COMPOSITION AND STRUCTURE OF MANAGED PINE STANDS COMPARED TO REFERENCE LONGLEAF PINE SITES ON MARINE CORPS BASE CAMP LEJEUNE, NORTH CAROLINA

Joan L. Walker, Andrea M. Silletti, Susan Cohen[1]

Abstract—We sampled the ground layer of 28 pine plantations to compare with ecological reference sites at Marine Corps Base, Camp Lejeune (MCBCL), NC. Plantations were ≥ 18 years old and had been burned within the previous year. Pines had been hand-planted on beds or flat-planted, and the plantations were burned every 3 to 4 years after age 7. Data from 39 reference sites were acquired from the Carolina Vegetation Survey database, and included MCBCL sites that had been maintained by regular burning. We used non-metric dimensional scaling to detect patterns in the data. Ordination arrayed plots by canopy structure and soil base saturation on one axis and by diversity measures on a second. Results of a multi-response permutation procedure indicated that the compositional difference between the groups was significant ($p<.0001$). Although species richness in plantations was consistently lower than that in reference sites, the differences were significant ($p<.05$) only at small scales. Results confirmed a reduction in desirable native ground layer species along with increased shrub cover and woody stem density, in spite of regular prescribed burning.

INTRODUCTION

The current Southeastern landscape has hundreds of thousands of hectares in pine plantations on sites once dominated by longleaf pine, and it is clear that plantation establishment and management will continue to be effective systems for increasing pine habitat. While there is considerable information available about the effects of plantation establishment, especially of site preparation methods, on ground layer vegetation, the longer-term effects of plantation establishment on ground layer vegetation are not well-documented. Walker and van Eerden (1996) and Smith and others (2002) reported reduced species richness at small scales in plantations (30 to 40 years old) compared to reference sites in the fall line sandhills. Species richness in xeric site plantations nearly equaled reference sites at a scale of 0.1 ha; however, several key ground cover species were significantly ($p<.05$) reduced. The cover of the dominant bunch grass, *Aristida stricta*, and the dominant dwarf shrub, *Gaylussacia dumosa*, were reduced in xeric longleaf pine plantations in Chesterfield County, SC (Walker and van Eerden 1996). Smith and others (2002) reported a similar pattern in stands sampled across a moisture gradient from xeric to sub-mesic sites at the Savannah River Site, SC; however, there is no information available to examine this hypothesis on mesic to wet-mesic sites. Understanding this relationship is important if we are to develop site-specific restoration protocols.

This study was undertaken to investigate the potential persistent or cumulative effects of pine plantation establishment and growth on ground-layer vegetation in sites that range from well-drained to somewhat poorly drained, and which were historically occupied by longleaf pine communities. We approached the problem by comparing established plantations with reference longleaf pine communities on similar site types. This report includes the preliminary analysis of these data; results of additional analyses will be reported elsewhere.

METHODS

Study Area

Marine Corps Base Camp Lejeune (MCBCL) near Jacksonville, NC, occupies 50 585 ha (125 000 acres) in the Atlantic Coastal Flatlands Section of the Outer Coastal Plains Mixed Forest Province (Bailey 1995, USMC 2001). The Atlantic Ocean forms its eastern border, and the New River inlet is a dominant feature in the center of the base. Camp Lejeune has both well-draining, gently rolling terrain and poorly draining broad, level flatlands. East of the New River, the flatlands range in elevation from 7.6 to 13.7 m; between New River and US Hwy 17, the changes in elevation are more pronounced—as high as 22.0 m, and west of US 17, elevation ranges from 11.9 to 21.0 m.

The natural longleaf vegetation type was wet, mesic, or xeric longleaf or mixed pine savannas (Frost 2001). The typical stands had an open canopy of longleaf or mixed pines (pond pine on wet sites) and a low ground layer that ranged from graminoid dominance with a high diversity of forbs to dwarf shrub dominance with a mixture of graminoids and forbs. The characteristic structure was maintained by a frequent, low-intensity, surface fire regime. The historical fire-return interval is estimated to be one to three years.

Recent management included prescribed burning with a return interval of about three years, although active weapon-firing ranges might burn annually. Through the 1970s and 1980s the natural resources staff managed pine stands to maintain production using even-aged systems typical of the general forest management practices of the time. Currently, pine stands are regenerated primarily to restore longleaf pine for red-cockaded woodpecker habitat, but existing plantations are managed to maintain their vigor and economic value. Most of the stands sampled in this study were artificially regenerated, but the intensity of site preparation varied.

