# Impacts of White-tailed Deer on Endangered and Threatened Vascular Plants

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**ABSTRACT**: To assess the impact of white-tailed deer (*Odocoileus virginianus*) on endangered and threatened flora, we reviewed pertinent literature and conducted a telephone survey of professional botanists, endangered species scientists, natural area managers, and U.S. National Park Service resource managers. Ninety-eight species of threatened or endangered plants were reported disturbed by deer. Monocots and dicots comprised 39.8% and 56.1%, respectively, of the species disturbed. Of the disturbed species, 38.7% belong to families Liliaceae and Orchidaceae.

## INTRODUCTION

The objective of this project was to determine to what extent the impacts of white-tailed deer (*Odocoileus virginianus*) on threatened and endangered plants have been identified and documented, and which families and genera of plants are most likely to be affected. As concerns about threatened and endangered species and the global loss of biodiversity increase, identifiying and understanding the processes that influence the rate at which species are disappearing have received much attention (Ehrlich and Ehrlich 1981, Simberloff 1986, Ehrlich 1988, National Science Foundation 1989). Some information exists regarding the threats posed by herbivores to threatened and endangered plants. White-tailed deer are known to dramatically alter vegetative communities (Hosley and Ziebarth 1935, Webb et al. 1956, Shafer 1965, Marquis 1981). As deer populations reach historically high population densities in many areas (Whittington 1984, Storm et al. 1989), the threat that deer might pose to the conservation of threatened and endangered plant species should be an important concern for natural land managers. More intensive monitoring and evaluation of impacts are needed.

Food preferences of white-tailed deer have been the subject of numerous scientific studies. Although most of the existing literature examines the effects of deer browsing on woody vegetation, only a few papers examine the effects of grazing on herbaceous flora, particularly forbs. Studies suggest that browsing and grazing by deer can have profound impacts on the regeneration, abundance, and distribution of certain plant species, especially if deer populations are high. An enclosure study in Pennsylvania found that high densities of deer in thinned, clearcut, and uncut stands had detrimental effects on species composition and development of regeneration (Tilghman 1989). In the Great Smoky Mountains, Bratton (1979) reported that areas in close proximity to open fields and intensively utilized by deer lost over 25% of their species compared to control areas. In northern Wisconsin, American yew (*Taxus canadensis*) essentially is restricted to rocky outcrops that are inaccessible to deer or to other areas with very low deer populations (Beals et al. 1960, Alverson et al. 1988).

In spring and summer, herbaceous plants become an important component of a deer's diet (McIlwain 1965, Everitt and Drawe 1974, Dublin 1980, Shissler 1985, McCullough 1985). Healy (1967), and Skinner and Telfer (1974) documented a change in diet from woody browse to herbaceous flora as the latter became available in spring. Causey (1964) in Louisiana, and Korschgen et al. (1980) in Missouri reported that herbaceous flora made up approximately 50% of deer diet during spring and summer, while Chamrad and Box (1968) reported 90% of the total diet in Texas was herbaceous. In Wisconsin, McCaffery et al. (1974) discovered that 87% of the summer diet of deer consisted of herbaceous material such as bluebead-lily (*Clintonia borealis*) and false lily-of-the-valley (*Maianthemum. canadense*). Crawford (1982) found that the diet of free-ranging tame deer during spring and summer consisted of 75% herbaceous flora.

The spring diet of white-tailed deer must be high quality to satisfy the nutritional requirements of fawning and milk production for does, and antler development for bucks (Shissler 1985). Shissler (1985) claims that deer herds will not reach their full growth potential on woody browse alone. A study conducted by Short (1975) concluded that foods consumed by deer in winter, mainly woody browse, yield only

enough energy to satisfy basal energy requirements. Spring forbs provide much more energy than woody twigs and grasses and supply more than enough energy for general maintenance requirements of deer.

