# IMPACTS OF WHITE-TAILED DEER ON THE VEGETATION OF CADES COVE, GREAT SMOKY MOUNTAINS NATIONAL PARK

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*Abstract:* The impact of a concentrated (.52 deer/ha) herd of white-tailed deer (*Odocoileus virginianus*) on the vegetation in Cades Cove is discussed. Utilization by cattle and horses had a greater impact on the woodlots in the cove than utilization by deer. Livestock reduced the number of vascular plant species and woody stem counts in all strata sampled. Deer utilization reduced the total plant species number and favored conifers in the 3 cm dbh and smaller stem size classes. Species such as dogwood (*Cornus florida*), white oak (*Quercus alba*), and redbud (*Cercis canadensis*), which were common on limestone elsewhere in the Great Smoky Mountains National Park, were much reduced around Cades Cove. The intensive impacts of deer on vegetation do not appear to extend more than 1 km from Cades Cove.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 33: 305-312

Among wildlife resource concerns in Great Smoky Mountains National Park (GSMNP), the white-tailed deer is the only native animal which presents a problem of apparent over-population. National Park Service policy favors natural ecosystem and population dynamics. Hunting is not permitted in GSMNP and no attempt has been made to either cull native animal populations or increase them by techniques such as habitat manipulation. Although the exotic European wild boar (*Sus scrofa*) has caused habitat degradation in a variety of plant communities in GSMNP (Bratton 1975, 1977), the white-tailed deer is generally considered to be in balance with ecosystems throughout the park. The exception is in the case of Cades Cove (the Cove), an historic district which uses agricultural management to maintain open vistas and a cultural landscape. Deer and other wildlife species are attracted by the abundance of food in the hayfields and pastures, complemented by the abundance of cover in the woodlots and adjoining forest.

Among the problems presented by the concentration of deer in Cades Cove are the possibility of disease outbreaks and die-offs (Fox and Pelton 1973), browse damage to native plants, and the alteration of the community structure of a number of unique habitats on limestone outcrops or in sinkholes. The purpose of the following study was to quantify possible deer impacts on the vegetation of Cades Cove and the surrounding area. Since several of the woodlots in the Cove had been included in cattle or horse pastures, the impacts of livestock also had to be discriminated.

I thank Uplands Field Research Laboratory staff, especially D. Kilgore, M. Harmon, and P. White, and the Ranger Division of GSMNP, especially S. Coleman, J. Clabough, and K. Higgins.

## MATERIALS AND METHODS

The study area, in the western end of GSMNP, Blount County, Tennessee, included Cades Cove, the lower end of Abrams and Panther Creeks, and Ledbetter Ridge. Cades Cove, an historic area, is in the National Register of Historic Places, and is excluded from natural area or wilderness management. Aside from fields, the Cove includes a number of historic structures and developments such as a campground, maintenance compound, and staff residences. The present system of hay and cattle leases was developed in 1967. It originally included provisions for grazing about 1,500 animals in the Cove, but the number was reduced to about 400 in 1977.

Cades Cove is actually a limestone "widow" where older sandstones and shales have been thrust over younger Ordivician limestone now exposed on the valley floor (King *et al*

1968). Limestone is an unusual substrate in the park (there are 3 other smaller windows), and the Cove contains unique geologic formations such as caves, outcrops, sinkholes, and sag ponds. Cades cove and Whiteoak Sink, the second largest limestone area, are important rare plant habitats (Bratton 1979). According to Burst and Pelton (1978), the 977-ha area of the Cove supported an estimated 519 deer in the summer of 1977 (.52 deer/ha).

The basic technique used in this study was the sampling of .1-ha vegetation plots in Cades Cove and in ecologically similar control areas with fewer deer. Sampling was conducted during the summers of 1976 and 1977. Forty-one plots were placed in fields, woodlots, and the forested edge zone around Cades Cove. An attempt was made to sample at least 1 area grazed by livestock and at least 2 areas utilized only by deer in each of 5 major forest types (based on F. Miller's 1936 vegetation survey and initial field observations on past agricultural succession): (1) white pine, hardwoods; (2) white oak, pine, hardwoods; (3) mixed hardwood stream flat (old homesite); (4) yellow pine; and (5) mixed oak, yellow pine. Control plots from Big Springs Cove and from the Abrams Creek and Panther Creek drainages were located to represent each of the above major forest types. An additional 20 plots placed at different aspects and elevations on Ledbetter Ridge were used to establish a gradient in elevation and distance from the edge of Cades Cove to the top of the ridge between Spence Field and Russell Field.