[1]Research Ecologist, Ecologist, USDA Forest Service, Southern Research Station, Clemson, SC; Ecologist, USDA Forest Service, Southern Research Station, Research Triangle Park, NC, respectively.

Citation for proceedings: Stanturf, John A., ed. 2010. Proceedings of the 14th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-121. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 614 p.

Site Selection

Plantations were sampled during the summers of 2003 and 2004. Sites were located on the following soil series: Kureb fine sand, Baymeade fine sand, Leon fine sand, Murville fine sand, Norfolk loamy fine sand, Onslow loamy fine sand, Stallings loamy fine sand, Wando fine sand, and Woodington loamy fine sand. We sampled sites at least 18 years old so that we could capture stands where intensive site preparation methods had been applied; the base began using a bedding plow for site preparation in 1986. By age 18, the canopy had closed and some stands had received a first thinning, usually a row thinning that removed every third row. Vegetation changes rapidly following fire; in order to minimize the effects of this change, we restricted site selection to areas that had been burned within 12 months prior to sampling. We included 28 stands in this analysis.

We acquired ecological reference plot data from the Carolina Vegetation Survey (CVS) plot database archived by the Herbarium at the University of North Carolina, Chapel Hill, NC. Data collection standards are described at http://www.bio.unc.edu/faculty/peet/lab/CVS/ (Site referenced June 1, 2007). From all plot data collected within the boundaries of Camp Lejeune, we selected 39 plots dominated by longleaf pine, or a mixture of longleaf with loblolly or pond pines. All soil series in reference plots were represented among plantations except Foreston loamy fine sand and Alpin fine sand.

Data Collection and Manipulation

Plots were sampled using the CVS protocol described by Peet and others (1998). This protocol is based on a 10 m by 10 m module, with an array of 10 modules representing a complete plot sample (0.1 ha). Within each of up to four intensively sampled modules, species presence was recorded in two sets of nested subplots sized 0.01 to 10 m^2. Within each plot, rooted vascular plant species richness (S) was estimated for six nested areas regularly spaced on a log-10 scale, from 0.01 to 1 000 m^2. Richness values for areas less than 0.1 ha were averaged to estimate richness at the plot level. Species cover was estimated at the module level using cover classes: 10 = 95 to100 percent, 9 = 75 to 95, 8 = 50 to 75, 6 = 10 to 25, 5 = 5 to 10, 4 = 2 to 5, 3 = 1 to 2, 2 = <1 to 1 = trace. For analyses, cover class values were converted to the mid-points of cover classes, averaged for the plot, and re-converted to cover classes for analyses. Mean plot abundance and richness at the plot level were used to calculate the Shannon-Weiner diversity index (H') and Simpson's diversity index (D). In each plot, trees greater than 2.5 cm d.b.h. were tallied by size class and species. We calculated density and basal area for all woody stems combined, for all pines, and for all hardwoods.

Five soil samples were collected from the top 10 cm of each plot, and pooled for analyses. Soils from managed pine stands were analyzed in the Forestry Sciences Lab, RTP, NC. Soils from CVS reference sites were analyzed by Brookside Labs, Knoxville, OH. The following soil variables were evaluated for correlations with ordination axes: cation exchange capacity (CEC), percent base saturation by K^+ (K_{sat}), Mg+2 (Mg_{sat}), and Ca^{+2} (Ca_{sat}); pH; organic matter (OM); extractable K^+, Mg^{+2}, Ca^{+2}; percent sand, silt, and clay.

Vascular plant taxonomic concepts and nomenclature were standardized to follow Kartesz (1999). In order to minimize the effects of possible plant identification inconsistencies among field crews, especially of difficult plant groups (e.g. vegetative *Dichanthelium* spp.), we combined taxa except those we judged to be easily identified correctly by most field botanists, and we did not recognize subspecific taxa.

Data Analysis

We used non-metric multidimensional scaling (NMS) ordination to represent the variation in ground layer communities in plantations and reference sites (Clarke 1993, Minchin 1997). Ordinations were performed with the number of dimensions ranging from 1 through 6, and to avoid local minima 40 different random starting configurations were used. A Monte Carlo test based on 50 randomizations of the vegetation data matrix was used to determine the probability that a similar final stress could have been obtained by chance. We ran the procedure for 400 iterations to get the final solution with real data. We examined the scree plot (line graph of minimum stress versus number of dimensions) to identify the number of dimensions beyond which further reductions in stress were relatively minor (Kruskal 1964).

