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Assessing the Vegetative Diversity of an East Texas Golf Course using Principles of Landscape Ecology

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ABSTRACT

The objectives of this study was to determine the vegetative diversity and the effects of the edge between fairways (introduced patches) and out-of-bounds areas (remnant patches) to determine if such management activities influence plant diversity. This study was conducted at the Pineywoods Country Club in the Pineywoods Region of East Texas near Nacogdoches, TX, USA by assessing the spatial distribution of these matrices and patches and their influence on edge effect composition and structure in the matrix; and, if species diversity and composition differed between these edges and interior of the matrices. Nested plots were placed along transects and canopy cover, percent cover, number of individuals by species, tree density, and percent cover of ground cover materials were analyzed using ordination. Dbh, shrub and herbaceous percent cover, and canopy cover were tested for normality utilizing a Shapiro-Wilk normality test, Wilcoxon-Mann-Whitney was used to analyze edge plots and interior plots, and @RISK goodness-of-fit measures were utilized to identify percent cover data distributions. Statistical differences (0.05 α level) between the edge and interior dbh and shrub datasets and a similarity between the edge and interior datasets of the overstory and herbaceous strata were found. Many of the interior shrub plots had a higher H' (Shannon-Wiener index) and D (Simpson's index) than the edge plots. Canopy cover was often over 70%, and herbaceous species abundance was often higher (1-11 species) than that of the shrub stratum (1-3 species). Beta diversity indicated that the remnant patches were diverse (β between 0.19-0.30) within all three strata. Natural and anthropogenic disturbances altered the structure and function of the remnant patches: tree density decreased in edge plots due to management. Canopy cover was high over edge plots; however, light was able to reach the ground at an angle across the fairway. Past and current management practices combined with disturbance events have caused the interior of the remnant patches to be disturbed to the degree that they were not representative of the Pineywoods eco-region. The exceptional drought in 2011 may have influenced these results. It was not determined whether the fairway patches within the forest matrix resulted in edge effects.

KEY WORDS: Edge effects, Biodiversity, Patches

INTRODUCTION

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Introduced patches, such as golf course fairways, are patches that are "dominated by an aggregation of individuals introduced into a matrix by people" and "remain as long as the human disturbance regime maintains them" (Forman and Godron 1981). The Pineywoods Country Club (PWCC) meets the definition of Forman and Godron (1981) as this matrix was a typical East Texas Pineywoods forest which was originally cleared for golf course construction in 1926 with additional fairways constructed in the 1960s. Golf course out-of-bounds can be considered remnant patches of the matrix if they are not intensively managed, based on Forman and Godron (1981). Ecological edge effects can occur where a remnant patch meets an introduced patch. Along this edge, the species composition differs from that of the interior of the remnant patch, much like a forested area meeting a grassland or pasture. In the case of golf courses, the introduced patch is a continuously maintained, anthropogenic disturbance in the natural environment, so succession may have an influence on the species found on this edge as the vegetation attempted to reestablish species that are best suited to that environment (Drury and Nisbet 1973). Only four studies (Fordham 1988; Terman 1997; Gange et al. 2003; Tanner and Gange 2005), all in the United Kingdom, have analyzed golf course vegetation diversity in the out-of-bounds of a naturalized golf course. Our objectives were to determine if the spatial distribution of these matrices and patches had an influence on edge effect composition and structure in the matrix and if species diversity and composition differed between these edges and interior of the matrices.

While there are a variety of methods utilized by community ecologists for assessing vegetative community structures and changes (Clements 1916 Tansley 1935; Weaver and Clements 1938; Daubenmire 1959, 1968; Ranney et al. 1981), landscape ecologists often assess these same areas to study the effects that humans have had on their surrounding environment (Forman and Godron 1981; Forman 1995; Wu 2007; Coulson and Tchakerian 2010), or how the vegetation has been affected by human disturbance (Turner 1989; Cullinan and Thomas 1992; Opdam et al. 2002; Wiens 2002). This study combines both perspectives to assess the effects on plant diversity of golf course fairways (introduced patches), on the still mostly natural, vegetated out-of-bounds areas (remnant patches) of an East Texas golf course.

MATERIALS AND METHODS

Study site and sampling design. The PWCC, encompassing 89.3 hectares, is a private golf club located 1.8 km south of Nacogdoches, Texas, United States, and is a naturalized golf course, using the region's natural contour of the land and natural vegetation in its design template. Fairways were "cut out" of the surrounding forest matrix. The fairway patches were not uniformly spaced, neither were they of the same size or shape, leaving oddly shaped remnant patches. Dominant tree species include shortleaf, longleaf, and loblolly pines (*Pinus, echinata, P. Palustris, P. taeda*), sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), and a variety of Oaks (*Quercus* spp.) and hickories (*Carya* spp.). The midstory and understory often include the above species plus Sassafras (*Sassafras albidum*), beautyberry (*Callicarpa Americana*), wax myrtle (*Morella cerifera*), American hornbeam (*Carpinus caroliniana*), and dozens of herbaceous species.

