# Plant Community Characteristics within an 18-year-old Deer Exclosure in Southern Mississippi

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*Abstract*: We recorded plant community characteristics in an 18-year-old, white-tailed deer (*Odocoileus virginianus*) exclosure in the Lower Coastal Plain of Mississippi during summer 1996. The 0.4-ha exclosure was constructed in 1977 within upland pine (*Pinus* spp.) forest of the Leaf River Wildlife Management Area in Perry County, Mississippi. Surveys at the time of exclosure construction revealed that similar plant cover and species richness existed inside and outside of the exclosure. Surveys were conducted during 1996 along 8 37-m transects located inside and outside the exclosure. Forest canopy did not differ between exclosure and control sites. Exclosure habitat supported 59 plant species and unprotected control sites contained 43 plant species. Density and coverage of midstory vegetation were greater ($P < 0.0001$) in exclosed sites than control sites. Deer forages, such as blueberries (*Vaccinium spp.*), hollies (*Ilex spp.*), and yellow jessamine (*Gelsemium sempervirens*), exhibited higher midstory and ground coverages along exclosure transects than along control transects. Our data revealed effects of browsing on plant community structure, coverage, and species richness, and demonstrated potential long-term effects of high deer densities on native flora and plant community characteristics.

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Many studies have focused on the effects of grazing by domestic and feral livestock on native plant communities and wildlife habitat (Dyksterhuis 1949, Bement 1969, Carothers et al. 1976, Kirsch et al. 1978, Taylor 1986, Schulz and Leininger

1990). Native herbivores also can cause long-term changes to habitat during periods of high population densities (Robinson et al. 1980). Plant community changes associated with high cervid populations have been reported in case studies, such as the Kaibab Plateau, Michigan's Beaver Basin, and St. Matthew's Island (Bolen and Robinson 1995). Browsing by white-tailed deer on forest regeneration sites in the northeastern and midwestern United States limited regeneration height growth, altered stand composition, and decreased stand densities (Jordan 1967, Anderson and Loucks 1979, Kittredge and Ashton 1995). Kittredge and Ashton (1995) reported that deer densities >9/km$^2$ were incompatible with regeneration of diverse forest in southern New England. Browsing by deer limited hardwood and northern hemlock forest regeneration and woody plant colonization in the northern United States (Brenneman 1982, Frelich and Lorimer 1985). Major changes in forest regeneration, growth, and composition have been attributed to the browsing pressures exerted by deer in Minnesota and Michigan (Ross et al., 1970, Frelich and Lorimer 1985).

Data on long-term browsing effects are limited for Mississippi. However, historical records of plant species diversity in Mississippi and Alabama indicated that species of strawberry bush (*Euonymus* spp.) were once common in forest communities (Bartram 1928). Strawberry bush is now considered rare in Mississippi forests and most observed specimens show signs of heavy browsing by deer (S. McDaniel, Inst. for Bot. Exploration, pers. commun.). The scarcity of strawberry bush is observed on public land bases such as wildlife refuges and state wildlife management areas where forest stands are generally managed for conservation of floral and faunal diversity.

Mississippi's white-tailed deer population recently has shown dramatic increases and currently has an estimated 1,750,000 animals (Miss. Dep. Wildl., Fish, and Parks [MDWFP] 1996). Complex resource and people management problems have developed with current densities of the state's deer population (MDWFP 1996). The need exists for resource agencies to educate the general public about potential ecological ramifications of high deer densities without population control.

State agency biologists have expressed concern about deer densities of 14 deer/km$^2$ at Leaf River WMA because of the carrying capacity of habitat in this region of Mississippi (B. Thomason and R. Browning, MDWFP, pers. commun.) Currently, MDWFP biologists are targeting a density of 2.5–3 deer/km$^2$ to allow for habitat recovery from sustained heavy browsing. Because increased intensity of deer harvest can be unpopular among nonconsumptive and consumptive wildlife users and the general public, MDWFP biologists have indicated an increased need for ecological information on effects of high deer populations (B. Thomason, MDWFP, pers. commun.). The objective of this study was to document the effects of deer browsing on plant community characteristics in an upland pine forest of the Lower Coastal Plain in Mississippi.

We thank biologists and resource managers of the Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP) and the U.S. Forest Service, DeSoto National Forest for their cooperation. We also thank W. Mitchell for conducting initial vegetation surveys on the study area at the time of exclosure construction.