We tested for community differences between plantations and reference sites using a multi-response permutation procedure (MRPP) (Biondini and others 1985, Mielke and Berry 2001). MRPP is a non-parametric procedure for testing the hypothesis of no difference between two or more groups of entities, in this case between entries in a distance matrix. The chance-corrected within-group agreement, A, describes within-group homogeneity compared to the random expectation. When all items are identical within groups, A = 1; if heterogeneity within groups equals expectation by chance, then A = 0; if there is less agreement within groups than expected by chance, then A<0. A>0.3 is high for ecological data (McCune and Grace 2002). NMS and MRPP were performed using PC-ORD version 4 (McCune and Mefford 1999).

We used analysis of variance procedures to test for a site type (reference versus managed pine) effect on density and basal area of all woody species, of pines, and of hardwoods; on species richness at various spatial scales; and on cover of selected species and species growth form groups (woody and herbaceous species).

RESULTS

The NMS ordination resulted in three dimensions as optimal for representing the variation in the plot data. The proportions of variance in the original distance matrix that were represented by NMS axes 1, 2, and 3 were 0.426, 0.205, and 0.252, respectively. Correlations of environmental and structural data were generally low (Table 1). Because pH was the only explanatory variable associated with Axis 2 with an r^2>0.15, and Axis 2 represented the least variance in data, we show the array of plots on Axes 1 and 3 only (fig. 1). In general, position on Axis 1 was correlated positively with stand age, Mg_{sat}, and Ca_{sat}, and negatively with the basal area of pines and total basal area, and K^+. Axis 3 was related most strongly with measures of plot diversity (S, H', and D).

Table 1—Pearson and Kendall correlations of environmental and stand structural parameters with NMS ordination axes

	Axis 1			Axis 3		
	r	r-square	tau	r	r-square	tau
CEC, μeq	0.327	0.107	-0.19	0.254	0.064	0.188
Ksat, %	0.027	0.001	0.278	-0.146	0.021	-0.128
Mgsat, %	0.585	0.342	0.416	-0.289	0.083	-0.227
Casat, %	0.503	0.253	0.298	-0.253	0.064	-0.263
pH	0.375	0.141	-0.331	0.069	0.005	0.027
OM, %	0.367	0.135	-0.368	0.256	0.065	0.208
K, ppm	0.427	0.183	-0.186	0.079	0.006	0.087
Mg, ppm	0.209	0.044	0.136	0.167	0.028	0.027
Ca, ppm	0.195	0.038	0.16	0.146	0.021	-0.085
Clay, %	0.068	0.005	0.028	-0.072	0.005	0.002
Silt, %	0.201	0.041	-0.059	0.208	0.043	0.093
Sand, %	0.191	0.036	0.059	-0.197	0.039	-0.093
Total tree density, stems/ha	0.179	0.032	-0.275	-0.026	0.001	0.063
Total basal area, m^2/ha	0.425	0.181	-0.405	-0.021	0	0.033
Pine density, stems/ha	-0.26	0.067	-0.193	-0.028	0.001	0.17
Pine basal area, m^2/ha	0.426	0.181	-0.355	0.015	0	0.1
Hardwood density, stems/ha	0.002	0	-0.181	-0.036	0.001	-0.076
Hrdwd basal area, m^2/ha	0.166	0.027	-0.212	-0.22	0.048	-0.152
Richness (S), number of species	0.054	0.003	0.005	0.572	0.327	0.403
Evenness (E)[a]	0.083	0.007	-0.064	0.471	0.222	0.339
Shannon-Weiner index (H')	0.042	0.002	-0.007	0.58	0.337	0.416
Simpson's index (D)	0.052	0.003	-0.017	0.539	0.291	0.432

[a] See McCune and Grace (2002) for definitions of E, H', and D.

MRPP generated a low A (0.06), but the difference was statistically significant at p<0.0001. A low A suggests that the differences within groups were not much greater than that expected by chance alone. This may result from the high variability among the managed pine stands, making it difficult for actual data to differ from randomly generated data in the permutation procedure. The result is consistent with the separation of groups by NMS.

Site type had a significant effect (p<0.0001) on species richness at scales of 0.1 m^2, 1 m^2 and 10 m^2, such that reference sites richness exceeded richness in managed pine stands (fig. 2). At spatial scales of 100 and 1000 m^2, differences between site types were not significant.