The plots were then divided into the following general groups: (1) Cattle - Grazing by cattle or horses within the last 15 years and also used by deer; (2) Deer - Possible intensive deer use (within 750 m of an open field in Cades cove but no recent history of livestock use); (3) Edge - Edge zone (more than 750 m from a field but below the 750 m elevation contour above Cades Cove); (4) Control plots - deer present but outside Cades Cove; (5) Elevation series - The elevation series from Cades Cove to Ledbetter Ridge.

Plots were placed away from the edge of woodlots and in as consistent vegetation as possible. Each plot was 20 x 50 m, with the 50-m side parallel to the contour. The diameter at breast height (1.4 m above the ground; dbh) for every stem from 1 cm to 9 cm in diameter (the understory) was recorded by species. All stems 10 cm or greater in dbh (the canopy) were mapped by distance and aspects from points on the center line and identified by species.

Twenty-five $4m^2$ shrub plots were established in diagonal lines of 5 plots each, starting in a random corner of each of the 5 10 x 20m subplots. Within each $4m^2$ quadrat, all shrub and seedling woody stems were counted by size class at 5 cm above the ground. The classes were: 0 to 2.0 mm; 2.1 to 6.0 mm; and greater than 6.0 mm. Cover was estimated by species for each 4 $m^2$ quadrat. This stratum is termed the shrub layer, although it also includes tree seedlings. Herb cover was estimated for a 1 $m^2$ quadrat in the lower corner of each 4 $m^2$ shrub quadrat. All additional vascular species found in the 20 x 50 m plots were listed and included in the total species counts. Other values collected for each plot included slope, aspect, distance from water, distance from the nearest ridge, grazing history, and distance from an open field. Wild boar rooting was estimated by percentage of the surface area disturbed and percentage bare soil.

Deer browse in this paper refers to any type of damage to woody plants, not just consumption of twigs (Table 1). As pointed out in Cushwa et al. (1970), leaves, buds, and succulent twigs are more important to southeastern deer than hardened twigs; field observations indicate this may also be ture in the Cove.

The first step in the data analysis was to obtain plot summaries and basal area, and total stems by species and stratum. The canopy data were then ordinated using principal components analysis (Orloci 1966, Gauch 1973), to determine similarities between plots based on the combined basal area of the canopy and understory. Forest typing was done using these ordinations (to check the decisions made in the field) and 5 groups of representative stands (1 cattle, 1 or 2 deer, and 1 or 2 control) were selected for use in some

TABLE 1. Deer browse classes used for evaluating browsing impact in Cades Cove, GSMNP.

| |
|---|
| 0 - No evidence of deer use |
| 1 - Small amount of browse, just a few twigs clipped from preferred species |
| 2 - General clippings of preferred species, no obvious mortality of seedlings |
| 3 - Moderate impact, clipping of a variety of species |
| 4 - Heavy impact, almost all shrubs show browse, mortality or height reduction evident deer trails in or near plot |
| 5 - Understory removal, shrubs and tree seedlings clipped back to the stem or to the ground, largely stump sprouts and first year seedlings present of preferred and staple species |

analysis of variance procedures where forest type differences were likely to influence the dependent variable. Means were computed using the Statistical Analysis System (Barr and Goodnight 1976) procedure MEANS. Linear models, including linear regression, analysis of variance (ANOVA) and analysis of covariance were computed using procedure GLM.

## RESULTS

Differences in species number and stem number for the upper strata of the cattle, deer, edge, and control plots are statistically significant at the .01 level of probability, using a one-way ANOVA between cattle, deer, and control plots. Basal area did not show a decrease with grazing or browsing and was generally higher in the Cades Cove plots than in the controls. These patterns are consistent from forest type to forest type, and corrections made for differences due to elevation (using linear regressions from undisturbed plot data including the elevation series and the controls) indicate that the slightly lower average elevation of the control plots is probably not responsible for the patterns.

Livestock impacts reduced the canopy plus understory species count to an average of 11.5 species per plot when the expected value was 22.5 species and reduced the stem count to an average of 116 stems per plot (not including evergreen heaths) when the control plots average 340 stems (Table 2). The impacts of livestock were so intensive, it is difficult to determine if they were at all species selective. Very few stems were left in the understory (Fig. 1).

Deer also caused an apparent reduction in plant spcies number per plot. Deer plots averaged 15.8 species per plot, which is about 6 species less than the expected value. The plot from Big Spring Cove, a limestone area very similar to the stream flats in Cades Cove, had 36 species present in the upper strata. Deer have not yet greatly reduced the number of stems found in the upper strata, nor have they influenced the total basal area of the plot (Table 2).