## Methods

The study site was located on the 18,623-ha Leaf River Wildlife Management Area (LRWMA) in Perry County, Mississippi. Leaf River WMA is a public land base, managed cooperatively by MDWFP and U.S. Forest Service, DeSoto Ranger District. As a part of a free-ranging cattle-deer competition study, 2 0.4-ha exclosures were constructed to restrict white-tailed deer in 1977. Exclosures were constructed with 4-m tall, creosote-treated posts and fenced with heavy-gauge hog wire to 3 m. Three strands of barbed wire were strung along the top of the fence. One of the exclosures was destroyed by a tornado during the early 1980s. The remaining exclosure was located in upland forest habitat on sandy Lower Coastal Plains soils.

Occurrence and coverage of forage plants inside and outside exclosure sites were measured from 1977 to 1980 (Mitchell 1980). Control and exclosure sites were located within the same forest stand. This stand was regenerated naturally through seed tree harvest in 1938 with minimal site preparation. Site index of the stand is estimated at 80 for slash (*Pinus caribaea*) and loblolly pine (*P. taeda*; J. Boykin, U.S. For. Serv., Desoto Ranger District, pers. commun.). Vegetation studies during 1977–1980 indicated that the exclosure site and adjacent sites were dominated by loblolly and slash pine, sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), and oaks (*Quercus* spp.) in the upper canopy; gallberry (*Ilex* spp.), blueberries, wax myrtle (*Myrica cerifera*), hollies (*Ilex* spp.), greenbriar (*Smilax* spp.), and yellow jessamine in the midstory; and panic grasses (*Panicum* spp.), broomsedge (*Andropogon* spp.), and forbs of the Asteraceae family in the understory (Mitchell 1980). Habitat management implemented inside and outside exclosed sites during the past 18 years included prescribed fire during winters at 5-year intervals and selective thinning of timber in 1981. Basal area was estimated at 32 $m^2$/ha before the 1981 thinning and 21 $m^2$/ha following thinning in 1981 (J. Boykin, U.S. For. Serv., DeSoto Ranger District, pers. commun.).

Three cattle were placed in the 526-ha compartment containing the exclosures during 1978 and 1979. No cattle were known to be present for ≥30 years prior to 1978 and have not been present after their removal in 1979. Deer populations on the study area have grown from an estimated 9 deer/$km^2$ in 1978 to 14 deer/$km^2$ in 1996 (B. Thomason, MDWFP, pers. commun.)

Vegetation surveys were conducted in summer 1996 to record plant community characteristics within and outside the exclosure. Two control sites (unprotected from deer herbivory) were systematically established outside the exclosure. Selection of control sites was based on similarity of topography, edaphic factors, and forest stand conditions (canopy closure and basal area) to the exclosure. Two 37-m transects were established randomly in each of the control sites. Four 37-m transects were established within the exclosure. All transects were placed at least 30 m apart and at least 10 m from control and exclosure site boundaries.

Measurements of basal area, vertical structure, species counts, and percent cover of overstory, midstory, and understory were conducted in the exclosure and each control site. Because overstory canopy development may influence midstory and under-

story plant communities through shading and competition, forest canopy overstory >5 m in height was measured at 5 randomly-selected sample points in each of the control and exclosure sites using a spherical densiometer. Overstory cover readings were taken in 4 cardinal directions at each sample point. The 4 readings were averaged to develop a canopy cover estimate for each sample point. Basal area was provided by DeSoto National Forest Ranger District personnel, Wiggins, Mississippi. Percent cover of vegetation was estimated using line intercept (Hays et al. 1981). Plant cover was categorized into understory (<1.5 m) and midstory (1.5–4.5 m). Vertical structure of vegetation was determined for 5 height categories at 6-m intervals along exclosure and control transects with a 2.5-m vertical profile board (Hays et al. 1981). This sampling design yielded measurements at 5 sample points along 4 control transects ($N = 20$) and 4 exclosure transects ($N = 20$) for each height category. Measurements for each height category were compared between exclosure and control sites with the Rank-sum Wilcoxon test (Daniel 1990). The number of plant species was evaluated by recording each genus and/or species encountered in a 100% ground cover survey within exclosure and control sites. Taxonomic identifications were cross-referenced with Radford et al. (1968) and McDaniel and Carraway (1996).