Summaries of variables associated with NMS ordinations are shown in Table 2. Compared to reference sites, plantation soils had higher pH, higher extractable potassium, lower Ca saturation, and lower Mg saturation. We found that plantations had significantly higher total and pine basal area than reference stands. Plantations and reference sites were not different with respect to three measures of ground layer vegetation structure (S, H', D) but there was a site type effect on evenness (E).

The total ground cover in reference sites exceeded that in plantations (113 versus 81 percent; table 3). The difference was mostly in the herbaceous component which had almost twice the cover in reference sites compared to plantations (43 vs. 24 percent). *Aristida stricta*, *Gaylussacia dumosa* and *Pinus palustris* were more abundant in reference sites than in plantations by factors of 5, 10 and 6 respectively. *Gaylussacia frondosa*, which is similar to *G. dumosa* in growth form but tends to be more abundant on wetter sites than *G. dumosa*, was not different between the site types.

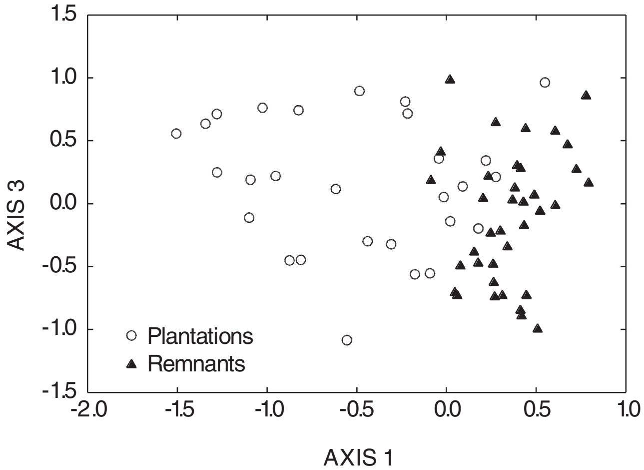

Figure 1—Non-metric multidimensional scaling (NMS) ordination of plantation and reference plots.

DISCUSSION

Overall, plantations ≥18 years old differ compositionally and structurally from ecological reference sites. The loss of potentially dominant groundcover species, such as *Aristida stricta*, *Gaylussacia dumosa*, and *Pinus palustris* seedlings, is consistent with observations in similar comparisons of plantations to reference stands in the sandhills of SC (Smith and others 2002, Walker and van Eerden 1996). In xeric sandhills plantations, species composition was similar to reference sites, except for the conspicuous losses of *A. stricta* and *G. dumosa*. As in the Camp Lejeune study, sandhills plantations had significantly higher pine densities and basal areas than comparable reference sites.

The lack of difference in species richness except at the smallest scales indicates that reasonably diverse communities are maintained in plantations, and suggests the potential for restoring a diverse groundcover without adding species. However, as noted previously, a few dominant species apparently are sensitive to habitat modifications created during establishment and growth of plantations. Although thinning the canopy and prescribed burning may invigorate the groundcover (Provencher and others 2001), we predict that the effectiveness of prescribed burning may be limited by the lack of fine fuels resulting from the significantly reduced herbaceous cover in plantations. Restoring the continuity of fine fuels is likely to require reintroducing the dominant large grasses found in reference sites.

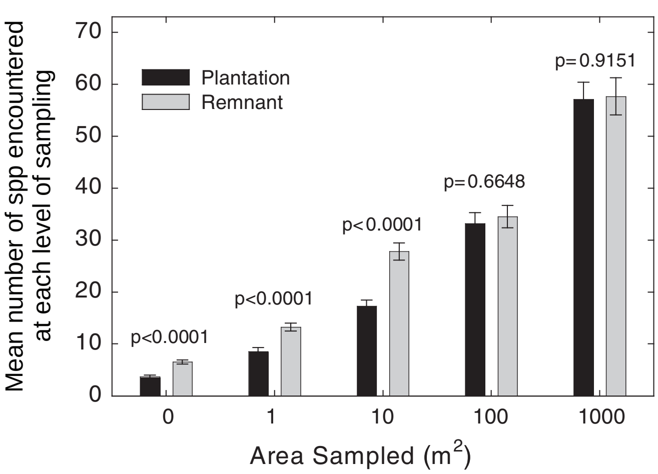

Figure 2—Species richness (number of species counted) at five different sampling scales in plantations and reference sites. Shown are means (±1SE). P-values above pairs of bars indicate result of one-way ANOVAs testing the effect of site type (plantation versus reference) on species richness at each scale.