Rather than greatly reducing the number of understory stems, deer utilization changed the species composition. The most notable shift was in the ratio of deciduous stems to conifers. Particularly in the 1 cm to 3 cm size classes, conifers were relatively more important in the deer plots (Fig. 2). Much of this increase was hemlock (*Tsuga canadensis*) and white pine (*Pinus strobus*). The changes in the ratios were statistically significant at the .05 level of probability using two-way ANOVA, both in respect to the type of disturbance (the selection for conifers does not apply to the cattle plots) and to the dbh class.

Of the deciduous species still present in the smaller stem size classes, red maple (*Acer rubrum*) was the most common in the deer plots. In the deer plots, oak saplings were

TABLE 2. Grazing and browsing impacts on forested plots in and near Cades Cove, GSMNP.

| | Plot average | | | | Probability + of a greater f | |
|---|---|---|---|---|---|---|
| | Cattle | Deer | Edge | Control | Cattle-Deer | Deer |
| Canopy plus understory | | | | | | |
| Number of plots | 6 | 20 | 7 | 13 | | |
| Elevation (m) | 555 | 565 | 665 | 427 | | |
| Number of species | 11.5 | 15.8 | 19.9 | 24.9 | .0001 | .0001 |
| Expected at elevation | 22.5 | 22.4 | 20.9 | 25.2 | | |
| Number of stems per .1 ha (minus evergreen heath) | 116 | 290 | 288 | 340 | .0048 | .4945 |
| Basal area ($m^2$/ha) | 40 | 33 | 36 | 28 | .0021 | .0122 |
| Understory | | | | | | |
| Basal area ($m^2$/ha) | .16 | .59 | .54 | .83* | .1254 | .4536 |
| Number of stems (minus ericads) | 216 | 694 | 500 | 732* | .0783 | .1959 |
| Total cover % | 4.3 | 19.5 | 23.4 | 43.4* | .0021 | .0012 |
| Cover without ericads | 3.6 | 10.2 | 11.2 | 18.7* | .0008 | .0061 |
| Number of species | 17.7 | 19.4 | 22.9 | 29.6* | | |
| Expected at elevation | 26.6 | 26.6 | 24.1 | 29.4 | .0001 | .0001 |

*Average for only 7 of the control plots, since some of the samples did not have total stem counts for all species.
+ The effect of status from two-way ANOVA's which tested for the significance of forest type. The first column is cattle/deer/control as classes and the second is just deer/control.

uncommon and species such as dogwood (*Cornus florida*) were much reduced. A control plot from Big Spring Cove, for instance, had 35 white oak (*Quercus alba*) saplings and 96 dogwood stems in the 1 cm to 3 cm size classes. Very few deer plots had more than 1 or 2 white oak in those size classes (most had none), and most deer plots had 5 or fewer dogwood stems.

The shrub stratum was naturally more variable in terms of total basal area and cover than were the upper strata. Shrub data, therefore, presented more difficulties in terms of analysis, and the patterns may not correspond directly to the canopy results. As in the case of the upper strata, there was a reduction in the species number in the shrub layer of the cattle plots, but it was less dramatic (Table 2). The difference in species between the cattle and deer plots was also not as marked as in the case of the canopy. Stem counts in the cattle plots were less than one-third those of the controls (although the difference was not statistically significant at the .05 level of probability) and the non-ericaceous cover was about 20% of the expected. Although the result may be partially due to the selection of woodlots with fewer heaths for livestock grazing, the cattle plots had about 10% of the shrub cover of the controls when ericads were included. In cattle plots, species whose mature height was less than 2 m had about 25% of the cover of those which could

