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# IMPACT OF WHITE-TAILED DEER ON FOREST COMMUNITIES WITHIN BROWN COUNTY STATE PARK, INDIANA

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ABSTRACT: The white-tailed deer (*Odocoileus virginianus*) is an herbivorous species that can significantly influence the structure of forest communities wherever it occurs in excessive numbers. This species has a propensity to increase beyond the carrying capacity of its habitat when predation pressure is reduced. The influence of white-tailed deer on the plant communities within Indiana's State Parks, which have been closed to hunting by man for several decades, are explored in this paper. During 1993 and 1994, sites (stratified by physiographic position) were sampled within Brown County State Park and adjacent State and National Forests (open to public hunting). A reduction in the percentage cover of the ground flora and the mature height of some specific plant species inside Brown County State Park as compared to external sites subjected to hunting pressure was noted. In addition, the recruitment of many woody species into larger size classes was reduced significantly within Brown County State Park. The current forest structure within Brown County State Park indicates that this reduction in recruitment has been occurring for many years. The reduction in recruitment, along with the damage documented within the herbaceous layer, suggests that the sustainability and structure of the forests within the park may ultimately be affected unless deer numbers are controlled and the forest understory is allowed to recover.

KEYWORDS: *Adiantum pedatum*, Brown County State Park, Indiana, percentage cover, plant communities, species richness, white-tailed deer.

## INTRODUCTION

White-tailed deer, along with large predators, had been eliminated from Indiana by 1900 (Mumford and Whitaker, 1982). In 1934, the Federal Aid to Wildlife Restoration (Pittman-Robertson Act) provided funds for the reintroduction of white-tailed deer into southern Indiana (Mumford and Whitaker, 1982). These introduced deer benefitted from a landscape of second-growth forests, openings, and farmlands that had been created by logging, clearing, and agriculture (Smith, 1991).

By 1948, the Pittman-Robertson project reported an overabundance of deer and deer-induced damage to agricultural and native plant communities, leading to the first modern hunt within 17 Indiana counties in 1951 (Mumford and Whitaker, 1982). State Parks in Indiana were closed to hunting and have remained so until recently. Restricted hunting has allowed the white-tailed deer populations in some State Parks to expand beyond the capacity of their habitat to support them.

Deer have a selective foraging strategy when food resources are abundant, but they change to a more generalist strategy as resources are depleted (Brown and Doucet, 1991; Strole and Anderson, 1992; Kohlman and Risenhoover, 1994). Selective foraging by a generalist species is a learned behavior which maximizes nutrient intake but is subject to constraints at low levels of food availability (Westoby, 1974). Deer are known to select a species according to its chemical composition, and intake has been found to be constrained by forage toxicity (McArthur, *et al.*, 1993). These foraging strategies often lead to browse species preference. Several studies show that deer select certain herbaceous and woody species over others (Korschgen, 1962; Nixon, *et al.*, 1970; McCaffery, *et al.,* 1974). This foraging strategy is termed the "optimization model," and the model implies that the grazing pressure on a species within a plant community may increase as that species becomes rarer (Westoby, 1974).

Foraging strategies have been found to be sensitive to changes in plant availability (Kohlman and Risenhoover, 1994). Deer avoid nonpreferred browse species even when more preferred species become depleted. Deer search for and consume preferred forage until it becomes rare before switching to an apparently less desired species (Gillingham and Bunnell, 1989). Deer density may also affect food selection. Preferred foods, such as acorns, were found to be utilized more quickly by a larger deer population (McCullough, 1985; Kohlman and Risenhoover, 1994). Therefore, at higher population levels, deer could significantly alter plant communities by extirpating the more preferred species.

Evidence of intensive browsing by white-tailed deer in forest plant communities has been documented (Marquis, 1974; Alverson, *et al.*, 1988; Strole and Anderson, 1992; Balgooyen and Waller, 1995) and found to negatively effect the regeneration of some tree species by reducing their recruitment and survival (Marquis, 1974; Strole and Anderson, 1992). This effect on regeneration has been studied in the eastern hemlock (*Tsuga canadensis*) forests of northeastern Wisconsin, where, in areas that are heavily browsed, sugar maple (*Acer saccharum*) rapidly replaces hemlock (Anderson and Loucks, 1979). However, Anderson and Loucks (1979) also found that once browsing pressure was relieved, the hemlock recovered. Their finding suggests that a species subject to intensive browsing may recover if the pressure is reduced. In addition, the amount of browsing pressure on certain preferred forage species could be used as an indicator of deer abundance within an area (Korschgen, 1962).