Soil series on the site were Libert (Loamy, siliceous, semiactive, thermic Arenic Plinthic Paleudults) found on ridges and uplands; Darco (Loamy, siliceous, semiactive, thermic Grossarenic Paleudults), Tenaha (Loamy, siliceous, semiactive, thermic

Grossarenic Paleudults) on gently sloping to steep slopes on broad interstream divides and side slopes, and Rentzel (Loamy, siliceous, semiactive, thermic Grossarenic Plinthic Paleudults) soils found in small concave drainageways (The Soil Survey of Nacogdoches County, Texas, 1980).

The PWCC was sampled Jun-Jul 2011 during the worst drought that Texas endured since 1789 (NOAA 2011). The property had previously sustained damage in the form of wind thrown trees from Hurricanes Katrina (2005), Rita (2005), and Ike (2008). Known past management activities, including select hazard tree removal, commercial thinning, and prescribed burning, were conducted on the site at various intervals. Non-managed cart trails also cut across the out-of-bounds areas between fairways.

A stratified random sampling technique was used for placement of transects and sample plots (Figure 1). The methods by Ranney et al. (1981) were modified to measure species biodiversity and to estimate edge effects. Transects were stretched across the entire width of each patch, and extended 1 m into the fairway to capture the change in vegetation as one moved from the fairway into the patch (William-Linera 1990), and plots alternated sides of the transect within five large areas (sampling areas A, B, C, D, and E), and placed at least 15 m apart (Fraver 1994). Transect lengths varied depending on the width of the sampling area.

The number of nested plots along each transect varied with the width of the sampling area, resulting in 42 edge plots and 121 interior plots. One 5 m edge of each nested plot was adjacent to a transect. Plots alternated sides with 15 m gaps between plot edges to decrease the likelihood of trampling plants (Figure 2). As an additional measure of percent cover, a modified version of the line-intercept method was used on each transect along the 5 m adjacent edge. Tree/sapling plots had dimensions of 10 meters x 5 meters. A tree was defined as a woody plant 6 m tall or taller with a diameter at breast height (dbh) of 7.6 cm or more. A sapling was defined as a young tree 6 m tall or taller with a dbh of less than 7.6 cm. Shrub plots had dimensions of 3 m x 1 m and were nested within tree plots. A shrub was defined as a woody plant less than 6 m and greater than 1 m tall with a dbh of less than 7.6 cm. Herbaceous plots were 1 m x 1 m and were nested within shrub plots. Herbaceous plants were defined as non-woody plants, juvenile woody plants, and juvenile woody vines (i.e., seedlings or sprigs) less than 1 m tall (USACE 1987). Trees per hectare (TPH) per plot was also calculated. All plots were sampled once during the growing season to capture community structure and composition when it is the most diverse and when it is expressing itself the most.