## METHODS

The impact of white-tailed deer on threatened and endangered plants was first determined by a systematic review of the literature. The literature review was supplemented by a telephone survey of 173 individuals consisting of knowledgeable professional botanists, endangered species scientists, natural area managers, and U.S. National Park Service resource managers from 46 states throughout the United States. We asked each individual a standard set of questions to determine which plant species were disturbed, and the extent of disturbance, by white-tailed deer. We used information on all plant species listed as state or federally endangered, threatened, rare, candidate to be listed, of special concern to state natural heritage programs, or as being on a watch list. Although most of the information gathered was from unquantified field observations, these observations represent the best information available. Since these species may be disturbed throughout their range and not only in the states where evidence was reported, or disturbance may occur only in local areas, this compilation presumably represents only a portion of the endangered and threatened flora disturbed by white-tailed deer and should be considered incomplete and subject to further additions and field verification.

## RESULTS

Fifty of the 173 scientists interviewed offered information regarding white-tailed deer impacts on threatened or endangered flora. Of the information received, 60% was from natural heritage inventory botanists; 6% from The Nature Conservancy land stewards; 6% from National Park Service resource managers; and 28% from experts affiliated with the U.S. Forest Service, U.S. Fish and Wildlife Service, universities, or other institutions. In addition, five published records of rare plant disturbance by white-tailed deer were included in the table of species disturbed.

The reports identified 36 families and 98 species of threatened or endangered plants disturbed by white-tailed deer (Table 1). The class Angiospermae comprised 95.9% (39.8% Monocotyledoneae and 56.1% Dicotyledoneae) of the species disturbed, while the class Gymnospermae and the order Filicales comprised 3.1% and 1.0%, respectively. Interestingly, 38.7% of the threatened or endangered species disturbed belong to the families Liliaceae and Orchidaceae, while none were graminoids.

**Table 1.** Plant species disturbed by white-tailed deer, listed by family, followed by botanical name, federal status, and U.S. states in which evidence of disturbance was found and status within that state, either legal or state status, or both.

| | SOURCE | FEDERAL STATUS | STATE STATUS | NATURAL HERITAGE RANK(S=state/G=global) |
|---|---|---|---|---|
| **AMARYLLIDACEAE** | | | | |
| *Hymenocallis* sp.[a] | PC/LIT | | | |
| **ARALIACEAE** | | | | |
| *Panax quinquefolium*[b] | PC | 3C | VA=T | MD=WL, VA=S3/G4 |
| **ASCLEPIADACEAE** | | | | |
| *Asclepias meadii* | PC | T | IL=E | |
| *Asclepias ovalifolia* | PC | NL | IL=E | |
| *Asclepias verticillata* | PC | NL | | MD=WL |
| **BETULACEAE** | | | | |
| *Betula uber* | PC | E | VA=E | VA=S1/G1Q |
| **BORAGINACEAE** | | | | |
| *Lithospermum caroliniense*[c] | LIT | NL | PA=E | PA=S1/G4G5 |
| **CAPRIFOLIACEAE** | | | | |
| *Lonicera canadensis* | PC | NL | MD=E | |
| **CARYOPHYLLACEAE** | | | | |
| *Silene polypetala* | PC | E | GA=E | GA=S2/G2 |
| **CELASTRACEAE** | | | | |
| *Euonymus americanus* | PC | NL | IL=T | |
| *Euonymus atropurpureus* | PC | NL | ND=T | |
| *Euonymus obovatus* | PC | NL | TN=R | |
| **COMPOSITAE** | | | | |
| *Eupatorium purpureum* | PC | NL | | LA=S1/G? |
| *Helianthus microcephalus* | PC | NL | MD=E | |
| *Liatris scariosa* var. *nieuwlandii* | PC | NL | RI=E | |