In 1993, a committee was established by the Indiana Department of Natural Resources to develop alternative solutions for managing the excessive popu-

lation of white-tailed deer within Brown County State Park, Indiana. The committee concluded that the deer were seriously damaging understory vegetation and recommended a limited hunt within the park boundaries. This hunt occurred in December 1993. The committee also initiated a study to investigate the effects of overbrowsing on understory vegetation (Brown County State Park Deer Study Committee, 1993). The forest communities within Brown County State Park, Yellowwood State Forest, and Hoosier National Forest (the latter two are both open to hunting) were sampled in 1993 by James Van Kley (a Ph.D. student at Purdue University) to determine the impact of white-tailed deer on the vegetation. Preliminary measurements of the structure of the plant community and the browse damage within Brown County State Park indicated that the deer were browsing heavily on selected herbaceous and woody species and significantly reducing the percentage cover, species richness, and mature heights of the ground flora species. This study also found a difference between the southwestern corner and the main body of Brown County State Park, with the southwestern corner showing less damage (Parker and Van Kley, 1993). Parker and Van Kley (1993) theorized that because the southwestern corner was bordered by Yellowwood State Forest and Hoosier National Forest, the deer in the southwestern corner of Brown County State Park experienced more hunting pressure than those within the main body of the park.

Permanent study areas were not established by Van Kley to observe trends in browse damage. Therefore, the current study was initiated in the spring of 1994 to determine the structure and composition of the plant communities following the removal of 392 deer in December 1993. Permanent plots were established to monitor changes in the plant communities in response to long-term change in deer populations.

## STUDY AREAS

Brown County State Park, located in south-central Indiana, was first opened in 1929 and is Indiana's largest State Park at 6,358 hectares. The park is located within the Brown County Hills Section of the Highland Rim Natural Region (Homoya, *et al.*, 1985). This area is defined by acid silt loam soils with a small amount of loess and characteristic topographic features such as deeply dissected uplands, steep slopes, and narrow hollows (Homoya, *et al.*, 1985; Van Kley and Parker, 1993). Uplands are dominated by oak-hickory forest (Homoya, *et al.*, 1985); common plants on the upper slopes are chestnut oak (*Quercus prinus*), common greenbrier (*Smilax rotundifolia*), low growing shrubs, and sedges (in particular, painted sedge (*Carex picta*)). The ravines contain mesic species (Homoya, *et al.*, 1985) such as beech (*Fagus grandifolia*), red oak (*Quercus rubra*), sugar maple (*Acer saccharum*), and white ash (*Fraxinus americana*). Control areas were selected within Yellowwood State Forest and the Pleasant Run Unit of the Hoosier National Forest, which border the southwestern section of Brown County State Park. Both the State and National Forests are open to annual deer harvest.

## METHODS

Twenty sites within Brown County State Park and ten control sites in Yellowwood State Forest/Hoosier National Forest were randomly selected to establish permanent study plots. The 20 sites in the park were divided into eight sites in the southwestern corner, where less browsing was observed (Parker and Van Kley, 1993), and 12 in the main body of the park. The Ecological Classification System developed for the Pleasant Run Unit of Hoosier National Forest was used to determine similar physiographical units inside and outside the park (Van Kley and Parker, 1993). Sites were limited to closed-canopy, relatively mature forests and divided into four ecological landtypes: mesic northerly or northeasterly slopes, dry southerly or southwesterly slopes, mesic bottomlands, and dry ridges. One or a combination of these landtypes were sampled at each site; a total of 19 landtypes were sampled in Yellowwood State Forest/Hoosier National Forest, 16 within the southwestern corner of Brown County State Park, and 27 in the main body of Brown County State Park. All the sites were sampled within two months of each other to avoid site-to-site variation.