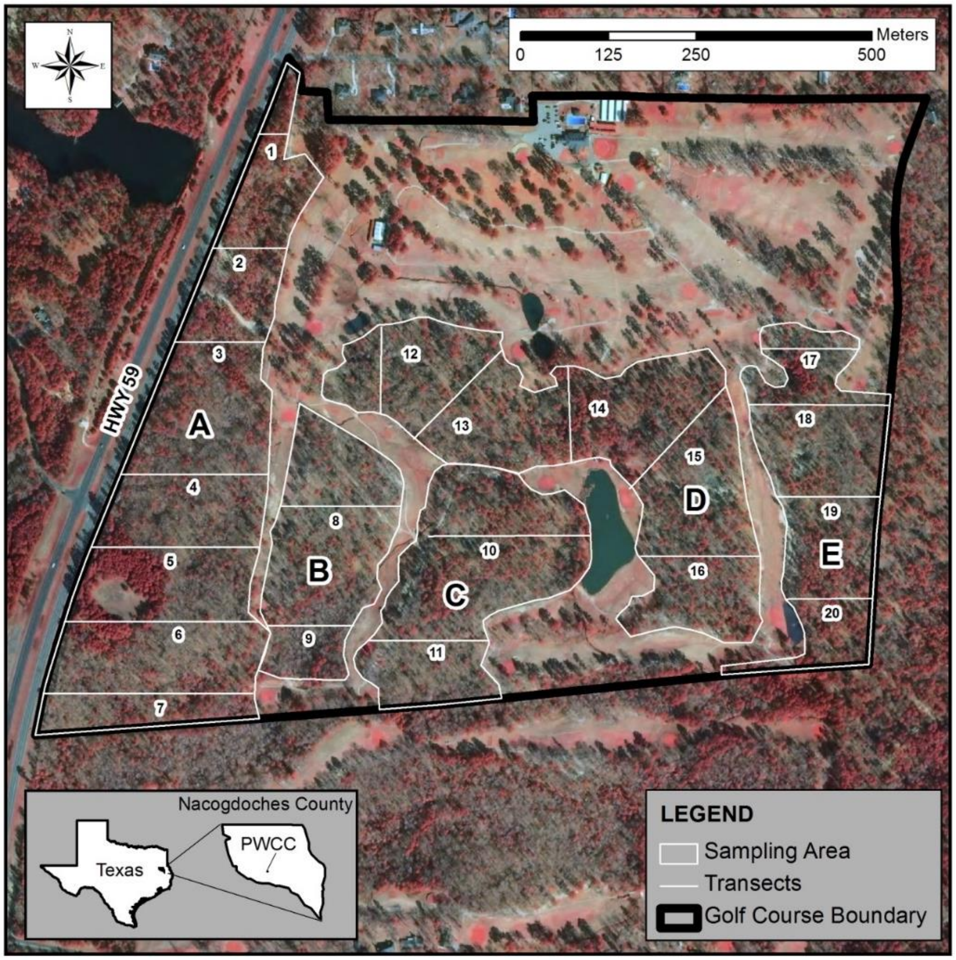

Figure 1. Pineywoods Country Club study area with sampling areas and transects used for measuring vegetation biodiversity and edge effects. Background image is 2010 National Agriculture Imagery Program (NAIP) 1 meter resolution natural color/color infrared (NC/CIR) aerial imagery retrieved from the Texas Natural Resources Information System. Map was created by Penny Gibson in the Arthur Temple College of Forestry and Agriculture Geographic Information Systems Laboratory.

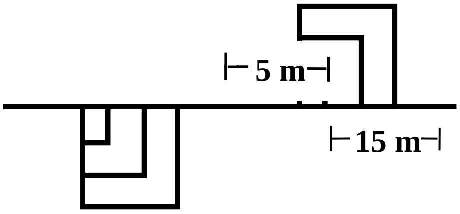

Figure 2. Tree plots with nested shrub and herbaceous vegetation plots will be placed on alternating sides of a transect.

Data measurement and analysis. Line-intercept data was converted to total length (cm) by species. Species abundance was determined by physically counting individual plants of each species within each plot. The dbh of each tree was measured and densiometer readings were taken from plot center to estimate canopy cover. Within the shrub and herbaceous plots, percent cover was visually estimated using Daubenmire classes (Daubenmire 1959). Percent cover data were analyzed using indices recommended by Peet (1974) and Hill (1973). Peet (1974) emphasized the need for measures of both heterogeneity and equitability, and Hill (1973) stated that it was equally important to add the total number of species. Three indices were calculated in PC-ORD (version 6, MjM software, Gleneden Beach, Oregon, USA) and Microsoft Excel 2010 software. Simpson's index (D) was used to determine heterogeneity (including both species richness and evenness) of common Pineywoods species. Equitability (evenness) of the rare species (species occurring once or on less than 5% of the plots) was measured using Shannon-Wiener index (H) based on Shannon and Weaver (1949) and Pielou's evenness index (E) based on Pielou (1969). The total number of species was determined by performing a simple species count. Simpson's index, Shannon's index, and Pielou's evenness index were calculated in PC-ORD 6 using the "Row and Column Summary" option. Plots that did not have any plants in that particular stratum were indicated by "N/A." Beta diversity (β) was utilized to distinguish a difference in diversity between sampling areas:

$$\beta = S/(\alpha - bar)$$

Individuals of each species were counted and summed for each sampling area (α). The mean (α-bar) and the total number of represented species across all sites (S) were determined.

Both percent cover and line-intercept data were statistically analyzed using ordination. Canonical correspondence analysis (CCA) ordination technique using PC-ORD was used to identify trends. The Shapiro-Wilk ("W" statistic) normality test was used to determine if the edge and interior datasets for dbh, shrub and herbaceous percent cover, and canopy cover were normally distributed. Afterward, a Wilcoxon-Mann-Whitney nonparametric test was used to determine if values between edge plots and interior plots were statistically different (0.05 α level). Dbh and shrub and herbaceous percent cover data distributions were identified using @RISK goodness-of-fit measures (Albright et al. 2010).

RESULTS

Statistical analyses. The CCA did not reveal any edge-to-interior trends, although various other trends were discovered. Species line trends are indicated by the first three letters of the genus and species. Plots trends are indicated by the letter of the sampling area, transect number, and plot number. In the overstory stratum, *Ostrya virginiana* (Mill.) K. Koch (OSTVIR) was only found in one plot (CT10P99), and was highly related to dbh size and frequency (Figure 3) but had little overall value ecologically in this study. There was no discernible trend from edge to interior in the shrub stratum. Those species that rarely occurred were only found in a moderately moist habitat while commonly observed species were often found along stream banks, in depressions, and in irrigated edge plots. While there were clusters of species found along the transects from the edge to the interior of the patches for herbaceous species (Figure 4), there were few trends identified.