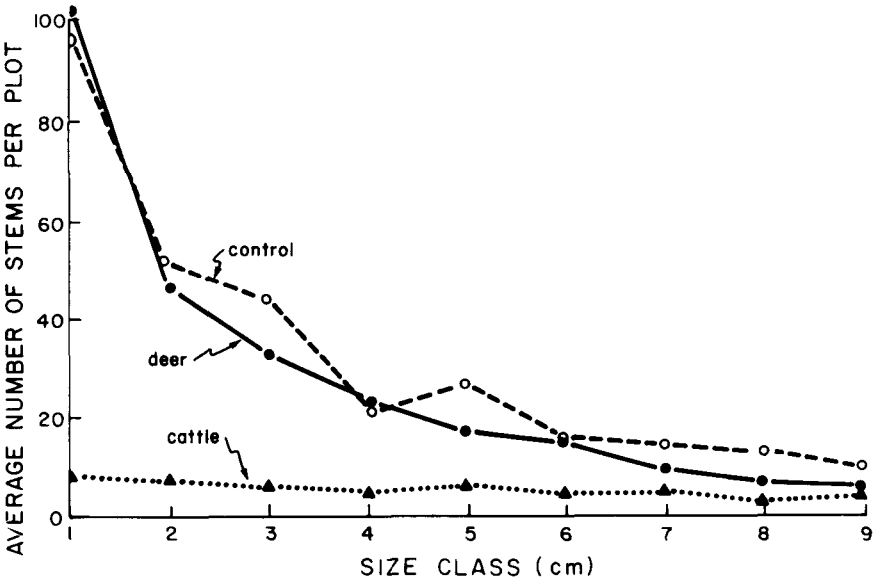


Fig. 1. The effect of deer and cattle on the average number of stems per plot. These curves were obtained from data adjusted for forest type (5 types represented) and with the evergreen heaths removed. The stem size classes are divided into 1 cm groups. Five cattle impacted plots, and nine each of deer impacted and control plots are included in the averages.

potentially be tree sized (8 m or greater). In all other types of plots, the cover of the smaller species in the shrub layer was greater than that of those which are potentially tree sized.

Deer plots had fewer species than expected (19.4 for deer plots, 26.6 expected) and their cover was about half that of the control plots. The edge plots were very similar to the deer plots in terms of shrub cover, species number, and stem count (Table 2).

As in the case of the canopy, conifers were relatively less impacted by deer than deciduous species. The average cover of hemlock and pine in the deer plots was 2.91% and in the control plots was 3.26%. The cover of deciduous, non-ericaceous species in the deer plots was 5.77% and in the control plots was 12.20%. A change in the cover to stem count ratio from the cattle plots (.02) to the deer plots (.05) to the control plots (.13) indicated a greater percentage of the coniferous cover in the cattle and deer plots was due to small seedlings. Deer may be browsing small conifers without killing them, or impacting the larger seedlings and leaving the smaller ones. The deciduous cover to stem ratio also changed, but not as strongly, from .02 in the cattle and deer plots to .04 in the control plots.

An attempt was made to divide the species present in the shrub layer into browse preference classes based on the literature available on the food habits of deer in the southern Appalachians. The cover reduction was of similar magnitude for all deciduous species - preferred, staple, or unknown preference, and all groups showed a statistically significant ($P<.05$) reduction in species number and cover. The reduction in species number per plot was greatest for species which are uncommon or of unknown preference, possibly because most of the preferred or staple species are relatively widely distributed or continue to reproduce in disturbed situations.