The following vegetative variables were measured using a series of nested plots at each sample location: the percentage cover of the ground flora, the species richness of the ground flora, and the stem density and species richness of the woody species within four size classes (1 = < 50 cm in height; 2 = 50 to 200 cm in height; 3 = > 200 cm in height and < 2.5 cm dbh; and 4 = > 200 cm in height and > 2.5 cm dbh). The mature heights of six herbaceous species were also recorded.

The percentage cover of the ground flora was measured using a ten-meter line transect running parallel to the contour of the slope in each landtype measured at a site. The length of overlap (cm) for the ground flora, including both herbaceous and woody class 1, was recorded and used to calculate the percentage cover for each species.

To record the number of stems and woody species in classes 1 and 2, a one meter by ten meter belt transect was established using the ten-meter line transect as its lower edge. The dbh of woody species in classes 3 and 4 was recorded within a 100 $m^2$ circular plot, the center of which was the start of the line transect.

Ground flora richness in each landtype was determined by recording all the herbaceous species found within the belt transect and circular plot. The species present within the circular plot were determined by walking concentric circles from the outer edge to the center.

Six species were chosen to test for differences in mature plant height within Yellowwood State Forest/Hoosier National Forest, the southwestern corner of Brown County State Park, and the main body of Brown County State Park. The chosen species showed dramatic differences in mean mature height in heavily browsed areas relative to less impacted ones (Parker and Van Kley, 1993). The species measured were: maidenhair fern (*Adiantum pedatum*), Jack-in-the-pulpit (*Arisaema triphyllum*), wild licorice (*Galium circaezans*), sweet cicely

(*Osmorhiza claytonii*), Christmas fern (*Polystichum acrostichoides*), and common greenbrier (*Smilax rotundifolia*). To determine mature height, the forbs were measured along the stem to the node with the highest leaf or whorl of leaves. For Christmas fern, the length of the longest frond was measured. Three to five plants of each species were measured within each belt transect and their heights were averaged to determine the mean height of the species. The percentage cover was also calculated for these species.

One-way analysis of variance was used to compare the means for vegetation variables among the sites within Yellowwood State Forest/Hoosier National Forest, the southwestern corner of Brown County State Park, and the main body of Brown County State Park. For tests of mature height and percentage cover of the individual species, only the landtypes in which the species were known to be common were used. These included mesic slopes and bottomlands for maidenhair fern, Jack-in-the-pulpit, wild licorice, sweet cicely, and Christmas fern. All sites were used for common greenbrier. An alpha level of $P < 0.10$ was used to delineate significant differences in the vegetation variables among the three sample areas.

## RESULTS

The average number of species was not significantly different in the three areas (Table 1). However, on average, more species were found in all landtypes in Yellowwood State Forest/Hoosier National Forest and the southwestern corner of Brown County State Park than in the main body of the park. The percentage cover of the ground flora was significantly reduced in the main body of the park compared to both its southwestern corner and the areas outside the park. The coverage of the ground flora averaged only 14.4% per sample site in all landtypes within the main body of Brown County State Park as compared to 27.8% in the park's southwestern corner and 21.7% in Yellowwood State Forest/Hoosier National Forest. The greatest difference in percentage cover of the ground flora was found on mesic and bottomland sites. Coverage within the main body of Brown County State Park was 50% less than inYellowwood State Forest/Hoosier National Forest.

Specific species exhibited differences in their percentage cover within the park when compared to the control areas (Table 2). Maidenhair fern and sweet cicely both exhibited a significantly lower percentage cover inside the southwestern corner and in the main body of the park when compared to Yellowwood State Forest/Hoosier National Forest. Sweet cicely did not intersect the transect within the park's southwestern corner at any sites and only overlapped the transect at 0.3% of the sites in the main body of the park as compared to 1.5% in Yellowwood State Forest/Hoosier National Forest. Christmas fern showed a significantly higher percentage cover in Yellowwood State Forest/Hoosier National Forest and the southwestern corner of the Brown County State Park relative to the main body of the park, where it averaged 0.9% per sample site. Common greenbrier had a significantly higher percentage cover in Yellowwood State For-