## Results

Vegetation surveys conducted during 1996 revealed similar forest basal area and overstory characteristics among control and exclosure sites. Overstory species composition, stand age, basal area, and overstory canopy cover were similar between exclosure and control sites. Loblolly and slash pine were the dominant tree species and composed >80% of the overstory. Codominant trees composing the remainder of the overstory included sweetgum, red maple, blackgum (*Nyssa sylvatica*), and oaks. Overstory cover did not differ ($P = 0.64$) between exclosed ($\bar{x} = 76.0\%$, $N = 10$) and control sites ($\bar{x} = 78.3\%$, $N = 5$). Basal area was 20.6 $m^2$/ha inside and outside the exclosure.

Vertical structure of vegetation differed between exclosure and control sites in each height category, with vertical structure being greater inside the exclosure than on control sites ($N = 20$; $Z$ range for 5 height categories $= 4.7$–$5.3$; $P < 0.0001$; Fig. 1) Within the exclosure, profile board foliar cover ranged from 72% (SE = 6.4) in the 2.0–2.5-m height category to 85% (SE = 4.2) in the <0.5-m height category. Vertical structure was less in control sites with cover of the profile board ranging from 12.8% (SE = 3.8) in the 1.5 to 2.0-m height category to 30.8% (SE = 6.8) in the 0.5-m height category (Fig. 1).

Line intercept surveys revealed that ground cover of the exclosure area was dominated by selected vines and shrubs that are favored deer browse plants (Halls and Ripley 1961). Primary understory (<1.5-m tall) plants were blueberry (*V. arboreum, V. myrsinites, V. ellioti, V. stamineum*), yellow jessamine, large gallberry (*Ilex coriacea*), and small gallberry (*I. glabra*). Browse species found only along exclosure transects included American holly (*I. opaca*), southern arrowwood (*Virburnum dentatum*), and ground blueberry (*V. myrsinites*). Midstory (1.5–4.6-m tall)

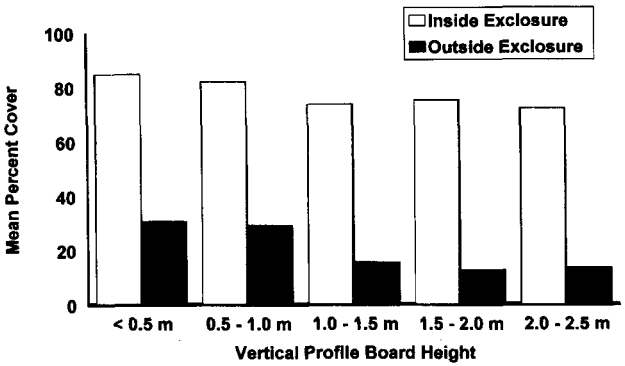


**Figure 1.** A comparison of horizontal foliar density at 5 height categories within an 18-year-old exclosure site and sites accessible to browsing by white-tailed deer on Leaf River Wildlife Management Area in Perry County, Mississippi in July 1996. ($N = 20$; $P < 0.0001$).

within the exclosure was dominated by blueberry, gallberry, yaupon (*I. vomitoria*), horse sugar (*Symplocus tinctoria*), and yellow jessamine. Southern arrowwood was found in the exclosure midstory, but was absent in midstory of control sites (Table 1), Black cherry (*Prunus serotina*), and selected oak species were present in exclosure midstory at slightly higher coverages than in control sites (Table 1). Plants dominating understory and midstory vegetation along control transects included spike grass (*Chasmanthium sessiliflora*), American beauty berry, sweetgum, red maple, and wild

**Table 1.** Mean (± SE) percentage cover of selected woody genera in understory (<1.5 m) and midstory (1.5–4.6 m) within an 18-year old deer exclosure and 2 unexclosed sites at Leaf River Wildlife Management Area, Perry County, Mississippi in July 1997.

