vegetated, much of it non-native with diminished potential to support wildlife; tree establishment and survival has not been successful.

In 2002, the Wildlife Information Center, now doing business as Lehigh Gap Nature Center (LGNC), purchased 756 acres on the Kittatinny just west of Lehigh Gap, including about 400 acres within the Superfund zone that needed remediation. The LGNC's goals for the site were complementary to EPA's but also included a desire to both retain the current natural contours of the mountain and establish high quality, native vegetation to create valuable wildlife habitat. The Center began researching methods that would mimic ecological processes. Since a variety of warm season grasses (WSGs) were already growing on the periphery of the site, LGNC saw them as a key to the reclamation of the site. Further research led LGNC to the work of the United States Department of Agriculture – Natural Resources Conservation Service (USDA- NRCS) in revegetating abandoned mine sites

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The Plant Materials Program of NRCS initiated a study of sand and gravel mine reclamation in 1975. That work, summarized by Gaffney and Dickerson (1987), compared the performance of native warm-season grasses (WSGs) with introduced cool season grasses (CSGs) and several introduced legumes over a ten-year period. The WSGs consistently outperformed the CSGs and the legumes on sites with low nutrient and water holding capacities. Further testing resulted in a refined listing of plant materials and planting recommendations that were reported in several publications including Dickerson et al. 1997; Dickerson 2001; Dickerson et al. 2002). The NRCS Plant Materials Program also had a long history with coal mine re-vegetation studies. The findings from the NRCS studies demonstrated the success of WSGs in growing on stressed sites in the Northeast and provided information on metal-tolerant species and cultivars, application rates, and seeding methods that would prove valuable in developing protocols for the LGNC.

As demonstrated by NRCS, WSGs have a number of characteristics that make them good candidates for reclamation projects: excellent root and biomass development, water and nutrient use efficiency, bunch-grass growth pattern and lodging resistant stems. These traits combine to promote soil development, erosion resistance, wildlife cover and food, cooler surface temperatures, greatly improved visual aesthetics, and opportunity for successful establishment of native woody species. Bare surfaces at the Palmerton Superfund site can reach temperatures of 62°C in May (Jordan, Isaac), but can be modified by WSGs. Plant structure, being more rigid than with the CSGs, is maintained through winters. Wildlife cover is retained and opportunity for snow trapping (improving spring moisture retention) is created. WSGs also have a positive impact on the wind erosion process.

In order to achieve the goals of both the EPA and the LGNC, we also searched for ecological models for the restoration. Those models were found in glaciation and serpentine soils. Following glaciation, areas were stripped of topsoil and left with exposed and often rocky mineral soil. In the mid-Atlantic region, warm-season grasses colonized those soils in the post-glaciation period. The WSGs were capable of colonizing mineral soils, stabilized the soil and built fertile, organic soil that became the foundation of the forest ecosystems that developed on the Appalachian ridges in this region. Serpentine barrens, found in southeastern Pennsylvania, about 100 km from the Lehigh Gap site, have soils derived from serpentine rocks. These soils have naturally high concentrations of metals. WSGs thrive in these barrens. The grasses apparently uptake relatively small quantities of the metals.

Materials and Methods Lehigh Gap Nature Center personnel developed a revegetation concept that utilizes WSGs to revegetate the contaminated slopes of the refuge. CBS Operations (formerly Viacom, Inc.), the responsible party under the Superfund law, assigned the task of turning this concept into a remedial action plan to its environmental engineering firm, Frank and West Environmental Engineers (F&W). F&W personnel worked with LGNC staff and advisors in a process that resulted in a design to create 56 one-acre test plots on LGNC land in 2003 (Frank 2003). The plan was approved by EPA and implemented in May 2003.

Previous results from the NRCS studies were used to determine the appropriate WSG species and cultivars; eight species were selected for the test plot applications (Table 1). NRCS study results were also used to advise the F&W engineers regarding soil amendments and application rates to be used on the test plots. F&W devised the planting methods. The final product was a negotiated plan that needed to satisfy the demands of the local conservation district, U.S. EPA, PA DEP, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and other agencies involved with oversight of the Palmerton Superfund site. The planting mix included lime, compost, commercial fertilizer, and grass seed. Frank and West developed two application methods. An aero spreader truck blew the planting mixture onto the land adjacent to an abandoned rail bed. Areas more than 30 meters from the rail bed and with a slope less than 25% were planted with a rubber-tracked Caterpillar Challenger tractor and manure spreader combination, which distributed the mix from the rear of the spreader. The test plots included various mixtures, but the primary variable was the compost. Application rates of seed and soil amendments are shown in Tables 1 and 2. The planting season was delayed, beginning in mid-May, but favorable weather with adequate rainfall prevailed and the seeding continued into July in 2003.

More lime per acre was used than indicated in the NRCS mine research. This was the result of EPA's Record of Decision, requiring that the metals be fixed in the soil and not allowed to be dissolved into runoff or groundwater. The metals involved are poorly soluble at neutral pH, but become more soluble as pH lowers. The pH of the soil on the site was an average of 4.5. Four tons/acre of lime was added to increase pH to about 6.5 to fix metals in the soil (Frank 2003). The compost was expected to serve four major purposes. First, it would provide for good seed-"soil" contact, which enhances germination. Second, the compost would serve as a source of nutrients after the nutrition from the commercial fertilizer diminished. Third, it would help retain moisture during the establishment year and enhance seedling survival. Finally, and perhaps most importantly, the compost would serve as a food source for decomposers, which were lacking throughout most of the site because of the high concentrations of metals in the soils.

To meet the erosion and sedimentation control requirement of the Carbon County (PA) Conservation District, applying PA DEP rules, we were required to add CSGs (Table 1) to the planting mixture on the step banks along the rail bed where the mix was applied with the aero spreader truck. Despite NRCS findings that CSGs delay the establishment of WSGs, LGNC was unsuccessful in removing this requirement.

In 2004, a test application on steep slopes using crop duster aircraft to distribute seed and fertilizer proved effective (West 2004b). Lime was added manually to three test strips in the aerial application zone in June 2004 at a rate of 1, 2, and 4 tons/acre. As a result, a plan evolved to revegetate steep slopes using fixed-wing aircraft and a mix of fertilizer, lime, and WSG seeds. Compost was eliminated from the mix because of its excessive weight, adding greatly to the cost of application, and because it would not be easily dispersed from the mechanism that released the seed mix.

Based on analysis of test plot performance over two years and visual examination of the results of the aerially applied seed, a plan was developed for full scale planting. Full-scale re-vegetation of the remaining areas of the Lehigh Gap Refuge and additional areas of private lands in the Palmerton Superfund area commenced in March 2006 and continued through July. Aerial application took place in late March and early April to several hundred acres, including the areas applied in 2004. Land based application commenced as soon as the aerial work was completed. By mid-June, most of the Wildlife Information Center lands were seeded (Frank 2006).

The mix used in 2006 for the aerial application included WSGs, limestone (1 ton/acre) and commercial fertilizer (N 160 lb/ac, P 130 lb/ac, K 290 lb/ac). The land based application used compost (mushroom compost or Lehigh County municipal compost), lime, and fertilizer at the rates shown in Table 2. Sand bluestem was removed from the WSG seed mix because of poor performance, and Canada wild rye (*Elymus canadensis* L.), a cool-season native perennial was added (15 lb PLS/ac) because of its excellent performance in the original plots. At the request of the oversight agencies, three additional native WSGs were added to the mix at 2 lb PLS/ac: deertongue (*Panicum clandestinum,* L.), purple top (*Tridens flavus* (L.) Hitch.), and broomsedge (*Andropogon virginicus* L.) (Frank 2006).

Ongoing monitoring of the site continues. EPA regulations mandate 5-year reviews and updates. In addtion, LGNC in conjunction with CBS consultant Arcadis, has established permanent monitoring plots to measure plant cover and track successional changes. Meanwhile, summer interns at LGNC have been employed to plant seeds in inaccessible areas and small spots where re-vegetation has not yet occurred. They also monitor invasive species emergence and kill any invasive plants with spot treatment of and herbicide, Crossbow (2,4 D and triplyclor) using backpack sprayers.

Results and Discussion Excellent growing conditions prevailed during 2003, allowing planting to continue through mid-July. Coastal panic grass and sand lovegrass were the dominant species seen in the establishment year (as expected), and many plants reached three to four feet in height, flowered, and set seed in 2003 (Kunkle 2003). Canada wild rye was also prominent where planted.

Again in 2004 the weather was wetter than average, leading to excellent growth. By the end of the second growing season, the grasses had already exceeded the proposed performance standard of 70% live grass and rocks greater than two inches, as measured by point counts at randomly selected locations in most test plots (West 2004a). In addition, total cover data showed a strong increase in 2004 compared with 2003 (Table 4). Not only were the grasses increasing in abundance within the plots, but also were spreading, primarily downhill, from the test plots, filling in the buffer zones and rendering the test plot boundaries indiscernible.

An exception to the success in establishing the WSGs was seen in the plots in which CSGs were added. The cool-season grasses established quickly, and the warm-season species were inhibited. It is visibly evident in 2008 that WSG establishment is still lagging far behind in the plots where CSGs were added to the seed mix.

Mushroom compost showed the best results in promoting grass germination, establishment, and growth in the first two years of the plots. Duck and turkey manure proved effective, but are unavailable at reasonable prices in large quantities. Lehigh County leaf compost is readily available in large quantities at a reasonable cost and also performed well. Biosolids and straw mulch performed poorly in the establishment year, but improved in the second growing season. Unmulched plots lagged in seed establishment and total cover. Based on these results and availability, it was decided that mushroom compost would be the preferred compost, with Lehigh County municipal compost used as a back up when full scale planting operations occurred.

Tests regarding metal uptake were performed by BBL, Inc. for CBS Operations. BBL also performed a risk assessment analysis based on the metal uptake data. The uptake studies showed relatively low levels of uptake compared to pioneering tree species, and there was no significant risk found for either wildlife or people from the levels of metals being taken into the grasses.

During the third growing season in 2005, a severe drought ensued. The WSGs in the original test plots performed as expected, having had two good growing seasons to establish deep root systems as reported by West in 2004. While the WSGs did not grow as tall in 2005, they seeded profusely and no mortality was seen. The most notable development in 2005 was the increase in number of the long-term species that were producing seeds, and the decrease in dominance of the bridge species. Eastern gamagrass, indiangrass, switchgrass, and big bluestem all became prominent species in the third year, while the prominence of sand lovegrass and coastal panicgrass decreased as expected. The grassland was becoming more balanced in terms of species composition of WSGs, and Canada wild rye continued to perform well (Kunkle 2005).

In the aerial test application area, the drought took a heavy toll. Much of this area is covered with rocks, with the seedlings sprouting from gaps between the rocks. Areas with less rock had responded well to the aerial seeding. By the end of 2004, many 6-12 inch seedlings were seen throughout the steep-slope area. Spring greening began before the drought hit, showing that the winter kill had been minimal. However, the drought killed as many as 50% of the seedlings in most areas, indicating that the plants had not developed deep enough roots in the establishment year in this stressed environment to survive the drought. Significantly, the strips with the lime tests did not suffer a great deal of seedling death, reinforcing the importance of adding lime to the aerial application (Kunkle 2005) The rate of the lime application did not seem to change the results – all lime test strips showed similar growth that was visibly better in both quantity and quality of the vegetation present.

In 2006, full scale planting occurred on the remaining barren acreage on LGNC property (Frank 2006). Establishment was very successful for all plantings, including the aerially applied zones. By 2008, preliminary tests indicate that all the goals of EPA and LGNC are being met by the growth of the grasses. Plant diversity continues to increase as succession proceeds. The grasses have developed structure, organic material for soil building, and a food source for a host of organisms that is supporting a thriving new ecosystem.

There were concerns that the aerially applied areas would lag in establishment and maturation of the grasses compared to the ground applied areas with compost. Surprisingly, the difference is not readily evident in most of the aerially applied areas, except where there is heavy boulder cover. Animal life is now returning rapidly and organic soil is beginning to form, as we see five years worth of dead grass stems on the ground in various stages of decomposition. Surveys of the re-vegetation areas are planned annually in succession test plots that were established in August 2008.
As the result of the success on LGNC lands, beginning in 2006, EPA and CBS Operations have been systematically planting all other barren areas in the extensive Superfund area. The only untreated property remaining as of August 2008 belongs to the National Park Service (NPS). The once barren landscape surrounding Palmerton, Pennsylvania, is now turning green with warm season grasses leading the reclamation process.