The Shapiro-Wilk test displayed a nonparametric distribution for both the edge and interior dbh datasets, while the @RISK analysis of the distributions displayed a Beta General, left-skewed distribution. Wilcoxon-Mann-Whitney identified a statistical difference ($p = 0.027$) between the two at the 0.05 alpha level. The Shapiro-Wilk test also found a nonparametric data distribution for both the edge and interior datasets in the overstory, shrub, and herbaceous percent cover data. The Wilcoxon-Mann-Whitney test identified a statistical difference ($p = 0.038$) between the edge and interior datasets for the shrub stratum at the 0.05 alpha level. The @RISK analysis of the distributions displayed an Inverse Gaussian, left-skewed distribution for shrub interior and herbaceous edge datasets and a Beta General, left-skewed distribution for shrub edge and herbaceous interior datasets.

Species diversity, tree density, and other variables. In many of the edge and interior shrub plots, only one individual was observed, indicating no diversity within that plot. Those plots with two or more shrub species had higher diversity and evenness results. When shrub diversity was compared between edge and interior plots, many of the interior plots had a higher H and D. Herbaceous species richness was often higher than that of the shrub stratum. Both the edge and interior plots of the herbaceous stratum had mixed high and low results and displayed no trends. Beta diversity values were low, indicating that the sampling areas were diverse (Tables 1 and 2).

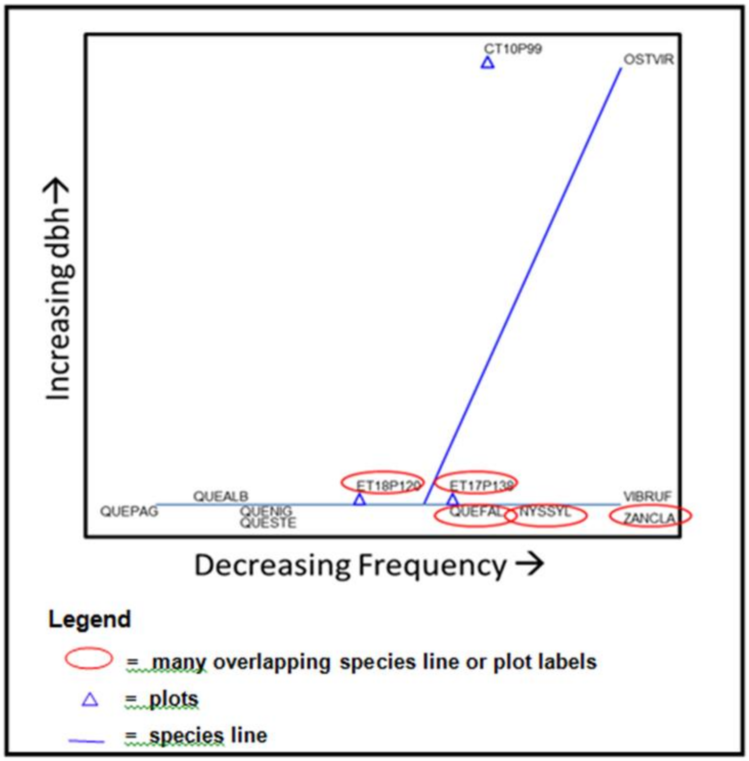

Figure 3. Canonical Correspondence Analysis (CCA) ordination of dbh measurements of trees within sample plots.