*Table 1 continued on following three pages.*



*Table 1 continued*

| | SOURCE | FEDERAL STATUS | STATE STATUS | NATURAL HERITAGE RANK(S=state/G=global) |
|---|---|---|---|---|
| **CORNACEAE** | | | | |
| *Cornus rugosa* | PC | NL | MD=E | |
| **CROOMIACEAE** | | | | |
| *Croomia pauciflora* | PC | C2 | GA=T | GA=S1/G3 |
| **CRUCIFERAE** | | | | |
| *Arabis serotina* | PC | E | | WV=S1/G1 |
| *Lesquerella filiformis* | PC | E | MO=E | |
| **ERICACEAE** | | | | |
| *Arctostaphylos uva-ursi* | PC | NL | PA=EE | PA=SX/G5 |
| *Rhododendron prunifolium* | PC | C2 | GA=T | GA=S2/G3? |
| **FABACEAE** | | | | |
| *Astragalus robbinsii* var. *jesupi* | PC | E | VT=E, NH=E | |
| *Cladrastis lutea* | PC | 3C | IN=T | |
| *Dalea foliosa* | PC | PE | TN=E | |
| *Lupinus perennis*[d] | LIT | NL | NH=T, PA=R | PA=S2S3/G5 |
| *Trifolium reflexum* | PC | NL | IL=E | |
| *Trifolium stoloniferum* | PC | E | OH=E, MO=EE, KY=E | WV=S1/G1, KY=S1/G1 |
| **FUMARIACEAE** | | | | |
| *Corydalis sempervirens* | PC | NL | | MD=WL |
| **LABIATAE** | | | | |
| *Pycnanthemum torrei* | PC | NL | MD=E | |
| **LAURACEAE** | | | | |
| *Lindera melissifolia* | PC | E | | SC=S1/G2 |
| *Litsea aestivalis* | PC | CU | | SC=S1/G4 |
| **LILIACEAE** | | | | |
| *Chamaelirium luteum* | PC | NL | NY=R | NY=S2/G5 |
| *Helonias bullata*[e] | PC/LIT | T | NC=T | NC=S1/G2 |
| *Lilium canadense* | PC | NL | TN=T | |
| *Lilium grayi* | PC | C2 | TN=E | |
| *Lilium iridollae* | PC | C2 | | AL=S1/G1 |
| *Lilium philadelphicum* | PC | NL | MD=EE, TN=E | |
| *Lilium superbum* | PC | NL | IL=E | |
| *Melanthium latifolium* | PC | NL | MD=EE | |
| *Melanthium virginicum* | PC | NL | | MD=WL |
| *Trillium cernuum* | PC | NL | | MD=WL |
| *Trillium cuneatum* | PC | NL | IL=E | |
| *Trillium decumbens* | PC | NL | TN=E | |
| *Trillium persistens* | PC | E | GA=E | GA=S1/G1, SC=S1/G1 |
| *Trillium pusillum* | PC | C2 | TN=E | |
| *Trillium pusillum* var. *texanum* | PC | C2 | | TX=S2S3/G2G3Q |
| *Trillium reliquum* | PC | E | | SC=S1/G1 |
| *Trillium rugelii* | PC | NL | TN=E | |
| **LOBELIACEAE** | | | | |
| *Lobelia kalmii*[f] | LIT | NL | PA=E | |
| **MALVACEAE** | | | | |
| *Iliamna remota* | PC | C2 | IL=E | |
| **NYCTAGINACEAE** | | | | |
| *Abronia macrocarpa* | PC | E | TX=E | TX=S1/G1 |
| **ONAGRACEAE** | | | | |
| *Gaura neomexicana* var. *coloradensis* | PC | C1 | | NE=S1/G4T1 |
| **ORCHIDACEAE**[g] | | | | |
| *Coeloglossum viride*[h] | PC | NL | MD=E | |
| *Corallorhiza trifida* | PC | NL | MD=E | |
| *Cypripedium acaule* | PC | NL | IL=E, GA=SC | GA=S3/G5 |
| *Cypripedium candidum* | PC | NL | OH=E | |
| *Cypripedium reginae* | PC | NL | MD=EE, NH=E, IL=E | WI=S1/G? |
| *Isotria medeoloides* | PC | E | NY=V, NC=E, NH=E | NY=SH/G2, NC=S1/G1 |
| *Isotria verticillata* | PC | NL | MO=E | |
| *Liparis loeselii* | PC | NL | KY=SC | KY=S2S3/G5 |
| *Listera smallii* | PC | NL | MD=E | |
| *Platanthera blephariglottis* | PC | NL | MD=T | |