In order to establish baseline ecological data for the refuge, LGNC engaged Natural Lands Trust of Media, PA to conduct an ecological assessment of the Lehigh Gap Wildlife Refuge. The final report of the ecological assessment (Steckel, et al. 2007) outlined an adaptive resource management plan for grassland management and enhancements on the lower slopes of the refuge, including monitoring protocols. We have implemented the major recommendation for monitoring by installing three pairs of permanent test plots in the grassland area. These will be monitored annually. In addition, the breadth of the ecological assessment is being expanded by LGNC and its network of academic research partners. Projects involving monitoring of birds, mammals, insects, aquatic macro-invertebrates, water quality, energy transfer in food chains, and interactions of competing plants in the reclamation area.

The conditions prevailing at the Palmerton Superfund site have changed dramatically since reclamation was begun by Lehigh Gap Nature Center and CBS Operations in 2003. The baseline assessment mapped 25 different communities with 374 plant species of which 264 are native (Steckel 2006). This provides an excellent, local seed source for ecosystem development with increasing diversity, but also presents the challenges of succession to forest and invasion by aggressive alien species. Sixteen of the plants found on the refuge are rare in Pennsylvania, with four on the state's endangered or threatened species list. The unlisted *Minuartia patula* is a known metal hyperaccumulator found in alpine areas and around mine reclamation sites.

Gray birch (*Betula populifolia* Masrsh.) and aspens (*Populus sp.*) appeared in small numbers in 2004. The birch saplings now show severe necrosis of the leaf margins and zinc levels in the leaf tissue accumulates to around 1100 ppm. The necrosis may be due to metal toxicity (oxidative stress) and/or nutrient deficiency. Various poplar species accumulate zinc to levels ranging from 500 to 2200 ppm but show relatively little signs of stress (Husic 2008). Studies are underway to better understand the mechanisms of metal toxicity and tolerance in various plant species and to guide conservation management plans for the future.

Other colonizers included desirable herbaceous plants that increase the diversity of the developing grassland ecosystem, but also invasive species posed a threat to the restoration project (Kunkle 2004). The main invader was butterfly bush (*Buddleja davidii* Franch.), with a lesser number of tree of heaven (*Ailanthus altissima* (Mill.) Swingle) also appearing, apparently from nearby seed sources along the Lehigh River and the abandoned rail beds. Beginning in 2004, an aggressive combination of mechanical removal and herbicide application was initiated. In the long term, succession and invasive species will erode the quality of the grassland habitat without proper management. Our intention is to manage the re-vegetated grassland areas of the refuge as grassland/savanna with the addition of scrub oaks and other oak species to the habitat. The plan also calls for continued enhancement of the habitat with other flowering species and the addition of more nest boxes.

In order to encourage the development of a more diverse grassland ecosystem, 11 species of native, herbaceous flowering plants were added to the original test plot area by hand seeding in 2006. If successful, we will add more of these species and others in coming years. Thus far, we have found butterfly milkweed, common milkweed, partridge pea, false sunflower, and black-eyed susans flowering in the grassland.

The once denuded areas of the Lehigh Gap are now sites of many studies monitoring insect, bird, mammal, lichen, mycorrhizal and microorganism diversity as the habitat restoration project continues. There are many signs that a functioning ecosystem is developing. Macroscopic soil organisms are increasing in abundance, and though no microscopic analysis has been performed, a decomposer system has apparently been developing. The diversity of wildlife on the site is increasing dramatically. Insect populations have developed creating a prey base for Eastern Bluebirds (*Sialia sialis*), Northern Mockingbirds (*Mimus polyglottos*), and a recently discovered pair of Blue Grosbeaks (*Guiraca caerulea*). Tree Swallows (*Tachycineta bicolor*) abound and Eastern Bluebirds are common, using nest boxes installed for these species. American Kestrels (*Falco sparverius*) are nesting in boxes provided by the Wildlife Center, and red foxes (*Vulpes vulpes*) denned on the refuge in 2006. The presence of breeding kestrels and foxes as well as ever-present Red-tailed Hawks (*Buteo jamaicensis*) and Black Rat Snakes (*Elaphe obsoleta*) indicates the building of a stable small mammal (mice, voles, chipmunks) population.

Seed eating birds such as sparrows, doves, and finches, have taken advantage of the grasses as a source of seed and cover. Groundhogs (*Marmota monax*), Wild Turkeys (*Meleagris gallopavo*), white-tailed deer (*Odocoileus virginianus*), timber rattlesnakes (*Crotalus horridus*), and coyotes (*Canis latrans*) have been sighted in the test plots. These animals are an indication of the habitat being created by the grasses and other species established on the refuge.

Conclusions In order to maintain grassland on the site, we recognize the need to control the trajectory of succession and the difficulty of doing so. We expect to use a management strategy that includes controlled burns along with physical removal and spot treatment with herbicides to control the invasives and most woody species to maintain the grasslands. The fire tolerant oaks will also be benefited by fire.

The Superfund law (CERCLA) requires 5-year reviews of the remediation. These reviews include re-evaluation of the effectiveness of the remedy, and will provide valuable information that will inform future management. These reviews will be supplemented by the ecological assessments, food chain studies and biochemical analyses that are ongoing.

The trifold challenge presented by EPA's Record of Decision (ROD) at the barren, lifeless Palmerton Superfund site – re-vegetate with native species, stop soil erosion, and sequester the metals in the soil – had not been met in 20 years of effort since designation of the site in 1983. The Lehigh Gap Nature Center, has implemented a successful strategy using native WSGs (and one native CSG) to meet the ROD. The Center's goals of creating a diverse ecosystem without altering the contours of the mountain were also met. The methods are transferable to other barren or poor-nutrient sites across temperate North America. While the project is ongoing, great progress has been made toward meeting all the goals of EPA and LGNC. That progress is largely due to the remarkable physiology and structure of the main reclamation species for this project – native American warm season grasses.

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Table 1. Grasses and application rates (sci. names have been presented in text except below Canada wild rye)

Grasses	**Application Rates**
Warm Season Grasses (all test plots)	lb PLS/ac
Big Bluestem (*Andropogon gerardii*, Niagara)	6
Sand Bluestem (*Andropogon hallii*, Goldstrike)	2
Little Bluestem (*Schizachyrium scoparium,* Aldous)	4
Switchgrass (*Panicum virgatum*, Shelter and Trailblazer)	6
Sand Lovegrass (*Erogrostis trichodes*, Bend)	4
Indian-grass (*Sorgastrum nutans*, Osage)	4
Coastal Panicgrass (*Panicum amarum*, Atlantic)	4
Eastern Gamagrass (*Tripsacum dactyloides*, Pete)	4
Annual Cool Season Grasses (selected test plots)	
Annual Rye (*Lolium multiflorum* L.)	5
Spring Oats (*Avena sativa* L.)	5
Perennial Cool Season Grasses (selected test plots)	
Canada Wild Rye (*Elymus canadensis*)	5
Hard Fescue (*Festuca sp.*)	5
Sheep Fescue (*Festuca ovina* L.)	5
Hairgrass (*Deschampsia flexuasa* (L.) Trin.)	5

Table 2. Soil amendments used in the revegetation work.

Amendments	Application Rates
Commercial Fertilizer	
Nitrogen	160 lb/ac
Phosphorus	80 lb/ac
Potassium	130 lb/ac
Limestone	4 tons/ac
Organic amendment (one of the following)	
Mushroom compost	10 tons/ac
Lehigh County municipal compost	10 tons/ac
Duck manure	10 tons/ac
Turkey manure	10 tons/ac
Pelletized sewage sludge	10 tons/ac
Straw mulch	1 bale/1000ft^2

Table 3. Total cover analysis data for LGNC test plots in 2003, 2004.

Total Cover Year/Properties	Mushroom Compost	Lehigh Co Compost	Duck Manure	Turkey Manure	Biosolids	Straw Mulch	No Mulch
2003 Live Grass	63%	47%	36%	53%	29%	35%	18%
2003 Live Grass, Rock>2”	74%	59%	49%	79%	43%	49%	44%
2004 Live Grass	81%	64%	65%	78%	64%	64%	39%
2004 Live Grass, Rock>2”	88%	78%	81%	92%	77%	77%	64%

Development of Seeding Technologies of Smooth Cordgrass for Tidal Marsh and Shoreline Restoration

Christopher Miller [1], William Skaradek [2], Melissa Alvarez [3]

Introduction Smooth cordgrass (*Spartina alterniflora*) is a highly rhizomatous, native warm-season wetland grass that grows in the intertidal zone of saline and brackish marshes throughout the Northeast, Mid-Atlantic, Southeast, and Gulf Coasts. It is typically planted as vegetative plugs for shoreline and tidal marsh restoration. However, this can be very costly for large projects at approximately $0.70-$1.00/plug planted on 1 to 1.5 foot centers depending on the wave energy of the site. If reliable seeding techniques could be developed for certain types of sites, establishing smooth cordgrass by direct seeding would be more cost effective by reducing the amount of plugs and labor required to plant. Smooth cordgrass has been successfully seeded on large, level mudflats in the Gulf Coast region where tidal elevations are low. However, in the Mid-Atlantic and Northeast states where tidal fluctuations are moderate to high, little is known about what soil and environmental site conditions are conducive to direct seeding smooth cordgrass for stabilization and restoration of shorelines and marshes.

Method In cooperation with the Army Corps of Engineers- New York District and the National Park Service- Gateway National Recreation Area, NY, the Cape May Plant Materials Center of the USDA-NRCS is working to develop cost effective strategies of establishing Spartina alterniflora as a component of the Army Corps- Jamaica Bay Islands Marsh Restoration Project. A seeding study was initiated on May 22, 2007 with *Spartina alterniflora* seed collected within the Park Service boundaries the previous fall (September 2006).

The seed was cleaned and stored over the winter of 2006-2007 and direct seeded into the dredged sand using a Planter Jr. single row push planter. Four seeded and four non-seeded (control) plots (25 ft. by 40 ft.) were seeded in both low and high energy sites for a total of ¼ acre. To ensure continuous flow of seed from the hopper to the opened furrow, the Spartina seed was mixed with non-clump forming (cheap) cat litter at a ratio of 50:50 by volume. The treatments were (1.) control with no seed applied and (2.) replicated plots seeded at 1.5"- 2"depths in rows parallel to the shoreline. Rows are on 1.5 foot centers. This resulted in 17 parallel rows per seeded treatment. The low energy plots were at the highest elevation of daily inundation with a 70 foot wide vegetated buffer of vegetatively planted smooth cordgrass in front of the seeding. Conversely, the high energy plots were lower in elevation (about mid-tide) and had only a 20 foot wide planted buffer of smooth cordgrass below it.

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Stem counts were taken in September 2007 randomly within the seeded rows to determine germination success. Follow up plot wide stem counts were taken in July 2008.

Results: As of September 19, 2007, four samples of 3 foot lengths of row were randomly sampled in each plot. Table 1 is a summary of stem counts near the end of the first growing season. Some individual plants were 9" tall. As expected, no seedlings were measured in the control (non-seeded) plots. Also, average stem densities within the seeded rows were lower in the high energy plots.

Table 1. Stem Density Counts - September 19, 2007

Treatment	Average # Stems/foot				**Average**
	Rep 1	Rep. 2	Rep. 3	Rep. 4	
Low Energy	6.33	3.25	1.67	1.67	**3.23**
Low Energy (control)	0	0	0	0	**0**
High Energy	0.25	1	4.5	4.75	**2.62**
High Energy (control)	0	0	0	0	**0**

On July 31, 2008 second year measurements were taken in the same plots. However, since individual rows could not be identified due to vegetative spread of the cordgrass, stems were measured across the plots diagonally from corner to corner. Table 2 summarizes the data collected from these plots. Since collection procedures were different in July 2008 than September 2007, you cannot compare the data from year to year. However, you can compare low energy and high energy counts within the same year.

Table 2. Stem Density Counts – July 31, 2008

Treatment	Average # Stems/foot				**Average**
	Rep 1	Rep. 2	Rep. 3	Rep. 4	
Low Energy	1.1	0.90	0.68	0.87	**0.88**
Low Energy (control)	0.30	0.70	0.18	0.07	**0.31**
High Energy	0	0.13	0.01	0.16	**0.07**
High Energy (control)	0	0	0	0.05	**0.01**

Note that a fair amount of plant recruitment occurred in the low energy control plots due to vegetative spread and seed drop from plants adjacent to the seeded plots. This process was greatly reduced in the high energy plots.

Conclusions: Successful seeding of smooth cordgrass is possible if the site is somewhat protected from wave energy, particularly in environments with a large tidal fluctuations. The outer, higher energy fringe will probably need to be planted with vegetative plugs.