We expected stronger relationships between ordination scores and environmental parameters; specifically, we expected stands would be ordered strongly by soil texture. The relationship of composition to soil texture, widely regarded as a surrogate for soil moisture availability, is well-established for natural stands (Christensen 1988, Peet and Allard 1993, Walker and Peet 1983). We predict that an analysis of the reference sites alone would reveal a compositional gradient that follows soil texture, but that such a relationship would not be found in an analysis of plantations. In a comparison of plantations and reference sites in the Fall-line sandhills of SC, Smith and others (2002) reported that the expected strong relationship between ground layer composition and soil texture was evident for both plantations and reference natural areas; however, the difference between plantations and reference sites was greater at the mesic end of the environmental gradient than in xeric sites. Thus, the strength of the relationship to soil texture is not simply related to the disturbance associated with plantation establishment.

We hypothesize that the degree to which plantation management disrupts natural diversity and community structure is related to both site conditions and management choices. On drier sites, less intense silviculture methods are required to establish longleaf plantations, thus the initial losses in the groundcover are less than in wet sites. In addition, re-growth of competing vegetation is slower on drier sites than on wet sites, resulting in a comparatively low loss of groundcover diversity (changing composition) in the early establishment period before prescribed fire can be introduced. Finally, in wetter sites, planted loblolly and slash pines were protected from prescribed burning for the first five to seven years, thus exacerbating the loss to aggressive shrubs and hardwoods. In summary, we hypothesize that plantations on wet sites are inherently more variable than those on drier sites, because establishment methods are more variable and early stand management varies with the species of pine planted. In the rapid and profound changes that occur on wet sites, characteristic species are lost to more widespread, weedy ones, both herbaceous and woody, thereby obscuring species habitat relationships that govern species distributions in the undisturbed landscape.

MANAGEMENT IMPLICATIONS

Compared to ecological reference sites, plantations (≥18 years old) at Camp Lejeune have a greater pine basal area (and total basal area) and reduced cover of the characteristic dominant grass (wiregrass). These results suggest that in

Table 2—Mean (standard error) of soil characteristics and structural variables correlated with NMS axes (r-square ≥ 0.15), by site type

	Reference (n=28)	Plantation (n=39)	F[a]	p[a]
pH	3.95(0.05)	4.18(0.05)	8.83	0.0042
K (mg/kg or ppm)	21.79(1.86)	38.10(3.56)	19.10	<0.0001
Ca saturation (%)	17.40(0.86)	5.50(0.79)	94.97	<0.0001
Mg saturation (%)	6.34(0.19)	2.32(0.34)	118.10	<0.0001
Total tree basal area (m^2/ha)	11.34(0.72)	23.07(4.31)	9.84	0.003
Pine basal area (m^2/ha)	9.98(0.75)	21.17(3.98)	10.36	0.002
Species richness (S)	54.51(2.90)	53.18(3.01)	0.10	0.756
Species diversity (H')	3.81(0.06)	3.82(0.07)	0.01	0.929
Species diversity (D)	0.97(0.002)	0.97(0.002)	0.01	0.905
Evenness (E)	0.96(0.002)	0.97(0.002)	4.30	0.042

[a]F and p are the test statistic and significance level, respectively, from the associated ANOVA for site type effect.

Table 3—Mean (standard error) percent cover in the ground layer vegetation (< 1 m tall) of (a) herbaceous, woody and all species and (b) selected species in plantations and reference forests

	Plantations (n=28)	References (n=39)	F[a]	p[a]
(a) Growth form group				
Herbaceous species	23.79(2.79)	43.20(4.48)	11.17	0.0014
Woody species	56.98(6.31)	70.04(6.05)	2.14	0.1480
Total cover	80.77(7.37)	113.24(6.12)	11.54	0.0012
(b) Selected species				
Aristida stricta	4.02(1.54)	21.83(3.82)	14.36	0.0003
Gaylussacia dumosa	0.51(0.11)	9.06(1.98)	13.36	0.0005
Gaylussacia frondosa	4.05(1.14)	7.95(1.53)	3.61	0.620
Pinus palustris	2.50(0.92)	15.28(2.59)	16.39	0.0001

[a]F and p are the test statistic and significance level, respectively, from the associated ANOVA for site type effect.

order to restore these plantations to reference conditions managers will have to both increase the bunch grass cover and thin the canopy. However, because thinning may release understory hardwoods that will compete with planted grasses, the order of treatments and subsequent competition control must be carefully considered.

ACKNOWLEDGMENTS

We appreciate the logistical support of the Camp Lejeune natural resources staff. Funding was provided by the Departments of Defense and Energy, Strategic Environmental Research and Development Program.

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