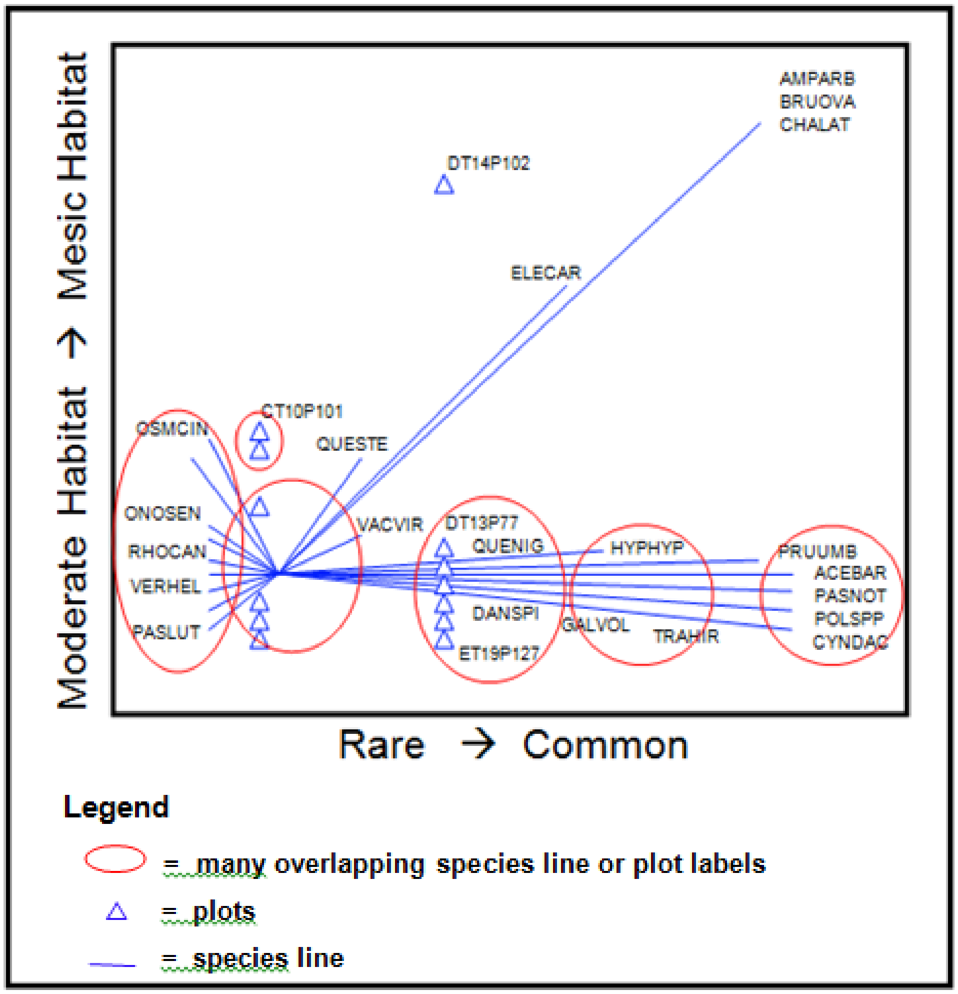

Figure 4. Canonical Correspondence Analysis (CCA) ordination of line-intercept measurements in the herbaceous stratum.

Table 1. Beta diversity values for each vegetative strata compared among 5 sampling areas.

Strata	β
Tree	0.38
Shrub	0.19
Herbaceous	0.20

Table 2. Species Richness and Diversity indices by plots for shrub and herbaceous strata.

	S	E	H	D
		Shrub		
Edge				
AT2P3	3	0.41	0.45	0.26
AT5P23	1	0.00	0.00	0.00
AT6P35	1	0.00	0.00	0.00
DT13P77	2	1.00	0.69	0.5
CT11P85	1	0.00	0.00	0.00
DT14P106	3	0.79	0.87	0.50
DT15P107	1	0.00	0.00	0.00
Interior				
AT2P4	1	0.00	0.00	0.00
AT2P5	3	0.74	0.81	0.52
AT2P9	3	0.87	0.96	0.57
AT3P10	4	0.33	0.46	0.21
AT3P11	2	0.92	0.64	0.44
AT3P12	3	0.85	0.94	0.57
AT3P13	1	0.00	0.00	0.00
AT4P15	1	0.00	0.00	0.00
AT4P17	1	0.00	0.00	0.00
AT4P19	1	0.00	0.00	0.00
AT4P21	1	0.00	0.00	0.00
AT5P27	1	0.00	0.00	0.00
AT5P28	1	0.00	0.00	0.00
AT5P31	2	0.96	0.67	0.47
AT5P32	2	0.24	0.16	0.07
AT5P33	1	0.00	0.00	0.00
AT5P34	3	0.85	0.93	0.55
AT6P36	1	0.00	0.00	0.00
AT6P38	1	0.00	0.00	0.00
AT6P39	1	0.00	0.00	0.00
AT6P40	1	0.00	0.00	0.00
AT6P41	1	0.00	0.00	0.00
AT6P43	2	0.24	0.16	0.07
AT6P45	1	0.00	0.00	0.00
AT6P46	1	0.00	0.00	0.00
AT6P47	2	1.00	0.69	0.5
AT7P50	2	0.97	0.67	0.48
AT7P51	2	0.59	0.41	0.24
AT7P52	2	0.81	0.56	0.38
AT7P54	1	0.00	0.00	0.00
AT7P55	2	0.75	0.52	0.34
AT7P56	3	0.95	1.04	0.63
AT7P57	1	0.00	0.00	0.00
AT7P58	2	0.86	0.6	0.41
AT7P59	2	1.00	0.69	0.5
AT7P60	4	0.85	1.18	0.65
AT7P61	1	0.00	0.00	0.00
BT9P63	1	0.00	0.00	0.00
BT9P66	3	0.87	0.95	0.56
BT9P68	3	0.67	0.74	0.41