The higher the wave energy, the greater the width of the vegetatively planted buffer will be necessary. However, seeding the interior or higher elevation portions of a shoreline could potentially reduce the cost of the planting. Given the amount of plant recruitment that occurred naturally in the protected, low energy site, this will supplement any seed that is drilled. If smooth cordgrass is planted or seeded during the optimal establishment window of April-June, the seeded plants will take about two years to fill in to the same density as the plugs do in one year, planted on 1.5 foot centers. This study was done on dredged sand which was uniform in particle size and consistency. A direct seeding on a different soil substrate may have a different result.

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Getting it Right The First Time – Simple Approaches to Planting Native Warm Season Species in South Carolina.

David N. Findley [1], Don Wardlaw [2], Gene Hardee [1]

Introduction Necessity has driven low-tech approaches to planting native warm season species in South Carolina. The cost of equipment and fuel has made this concept a practical and economical approach to planting small fields or acreages for wildlife habitat, pasture or hayland plantings.

Materials and Methods In many cases, one acre can be planted per hour with a hand planter. The equipment utilized ranges from items found on site, such as a spin spreader, to simpler materials on hand, such as pine saplings or a section of chain link fence to cover the seed. The end results have been more impressive than the modern drills designed to plant natives. Before the planting can be done the proper herbicides must be selected and applied based on existing weed competition and those that will likely appear based on local conditions. The key to this approach is that time is taken to make adjustments to the seeding rate based on Pure Live Seed (PLS). This is the most misunderstood and often overlooked step in planting native species. The next step that must be understood, considering the fluctuating cost of the native seeds, is calibration. The method consist of measuring and flagging one acre plots of a field to be planted, calculating the PLS for each specie in the mix, making necessary adjustments and adding the amount of seed needed to plant that one acre. This procedure should continue according to these steps until the entire field is planted. The spreaders can be calibrated and adjusted by laying plastic on the ground and driving or walking over the area at the same pace or speed to be used when planting. As this is done, broadcast the actual seed or seed mixture and count the number of seed per square foot, referring to the chart below for the common species. Start with the opening of the planter as small as possible to prevent spinning all of your seed out in a few feet, and adjust accordingly until the desired number of seed per square foot is achieved. These guidelines are being offered to those interested in planting native species but lack access to the expensive equipment, and are driven to do their part by being stewards of the land. This may be achieved whether the planter is driving a "Yugo or a Hummer".

Results and Discussion It is best to just walk away after planting to reduce the likelihood of trying to improve the outcome, since most tend to terminate the stand. The rewards will come to those who remain patient. The natives will seem to appear out of nowhere. In my comparisons percent cover was checked after the first and second growing season to determine weed pressure and stand densities.

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Murphy's Law: Establishing Native Warm Season Grasses, Wildflowers and Legumes in North Carolina

[1]Laura M. Fogo and [2]John Isenhour

Within the Piedmont of North Carolina and South Carolina, remnant "Piedmont Prairies" once existed. Rare, associated natural communities and habitat guilds, including Piedmont longleaf pine savanna, Xeric Hardpan Forests, Diabase glades and sills, and Semi-natural grasslands are high priority conservation concern to merit restoration. The restoration and establishment of several acres of native warm season grasses, wildflowers and legumes have been undertaken between 2006 and 2008 within the Uwharrie region and beyond, an area replete with our ancestral Pee Dee Native American culture. The purpose is to restore remnant natural communities, help recover the federally endangered Schweinitz's sunflower (*Helianthus schweinitzii),* and to provide wildlife habitat for resident and migratory grassland birds.

Traditional and non-traditional methods were conducted to restore several sites depending on the goals and objectives of private landowners. Preliminary results suggest Murphy's Law, "If anything can go wrong, it will." However, varying site preparation, and management techniques have been used to avert problems. In addition, preliminary results of the establishment of NC ecotypes are also examined. Partners include the US Fish and Wildlife Service, the North Carolina Wildlife Resources Commission, the Natural Resources Conservation Service, and Pilot View Resource Conservation & Development.

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POSTER PAPERS

Sag Ponds: Rare and Unique Wetlands of Mountain Longleaf Pine Woodlands, Northwest Georgia, USA.

Anita Goetz[1] and Johnny Stowe[2]

Sag ponds are rare and unique freshwater wetlands scattered in parts of the ridge and valley physiographic province of Northwest Georgia. Greear, in his seminal work on these habitats, noted that they contain plants having both coastal plain affinities as well as those representing relics of northern populations, most likely as a result of climate fluctuations during the late Quarternary. Many of these karst wetlands have been destroyed or altered compositionally, structurally, hydrologically, and/or by fire-suppression, leaving the remaining few among the most critically imperiled community types in the world. While the threat to longleaf pine ecosystems regionwide, and to certain isolated, freshwater depressions (limestone sinks, Grady ponds, Carolina Bays, and depression meadows) embedded within longleaf pinelands has been recognized, much less is known about montane longleaf pine woodlands and their associated wetlands. Montane longleaf ecosystems are particularly imperiled and in need of immediate conservation action because of their proximity to major metropolitan areas (Atlanta and Birmingham) that are metastasizing at alarming rates. We highlight recent partnerships to conserve and protect montane longleaf pine woodland and sag pond wetland complexes on two privately owned tracts in Bartow and Floyd counties, Georgia. We call for quick action to assess, inventory, and prioritize for conservation the remaining sag ponds, especially those identified by Greear, and their associated upland habitats.

[1] US Fish and Wildlife Service, Asheville, North Carolina
[2] SC Department of Natural Resources

Grasses of Burks Mountain Ultramafic Woodland, Columbia County, Georgia

Michael Wayne Morris

Introduction. Ultramafic woodlands and barrens are rare community types in the Southeast characterized by soils and rocks typically high in magnesium and low in calcium. The Burks Mountain Complex near the Savannah River and just above the Fall Line in Columbia County, Georgia is a good example of this habitat. At this site, open pine-oak woodlands and xeric grassy barrens are conspicuous in the landscape. A floristic study of the vascular plants of Burks Mountain and environs supported by a grant from the Georgia Native Plant Society was conducted, and the grasses documented are presented here.

Methods. Thirteen collecting trips were made at regular intervals during the growing season from September, 2005 through October, 2006. Those sites visited within the Burks Mountain Complex and found to support extraordinary examples of special concern plants and communities, often including areas with high grass diversity, were repeatedly visited and thoroughly inventoried. In addition, voucher specimens of each taxon encountered were prepared using standard herbarium methods. Care was taken not to decimate the populations of any plant species.

Results and Discussion. Of 481 vascular plant species documented at Burks Mountain, 71 taxa are grasses. The grass family, Poaceae, is the largest family of angiosperms at this site, closely followed by 65 species in Asteraceae, which includes sunflowers, asters, and goldenrods. Naturally occurring grasses are significant components of the flora in every major habitat type at Burks Mountain. Habitats present are the following: xeric grassy barrens and open pine-oak woodlands, upland oak-hickory-pine forest typical of the Piedmont, mesic hardwoods on the lower northern slopes in the area, seepage areas and streambanks, alternating bottomland hardwoods and open marshes along Lloyds Creek, and disturbed habitats, such as roadsides and powerline rights-of-way.

Grassy barrens are open communities closely associated with outcrops of ultramafic, or altered serpentinite, rock. Among the grasses found here are species that are prairie indicators, taxa characteristic of sandhills in the coastal plain, those more commonly found on granite outcrops, and species typical of dry habitats in the Piedmont. Representing these different groups respectively are the following: sideoats grama (*Bouteloua curtipendula*)*,* pineywoods dropseed (*Sporobolus junceus*)*,* Elliott's bentgrass (*Agrostis elliottiana*)*,* and bearded skeletongrass (*Gymnopogon ambiguus*). Other grass species occurring here are big bluestem (*Andropogon gerardii*), threeawns (*Aristida dichotoma, A. oligantha, A. purpurascens*), silky oatgrass (*Danthonia sericea*), hairawn muhly (*Muhlenbergia capillaris*), little bluestem (*Schizachyrium scoparium*), and the Indiangrasses (*Sorghastrum elliottii* and *S. nutans*).

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Forage Production of Native Warm-Season Grass Varieties in Beltsville, MD

R. Jay Ugiansky[1], Lester Vough[2], Elmer Dengler[3]

There are many available species and cultivars of native warm-season grasses that could be used to provide valuable summer forage in rotational grazing systems. To better utilize these grasses, more forage productivity data is needed for specific growing regions. Forage production information will help farmers to optimize production in a sustainable manner that will conserve natural resources and benefit their bottom line. Total yield and seasonal growth curve data will be incorporated into the C-Graz gazing model which is a valuable tool for planning and optimizing rotational grazing systems. The objective of this study was to determine the seasonal and total yield of warm-season grasses when grown in Maryland in a simulated rotational grazing system. Included in this study are a total of 36 varieties of eastern gamagrass (*Tripsacum dactyloides*), switchgrass (*Panicum virgatum*), big bluestem (*Andropogon gerardii*), indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparium*), Florida paspalum (*Paspalum floridanum*), and coastal panicgrass (*Panicum amarum*).

Grasses were planted with a cone-seeder in June, 2005 at the NRCS National Plant Materials Center located at Beltsville, Maryland. Experimental design was a randomized complete block with four replications. Cuttings were made using a Carter flail-type harvester at a height of 8 inches. The plots were not harvested until 2007 to allow grasses to fully establish.

For 2007, the five most productive varieties were 'Carthage' switchgrass, 'Atlantic' coastal panicgrass, 'Kanlow' switchgrass, 'Cave in Rock' switchgrass, and 'Shawnee' switchgrass, listed in order of most productive first. Eastern gamagrass, Florida paspalum, and coastal panicgrass continued growth later than other species, providing the greatest late season yield. Stands have filled in more and yields have been higher in 2008. Of particular note, Florida paspalum, which yielded well in 2007, has yielded exceptionally well in 2008 perhaps due to higher rainfall.

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Woodland Grazing in the Southeastern United States: From Cracker Culture to Present

Bob Franklin, Clemson University Extension Service;
Johnny Stowe, SC Department of Natural Resources

Raising livestock on native grasslands in the Southeastern United States is a practice steeped in traditions running back to the Old World, and though circumstances have changed since the frontier days of free range in the region, the natural and cultural heritage of savanna and woodland grazing remains relevant and the practice is regaining popularity. We discuss the dynamics of this phenomenon from its advent in early settlement days, and throughout the centuries as it rose and fell in popularity, setting the foundation for what we view as its potential role in natural resource and livestock management in contemporary times and the future.

The Coalition of Prescribed Fire Councils: Partnering to Promote Understanding of Prescribed Fire, and Address Management, Policy, and Regulatory Issues

[1]Johnny Stowe, [2]Mark Melvin, and [3]Dale Wade

As North America continues to experience rapid changes in land use and demographics, and to suffer from the resulting loss and degradation of ecosystems and landscapes, prescribed fire managers face increasingly complex challenges that limit or threaten the use of this ancient conservation tool. Across the continent, common prescribed fire issues related to public health and safety, ecological stewardship, liability, public education, air quality regulation and the wildland urban interface (WUI) concern the prescribed fire community. Networking existing state and provincial prescribed fire councils' efforts is proving synergistic in increasing communication, effectiveness of public education, participation in fire policy decisions, and representation in forums dealing with regional, national and international regulatory issues. In November 2006, a diverse group of private, federal and state agency, and non-governmental organization leaders agreed to form an overarching umbrella prescribed fire organization to facilitate formation of new fire councils, to serve as a repository for fire information and expertise, to provide a forum for discussion of current issues, and to speak as a unified voice for member councils. They chose to call this organization the National Coalition of Prescribed Fire Councils, and developed a strategic plan that includes a mission statement, purpose, goals, and plan of action. This Scoping Committee is pleased to announce formation of the inaugural Board of Directors, which comprises 9 members, each with an enviable track record and national reputation. Board members come from across the country and will meet 3-5 November 2008 to take over the reins from the Scoping Committee, peruse draft documents developed by the various interim committees, and tackle the tasks associated with making the Coalition relevant and effective, including incorporation, staffing issues, and funding sources. The Board realizes it has to work quickly if it is to effectively serve the needs of the state fire councils, as the number of states having such councils has grown from five in 2006, to 21 as of 1 October 2008, with some states having multiple councils. These 21 states represent 12 million acres of annual prescribed fire. The National Coalition of Prescribed Fire Councils already serves on regional, national and international platforms and looks forward to expanding its efforts to ensure that the ecological values and other public benefits of prescribed fire are secure for the future.