| | Understory | | | | Midstory | | | |
|---|---|---|---|---|---|---|---|---|
| | Control | | Exclosure | | Control | | Exclosure | |
| Plant genus | $\bar{x}$ | SE | $\bar{x}$ | SE | $\bar{x}$ | SE | $\bar{x}$ | SE |
| *Acer* | 6. 2 | 4.0 | 3.3 | 1.21 | 3.9 | 2.41 | 7.6 | 3.9 |
| *Calicarpa* | 0.3 | 0.3 | 0.0 | | 2.8 | 1.3 | 0.0 | |
| *Gelsemium* | 0.9 | 0.6 | 20.1 | 5.3 | 0.0 | | 3.0 | 1.8 |
| *Ilex* | 0.0 | | 22.0 | 2.8 | 0.7 | 0.5 | 10.4 | 4.8 |
| *Liquidambar* | 1.0 | 0.4 | 0.2 | 0.1 | 5.7 | 0.3 | 2.0 | 1.2 |
| *Prunus* | 0.0 | | 0.8 | 0.9 | 2.5 | 0.7 | 8.4 | 4.7 |
| *Rubus* | 0.9 | 0.4 | 0.8 | 0.3 | 0.0 | | 0.0 | |
| *Smilax* | 0.3 | 0.2 | 2.3 | 0.3 | 0.2 | 0.2 | 0.7 | 0.7 |
| *Symplocus* | 0.7 | 0.7 | 1.3 | 0.8 | 0.3 | 0.2 | 8.0 | 2.9 |
| *Vaccinium* | 1.7 | 1.0 | 31.3 | 7.4 | 0.5 | 0.5 | 23.0 | 8.2 |
| *Viburnum* | 0.0 | | 1.7 | 1.6 | 0.0 | | 2.0 | 1.4 |
| *Vitis* | 10.7 | 4.5 | 3.7 | 1.2 | 1.9 | 1.9 | 2.4 | 0.6 |
| *Quercus* | 2.8 | 0.9 | 3.8 | 1.5 | 1.8 | 1.1 | 16.4 | 2.9 |
| Total cover | 26.1 | (a)[a] | 92.4 | (b) | 18.6 | (a) | 83.9 | (b) |

a. Different letters in parentheses denote difference at $P < 0.05$ level.

grape (*Vitis* spp.; Table 1). Bare ground and detritus where no vegetation was growing averaged 62.8% (SE = 20.1) in control sites, compared to 16.0% (SE = 2.1) within the exclosure.

Ground cover surveys revealed 43 species on control sites and 59 species on the exclosed site. Thirteen species of soft-mast-producing shrubs and vines and 3 herbaceous species were restricted to exclosure habitat. These plants included 4 species of greenbriar, 3 species of wild grape, 2 species of hawthorne (*Crateagus* sp.), huckleberry (*Gaylussacia* sp.), southern arrowwood, American holly, wild azalea (*Rhododendron canescens*), and rosebud orchid (*Cliestes divaricata*), a rare, state-listed species.

## Discussion

Our study exhibited how white-tailed deer have affected shrub and vine coverage, vertical structure, and plant species richness on a localized basis under specific forest stand conditions over an 18-year period. The lack of replicated exclosure sites was a weakness in our study; however, the vast differences in plant species richness and plant community structure observed between exclosed and control sites is noteworthy from a resource management standpoint. An important condition documented in our study was the difference in plant species composition of midstory and understory between unprotected and protected sites. Two major factors probably contributed to the development of the different plant communities. The 18-year time span of protection from browsing by deer allowed an extended period of time for community development with and without cervid herbivory. Additionally, the exclosure was established at a time when densities were estimated at 9 deer/km$^2$. If establishment of exclosure had occurred at excessive deer densities, palatable browse and herbaceous species may have been impacted beyond recovery within exclosed areas prior to fencing. Waller and Alverson (1997) recommended establishment of exclosures before deer become so numerous that palatable herbaceous plants were extirpated.

Several studies have reported browsing impacts on plant diversity and survival of protected flora on lands managed specifically for conservation and restoration of native biological diversity (Waller and Alverson 1997, Miller et al. 1992). Augustine (1997) reported selective browsing on *Trillium* and *Uvularia* even when these plants became scarce. Ninety-eight species of rare orchids, lilies, and dicots were reported to be adversely affected by deer herbivory (Miller et al. 1992). Browsing effects have become so severe in some areas that conservatory preserves resort to fencing of rare plant colonies (Miller et al. 1992). Confinement of a state-listed orchid within our exclosure raises questions about deer browsing effects on rare plants in Mississippi.