	S	E	H	D
		Shrub		
BT8P69	1	0.00	0.00	0.00
BT8P70	2	0.21	0.14	0.06
DT12P72	3	0.57	0.62	0.39
DT12P73	2	0.41	0.28	0.15
DT12P75	2	0.44	0.31	0.17
DT12P76	1	0.00	0.00	0.00
DT12P78	4	0.33	0.46	0.23
DT12P79	3	0.13	0.14	0.06
DT13P81	6	0.66	1.18	0.64
DT13P82	1	0.00	0.00	0.00
DT13P84	1	0.00	0.00	0.00
CT11P86	1	0.00	0.00	0.00
CT11P87	1	0.00	0.00	0.00
CT11P89	3	0.51	0.56	0.29
CT10P91	3	0.98	1.08	0.65
CT10P92	2	0.97	0.67	0.48
CT10P93	2	0.76	0.53	0.35
CT10P95	1	0.00	0.00	0.00
CT10P96	2	0.34	0.23	0.12
CT10P97	4	0.98	1.35	0.73
CT10P98	2	0.97	0.67	0.48
CT10P99	1	0.00	0.00	0.00
CT10P100	1	0.00	0.00	0.00
CT10P101	1	0.00	0.00	0.00
DT14P104	4	0.56	0.78	0.39
DT14P105	1	0.00	0.00	0.00
DT15P108	4	0.38	0.52	0.24
DT15P109	3	0.67	0.73	0.48
DT15P110	3	0.53	0.58	0.3
DT15P111	6	0.91	1.63	0.78
DT15P112	2	0.52	0.36	0.21
DT16P113	1	0.00	0.00	0.00
DT16P115	6	0.52	0.93	0.46
DT16P116	1	0.00	0.00	0.00
DT16P117	1	0.00	0.00	0.00
DT16P118	1	0.00	0.00	0.00
DT16P119	5	0.82	1.32	0.71
ET18P121	1	0.00	0.00	0.00
ET18P122	3	0.71	0.78	0.47
ET18P123	2	0.92	0.64	0.44
ET18P124	1	0.00	0.00	0.00
ET19P128	2	0.97	0.67	0.48
ET19P129	3	0.90	0.99	0.59
ET20P132	2	1.00	0.69	0.50
ET20P133	1	0.00	0.00	0.00
ET17P135	3	0.92	1.01	0.61
ET17P137	1	0.00	0.00	0.00

Species richness = S; Pielou's evenness index = E; Shannon's diversity index = H'; Simpson's index = D. Plot codes (e.g. ET17P134) sampling area (A-E); Transect number (T 1-20); Plot = (P 1-xx). 14 plots in the shrub strata didn't support any shrubs and 30 plots didn't support any herbaceous plants. These are not reported.

No edge to interior pattern was identified among tree density values. Both edge and interior plots have occurrences where there are no trees within a plot. Many interior plots had zero or few trees, while two edge plots had an especially high number of trees. Most canopy cover measurements in both edge and interior plots were between 70% and 100%. Only five out of 21 edge plots had less than 70% canopy cover. Leaf litter was the most common "other" material observed. Edge plots had the most consistent thickness and percent cover of "other" materials. The majority of thick leaf litter layers were in the interior. The large interior trees contributed significantly to the leaf litter. The second most common "other" material was woody debris, especially in areas that had been cleared for the purpose of storing debris left from the construction of fairways and from hurricane cleanup.

DISCUSSION

The structure and function of the remnant patches has been altered over time. Natural disturbances, such as drought and hurricanes, and anthropogenic disturbances, such as past management practices, have caused significant changes in the remnant patches. Anthropogenic disturbances have caused the out-of-bounds to appear less like the natural Pineywoods forest. It is very likely that the interior of these remnant patches were not truly representative of the Pineywoods region. Instead, these areas reflected disturbance ecology. The geometric shape of the patches (i.e., the northern portion of Sampling Area A and mid-sections of Sampling Areas C and D) could have been too narrow to contain a true interior (Figure 1). The interior of these elongated patches may have been influenced by light from the edge, in some cases from two sides.

Hophornbeam (*Ostrya virginiana* (Mill.) K. Kock) serves as a representative species of the many infrequently observed species that had a relatively small dbh size. Most of these species were infrequent and most had a small dbh with the exception of Sweetbay (*Magnolia virginiana* L.), winged elm (*Ulmus alata* Michx.), and eastern redcedar (*Juniperus virginiana* L.). One plot contained the only observed *Ostrya virginiana* in the tree stratum in this study. White (*Quercus alba* L.) and cherrybark (*Quercus pagoda* Raf.) oaks were frequently observed in the tree stratum throughout the landscape.

Many of the species in the herbaceous clusters moving from left to right in Figure 4 were a mixture of sun and shade, rare and common, moderate and mesic habitat species. One explanation is that many of the sites have been altered by both human activities and natural events. Management activities such as the introduction of fairway grasses, select thinning of the overstory, development of clearings for storage of woody debris, and burning of woody debris in large piles could have had an effect on the openness of the canopy, mineral content of the soil, and species content of the herbaceous stratum. Natural occurrences, such as Hurricanes Katrina, Rita, and Ike, caused gaps in the canopy. The dynamic nature of the golf course leads to a non-normal distribution in the percent cover of both the shrub and herbaceous strata. The difference between edge and interior shrubs suggests that it is possible for edge effects to be present in this stratum.