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Silvicultural Options to Restore Shortleaf Pine (*Pinus echinata*) -Bluestem Grass (*Andropogon gerardii* and *Schizachyrium scoparium*) Communities within the Southern Appalachians

Amanda C. Newman[1], Ronald L. Hendrick, Jr. [1], Katherine J. Elliott[2]

Historically, shortleaf pine (*Pinus echinata*) and big bluestem and little bluestem grasses (*Andropogon gerardii* and *Schizachyrium scoparium*) occurred in mixed pine/oak forest grasslands. These communities support grazing and habitat areas for wildlife and agricultural animals as well as open areas for hunting. These systems are maintained by hot fires, but the reduction in prescribed burning and suppression of anthropogenic and natural fires have promoted succession to fire independent, shade tolerant species. This succession, along with the impact of repeated southern pine beetle attacks, high wildfire potential, and the absence of viable mixed pine/hardwood and grass seed in the seedbed, are all factors affecting the establishment of shortleaf pine bluestem grass communities within the southern Appalachians.

As part of a larger effort to promote the re-establishment of these communities in the region, we evaluated the effects of burning and partial felling with burning on shortleaf pine seedling success and bluestem grass establishment in the Cherokee National Forest, Tennessee. We applied three experimental treatments in degraded shortleaf pine communities: burn only, partial fell with burn, and no burn. Following these treatments, we planted shortleaf pine seedlings and broadcast big bluestem and little bluestem grass seed. We measured soil volumetric water content, initial and final seedling height and basal diameter, and bluestem grass occurrence, cover, number of clumps, and clump heights. The partial fell with burn treatment was the most successful in promoting shortleaf seedling growth and bluestem grass establishment and cover. The hotter fires of this treatment greatly reduced the competitive understory and scarified the soil for seedling and grass establishment. All of the study sites experienced extreme drought conditions, the negative effects of which were most pronounced in the burn and partial fell with burn treatments. Seedling survival was poorest within the partial fell with burn treatment, but this poor survival is most likely attributable to both poor planting and drought conditions.

Currently, minimal research exists on southern Appalachian shortleaf pine-bluestem communities. The results of this research and collaborative studies will be used to assist in the management efforts of returning this system to the southern Appalachians.

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The Restoration of Strip Mine Fields with Native Grasses

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Introduction The Natural Resources Section of the West Virginia Army National Guard (WVARNG) at Camp Dawson is currently restoring old strip mine fields located in a military training area with native grasses. Native grasses are being planted on small areas of 5-15acres to establish a more durable surface for tracked vehicles during training exercises. Soil conditions are poor with little nutrient availability, poor drainage and low pH. After turning the soil, liming, and removing large aggregate we have established viable stands of native grasses that are withstanding military training. Stem counts are slowly increasing each year and soil profiles are improving.

Methods The Natural Resources Section conducts yearly stem counts on all native grass stands that have at least one year of growth. Vegetative surveys are conducted during the fall of the year when seed heads are prevalent. Stem counts are taken using a 1 meter plot area/acre of grass field. All sites are entered into a GPS unit and mapped using ArcGIS software. Stem counts are conducted on the same sites on a yearly basis. Data recorded includes individual stem counts for each of our native grass species including; *Schizachyrium scoparium,* little bluestem 'camper', *Andropogon gerardii,* big bluestem 'niagra', *Sorghastrum nutrans,* indiangrass 'rumsey', *Panicum virgatum,* switchgrass 'Cave Rock', and *Elymus virginicus,* virginia wild rye. Additional undesirable vegetation is recorded as a percentage of ground cover. Management techniques including mowing and prescribed fire (every three years) are documented and assigned to the respective fields within the database. Site conditions, field preparation, soil pH, and lime tonnage/acre are also documented.

Results and Discussion The West Virginia Army Guard has had measurable success establishing native grasses in the poor soil conditions associated with abandoned strip mines. Stem counts of native grasses are increasing on a yearly basis and undesirable vegetation is decreasing due to aggressive competition from the native grasses. Propogation by seed has been best when the existing soil has been turned and all large aggregate has been removed before liming. Fields have been established using herbicide and mechanical removal of undesirable species, but with less significant results. The re-occurrence of the invasive *Polygonum cuspidatun,* (Japanese Knotweed) has decreased continuity in seed propagation. Military training on established fields (3 yrs or older) has proven the durability of native grasses. Sites that have been tracked and trampled heavily will respond with strong growth during the season and into the next year.

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Long-term survivability and performance of native grasses (switchgrass) and cool-season species on a reclaimed Appalachian surface mined land

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Introduction In far southwest Virginia, coal mining has been the dominant economic activity for years. The depleted surface mined lands may be difficult to revegetate because of many factors. When the soils are constructed from rock overburden materials, they lack nitrogen, phosphorus, and organic matter prior to reclamation and vegetation reestablishment. Phosphorus availability, acid forming parent material, and heavy metal concentrations are all used to determine the quality of a soil (Torbert et al., 1989, Daniels and Zipper, 1988, Daniels and Amos, 1981). Soil compaction, which occurs when heavy mining equipment is operated on an area after the surface soils have been placed, can also limit revegetation success. All of these factors are very important on disturbed soils like surface mined land. If vegetation is going to be present and sustained, the growth limiting factors of the soil must be known and treated accordingly. In the early stages of succession, abiotic factors such as time, climate, parent material, and nutrient availability are what allow establishment and growth, while the latter stages are governed by biotic factors and the nutrient cycling provided by vegetation (Waring and Schlesinger, 1985).

The revegetation of surface mined sites can be a difficult and time-consuming process if surface soils are not prepared for revegetation properly. Successful revegetation will improve the soils' chemical and physical properties, reduce runoff, and reestablish a land use value for the landowner. Many surface mined lands have been successfully revegetated to forest lands (Burger and Torbet, 1992). Another option that has proven successful is to revegetate the land using a combination of grasses, forbs, and legumes. Grasses are generally established quickly and tend to have extensive shallow root systems that help to hold the soils in place, preventing any further erosion and reducing runoff. One of the problems with using grasses as a means of revegetating surface mined lands is the high nutrient requirement of grasses. The addition of legumes to the revegetation mix can help provide essential nitrogen for the grasses. The objective of this experiment was to determine individual plant species and species mixes to provide long-term productive and sustainable ground cover on reclaimed mine soils.

Materials and Methods: In the summer of 1990, an experiment using 16 different plant species and mixtures of species was established on partially reclaimed mine soils. The experimental design was a completely randomized block. Each one of the 16 treatments was replicated four times. Prior to the establishment of these plant species, a mixture of 2:1 wood chips and sewage sludge was mixed into the soil to provide initial nutrients. No other fertilizer was applied after the initial fertilization. Surface soils were loosened to a depth of about 1 foot so as to incorporate the biosolids – wood chip mixture, but subsurface materials remained below the loosened materials at the surface. The plots were 3.9 by 3.9 m, separated by alleys planted with tall fescue. The treatments were initially planted in July 1990, but a second planting was necessary in April 1991 due to poor establishment. The plots have been mowed annually to stimulate re-growth. The plant species treatments are listed in Table 1.

Table 1. The original sixteen plant species and species mixtures established in 1990.

Common name	Scientific name		Common name	Scientific name
Tall fescue	*Festuca arundinacea* L.		AULotan Sericea lespedeza	*Lespedeza cuneata* {Dum. Cours.} G. Don)
Orchardgrass	*Dactylis glomerata* L.		Switchgrass	*Panicum virgatum* L.
Ladino clover*	*Trifolium repens L,*		Caucasian bluestem	*Bothriochloa caucasia* (Trin.) C.E. Hubb.
Crown vetch	**Coronilla varia *L.***		Tall fescue/Ladino clover	*Festuca arundinacea/ Trifolium repens*
Birdsfoot trefoil	*Lotus corniculatus* L.		Tall fescue/Alfalfa	*Festuca arundinacea/ Medicago sativa*
Alfalfa	*Medicago sativa L,*		Orchardgrass/Birdsfoot trefoil	*Dactylis glomerata/ Lotus corniculatus*
Reed canarygrass	*Phalaris arundinacea* L.		Switchgrass/AULotan	*Panicum virgatum/ Lespedeza cuneata*
Common Sericea lespedeza	***Lespedeza cuneata* {Dum. Cours.} G. Don)**		Reforestation Mix**	

*Shaded areas not sampled since 2000.
**Reforestation Mix = foxtail millet, perennial ryegrass, red top, Kobe lespedeza, Appalow lespedeza, and birdsfoot trefoil.

Plant samples were collected in the fall of 1996, 1997, 1998, 2002 and 2006. Samples were separated by target species (the species originally planted), grasses (other than target grass species), forbs (broad leaf weeds), and other legume species (other than target legumes) then dried. A bioefficiency indicator was calculated for each of the 16 plant treatments by dividing the dry matter of the target species by the total dry mass of all plant materials from each sampling. Routine soil test laboratory analyses were conducted for pH and Mehlich I (0.05M HCl and 0.0125 H_2SO_4)-extractable P, K, Ca, Mg, Mn, and Zn as determined by the Virginia Cooperative Extension Soil Test Laboratory procedures (Donohue, 1992). Variances in treatment results were analyzed by an ANOVA.

Results and Discussion:

Soil The application of the biosolids provided a uniform research site with soil test values (pH and Mehlich I-extractable P, K, Ca, and Mg) that were adequate for plant growth for the duration of the study (Table 2; Donohue and Heckendorn, 1994). The vegetative treatments did not affect soil test variables in 1996 or 1997, but the soils where the legume treatments predominated were higher in soil test Ca and Mg in 2002 (Table 4). Calcium (Loneragan and Snowball, 1969) and Mg (Eakin, 1972) are accumulated at higher concentrations in the top growth of dicotyledons (esp., legumes) than monocotyledons (i.e., grasses); thus, the higher topsoil concentrations of Ca and Mg may have been due to greater assimilation into and release from above-ground tissue of legumes than other species during the 12 years of vegetative production. There were some differences among treatments in Mehlich I-extractable Zn, Cu, Fe, and B, but no rationale could be offered to explain the patterns among vegetation types.

Table 2. Mean values of soil pH and Mehlich I extractable P, K, Ca, Mg, Mn, Zn and Cu for the treatments sampled in 1990, 1996, 1997, 2002 and 2006.

Year	pH	P	K	Ca	Mg	Mn	Cu	Zn
		----------------------------------mg kg^{-1}----------------------------------						
Before application†	5.6	33	62	615	209	50	ND	3
1990	6.1	>120	89	>1200	>120			
1996	6.4	202	58	1623	292	25	6	52
1997	6.3	218	70	1667	284	26	6	54
1998	No soil samples taken							
2002	5.8	148	71	1823	324	27	6	55
2006	6.2	126	58	1338	254	17	5	35

†Soil test values before application are from adjacent land that was managed in the same manner as the experimental site. ND = not determined.

Target species In 1996, four years after the initial establishment of the forage species, the amounts of alfalfa, ladino clover, and birdsfoot trefoil were significantly lower than sericea lespedeza, reed canarygrass, switchgrass, switchgrass + AULotan and tall fescue + alfalfa (Table 3). Among the mixtures, AULotan sericea lespedeza and switchgrass produced the most biomass compared to any one of the forage species in a mixture or pure stand. Switchgrass grown in pure stand and mixed with AULotan were the dominant species. The addition of AULotan to switchgrass significantly increased the biomass (Table 3). Generally, the treatments containing AULotan sericea lespedeza, common sericea lespedeza, switchgrass, and the mixes containing switchgrass – AULotan, were the dominant vegetation growing in their respective plots. In 1997, which was a drier year, biomass production was much lower than 1996 (Table 4). Among the legume species, common sericea lespedeza was the dominant vegetation while switchgrass was the dominant grass. Unlike the 1996 growing season, no significant difference in biomass production was observed between the pure stand of switchgrass and in mixture with AULotan. In 1998, the production of most of the forage species continued to decline with the exception of crown vetch, orchardgrass, orchardgrass + birdsfoot trefoil, reed canarygrass, pure stand switchgrass and tall fescue (Table 5). Similar to 1996 and 1997, switchgrass remained the dominant vegetation on these partially reclaimed soils (Table 5). In 2001 and 2002, the productivity of all forages continued to decline. Among grasses, switchgrass produced the most biomass followed by reed canarygrass and tall fescue (Table 6). By 2006, only 44% of the original treatments remained where planted. Again, among the species left in the plots, switchgrass and switchgrass + AULotan sericea lespedeza remained dominant.

Table 3. The Target Biomass, Total Biomass and bioefficiency of various forage species grown on partially reclaimed surface-mined soils, 1996.