Table 1. Mean ground flora richness measured within a 10 $m^2$ belt transect and a 100 $m^2$ circular plot, and the percentage cover of the ground flora measured on a 10 m line transect observed at sample locations outside Brown County State Park, in the southwestern corner of Brown County State Park, and in the main body of Brown County State Park during 1994. Row means with different letters are significantly different ($P < 0.10$).

| Variable Sampled at Each Ecological Landtype | Yellowwood State and Hoosier National Forests | Southwestern Corner of Brown County State Park | Main Body of Brown County State Park |
|---|---|---|---|
| **All Sites** (n = 62) | | | |
| Ground flora richness | 21.5 a | 22.1 a | 19.8 a |
| Percentage cover of ground flora | 21.7 a | 27.8 a | 14.4 b |
| **Mesic Bottomlands** (n = 15) | | | |
| Ground flora richness | 32.0 a | 30.1 a | 28.9 a |
| Percentage cover of ground flora | 33.7 a | 40.9 a | 14.5 b |
| **Mesic Slopes** (n = 22) | | | |
| Ground flora richness | 24.6 a | 24.2 a | 21.5 a |
| Percentage cover of ground flora | 18.0 a | 22.0 a | 8.0 b |
| **Dry Slopes** (n = 15) | | | |
| Ground flora richness | 13.6 a | 14.0 a | 12.8 a |
| Percentage cover of ground flora | 22.3 a | 34.9 a | 23.1 a |
| **Dry Ridges** (n = 10) | | | |
| Ground flora richness | 7.5 a | 15.3 a | 13.0 a |
| Percentage cover of ground flora | 11.2 a | 14.7 a | 12.2 a |

est/Hoosier National Forest than in either area of the park. The percentage cover of greenbrier was significantly greater in the southwestern corner relative to the main body of Brown County State Park. Jack-in-the-pulpit and wild licorice displayed no significant differences in coverage among the three areas.

The mean heights of the mature plants for the six selected species were also compared (Table 2). Jack-in-the-pulpit and common greenbrier were found to be significantly taller in Yellowwood State Forest/Hoosier National Forest than in both the southwestern corner and main body of Brown County State Park. Maidenhair fern and Christmas fern were significantly shorter in the main body of Brown County State Park when compared to the southwestern corner of the park and Yellowwood State Forest/Hoosier National Forest. Both Jack-in-the-pulpit and maidenhair fern were approximately 10 cm taller within Yellowwood State Forest/Hoosier National Forest than in both the southwestern corner and the main body of the park. Common greenbrier averaged 45 cm taller in Yellowwood State Forest/Hoosier National Forest when compared to both

Table 2. The mean percentage cover and mean height for selected species observed within a 10 $m^2$ belt transect at sample locations outside Brown County State Park, in the southwestern corner of Brown County State Park, and in the main body of Brown County State Park during 1994. The values used are from landtypes where the species was common. Row means for heights and percentage cover of the ground flora with different letters are significantly different ($P < 0.10$).

| Critical Species and Variable Tested | Yellowwood State and Hoosier National Forests | Southwestern Corner of Brown County State Park | Main Body of Brown County State Park |
|---|---|---|---|
| ***Adiantum pedatum***[1] | | | |
| Percentage cover | 2.3 a | 0.4 b | 0.1 b |
| Height (cm) | 31.1 a | 32.2 a | 22.0 b |
| ***Arisaema triphyllum***[1] | | | |
| Percentage cover | 0.9 a | 0.9 a | 1.2 a |
| Height (cm) | 22.3 a | 12.9 b | 12.0 b |
| ***Galium circaezans***[1] | | | |
| Percentage cover | 0.1 a | 0.07 a | 0.08 a |
| Height (cm) | 15.4 a | 15.0 a | 14.6 a |
| ***Osmorhiza claytonii***[1] | | | |
| Percentage cover | 1.5 a | 0 b | 0.3 b |
| Height (cm) | 35.2 a | 24.0 ab | 11.2 b |
| ***Polystichum acrostichoides***[1] | | | |
| Percentage cover | 4.7 a | 2.8 a | 0.9 b |
| Height (cm) | 51.5 a | 41.9 a | 26.5 b |
| ***Smilax rotundifolia***[2] | | | |
| Percentage cover | 4.9 a | 3.1 b | 2.1 c |
| Height (cm) | 141.1 a | 95.9 b | 93.1 b |

[1] Mesic slopes and bottomlands.
[2] All sites.

areas within Brown County State Park. Sweet cicely was significantly taller in Yellowwood State Forest/Hoosier National Forest than in the main body of the park, averaging 35.2 cm within Yellowwood State Forest/Hoosier National Forest and 11.2 cm within the main body of Brown County State Park. Wild licorice displayed no significant difference in mean height among the three sampling areas.