Although our study did not examine the direct effects of browsing on other trophic levels, we can infer effects because of the differences in soft-mast-producing shrubs between control and exclosure sites. Shrubs, such as blueberries, viburnums, and hollies, that were scarce on browsed sites produce foods for songbirds, woodpeckers, rodents, and selected furbearers (Halls and Ripley 1961, Martin et al. 1961). Additionally, flowers of these species produce nectar and pollen, which attract insects

that may be rare or important as a food source for other organisms. Depressed populations of the federally-endangered Karner blue butterfly (*Lyaceides melissa samuelis*) resulted from heavy browsing on its host plant, lupine, in New Hampshire (Miller et al. 1992). Breeding birds, such as yellow-billed cuckoo (*Coccyzus americanus*), wood thrush (*Hylocichla mustelina*), and forest-dwelling warblers (*Vermivora, Dendroica,* and *Wilsonia spp.*) depend almost exclusively on insect and invertebrate foods during spring and summer months (Martin et al. 1961). Soft mast of shrubs and vines composed >60% of spring and summer diets of the federally-threatened Louisiana black bear (*Ursus americanus luteolus*) in Mississippi forests (B. D. Leopold, Miss. State Univ., unpubl. data). Availability and periodicity of berry production by blueberries, swamp privet (*Foresteria acuminata*), and blackberry in Mississippi influenced movement patterns of Louisiana black bears (B. D. Leopold, Miss. State Univ. unpubl. data).

Reduction in vertical structure within forest stands can have negative effects on nesting and escape cover for selected nongame birds. In Pennsylvania, DeCalesta (1994) found that canopy nesting birds declined in abundance and species diversity when deer populations exceeded ≥14.9 deer/km$^2$. McShea et al. (1997) reported that high deer densities had multiple effects on bird species nesting at several forest layers and involved complex species interactions. Loss of midstory structure combined with changes in plant species composition may affect microsite conditions for nesting birds. In our study, vertical structure differences between control and exclosure sites can be attributed to differences in height of plants, variations in growth form and horizontal foliar density between species, and differences in stem densities. Due to foliage density and growth form, control site trees (sweetgum and red maple) and shrubs (beauty-berry) produced less dense horizontal cover than exclosure site shrubs (hollies and blueberries) even when heights were similar. These differences may impact nesting and escape cover for birds. However, literature addressing potential microsite variations between different midstory tree and shrub species is lacking for the southeastern United States. At least 38 forest-dwelling bird species, including residents, temperate migrants, and neotropical migrants, nest or feed in dense cover that is ≤2 meters in height (Hamel et al. 1982). Selected birds of this group, such as yellow-billed cuckoo, wood thrush, Kentucky warbler (*Oporornis formosus*), hooded warbler (*Wilsonia citrina*), worm-eating warbler (*Helmitheros vermivorus*), painted bunting (*Passerina ciris*), and Swainson's warbler (*Limnothlypis swainsonii*), are experiencing population declines over their range and have high concern ratings in Mississippi (M. Woodrey, Nat. Heritage Program-MDWFP, unpubl. data). Habitat loss and changes caused by anthropogenic activities are primary factors in the decline of these species. However, high rates of herbivory may limit bird species richness, even on lands specifically managed for avifauna (Casey and Hein 1983, McShea et al. 1997).

Long-term exclosure studies can assist wildlife managers in demonstrating the ecological ramifications of maintaining deer or other herbivore populations within the bounds of habitat carrying capacity. However, these studies should be well-designed to produce reliable data. We recommend several considerations for the design of future exclosure studies. Although our study was based on results from a

single exclosure, the length of time the exclosure existed facilitated detection of changes in plant species composition. Exclosures should be maintained for a minimum of 5 years for detection of species compositional changes. Researchers should consider pre-project herbivore densities and potential impacts on vegetation within study sites when interpreting data. Exclosure studies should be replicated in several forest types and soil resource areas to account for variability related to edaphic and vegetation conditions. History of land use, ongoing land management, and large herbivore populations should be considered in selection of control and exclosure sites. If data on habitat use by small mammals, birds or herpetofauna is desired, exclosures of ≥2.0 ha are recommended. In addition to the vegetation parameters measured in this study, quantification of flower and fruit production and stem height is advised.

Biological data produced by well-designed exclosure studies can be important in public education concerning the need for regulation of deer numbers. This approach may be important in providing sound, biological information in addressing anti-hunting literature and organizations. In a recent issue of The Fund for Animals, contraception for population control and fencing for protection of rare plants was proposed to win arguments against the need for deer harvest (The Fund for Animals 1997). Exclosure studies may show that fencing will protect rare plant communities. However, Leaf River WMA and surrounding DeSoto National Forest provides habitat for >60 species of state-listed flora and fauna. Fencing >100,000 ha of these public lands is not a cost-effective approach to limit the effects of an overpopulated deer herd. Management of cervid populations through regulated harvest provides multiple benefits to users, including subsistence, recreational, and ecotourism values. We believe that population management of white-tailed deer should be viewed as an integral component in the maintenance diversity of native plant and animal communities.

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