Treatment	Target Biomass (Kg/ha)	Total Biomass (Kg/ha)	Bioefficiency (target/total)
Alfalfa	896[fg]	4681[de]	.180
AULotan	7133[bc]	8334[bcd]	.827
Birdsfoot trefoil (BT)	19[g]	4315[e]	.004
Caucasian bluestem	3209[cdefg]	6942[bcde]	.816
Sericea lespedeza	7237[bc]	8980[bc]	.81
Crown vetch	2618[defg]	4593[de]	.641
Ladino clover (LC)	139[g]	3854[e]	.034
Orchardgrass	2507[defg]	4435[e]	.553
Orchardgrass + BT	4153[cdefg]	4716[de]	.879
Reed canarygrass	5139[bcde]	5480[cde]	.918
Reforestation mix	1708[efg]	4905[de]	.397
Switchgrass	9042[b]	9292[b]	.972
Swithgrass + AULotan	13175[a]	13196[a]	.998
Tall fescue	4584[cdef]	6964[bcde]	.654
Tall fescue + alfalfa	6137[bcd]	6571[bcde]	.943
Tall fescue + LC	2548[defg]	3263[e]	.741

[1]Values followed by the same letter within column do not differ significantly at the 5% probability level.

Table 4. The Target Biomass, Total Biomass and bioefficiency of various forage species grown on partially reclaimed surface-mined soils, 1997.

Treatment	Target Biomass (Kg/ha)	Total Biomass (Kg/ha)	Bioefficiency (target/total)
Alfalfa	0[e]	2688[de]	0
AULotan	2125[cde]	3213[de]	.620
Birdsfoot trefoil (BT)	0[e]	2340[de]	0
Caucasian bluestem	320[e]	4230[cde]	.055
Sericea lespedeza	4730[b]	7369[abc]	.687
Crown vetch	1299[cde]	5681[bcd]	.308
Ladino clover (LC)	0[e]	2667[de]	0
Orchardgrass	708[de]	2868[de]	.243
Orchardgrass + BT	1208[cde]	2472[de]	.459
Reed canarygrass	792[cde]	1486[e]	.601
Reforestation mix	174[e]	2653[de]	.094
Switchgrass	8160[a]	10480[a]	.827
Swithgrass + AULotan	8660[a]	8660[a]	1.00
Tall fescue	1965[cde]	2361[de]	.825

Table 4. The Target Biomass, Total Biomass and bioefficiency (cont.)

Tall fescue + alfalfa	2917^{bc}	2938^{de}	.983
Tall fescue + LC	2514^{cd}	3354^{de}	.678

[1]Values followed by the same letter within column do not differ significantly at the 5% probability level.

Table 5. The Target Biomass, Total Biomass and bioefficiency of various forage species grown on partially reclaimed surface-mined soils, 1998.

Treatment	Target Biomass (Kg/ha)	Total Biomass (Kg/ha)	Bioefficiency (target/total)
Alfalfa	0^{1de}	1596^{bc}	0
AULotan	2052^{cde}	2480^{bc}	.83
Birdsfoot trefoil (BT)	0^{de}	1860^{bc}	0
Caucasian bluestem	148^{de}	1940^{bc}	.08
Sericea lespedeza	1272^{cde}	1572^{bc}	.81
Crown vetch	2636^{cd}	3728^{b}	.71
Ladino clover (LC)	0^{de}	1188^{bc}	0
Orchardgrass	2040^{bc}	4120^{cde}	.50
Orchardgrass + BT	4360^{cde}	7480^{c}	.58
Reed canarygrass	800^{de}	2632^{bc}	0.30
Reforestation mix	528^{a}	944^{a}	.56
Switchgrass	9424^{a}	9528^{a}	.99
Swithgrass + AULotan	1212^{cde}	2544^{bc}	.48
Tall fescue	2064^{cde}	3140^{bc}	.65
Tall fescue + alfalfa	6120^{cde}	9560^{c}	.64
Tall fescue + LC	4520^{bc}	6800^{b}	.66

[1]Values followed by the same letter within column do not differ significantly at the 5% probability level.

Table 6. The Target Biomass, Total Biomass and bioefficiency of various forage species grown on partially reclaimed surface-mined soils, 2002†.

Treatment	Target Biomass ($Kg\ ha^{-1}$)	Total Biomass ($Kg\ ha^{-1}$)	Bioefficiency ($target\ total^{-1}$)
AULotan	7784bc	8946bc	0.87a
Common sericea lespedeza	4196cde	5723c	0.69a
Crown vetch	3507de	4655c	0.69a
Orchardgrass	811e	5885c	0.26b
Reed canarygrass	4980cd	5318c	0.93a
Switchgrass	16,446a	16,791a	0.98a
Switchgrass + AULotan	11277b	11,905b	0.96a
Tall fescue	4750cd	5412c	0.91a

†Values followed by the same letter within column do not differ significantly at the 5% probability level.

Total biomass In general where the target species were less competitive, total biomass production, which included the target plant species as well as other grasses and forbs, was more than the yield of the target species (Tables 3-7). The diversity and the amount of invasive plant species found in all the treatments depended on the competitive and/or aggressiveness of the target species (Tables 3-7). That is, in most cases, where the target species is the dominant species in the plot, the number and the kind of invasive species were significantly less. This suggests the lack of competitive advantage of invasive plant species over the target species. In general, by 2006, we observed significantly less target species compared with the previous years, suggesting possible further soil nutrient depletion from the plots where the forage species are grown.

Bioefficiency Generally the bioefficiency of the forage species ranged from 0 to 99 percent. Among the various forage species used in this experiment, AULotan, sericea lespedeza, crown vetch, switchgrass, tall fescue and tall fescue + alfalfa resulted in bioefficiency levels ranging from 64% to 100% in 1998. Overall the bioefficiency of most plant species was lower in 1998 compared with 1996 and 1997. This could be due to the fact that plots were not mowed in the fall of 1997 as was done in the previous years to promote tillering (new growth) for the following spring. Although it is not the same, mowing was intended to simulate the effects of grazing. Lack of cutting or grazing management may have created conditions favorable to species that thrive in unmanaged environments. By 2006, the bioefficiency of most target species declined further with the exception of switchgrass and switchgrass + AULotan sericea which was 99 and 100%, respectively.

Table 7. The Target Biomass, Total Biomass and bioefficiency of various forage species grown on partially reclaimed surface-mined soils, 2006†.

Treatment	Target Biomass (Kg ha^{-1})	Total Biomass (Kg ha^{-1})	Bioefficiency (target total^{-1})
AULotan	3270b	5470b	0.59ab
Common sericea lespedeza	3680b	4670b	0.79ab
Crown vetch	130b	2440b	0.06c
Reed canarygrass	1740b	3410b	0.47b
Switchgrass	11,090a	11,100a	0.99a
Switchgrass + AULotan	11,430a	11,430a	1.00a
Tall fescue	810b	1410b	0.61ab

†Values followed by the same letter within column do not differ significantly at the 5% probability level.

Conclusions: The legumes and legume/grass mixtures grew the best the first year of sampling. The mined soil was still very low in nutrients and the added N from the legumes assured successful growth. The treatments that grew poorly in the first year continued to grow poorly the second year. Fifteen years after establishment, the treatments that were still showing the most growth and sustainability were the switchgrass – AULotan mix. The treatments that had over 60% biomass present included switchgrass alone, and two of the legume treatments, common sericea lespedeza and AULotan sericea lespedeza, both growing alone. Among the mixtures, AULotan sericea lespedeza and switchgrass produced a reasonable amount of biomass. In most years, data indicated an increase in biomass when AULotan and switchgrass were grown in a mix sward compared to AULotan and switchgrass grown in pure stand. Generally, switchgrass out yielded the other grasses and legumes by up to 70-80%. Switchgrass is a warm season grass that needs little fertilization. As a warm season grass that is adapted to growing in areas with relatively low moisture availability, it was able to thrive in these relatively shallow and compacted mine soils where moisture availability was restricted by physical factors. This is the one treatment that had very high biomass for all years of sampling. Whether the switchgrass was grown alone or with a legume, it was able to become established and thrive in the reclaimed mine soil. Establishing vegetation on surface mined soils takes time and effort. A pool of nutrients must be present in the soil for vegetation to become established and continue to grow. The establishment and maintenance of forage species on mine-land relies on adequate soil moisture and nutrient status. In addition to the availability of plant nutrients, lack of management such as grazing or cutting can minimize the survival and productivity of forage species. Our results clearly indicated that those species which are effective in maintaining growth under limited soil nutrient conditions are best suited for mined land reclamation on lands that have been compacted by mining equipment if herbaceous biomass production is a reclamation goal. On this site, switchgrass was a highly productive species.

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Switchgrass (*Panicum virgatum*) Research and Outreach Program at the Clemson University Pee Dee Research and Education Center

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Introduction Switchgrass should be well adapted for production as a biomass crop on the sandy Coastal Plain of South Carolina because of its good drought and overall stress tolerance. However, little is known with respect to production practices needed to optimize biomass yield and biomass quality; specific pest problems that may occur, and whether management affects potential environmental benefits related to soil quality, water quality, and wildlife. Therefore, a holistic approach is needed to evaluate both the short- and long-term impacts of producing switchgrass as a biofuel crop in this region of the USA.

Objectives To develop agronomic production systems for switchgrass on the southeastern Coastal Plain that will result in optimum biomass yields and profitability, maximum energy efficiencies, little need for chemical pest control, and greatest environmental benefits.

Methods Switchgrass was planted in the spring of 2007 and 2008 at the Pee Dee Research and Education Center located near Florence, South Carolina. A number of diverse soil types were used for our studies so that site-specific management practices could be developed over time. Management practices being evaluated include harvesting number and timing, spring N fertility rate, insect and nematode control strategies, variety selection, mixed species production, weed control strategies, deep tillage, and seeding rate. Switchgrass is being examined for both ethanol production and combustion purposes. Twenty four scientists are working on this program from several different agencies including Clemson University, USDA-ARS, USDA-NRCS, the Savannah River National Laboratory, and South Carolina State University. Research data collection has been initiated and results will be presented as part of the Conference's Coastal Plain/Sandhills Field Tour on October

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Relative Merits of Switchgrass (*Panicum virgatum*) Monoculture vs. Mixed Native Warm-Season Grasses for Wildlife Habitat and Cellulosic Ethanol Production

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Introduction The production of native grasses, particularly switchgrass (*Panicum virgatum*), as biofuel feedstock has been proposed as a means of creating habitat for grassland birds and other wildlife. Questions remain as to optimal methods of production, such as monoculture versus mixed-species plantings, planting rates and subsequent stand densities, and timing of harvest. The primary objective of this study is to determine the effects of native grassland management practices on wildlife habitats. This research will seek to evaluate structural differences in vegetation from switchgrass monocultures and mixed grass species in the context of habitat suitability for the northern bobwhite quail (*Colinus virginianus*) and other grassland bird species.

Methods Experimental plots were planted during the first week of June, 2007. Research treatments include species composition and planting rate. Species mixes consist of: a pure stand of switchgrass; a mix of native warm-season grasses including switchgrass, little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), and big bluestem (*Andropogon gerardii*); the above grass mixture with the addition of legume species, consisting of Illinois bundleflower (*Desmanthus illinoensis*), partridge pea (*Chamaecrista fasciculata*), roundhead lespedeza (*Lespedeza capitata*), and wild blue lupine (*Lupinus perennis*). Planting rates for grass species were 8 lbs PLS/acre, typical of a biomass or grazing density, and 4 lbs PLS/acre, a typical rate for wildlife habitat and seed production. Legume species were added at a rate of 5 lbs/acre to biomass mixtures and 2.5 lbs/acre to wildlife habitat mixtures. Experimental plots are 7 m wide x 17m long, arranged as a randomized complete block design in the field, and replicated 5 times.

Our evaluation of different regimes of native grass production for biofuel will utilize a habitat suitability index (HSI) model for the northern bobwhite quail. The model synthesizes habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). Model variables include winter food availability, cover habitat, nesting habitat, and resource composition and interspersion. Variables will be measured using a combination of point intercept and graduated rod or cover board techniques.

In addition to habitat suitability, three 1-m^2 sections of each plot will be harvested at maturity, separated by plant species, dried, and weighed to determine plant species shifts over time which may explain possible changes in habitat suitability. These samples will also be used to compare biomass production between treatments and thereby determine relative values as biofuel feedstocks.

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Evaluation of sweetgrass for dune restoration in coastal South Carolina

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The Brooksville PMC is cooperating with Clemson University in a research trial using native coastal grasses to restore dune vegetation after the exotic invasive shrub, beach vitex (*Vitex rotundifolia*), has been removed. The project addresses two issues, dune stabilization and restoration of sweetgrass populations in South Carolina. Gulf hairawn muhlygrass (a.k.a., sweetgrass, *Muhlenbergia filipes*) is native to the coastal areas of the south Atlantic and along the Gulf. In addition to being an important component of the coastal community, sweetgrass is the foundation material for African-coiled basketry in the Southeast, particularly in the Gullah/Geechee community around Mt. Pleasant, South Carolina.