Overall, the number for woody stems (class 1) was significantly greater in the southwestern corner of Brown County State Park relative to Yellowwood State Forest/Hoosier National Forest and the main body of the park (Table 3). The greatest difference occurred on mesic slopes and dry ridges where the num-

Table 3. The number of stems for woody species and the species richness within four size classes recorded at sample sites outside of Brown County State Park, in the southwestern corner of Brown County State Park, and in the main body of Brown County State Park during 1994. Row means with different letters are significantly different ($P < 0.10$). Size class 1 = stems < 50 cm in height, size class 2 = stems 50 to 200 cm in height, size class 3 = stems > 200 cm in height and < 2.5 cm dbh, and size class 4 = stems > 200 cm in height and > 2.5 cm dbh. The density of size classes 1 and 2 are per 10 $m^2$ plot and for size classes 3 and 4 are per hectare.

| Critical Species and Variable Tested | Yellowwood State and Hoosier National Forests | Southwestern Corner of Brown County State Park | Main Body of Brown County State Park |
|---|---|---|---|
| **All Sites** | | | |
| Size class 1 | | | |
| Density | 39.6 a | 67.6 b | 39.4 a |
| Species richness | 8.4 a | 8.8 a | 6.1 b |
| Size class 2 | | | |
| Density | 1.3 a | 0.6 ab | 0.2 b |
| Species richness | 0.8 a | 0.5 a | 0.04 b |
| Size class 3 | | | |
| Density | 405 a | 94 b | 159 b |
| Species richness | 1.8 a | 0.7 b | 1.0 b |
| Size class 4 | | | |
| Density | 932 a | 831 a | 833 a |
| **Mesic Bottomlands** | | | |
| Size class 1 | | | |
| Density | 47.0 a | 45.3 a | 48.0 |
| Species richness | 8.5 a | 10.0 a | 5.9 b |
| Size class 2 | | | |
| Density | 1.0 a | 0.3 a | 0.6 a |
| Species richness | 1.0 a | 0.2 b | 0.14 b |
| Size class 3 | | | |
| Density | 200 a | 75 a | 143 a |
| Species richness | 1.0 a | 0.8 a | 0.9 a |
| Size class 4 | | | |
| Density | 700 a | 750 a | 671 a |
| **Mesic Slopes** | | | |
| Size class 1 | | | |
| Density | 38.9 a | 90.0 b | 30.3 a |
| Species richness | 8.1 a | 7.3 a | 5.5 a |
| Size class 2 | | | |
| Density | 2.0 a | 0.8 ab | 0 b |
| Species richness | 1.0 a | 0.6 a | 0 b |
| Size class 3 | | | |
| Density | 450 a | 150 b | 175 b |
| Species richness | 2.4 a | 0.8 b | 1.1 b |
| Size class 4 | | | |
| Density | 875 a | 833 a | 838 a |

*Table 3 (Continued)*

| Critical Species and Variable Tested | Yellowwood State and Hoosier National Forests | Southwestern Corner of Brown County State Park | Main Body of Brown County State Park |
|---|---|---|---|
| **Dry Ridges** | | | |
| Size class 1 | | | |
| Density | 18.0 a | 73.3 b | 25.0 a |
| Species richness | 6.0 a | 9.0 b | 5.6 a |
| **Dry Slopes** | | | |
| Size class 1 | | | |
| Density | 43.4 a | 46.7 a | 51.6 a |
| Species richness | 9.8 a | 9.7 a | 7.3 a |
| **Dry Slopes and Ridges** | | | |
| Size class 2 | | | |
| Density | 0.7 a | 0.7 a | 0 b |
| Species richness | 0.6 a | 0.5 a | 0 b |
| Size class 3 | | | |
| Density | 471 a | 50 b | 142 c |
| Species richness | 1.7 a | 0.5 b | 0.9 b |
| Size class 4 | | | |
| Density | 1128 a | 883 a | 925 a |

ber of stems in the southwestern corner of the park averaged 90.0 and 73.3, respectively. Dry slopes and mesic bottomlands did not exhibit any significant differences among the three areas.