Dbh data distributions were not normal because of the diverse species composition within the dataset. If the dataset were comprised of only pine species or only hardwood species, the data would most likely be normally distributed. For example, comparing the dbh of a mature Hornbeam (*Carpinus caroliniana* Walt.) to a mature loblolly pine (*Pinus taeda* L.) is not reasonable. Loblolly pine is capable of reaching a much greater dbh at maturity. The statistical difference between the edge and interior dbh datasets suggests that it is possible for edge effects to be present.

Many of the Shannon's index results were not within the typical 1.5 to 4.5 range, probably because there was not a high diversity observed within each individual plot. The beta diversity values for all three strata indicated that there was little overlap of similar species between sampling areas. For example, sampling area B had many mesic species while sampling area E had many xeric species.

Species abundance was higher in the herbaceous stratum than in the shrub stratum for many reasons. Non-woody plants such as ragweed (*Ambrosia artemisiifolia* L.), goldenrod (*Solidago* spp.), and dogfennel (*Eupatorium capillifolium* (Lam.) Small) occupied space where there was high light availability that would otherwise have been occupied by woody shrubs. Fallen trees crushed shrubs and broke limbs off neighboring trees. With the added light, herbaceous species quickly took advantage of the favorable conditions. Tractors and other equipment that took shortcuts through the out-of-bounds crushed shrubs in their path. Shrubs were also removed along the edge of fairways to assist golfers in finding lost golf balls (personal communications PWCC staff).

Many of the edge plots consisted of few or no shrubs, and little or no diversity was observed. There were fewer dominant species and a higher diversity in the interior compared to the edge. It was expected that the edge plots would have higher species diversity in the herbaceous stratum because there was greater access to light and less leaf litter. The presence of clearings, leaf litter and woody debris, fairways, burned areas, and cart paths caused mixed results among the diversity indices for this stratum.

It was also expected that there would be a greater tree density near the edge, but that it would decrease as one moved to the interior. However, the same human and natural disturbance effects that the herbaceous stratum had displayed have expressed themselves in the structure of the overstory. Gaps caused by Hurricane Ike occurred in some plots, resulting in no trees. Pine trees grew closer together, while hardwoods branched out further and caused larger spacing, and some plots occurred in the spaces between the large canopy trees. Streams, which passed through a few of the plots, had trees only on the banks. These streams were about 2-3 m wide. Cart paths, downed woody debris, clearings, and select hazard-tree removal occasionally affected the abundance of trees in a sample plot.

Wind thrown trees that resulted from the hurricanes altered the microenvironmental conditions. Light was able to reach the shrub and herbaceous strata through gaps. Therefore, shrub and herbaceous species that once thrived on the edge of the patch had begun to thrive in the interior. Cheplick (1998) stated that disturbances that remove intact vegetation, whether natural or man-induced, tend to promote seedling establishment of grasses.

Materials that were classified as "other" were found to be incredibly variable, except within edge plots. Edge plots had a large amount of exposed soil because mowers mulched the leaves or scraped the soil surface. Golfers often sent leaves flying each time they struck a ball. Leaf litter and woody debris layers were thicker in the interior, depending on if the area was frequently disturbed (i.e., shortcuts taken by Grounds' tractors through out-of-bounds, extraction of firewood, burn piles). This layer often changed due to active/passive management and spatial and temporal changes (i.e., thicker leaf litter in autumn). The high number of large canopy trees contributing to the patch interior leaf litter and woody debris layers contributed to lower percent cover in the herbaceous layer in various plots.

Sunlight could easily reach the herbaceous layer of an edge plot at an angle from at least one direction. Because the fairway consists of no trees or shrubs, sunlight was able to shine across the fairway and under the tree canopy (Figure 4). This allowed grasses to grow along the patch edge, such as bermudagrass (*Cynodon dactylon* (L.) Pers.), crabgrass (*Digitaria* spp.), and St. Augustine grass (*Stenotaphrum secundatum* (Walter) Kuntze). Other forbs such as spoonleaf purple everlasting (*Gamochaeta purpurea* (L.) Cabrera) and Carolina ponysfoot (*Dichondra carolinensis* Michx.) were also found.

The slope and well-drained texture of the soils discouraged inundation and therefore did not promote the growth of plants that are typical of more mesic environments. The soils did support a variety of plant species that favored sandy and loamy soil textures. Bottomland species, including *Magnolia virginiana* L., *Symplocos tinctoria* (L.) L'Hér., and many fern species (*Osmunda, Onoclea*) were commonly observed growing in the somewhat poorly-drained Rentzel soils in drainageways, particularly in the southern portion of Sampling Area B. Upland species, including *Quercus stellata* Wangenh., *Juniperus virginiana* L., *Viburnum rufidulum* Raf., *Callicarpa americana* L., *Acalypha virginica* L., *Schizachyrium scoparium* (Michx.) Nash, and *Cnidoscolus texanus* (Müll. Arg.) Small, were commonly observed on upland sites and ridges in Lilbert and steeply sloped Darco soils, especially in the southern portion of Sampling Area D and eastern portion of Sampling Area E. Soil moisture data was not sampled. It is likely that soil moisture levels could have been steadily dropping, therefore affecting the vegetation for the past five years (Table 2). Past prescribed burns, including controlled burn piles for disposing of hurricane debris, have allowed for more nutrient cycling within the out-of-bounds.