A sweetgrass accession from South Carolina (9060701) and nine different muhlygrasses (*M. capillaris*) or sweetgrasses from Florida (9059224, 9059516, 9059523, 9059524, 9059885, 9060044, 9060048, 9060317, and 9060437) were used. The plants (n=30 plants per accession) were planted in August 2007 on 18-inch centers in three replicated rows at ten sites from Sullivan's Island to Garden City, SC, where the beach vitex had been killed by herbicide application and the dead material removed. Plants were rated as good (at least 50% of the stems green), fair (less than 50% of the stems green), poor (at least one green stem present), dead (no green stems), or absent between 5-21 Dec. 2007. In addition, the presence of an inflorescence was noted for each plant present (alive or dead). All sites except one had good survival and growth; this site was not included in the analysis. A weighted value score (the sum of the condition scores of plants within an accession, based on 3 = good, 2 = fair, 1 = poor, 0 = dead or absent - maximum potential score = 87 based on 29 plants all rating 3) also was calculated for each accession. The South Carolina sweetgrass (9060701), with 76% survival, had the lowest survival of the accessions tested (range 76 to 100% survival). Lower survival of the SC accession was probably due to the divisions of this accession being somewhat younger and smaller than the Florida accessions at the time of planting. Based on the condition ratings, 9059224, from Levy County, FL, was clearly superior with 19 good ratings and only one poor rating. However, when the weighted value scores were considered, the accessions sorted out into two groups; those scoring ≥60 (9059224, 9059516, 9060317, 9060044, and 9060437) and those scoring ≤50 (9059523, 9059524, 9059885, 9060048, and 9060701). About 40 to 50% of the surviving plants per accession flowered; the exception was accession 9059516, where even though all 29 plants survived, only 8 of the plants flowered. Based on the combination of weighted value score and flowering percent, 9060437, an accession from Collier County, FL, was the best accession during establishment year because it had the highest weighted value score (65) and highest flowering percent (59%). In the second tier were 9060044 (score 59 and flowering 46%), 9059224 (score 64 and flowering 46%), and 9060317 (score 62 and flowering 52%), with high value codes and flowering percents. The SC sweetgrass (score 51 and flowering 45%) ranked just below this group, primarily due to lower plant survival.

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Reintroducing Native Plants on Eroded Sites in the Sumter National Forest In South Carolina

Dennis L. Law[1] and J. Swafford[2]

The Sumter National Forest was acquired in the early 1930s under the Weeks Law of 1911 to provide sustained timber and water resources. Most areas were logged, over-farmed, eroded, and nutrient-depleted to the extent that soil productivity was impaired. The practices accelerated surface erosion, gully formation and destroyed most native vegetation. Watershed characteristics were improved by planting loblolly pine trees. Recovery from erosion was slow until the needle cast from pine trees provided ground cover. In intermediate pine stands, needle cast provided ample soil cover and erosion control, but the needles limited the development or understory vegetation and surface soil.

Revegetation with grasses has been a regular part of treating actively eroding and barren lands. Until recently, the less expensive and effective non-native species were commonly used. Commonly used species included sericea lespedeza, tall fescue, bahiagrass, orchardgrass and bermudagrass. Clovers, browntop millet, oats, wheat, and other plants provide variety for wildlife habitat purposes. Some of the grasses used in the past are exotic invasive or persistent species.
Recent and ongoing efforts have turned to native plant species for erosion control and soil building. From limited field trials, the native plants thrived through several years of drought, while some non-native grass suffered some mortality. Recent forest activities are focusing on thinning tree stands to improve forest health and habitat. Opening tree stands to sunlight and to low to moderate intensity prescribed fire encourage the reintroduction of native grasses. Native plants with their greater root densities are desirable for soil improvement based on their resiliency to drought, nutrient-deficient soils and fire. These conditions are common within the piedmont forest.

The US Forest Service has cooperated with USDA-NRCS, South Carolina Native Plant Society, South Carolina Department of Natural Resources and Clemson University to implement seed collection of local ecotypes of native species, testing, and planting fields for future harvest. Species include little bluestem, big bluestem, splitbeard bluestem, bushy bluestem, purpletop, Indiangrass, beggarweed and partridge pea. Initial plantings of some of the native grasses have shown some difficulty with individual species such as big blue stem in regeneration, but generally we have found good results under greenhouse, plug planting and broadcast sowing in selected areas. The Sumter National Forest Native Grass Program is growing with the addition of a Flail-Vac Seed Harvester, Truax No-till Planter, seed cleaning and drying equipment. We have done some limited aerial seeding with more planed in the spring along with other seeding projects on the Enoree District.

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Native Grass Cultivars, Ecotypes, Germplasm, and Their Adaptations for the Eastern United States

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The widespread use of native grasses depends on an inexpensive, reliable supply of seed with dependable growers and known ranges of adaptation. Over the past sixty, years, the USDA, Natural Resources Conservation Service, USDA, Agricultural Research Service, State Agricultural Experiment Stations, and private seed companies have developed cultivars of grasses to restore ecosystems and produce forage and wildlife habitat. Each cultivar has a known production capability in the nursery and seed production field as well as the situation into which it is established. Each cultivar has a known range of adaptation to climate, soil characteristics, hydrology, and stress such as grazing within which it will perform. Knowledge of these adaptations has allowed the effective use of these cultivars beyond the area in which they were originally collected. Since the largest market for the tall prairie grasses is in the Midwest, much of the cultivar development has occurred in the states from Texas to North Dakota. Knowledge of the culitvars' adaptations has allowed their use in the eastern part of the United States until more local origins are developed. Recently, ecotypes and germplasm have been released for use in very localized areas. The poster presents a list of the released cultivars, source-identified material, and germplasm, their intended uses, and range of adaptation.

Switchgrass (<u>Panicum virgatum</u>)					
	Origin		Adaptation		
Cultivar/ Germplasm	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land Resource Areas	**Special Characteristics**
Miami	Florida	10b	10b	U	Local Ecotype
Stuart	Florida	9b	9b	U	Local Ecotype
Wabasso	Florida	9b	9b	U	Local Ecotype
Alamo	Texas	9a	7a – 10b	H,I,J,M,N, O,P.T,U	Lowland Type, Stiff-Stemmed
High Tide	Maryland	7a	7a	T	Lowland Ecotype
Kanlow	S. Oklahoma	7a	5a – 8b	H,J,M,N,O, P,S	Lowland Type, Stiff-Stemmed
Carthage	North Carolina	7a	6a – 8b	N,O,P,S,T	Adapted to Eastern Coastal Plain
Durham	North Carolina	7a	6a – 8b	N,P,T	Adapted to Southeastern Piedmont
Blackwell	N. Oklahoma	6b	5a – 7b	D,G,H,J,L, M,N,O,P,R ,S	Low Fertility and Water Requirement
Shelter	West Virginia	6a	4a – 7a	L,M,N,O,P, R,S,T	Stiff-Stemmed
Southlow Michigan	Michigan	5b	4a – 5b	K,L,M	Local Ecotype
Cave-in-Rock	Illinois	5b	4b – 6b	H,M,N,O,P, S	Forage Quality, Grazing Persistence
Shawnee	Illinois	5b	4b – 6b	H,M,N,O,P, S	Selection from Cave-in-Rock
Central Iowa	Iowa	4b	4b	M	Local Ecotype

Big Bluestem (Andropogon gerardii)					
	Origin		Adaptation		
Cultivar/ Germplasm	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceAreas	**Special Characteristics**
Suther	North Carolina	7b	7b	P	Local Ecotype
Earl	Texas	7a	7a – 10b	H,I,J,N,O,P.T,U	Long Growing Season
Refuge	Arkansas	6b & 7a	6b - 7a	N	Adapted to Ozarks
OH370	MO, AR, IL, OK	6a & 6b	5a – 7b	N	Adapted to Ozarks
OZ-70	MO, AR, IL, OK	6a & 6b	5a – 7b	N	Adapted to Ozarks
Niagara	New York	6a	4a – 7b	L,M,N,O,P,S	Adapted to Humid East
Hampton	Missouri	6a	6a – 6b	N	Adapted to Ozarks
Southlow Michigan	Michigan	5b	4a – 5b	K,L,M	Local Ecotype
Kaw	Kansas	5b	4a – 6b	H,J,M,N,O,P,S	Lowland Type, Stiff-Stemmed
Prairie View	Indiana	5a&5b	5a - 5b	M	Local Ecotype
Roundtree	Iowa	5a	4b – 6a	M,N,P,S,R	Forage and Seed Production
Pawnee	Nebraska	5a	5a – 6b	D,G,H,J,L,M,N,O,P,R,S	Earlier Seed Maturity then Champ
Northern Missouri	Missouri	5a	5a	M	Local Ecotype
Southern Iowa	Iowa	5a	5a	M	Local Ecotype
Central Iowa	Iowa	4b	4b	M	Local Ecotype
Northern Iowa	Iowa	4b	4b	M	Local Ecotype
Champ	Nebraska	4b	4a – 5b	G,H,L,M,N,R,S	Later Seed Maturity then Pawnee

Indiangrass (Sorghastrum nutans)					
	Origin		Adaptation		
Cultivar/ Germplasm	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceAreas	**Special Characteristics**
Americus	Alabama and Georgia	8a	7a – 8b	P,T	Best Cultivar Adapted to Southeast
Lometa	Texas	7b	7a – 10b	H,I,J,M,N,O,P.T,U	Best Forage Production in Texas
Newberry	South Carolina	7b	7b	P	Ecotype Adapted to Southeastern Piedmont
Suther	North Carolina	7b	7b	P	Ecotype Adapted to Southeastern Piedmont
Cheyenne	Oklahoma	6b	5b – 7b	H,M,N,O,P,R,S	Earliest Release
Osage	Oklahoma	6b	4a – 7b	H,M,N,O,P,R,S	Late Maturing
Rumsey	Illinois	6a	4a – 7a	H,M,N,O,P,R,S	Forage Production and Quality
Hampton	Missouri	6a	6a – 6b	N	Ecotype Adapted to Ozarks
Coastal	Connecticut, Rhode Island, Massachusetts	6a	6a – 6b	R	Ecotype Adapted to New England
Southlow Michigan	Michigan	5b	4a – 5b	K,L,M	Local Ecotype
Northern Missouri	Missouri	5a	5a	M	Local Ecotype
Southern Iowa	Iowa	5a	5a	M	Local Ecotype
Central Iowa	Iowa	4b	4b	M	Local Ecotype
Northern Iowa	Iowa	4b	4b	M	Local Ecotype

Little Bluestem (Schizycharium scoparium)					
	Origin		Adaptation		
Cultivar/ Germplasm	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land Resource Areas	**Special Characteristics**
Suther	North Carolina	7b	7b	P	Local Ecotype
Cimarron	Oklahoma/Kansas	6a	4b – 7a	E,G,H,N,O,P,R,S	Most Recent Release
Southlow Michigan	Michigan	5b	4a – 5b	K,L,M,	Local Ecotype
Pastura	New Mexico	5b	4a – 6b	G,H,M,N,O,P,R,S	Excellent Seedling Vigor
Aldous	Kansas	5b	4a – 6b	F,G,H,M,N,O,P,R,S,T	Medium to Late Maturity
Southern Missouri	Missouri	5b	5b	N	Local Ecotype
Prairie View	Indiana	5a & 5b	5a – 5b	M	Local Ecotype
Blaze	Kansas/ Nebraska	5a	4a – 6a	G,H,M,N,R,S	Late Maturing
Camper	Kansas/ Nebraska	5a	4a – 6a	G,H,M,N,R,S	Better Establishment and Forage
Northern Missouri	Missouri	5a	5a	M	Local Ecotype
Southern Iowa	Iowa	5a	5a	M	Local Ecotype
Central Iowa	Iowa	4b	4b	M	Local Ecotype
Northern Iowa	Iowa	4b	4b	M	Local Ecotype

Seacoast Bluestem (Schizachyrium littorale)					
	Origin		Adaptation		
Cultivar	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceAreas	**Special Characteristics**
Dune Crest	New Jersey and Delaware	7a	7a	T	Local Ecotype