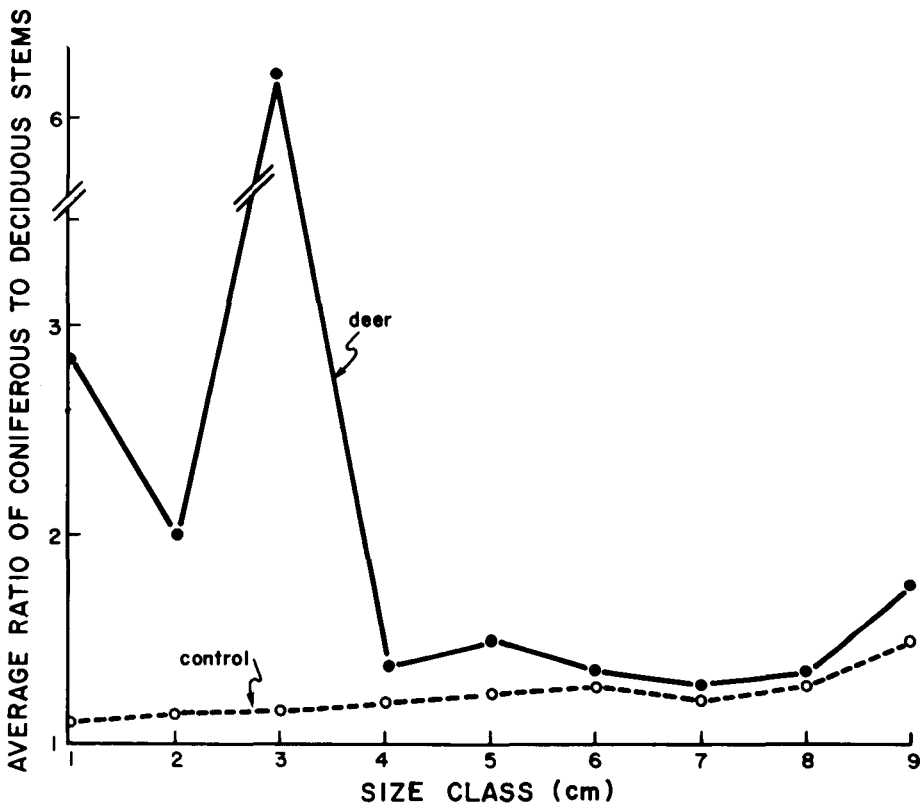


Fig. 2. The effect of deer on the ratio of coniferous to deciduous stems by size class. Intensively deer browsed stands show a relative increase in the number of coniferous stems present in the smaller size classes. The graph shows the average ratio (not the ratio of the averages) for nine sites each from deer impacted and control areas. The stands are adjusted in matched pairs by forest type.

The herbaceous components of the sample plot were even more variable than the woody understory and trends were difficult to establish. The open fields were dominated by grasses, such as crab grass (*Digitaria* spp.), and forbs such as clover (*Trifolium* spp.) and plantains (*Plantago* spp.). Cattle plots, however, tended to have almost no herbs or else were dominated by a grass resistant to grazing, *Microstegium vimineum*. *M. vimineum* was also common in some deer plots but the herb diversity was much greater.

An analysis of the elevation series plots did not show any significant correlations between deer browse ratings and their elevation. Although all plots sampled within 1 km of an open field had a rating of 3 or higher (Table 1), no plot over 1 km from an open field had a rating over 3. Deer browsing activity did appear to decrease on the slopes above the lower deciduous coves but probably increased slightly again around the grassy balds, which are open successional areas, and in the higher elevation hardwood forest.

## DISCUSSION

The results showed that livestock grazing, browsing, and trampling removed the smaller stems and had a much greater impact on the stands than did deer utilization by

itself. The most severe browse lines were due to livestock rather than to deer; however. sites where stock had been excluded within the last 5 years showed very little recovery in the understory, probably because deer continue to use these stands and to consume the younger, more succulent shoots and seedlings. Livestock utilizatin may have a relatively greater impact on shrub species per se than on tree species present in the shrub layer, possibly because trees often root or stump sprout, and a number of tree specie have widely dispersed seedlings.

With intensive utilization, the species composition of the stands in the cove can be expected to change through time, resulting in forests that may be "unnaturally" poor in hardwood species. the reduction in species number per plot indicates that deer utilization may be a threat to some of the less abundant plant species. Deer could impact the reproduction of plants like *Itea virginica*, known only from a few locations in GRSM.

The reductions in species number found during this study may actually be conservative estimates of change, as most of the control plots are underlain by sandstone and shale, and limestone areas often support more diverse plant communities than acidic sites. The impact of the deer attracted to Cades Cove may extend into some of the old homesites and other deciduous successional areas above the 2,000-foot contour, which is the official boundary of the historic area, but intensive disturbance of forest reproduction is largely confined to the woodlots in the Cove and the first few hundred meters of the forest edge. This indicates that at present there need be little concern for impacts on the adjoining natural area.

Although it is difficult to determine if deer have degraded flowering displays, redbud (*Cercis canadensis*) was conspicuously absent from the limestone outcrop and stream flat plots in Cades Cove; yet it is a common understory species in other limestone areas like Whiteoak Sink. The reduction of small stems of dogwood may eventually result in its absence from most of the forested areas near open fields.

Future research needs for Cades Cove include further population monitoring of the deer herd and the gathering of information of their movements in and out of the Cove. The impacts on woody plants reflect what is already known about deer food habits in the mountains and in agricultural areas. The studies by Harlow and Hooper (1970), Harlow and Downing (1970), Harlow et al. (1975), Ripley and McClure (1963), Cushwa et al. (1970), and Nixon et al. (1970) already provide a firm base for predicting what deer are consuming, and the field observations of the author indicate their work is generally applicable in GSMNP. The data show, however, that browse preference classes may not be very useful for predicting the presence or absence of the various deciduous species in a stand. It would be valuable to establish a system for monitoring rare plant populations and determine if the reproduction of any of the uncommon woody species is being significantly reduced by deer.

If direct reduction of the deer were attempted, these results indicate that a short program, 2 to 5 years, for example, would not allow for complete recovery, since the impacts extend to the 3-cm size class. The possibility of fencing some of the sensitive sites and unique plant communities should be seriously considered, but the areas should first be surveyed in detail and the project designed so it could be integrated with work on wild boar impacts.

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