The number of species observed in the one meter by ten meter belt transect was significantly higher for all landtypes in Yellowwood State Forest/Hoosier National Forest and the southwestern corner of Brown County State Park than in the main body of the park. The difference was most evident in the mesic bottomland sites in Brown County State Park which averaged 5.9 species per sample site compared to 8.5 in Yellowwood State Forest/Hoosier National Forest and 10.0 in the southwestern corner of the park. The other landtypes did not show any significant differences with the exception of dry ridges, where a significantly higher number of species was observed in the southwestern corner of Brown County State Park than in either Yellowwood State Forest/Hoosier National Forest or the main body of the park.

The overall number of stems for all woody species (class 2) per sample site for all landtypes was significantly higher in Yellowwood State Forest/Hoosier National Forest when compared to the main body of the park (Table 3). Sites averaged 1,300 stems per hectare in Yellowwood State Forest/Hoosier National Forest as compared to 200 stems per hectare inside the main body of the park. Mesic slopes as well as dry slopes and ridges also exhibited this pattern; however, significant differences were not observed for these landtypes in the southwestern corner of Brown County State Park relative to either Yellowwood

State Forest/Hoosier National Forest or the main body of the park. Mesic bottomlands did not show any significant differences among the three areas. The number of woody species in size class 2 was also significantly higher in Yellowwood State Forest/Hoosier National Forest and the southwestern corner of Brown County State Park than in the main body of the park, where papaw (*Asimina triloba*) was the only species found on transects (Table 3).

The number of woody stems (class 3) per hectare was significantly reduced on all sites except mesic bottomlands within the park when compared to Yellowwood State Forest/Hoosier National Forest (Table 3). Species richness for this size class followed the same pattern (Table 3). Significantly more species per sample site were found within Yellowwood State Forest/Hoosier National Forest, which averaged 1.8 species per sample site, than in the southwestern corner (0.7) or the main body (1.0) of the park.

The number of woody species (class 4) per hectare was not significantly different inside Brown County State Park when compared to Yellowwood State Forest/Hoosier National Forest (Table 3). The number of stems averaged 932 per hectare for all landtypes within Yellowwood State Forest/Hoosier National Forest as compared to 831 in the southwestern corner and 833 in the main body of the park, respectively. This pattern was observed for all the different landtypes.

The same vegetation variables were also measured in 1993 within Brown County State Park and Yellowwood State Forest/Hoosier National Forest by Van Kley, and the means of these variables show similar trends between the two years (Table 4). For example, the average number of ground flora species per site found outside the park in 1994 was similar to the number found in 1993 (21.5 in 1994 and 23.3 in 1993). However, the number of species found per site in the southwestern corner and main body of Brown County State Park was higher in 1994. Percentage cover of the ground flora was similar in both years within the main body of Brown County State Park, averaging 14.4% in 1994 and 14.7% in 1993. However, Yellowwood State Forest/Hoosier National Forest exhibited a slightly lower percentage cover, and the southwestern corner of Brown County State Park exhibited a higher percentage cover in 1994. The southwestern corner of Brown County State Park also exhibited an increase in the number of seedlings in 1994. In contrast, sapling numbers stayed constant between the two sampling seasons.

## DISCUSSION

Excessive browsing within Brown County State Park has resulted in reduced numbers and sizes for some plant species, a conclusion consistent with those of Alverson, *et al.* (1988) and Balgooyen and Waller (1995). These researchers found that white-tailed deer could directly and indirectly affect the abundance and structure of many herbaceous species, thereby influencing forest composition. Likewise, Balgooyen and Waller (1995) indicated that many herbaceous species, especially preferred browse species, were jeopardized by high deer den-