This study occurred during one of the worst summer droughts in over 200 years. Most of Texas was under an exceptional drought by August 2011 (NOAA 2011). Data were collected for one field season and therefore provided only a snapshot of the conditions and vegetative species that might be observed during such an extensive drought. Data collection began June 2, 2011 and was completed July 29, 2011. In August 2011, mortality became visually evident. As a result of a five-year cycle of drought, many of the plant communities, especially in the herbaceous stratum, may have changed in the last five years. For example, mesic bottomland areas dried up and were capable of supporting xeric species. Xeric species became more prevalent in the bottomlands and formed communities that resembled those of an upland environment. Plant species may not have expressed normal habitat requirements due to this change.

Sampling areas in the midst of the golf course were more disturbed than those along the eastern and western property boundaries (A and E). Sampling Areas B, C, and D had dirt paths created by tractors, mowers, 4-wheeled off-road vehicles, and some foot traffic where shortcuts were taken across the out-of-bounds going from one fairway to the next. Sampling Area A was subject to a corridor effect from Hwy. 59, such as increased light or runoff coming from the highway. There was also a man-made clearing in the southern portion of Sampling Area A that connects to the highway. Sampling area E was protected on the eastern side by the forest, which continued onto the adjacent property.

CONCLUSIONS

Certain species played an unexpected role in the floral relationships within the out-of-bounds patches. *Chionanthus virginicus* L., *Brunnichia ovata* (Walter) Shinners, *Ampelopsis arborea* (L.) Koehne, and *Chasmanthium latifolium* (Michx.) Yates suggested a relationship between increasing site moisture and increasing distance from the edge, therefore, an increasing buffer from the evaporative heat of the sun. *Paspalum floridanum* Michx. and *Gamochaeta purpurea* suggested a site that was very sunny. *Elymus virginicus* L. and *Rhododendron canescens* (Michx.) Sweet indicated that the area could support plants with medium light requirements. *Carya cordiformis* (Wangenh.) K. Koch and *Melia azedarach* L. could be found on sites with low moisture. *Rhus aromatica* Aiton and *Carya alba* (L.) Nutt. seem to indicate areas that can support more xeric, less shade intolerant species. Other species, such as *Stenotaphrum secundatum* (Walter) Kuntze, displayed the expected relationship of appearing in introduced patches that were shaded and irrigated.

It was expected that a trend would be found indicating the presence or absence of edge effects. Species favoring higher moisture availability were expected to be observed in the interior of the patches where the sun's rays did not cause accelerated evaporation. However, the frequent irrigation of the fairways made it more likely that species favoring high moisture availability were found on the edge. In regard to the availability of light, it was expected that species with higher light requirements would be observed on the edge and more shade tolerant species would be observed in the interior. This appeared to be true for the shade tolerant species, and largely true for the species with high light requirements, except in the case of St. Augustine grass. The act of "cookie-cutting" the fairways out of an existing forest had caused older, larger trees to be left near the fairways. These trees (often large canopy *Quercus alba*) shaded parts of the fairways, which allowed at least one shade-loving species to flourish on the edge.

The fairways did limit the shrubs and trees that were found in the edge plots, and therefore caused species richness and diversity to appear lower on the edge than the interior. This conflicted with the expected result that species richness and diversity would be higher where there was an earlier successional stage and less competition for light. Fewer dominant species were observed in the interior where the plant community was in a higher successional stage. The diversity of the overall PWCC landscape was found to be very high. .

Herbaceous species were expected to be found on the edge where there were fewer trees and shrubs to intercept the sunlight. However, both ordinations and diversity indices indicate that natural and human activities on the site have caused unexpected results in the presence, abundance, and diversity of the herbaceous species. The presence of edge effects cannot be justified judging by the herbaceous stratum. The same phenomenon was observed in the overstory with respect to tree density. Past and current management practices combined with disturbance events have caused the interior of the remnant patches to be disturbed to the degree that they were not representative of the Pineywoods eco-region. The anthropogenic and natural disturbances very likely contributed to the results concerning edge effects and biodiversity.

Due to the dynamic nature of the PWCC landscape, no biodiversity differences between edge and interior vegetation were identified. It could not be determined if the heavily managed fairway patches interspersed within the forest matrix caused any edge effects in the vegetation. However, it was determined that the plant species within the entire landscape were very diverse. As such, current management of this golf course does not appear to have resulted in dramatic changes in vegetative diversity in the remnant patches of the out-of-bounds areas, and could be used by course management as a selling point for golfers desiring to play the game on fairways within a very natural East Texas environment.

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