Sideoats Grama (Bouteloua curtipendula)					
	Origin		Adaptation		
Cultivar/ Germplam	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land Resource Areas	**Special Characteristics**
Haskell	Texas	7b	7a – 9a	H,I,J,N,O,P	Good Rhizome Production
Niner	New Mexico	7a	4a – 8b	D,G,H,N,O,P	Even Seed Maturity
El Reno	Oklahoma	6b	5a – 7b	D,G,H,J,M,N, O,P	Outstanding Forage
Vaughn	New Mexico	6a	4a – 7a	D,E,G,H,N,O, P	Good Drought Tolerance
Southern Iowa	Iowa	5a	5a	M	Local Ecotype
Central Iowa	Iowa	4b	4b	M	Local Ecotype
Northern Iowa	Iowa	4b	4b	M	Local Ecotype
Butte	Nebraska	4b	4a – 5b	F,G,M,N,R,S	Early Maturing
Trailway	Nebraska	4b	4a – 5b	H,M,N,R,S	Late Maturing

Deertongue (Dichanthelium clandestinum)					
	Origin		Adaptation		
Cultivar	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceArea s	**Special Characteristics**
Tioga	Pennsylvania	5a	4a – 7a	L,M,N,R,S	Tolerates ph of 4.0, And Toxic Al and Mn

Velvet Rosettegrass (Dichanthelium scoparium)					
	Origin		Adaptation		
Cultivar	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceArea s	**Special Characteristics**
Pilgrim	Texas	7b	7b – 8a	P	Local Ecotype

Eastern Gamagrass (Tripsacum dactyloides)					
	Origin		Adaptation		
Cultivar/ Germplasm	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land Resource Areas	**Special Characteristics**
Martin	Florida	9b	9a - 9b	U	Local Ecotype
St. Lucie	Florida	9b	9a - 9b	U	Local Ecotype
Jackson	Texas	9a	8a – 9b	J,N,O,P,T	
Medina	Texas	8b	8a – 9b	J,N,O,P,T	
Hays	Texas	8b	7a – 9b	J,H	Local Ecotype
Iuka	Oklahoma	7a	6a – 8a	H,N,O,P,R,S	
Meadowcrest	Maryland	7a	6a – 8a	P, S	Tetraploid Adapted for Mid-Atlantic
Bumpers	Arkansas	6b	6a – 8a	N	Adapted to Ozarks
Highlander	Tennessee	6b	6a – 8a	N,O,P,R	Adapted to Southeast
Pete	Kansas	6a	5b – 7a	H,M,N,O,P,R,S	First Release
SG4X-1	Synthetic	5b	5a – 7a	N,P,R,S	Tetraploid

Virginia Wildrye (Elymus virginicus)					
	Origin		Adaptation		
Cultivar/ Germplasm	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceAreas	**Special Characteristics**
Kinchafoonee	Texas	8a	7a – 8b	P	Adapted to Southern Piedmont
Northern Missouri	Missouri	5a	5a	M	Local Ecotype
Cuivre River	Missouri	5b	5b	M	Local Ecotype
Omaha	Nebraska	5b	4b – 6b	H,L,M,N,R,S	Shade Tolerant

American Beachgrass (Ammophila breviligulata)					
	Origin		Adaptation		
Cultivar	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceAreas	**Special Characteristics**
Hatteras	North Carolina	8a	7a – 9a	T	Better Adapted To South Atlantic
Cape	Massachusetts	7a	5a – 8b	R,S,T	First Release

Coastal Panicgrass (Panicum amarum var. amarulum)					
	Origin		Adaptation		
Cultivar	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceAreas	**Special Characteristics**
Atlantic	Virginia	7b	5a – 8b	R,S,T	Suitable for Inland and Coastal Use

Bitter Panicgrass (Panicum amarum)					
	Origin		Adaptation		
Cultivar	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceAreas	**Special Characteristics**
Southpa	Florida	10a	8a – 10a	T,U	Better Adapted To S. Atlantic & Gulf
Fourchon	Louisiana	9a	8a – 10a	T	Better Adapted To Western Gulf Coast
Northpa	North Carolina	7a	6a – 8a	T	Better Adapted To Mid-Atlantic Coast

Seaoats (Uniola paniculata)					
	Origin		Adaptation		
Germplasm	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceAreas	**Special Characteristics**
Caminada	Louisiana	9a	9a	T	Local Ecotype

Saltmeadow Cordgrass (Spartina patens)					
	Origin		Adaptation		
Cultivar	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceAreas	**Special Characteristics**
Gulf Coast	Louisiana	9a	8a - 10a	T	Better Adapted To Western Gulf Coast
Sharp	Louisiana	9a	8a - 10a	T,U	Better Adapted To S. Atlantic & Gulf
Flageo	North Carolina	8a	7a - 9a	T	Better Adapted To Mid-Atlantic
Avalon	New Jersey	7a	6a - 8a	R,S,T	First Release

Smooth Cordgrass (Spartina alterniflora)					
	Origin		Adaptation		
Cultivar	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceAreas	**Special Characteristics**
Vermillion	Louisiana	9a	8a - 10a	T,U	Better Adapted To S. Atlantic & Gulf
Bayshore	Maryland	7a	6a – 9b	T	Better Adapted To N. & Mid-Atlantic

Seashore Paspalum (Paspalum vaginatum)					
	Origin		Adaptation		
Cultivar	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceAreas	**Special Characteristics**
Brazoria	Texas	9a	9a	T	Local Ecotype

Maidencane (Panicum hemitomon)					
	Origin		Adaptation		
Cultivar	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceAreas	**Special Characteristics**
Citrus	Florida	9a	8b – 9b	T,U	
Halifax	North Carolina	7b	7b – 8a	P,T	First Cultivar

Giant Cutgrass (Zizaniopsis miliacea)					
	Origin		Adaptation		
Cultivar	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceAreas	**Special Characteristics**
Wetlander	Louisiana	9a	8b – 9b	P,T,U	First Cultivar

Tall Dropseed (Sporobolus compositus)					
	Origin		Adaptation		
Cultivar	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceAreas	**Special Characteristics**
Northern Missouri	Missouri	5a	5a	M	Local Ecotype
Southern Iowa	Iowa	5a	5a	M	Local Ecotype
Central lowa	Iowa	4b	4b	M	Local Ecotype
Northern lowa	Iowa	4b	4b	M	Local Ecotype

Florida Paspalum (Paspalum floridanum)					
	Origin		Adaptation		
Cultivar	**State**	Plant Hardiness Zone	Plant Hardiness Zones	Major Land ResourceAreas	**Special Characteristics**
Harrison	Texas	8a	8a	P	Local Ecotype

Traditional Establishment Recommendations for Native Warm Season Grasses

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Introduction Over the past sixty years, the USDA, Natural Resources Conservation Service, USDA, Agricultural Research Service, and State Agricultural Experiment Stations have developed establishment technology to restore ecosystems and produce forage and wildlife habitat. In the eastern United States, poor technology transfer, low levels of utilization of the technology by producers and agency and university employees, and employee turnover has resulted in a low level of awareness of traditional establishment technology. The simplest of establishment principles such as seed stratification, seeding dates to overcome stratification, seeding dates, the importance of firm seedbeds, the necessity of drilling, PLS calculation, drill calibration, seedbed preparation, and weed control have been developed and must be reinforced. The poster will present these principles.

Summary Recommendations:

Site Preparation:

Introduced Species Stands – Kill the stand with herbicide while the grass is actively growing (previous summer for warm season grasses, previous fall for cool season grasses). Sow seed no-till to avoid exposing dormant seeds to optimum germination conditions.

Row Crops – Practice good weed control the previous growing season to control annual weeds. Sow seed with or without tillage.

Seeding Rate: Sow seed at the standard rates specified in Table 1 or adjust to desired seed densities specified in Table 2. Check spacing with data in Table 3.

Seeding Dates: Sow unstratified seed before the date of last frost in the spring with most species (Table 4). Sow unstratified seed of eastern gamagrass before December 1, stratified seed at normal corn planting time. Sow coastal panicgrass before June 1.

Seeding Method: Drill into firm seedbed preferred. Pack after the drilling.

Weed Control:

Perennial Introduced Grass Species - Glyphosate or paraquat before seeding or during the winter. Plateau any time recommended on the label.

Annual Species – mow tops after flowering and before seed production, apply 2,4-D and/or dicamba to kill all broadleaf plants, apply Plateau to kill grass and broadleaf weeds and allow native forbs to survive.

Fertilization:

Establishment Year - Apply phosphorus and potassium to soil test to produce 100 bushels of corn per acre. Apply nitrogen when a stand is established at 40-50 pounds per acre (mid-year).

Maintenance - Apply phosphorus and potassium to soil test to produce 100 bushels of corn per acre. For forage or biofuel, apply nitrogen at 40-50 pounds per acre (70-80 for eastern gamagrass) as growth begins and 40-50 pounds per acre (70-80 for eastern gamagrass) in the middle of the growing season. For wildlife or erosion control, apply nitrogen at 20-25 pounds per acre as growth begins and 20-25 pounds per acre in the middle of the growing season.

Harvesting:

Grazing – Remove half the height growth when the grass is 8-12 inches tall (leave 4-6 inches of stubble).

Hay – Mow when the grass is 24 inches tall and leave a stubble height of 6 inches.

Wildlife Stand Management: Burn every three years. It is best to burn 1/3 of the area every year on a three-year rotation so there are two other areas with different levels of residue in the stand.

Table 1 - Seeding Rate (Pounds of Pure Live Seed Per Acre)						
Species	**Erosion Control/Forage Production**		**Wildlife Habitat Development(Calibrate to Ratefor 8-Inch Rows)**			**Example 3- Species Mixture**
	Drilled in 8-Inch Rows	**Broadcast**	**Drilled in 16-Inch Rows**	**Drilled in 24-Inch Rows**	**Drilled in 32-Inch Rows**	**Drilled in 8-Inch Rows**
Eastern Gamagrass	8-16(30" Rows)	N/A	N/A	N/A	N/A	
Big Bluestem	8-12	12-18	4-6	3-4	2-3	3-4
Indiangrass	8-12	12-18	4-6	3-4	2-3	3-4
Sideoats Grama	8-12	12-18	4-6	3-4	2-3	
Deertongue	12-16	18-24	6-8	4-5	3-4	
Little Bluestem	8-12	12-18	6-8	4-5	3-4	
Coastal Panicgrass	10-15	15-20	5-8	3-5	2-4	
Switchgrass	6-8	10-12	3-4	2-3	1-2	2-3

Table 2 - Pounds Of Seed Per Acre												
Species	**Seeds Per Pound**	**Seeds Per Square Foot**										
		1	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
Eastern Gamagrass	6,000	7	14	73								
Big Bluestem	165,000			3	5	8	11	13	16	18	21	24
Indiangrass	175,000			2	5	7	10	12	15	17	20	22
Sideoats Grama	191,000			2	5	7	9	11	14	16	18	21
Deertongue	225,000			2	4	6	8	10	12	14	15	17
Little Bluestem	260,000			2	3	5	7	8	10	12	13	15
Coastal Panicgrass	300,000			1	3	4	6	7	9	10	12	13
Switchgrass	390,000			1	2	3	4	6	7	8	9	10

Table 3 - Seeds Per Square Foot							
Row Spacing		**Seed Spacing In Inches (Seed per Foot)**					
Inches	**Feet**	**.25(48)**	**.50(24)**	**.75(16)**	**1.00(12)**	**2.00(6)**	**4.00(3)**
8	0.67	71	35	24	17	9	5
16	1.33	36	18	12	9	5	3
24	2.00	24	12	8	6	3	1.5
30	2.50	19	10	7	5	3	1.5
32	2.67	18	9	6	5	3	1.5
36	3.00	16	8	5	4	2	1
40	3.33	14	7	5	4	2	1
48	4.00	12	6	4	3	1.5	.75

Table 4- Dates of Last Frost of Selected Locations (10% of Frost after Dates)

Date	**City**	**Date**	**City**	**Date**	**City**
February 1	Ft Lauderdale, FL	April 15	New York, NY	May 15	Bar Harbor, ME
February 15	Fort Pierce, FL		Philadelphia, PA		Hartford, CT
March 1	Orlando, FL		Virginia Beach, VA		Syracuse, NY
March 15	Brunswick, GA		Beaufort, NC		Williamsport, PA
	Jacksonville, FL		Columbia, SC		Lexington, VA
	Mobile, AL		Augusta, GA		Middleboro, KY
	Biloxi, MS		Birmingham, AL		Cleveland, OH
April 1	Manteo, NC		Tupelo, MS		Fort Wayne, IN
	Beaufort, SC		Nashville, TN		Rockford, IL
	Savannah, GA		Evansville, IN		Detroit, MI
	Gainesville, FL	May 1	Boston, MA		Madison, WI
	Montgomery, AL		Harrisburg, PA	June 1	Portland, ME
	Jackson, MS		Williamsburg, VA		Hyannis, MA
	Memphis, TN		Raleigh, NC		Nashua, NH
	Cairo, IL		Greenville, SC		Montpelier, VT
			Kingsport, TN		Elmira, NY
			Wheeling, WV		Erie, PA
			Lexington, KY		Buckhannon, WV
			Columbus, OH		Athens, OH
			Indianapolis, IN		Lansing, MI
			East St. Louis, IL		Green bay, WI

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Effects of Stratification Periods on Seed Germination of 'Highlander' Eastern Gamagrass

[1]Janet Grabowski, [2]Joel Douglas, [3]Brian Baldwin

Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] is a native grass that provides is capable of producing a high quality, palatable forage with proper management; however, seed dormancy is a major hindrance to establishing this grass from seed. A major factor cited for this dormancy is mechanical restriction to emergence caused by the hard fruitcase surrounding the caryopsis. The standard recommendation is to stratify eastern gamagrass seed at 5-10°C for 6 to 8 wk prior to planting to soften these tissues; however, responses to stratification have been shown to be quite variable between genotypes. 'Highlander' is a cultivar developed for use as livestock forage and for soil conservation in the southeastern United States. The first objective of this study was to determine the response of Highlander seed to biweekly stratification periods ranging from 0 to 10 wk.