Table 4. The mean species richness and percentage cover of the ground flora as well as the mean density of woody stems in size classes 1 and 2 recorded at sample sites outside Brown County State Park, in the southwestern corner of Brown County State Park, and in the main body of Brown County State Park during 1993 (Parker and Van Kley, 1993). Row means with different letters are significantly different ($P < 0.10$). Size class 1 = stems < 50 cm in height, and size class 2 = stems 50 to 200 cm in height.

| Critical Species and Variable Tested | Yellowwood State and Hoosier National Forests | Southwestern Corner of Brown County State Park | Main Body of Brown County State Park |
|---|---|---|---|
| **All Sites** | | | |
| Ground flora richness | 23.3 a | 16.6 b | 14.7 b |
| Percentage cover of ground flora | 34.1 a | 18.6 b | 14.6 b |
| Woody size class 1 | 33.3 a | 23.7 b | 13.9 c |
| Woody size class 2 | 3.9 a | 0.5 b | 0.4 b |
| **Mesic Bottomlands** | | | |
| Ground flora richness | 34.8 a | 22.4 b | 20.8 b |
| Percentage cover of ground flora | 39.0 a | 28.3 a | 13.1 b |
| Woody size class 1 | 47.2 a | 13.2 b | 8.8 b |
| Woody size class 2 | 5.0 a | 0.6 b | 0.5 b |
| **Mesic Slopes** | | | |
| Ground flora richness | 30.3 a | 21.3 b | 17.1 b |
| Percentage cover of ground flora | 32.4 a | 10.9 b | 8.0 b |
| Woody size class 1 | 35.8 a | 16.9 b | 11.5 b |
| Woody size class 2 | 4.0 a | 0.1 b | 0.5 b |
| **Dry Slopes** | | | |
| Ground flora richness | 14.0 a | 12.1 ab | 9.9 b |
| Percentage cover of ground flora | 29.2 a | 23.6 a | 21.2 a |
| Woody size class 1 | 25.6 ab | 33.9 a | 16.8 b |
| Woody size class 2 | 4.6 a | 0.8 b | 0.2 b |

sities. The significant reduction in both percentage ground cover and the size of several herbaceous species within Brown County State Park when compared to Yellowwood State Forest/Hoosier National Forest indicates that the deer population had exceeded the carrying capacity of their habitat within the park.

The southwestern corner of Brown County State Park was less affected by deer browsing than the main body of the park in both 1993 and 1994. The shared boundary with Yellowwood State Forest/Hoosier National Forest might have allowed increased hunting pressure in the southwestern corner of the park.

No consistent significant difference for woody stem density (class 1) was found between the park and the State and National Forests. However, the higher number of woody stems (class 2) outside the park when compared to both areas within the park suggests that the trees are successfully reproducing, but repeated browsing prevents seedlings from growing into the larger size classes.

Marquis (1974) found that browsing by white-tailed deer on the Allegheny Plateau in Pennsylvania prevented stems from growing beyond the seedling stage. His conclusions agree with those of Frelich and Lorimer (1985) and Anderson and Katz (1993), who both concluded that browsing by white-tailed deer was severely affecting the reproduction and recruitment of eastern hemlock into larger size classes.

The large number of plant species still found within Brown County State Park in 1993 and 1994 indicates a potential for recovery of the plant communities if deer populations are maintained at lower levels. Other researchers have also suggested that controlling deer numbers can effectively decrease browse damage (Anderson and Loucks, 1979; Frelich and Lorimer, 1985; Alverson, *et al.*, 1988; Anderson and Katz, 1993). Anderson and Loucks (1979) suggest that wildlife should be maintained at a level that would not be detrimental to important tree species. They also suggest that in areas where wildlife is having a detrimental effect, hunting regulations should be relaxed to prevent changes in tree species composition. Significant improvement in the understory could occur within a few years if deer numbers were maintained at lower levels (Anderson and Loucks, 1979). However, a significant period of time will be needed before the forest can completely recover. Anderson and Katz (1993) suggest that the time needed for recovery after release from browsing pressure is directly proportional to the time the forest was subjected to this pressure.

The limited removal of 392 deer (17 deer per square mile or 2.590 $km^2$) from the park in 1993 may have been responsible for the slight improvement in the condition of the understory vegetation. An increase in the number of plant species found per site occurred within the park in 1994. However, this increase in species number might be the result of deer reduction or annual variation. Before concrete conclusions can be reached about the specific damage caused by deer, more data needs to be collected during subsequent growing seasons. Continued studies of the understory vegetation could show not only differences in the degree of impact due to white-tailed deer browsing but also variation in the vegetation due to annual variability and the timing of sampling within the growing season.

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## LITERATURE CITED

Alverson, W.S., D.M. Waller, and S.L. Solheim. 1988. Forests too deer: Effects in northern Wisconsin. Cons. Biol. 2: 348-358.

Anderson, R.C. and A.J. Katz. 1993. Recovery of browse-sensitive tree species following release from white-tailed deer (*Odocoileus virginianus* Zimmerman) browsing pressure. Biol. Cons. 63: 203-208.

_____ and O.L. Loucks. 1979. White-tailed deer (*Odocoileus virginianus*) influence on structure and composition of *Tsuga canadensis* forests. J. Appl. Ecol. 16: 855-861.

Balgooyen, C.P. and D.M. Waller. 1995. The use of *Clintonia borealis* and other indicators to gauge impacts of white-tailed deer on plant communities in northern Wisconsin, USA. Natur. Areas J. 15: 308-318.

Brown County State Park Deer Study Committee. 1993. A report to the Natural Resources Commission. Indiana Dep. Natur. Res., Indianapolis, 12 pp.

Brown, D.T. and G.J. Doucet. 1991. Temporal changes in winter diet selection by white-tailed deer in a northern deer yard. J. Wildlife Manage. 55: 361-376.

Frelich, L.E. and C.G. Lorimer. 1985. Current and predicted long-term effects of deer browsing in hemlock forests in Michigan, USA. Biol. Cons. 34: 99-120.

Gillingham, M.P. and F.L. Bunnell. 1989. Effects of learning on food selection and searching behavior of deer. Can. J. Zool. 67: 24-32.

Homoya, M.A., D.B. Abrell, J.R. Aldrich, and T.W. Post. 1985. The natural regions of Indiana. Proc. Indiana Acad. Sci. 94: 245-268.

Kohlman, S.G. and K.L. Risenhoover. 1994. Spatial and behavioral response of white-tailed deer to forage depletion. Can. J. Zool. 72: 506-513.

Korschgen, L. 1962. Foods of Missouri deer, with some management implications. J. Wildlife Manage. 26: 163-172.

Marquis, D.A. 1974. The impact of deer browsing on Allegheny hardwood regeneration. U.S. Dep. Agr., U.S. Forest Serv. Paper NE-308, 8 pp.

McArthur, C., C.T. Robbins, A.E. Hagerman, and T.A. Hanley. 1993. Diet selection by a ruminant generalist browser relative to plant chemistry. Can. J. Zool. 71: 2236-2243.

McCaffery, K.R., J. Tranetzki, and J. Piechura, Jr. 1974. Summer foods of deer in northern Wisconsin. J. Wildlife Manage. 38(2): 215-219.

Mumford, R. and J. Whitaker, Jr. 1982. Mammals of Indiana. Indiana Univ. Press, Bloomington, Indiana, 537 pp.

Nixon, C., M.W. McClain, and K.R. Russell. 1970. Deer food habits and range characteristics in Ohio. J. Wildlife Mgt. 34(4): 870-886.

Parker, G.R. and J.E. Van Kley. 1993. Brown County State Park: Final report on vegetation damage by white-tailed deer. Unpubl. report.

Smith, W.P. 1991. *Odocoileus virginianus*. Mammalian Spec. 388: 1-13.

Strole, T.A. and R.C. Anderson. 1992. White-tailed deer browsing: Species preferences and implications for central Illinois forests. Natur. Areas J. 12(3): 139-144.

Van Kley, J.E. and G.R. Parker. 1993. An ecological classification system for the Central Hardwoods Region: The Hoosier National Forest, Indiana. Proc. 9th Central Hardwoods Conf., U.S. Dep. Agr., Forest Serv., North Central Forest Exp. Stat., Gen. Tech. Rep. NC-161, pp. 308-326.

Westoby, M. 1974. An analysis of diet selection by large generalist herbivores. Amer. Natur. 108: 290-304.