One-hundred seed of the 2001-2003 production year were planted in flats of commercial potting soil and placed in a greenhouse with germination counts performed every 7 d for 35 or 36 d. Germination ranged from 30.5 to 33.6% for the seed lots tested. Germination was highest for the 8-wk stratification period at 41%, but there was no significant difference between the 6-, 8-, and 10-wk treatments ($P < 0.05$). Because seed growers may not be able to market all the seed treated with wet stratification within a given year, the second objective of this study was to determine the effect of long term stratification periods ranging from 0 to 12 mo on germination. Flats were placed in a controlled environment chamber set at 20/30°C for 14 hr/10 hr with light. Germination declined with increasing length of stratification period, but the decrease in germination was not significant ($P < 0.05$), indicating that Highlander seed have a high tolerance to storage under these conditions. Results from this study suggest that Highlander seed be stratified for 6 to 8 wks and stored for no longer than 6 mo under these conditions.

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Comparison of Pure Live Seeding Rates for Establishment of Florida Paspalum

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Florida paspalum (*Paspalum floridanum*) is a native warm season grass that occurs throughout the southeastern United States and is useful to wildlife. Harrison germplasm Florida paspalum was selected and released in 2004 by the USDA-Natural Resources Conservation Service East Texas Plant Materials Center (PMC). The most economical method for establishment of this species is by seed.

This study was conducted to determine an optimum pure live seed (PLS) planting rate for conservation plantings. Five PLS planting rates of 4, 6, 8, 10 and 12 PLS lb/acre were planted in 2-ft x 6-ft plots on an Attoyac fine sandy loam (fine-loamy, siliceous, thermic Typic Paleudalfs) at the PMC in April 2004-2006. Percent cover measurements were taken by line transect method in April 2007 and 2008.

Average percent cover for 2004 and 2005 for each planting rate was 46, 55, 55, 48 and 50% for 4, 6, 8, 10, and 12 PLS planting rate, respectively. There were no significant differences in percent cover between PLS planting rates after three years. Results from this study suggests 8 PLS lb/acre planting rate for Harrison germplasm Florida paspalum would be recommended for conservation plantings in the southeastern United States.

Coastal Native Grass Technology Development

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Introduction: The USDA, Natural Resources Conservation Service and its cooperators have developed native grass technology for restoring coastal dune and marsh communities over the past forty years. This technology includes methods for propagating the grasses in cultivation, processing vegetative plant material and seed, and establishing them on restoration sites in the field. It also includes the development of regional cultivars capable of tolerating environmental extremes and producing dependable quantities of quality seed and vegetative plant material. The establishment techniques and cultivars vary from north to south with different species and cultivars playing different roles in the different regions.

American Beachgrass (*Ammophila breviligulata*)

Function: quick erosion control on frontal dunes with active erosion and sand accumulation, declines when there is no sand deposition

Geographic Range: North and Mid-Atlantic Coast, Great Lakes

Propagation: division of plant

Field Establishment: primarily bareroot planting of divided culms, (2 culms per planting hole), also containerized plants

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivars (date cultivar was released for commercial production) - adaptation:

Cape (1970) – North Atlantic and Great Lakes Coasts
Hatteras (1969) – Mid- Atlantic Coast

Bitter Panicum (*Panicum amarum var. amarum*)

Function: quick erosion control on frontal dunes with active erosion and sand accumulation, persists when there is no sand deposition

Geographic Range: North, Middle, and South Atlantic Coast, Gulf Coast

Propagation: cuttings of stolons (seed stalks), division of plant

Field Establishment: primarily containerized plants, also bareroot planting and stolon planting

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivars (date cultivar was released for commercial production) - adaptation:
Northpa (1992) – Mid-Atlantic Coast
Southpa (1992) – South Atlantic and Eastern Gulf Coast
Fourchon (1998) – Western Gulf Coast

Coastal Panicgrass (*Panicum amarum var. amarulum*)

Function: quick erosion control on frontal dunes with active erosion and sand accumulation, persists when there is no sand deposition

Geographic Range: North, Middle, and South Atlantic Coast

Propagation: primarily seed, also division of plant

Field Establishment: primarily containerized plants, also bareroot planting and seeding

Spacing of Planting: seed at 15 pounds of pure live seed per acre, plants 12-36 inches between plants and rows, typically 18 inches

Cultivar (date cultivar was released for commercial production) - adaptation:
Atlantic (1981) – North, Middle, and South-Atlantic Coast

Seaoats (*Uniola paniculata*)

Function: long term dune stabilization, persists when there is no sand deposition

Geographic Range: Middle and South Atlantic Coast, Gulf Coast

Propagation: primarily seed, also division of plant

Field Establishment: primarily containerized plants, also bareroot planting

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivar (date cultivar was released for commercial production) - adaptation:
Caminada (2001) – Western Gulf Coast

Saltmeadow or Marsh Hay Cordgrass (*Spartina patens*)

Function: long term stabilization of back dunes and salt marshes above high tide line, persists when there is no sand deposition

Geographic Range: North, Middle, and South Atlantic Coast, Gulf Coast

Propagation: division of plant

Field Establishment: primarily containerized plants, also bareroot planting

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivars (date cultivar was released for commercial production) - adaptation:
Avalon (1986) – North Atlantic Coast
Flageo (1990) – Middle and South Atlantic Coast, Gulf Coast
Sharp (1994) – South Atlantic Coast, Gulf Coast
Gulf Coast (2003) – Western Gulf Coast

Seacoast Bluestem *(Schizachyrium littorale*)

Function: long term stabilization of back dunes, persists when there is no sand deposition

Geographic Range: North, Middle, and South Atlantic Coast, Gulf Coast

Propagation: seed or division of plants

Field Establishment: usually planted in a mixture with other adapted plant species to add diversity to the plant community containerized plants and bareroot planting recommended, direct seeding with a grass drill possible on protected sites accessible by equipment, broadcasting of straw with seed attached and discing straw into the soil is also possible

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivars (date cultivar was released for commercial production) - adaptation:
Dune Crest (2007) – Middle Atlantic Coast

Seashore Paspalum (*Paspalum vaginatum*)

Function: long term stabilization of back dunes and salt marshes above high tide line, persists when there is no sand deposition

Geographic Range: North, Middle, and South Atlantic Coast, Gulf Coast

Propagation: division of plant, creeping stolons

Field Establishment: primarily containerized plants, also bareroot planting

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivar (date cultivar was released for commercial production) - adaptation:
Brazoria (1999) – Western Gulf Coast

Smooth Cordgrass (*Spartina alterniflora*)

Function: long term stabilization of salt marshes below high tide line

Geographic Range: North, Middle, and South Atlantic Coast, Gulf Coast

Propagation: primarily seeds, division of plant

Field Establishment: primarily containerized plants, also bareroot planting

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivars (date cultivar was released for commercial production) - adaptation:
Bayshore (1992) – North Atlantic Coast
Vermilion (1989) – Western Gulf Coast

Switchgrass (Panicum virgatum)

Function: long term stabilization of freshwater tidal areas

Geographic Range: North, Middle and South Atlantic Coast, Gulf Coast

Propagation: seed and division of plant

Field Establishment: containerized plants and bareroot planting

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivar (date cultivar was released for commercial production) - adaptation:
High Tide (2007) – Middle Atlantic Coast

Giant Cutgrass (*Zizaniopsis miliacea*)

Function: long term stabilization of freshwater marshes and shorelines with water up to 3 feet deep

Geographic Range: Middle and South Atlantic Coast, Gulf Coast
Propagation: stolons (seed stalks), division of plant

Field Establishment: stolons, containerized plants, bareroot planting

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivar (date cultivar was released for commercial production) - adaptation:
Wetlander (1993) – South Atlantic and Gulf Coast

Maidencane (*Panicum hemitomon*)

Function: long term stabilization of freshwater marshes and shorelines with water up to a foot deep

Geographic Range: Middle and South Atlantic Coast, Gulf Coast

Propagation: rhizomes (underground runners), division of plant

Field Establishment: rhizomes, containerized plants, bareroot planting

Spacing of Planting: rhizomes in continuous trenches one inch deep and one foot apart, plants 12-36 inches between plants and rows, typically 18 inches

Cultivars (date cultivar was released for commercial production) - adaptation:
Halifax (1974) – Middle and South Atlantic Coast
Citrus (1998) – South Atlantic and Gulf Coast

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Native Grass for Coastal Carolina

Mike Owsley, USDA-NRCS Jimmy Carter Plant Materials Center
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The USDA - Natural Resources Conservation Service (NRCS), Jimmy Carter Plant Materials Center (PMC) in Americus, Georgia is involved in several studies evaluating native warm season grasses for forage production and wildlife habitat improvement. Some native warm season grasses such as switchgrass (*Panicum virgatum* L.) can be used for soil stabilization.

Residential and commercial development adjacent to high marsh areas is increasing along the South Carolina coast. Switchgrass has potential to fit a niche as a soil conservation plant along the transition between high marsh and maritime forested areas.

The Jimmy Carter PMC, in cooperation with the NRCS in South Carolina and Mepkin Abbey in Moncks Corner, South Carolina, is in the process of increasing a local South Carolina switchgrass source collected near Penn Center growing in a transition zone between the high marsh and maritime forest. Associated plants growing with the switchgrass are marshhay cordgrass [*Spartina patens* (Ait.) Muhl.], black needlerush (*Juncus roemerianus* Scheele.), marsh elder (*Iva frutescens* L.), sea myrtle (*Baccharis halimifolia* L.), cabbage palm [*Sabal palmetto* (Walt.) Lodd. ex Schult.& Schult.], live oak (*Quercus virginiana* Mill.), and southern red cedar [*Juniperus silicicola* L. var. *silicicola* (Small) J. Silba]. After the switchgrass has been increased vegetatively at the Jimmy Carter PMC and Mepkin Abbey, plans will be made to release the material as Penn Center germplasm switchgrass. Penn Center germplasm will be a source identified release for conservation plantings in the low country of South Carolina.

Penn Center is a Historic Landmark in coastal South Carolina. Penn School was established in 1862 as an experimental program to educate Sea Island slaves freed at the beginning of the Civil War, By 1900 the school was called Penn Normal and provided teacher training and various other vocational training. During the 1960's, Dr. Martin Luther King, Jr. and members of the Southern Christian Leadership Conference utilized Penn Center as a training site and retreat. Penn Center promotes and preserves the history and culture of the Gullah people of the South Carolina low country.

Native Plants for Soil Stabilization, Ecological Integrity, Aesthetics and "Local Character" in Highway and other Rights-of-Way

Johnny Stowe, SC Department of Natural Resources,
Dhaval Vyas, GA Department of Transportation

Abstract: The damage from alien species is well-documented, and the movement toward native plant species is promising. But many groups continue to plant and foster aliens, including invasive species. We examine the reasons for continued use of these noxious species, and suggest paths by which to overcome this trend. One particularly salient issue is the need to immediately stabilize soil during construction projects. This practicality often presents ostensible conflicts between the utilization of invasive species versus the use of native species, with the former too often prevailing because of "time-tested" and customary practices. Efforts must be expanded to publicize the harm from invasive alien plant species in public projects, and to provide practical native plant alternatives that support ecosystem integrity, aesthetics and natural characteristics of the landscape.

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