*Table 1 continued*

| | SOURCE | FEDERAL STATUS | STATE STATUS | NATURAL HERITAGE RANK(S=state/G=global) |
|---|---|---|---|---|
| *Platanthera ciliaris* | PC | NL | MD=T | |
| *Platanthera cristata* | PC | NL | MD=T | |
| *Platanthera flava* | PC | 3C | MD=T | |
| *Platanthera grandiflora*[i] | PC | NL | MD=T | |
| *Platanthera integrilabia* | PC | C2 | KY=E | KY=S1/G2 |
| *Platanthera leucophaea* | PC | T | ND=E, NE=T | NE=S1/G2 |
| *Platanthera peramoena* | PC | 3C | MD=T, TN=T, NC=C | NC=S1/G5 |
| *Platanthera praeclera* | PC | T | IA=E | KS=S1/G2, IA=S1/G2 |
| *Platanthera psycodes* | PC | NL | MD=EE, IL=E | |
| *Spiranthes diluvialis*[j] | PC | C1 | | CO=S1/G? |
| *Spiranthes ochroleuca* | PC | NL | MD=E | |
| **PINACEAE** | | | | |
| *Abies balsamea* | PC | NL | | MD=HR, VA=S1/G1 |
| **PLANTAGINACEAE** | | | | |
| *Plantago cordata* | PC | 3C | IL=E | |
| **POLYPODIACEAE** | | | | |
| *Woodwardia virginica* | PC | NL | TN=SC | |
| **PRIMULACEAE** | | | | |
| *Lysimachia quadriflora*[k] | LIT | NL | | NY=S1/G5? |
| **RANUNCULACEAE** | | | | |
| *Aconitum noveboracense* | PC | T | OH=E, NY=T | NY=S2/G3 |
| *Clematis socialis* | PC | E | | AL=S1/G1 |
| *Delphinium exaltatum* | PC | C2 | MD=E | |
| *Thalictrum cooleyi* | PC | E | NC=E | NC=S1/G1 |
| **ROSACEAE** | | | | |
| *Filipendula rubra* | PC | NL | MD=E | |
| *Neviusia alabamensis* | PC | C2 | AR=T | AR=S1S2/G2 |
| *Prunus pumila* | PC | NL | PA=R | PA=S3/G5 |
| *Rosa acicularis* | PC | NL | IL=E | |
| **SARRACENIACEAE** | | | | |
| *Sarracenia oreophila* | PC | E | GA=PE | GA=S1/G2 |
| *Sarracenia purpurea* | PC | NL | GA=E | GA=S1/G5 |
| **SAXIFRAGACEAE** | | | | |
| *Ribes hirtellum*[l] | PC | NL | | MD=HR |
| *Saxifraga micranthidifolia* | PC | NL | | MD=WL |
| **SCROPHULARIACEAE** | | | | |
| *Pedicularis furbishiae* | PC | E | ME=E | ME=S2/G? |
| *Penstemon haydennii* | PC | E | NE=E | NE=S1/G1 |
| *Penstemon lemhiensis* | PC | C2 | | MT=S2/G3 |
| *Schwalbea americana* | PC | C1 | | GA=S1/G2 |
| **STYRACACEAE** | | | | |
| *Styrax texana* | PC | E | TX=E | TX=S1/G1 |
| **TAXACEAE** | | | | |
| *Taxus canadensis* | PC | NL | | MD=WL |
| *Torreya taxifolia* | PC | E | FL=E | FL=S1/G1 |
| **THYMELAEACEAE** | | | | |
| *Dirca palustris* | PC | NL | MD=E | |
| **UMBELLIFERAE** | | | | |
| *Oxypolis canbyi* | PC | E | | SC=S1/G1 |

[a]Members of the genus *Hymenocallis* are browsed in Florida, but it is not known which species are affected.
[b]Warren and Ford 1990.
[c]Campbell et al. 1989.
[d]Campbell et al. 1989.
[e]Sutter 1984.
[f]Campbell et al. 1989.
[g]*Platanthera* = *Habenaria*.
[h]Warren and Ford 1990.
[i]Warren and Ford 1990.
[j]Possibly browsed by mule deer (*Odocoileus hemionus*).
[k]Watts 1964, Sauer et al. 1969.
[l]Warren and Ford 1990.



*Table 1 continued*

**EXPLANATION OF CODES**

**Source**
PC= Reported by personal communication.
LIT= Reported in existing literature.

**Federal Status**
E= Endangered.
T= Threatened.
PE= Proposed Endangered.
C1= Candidate to be listed, highly rare.
C2= Candidate to be listed, possibly rare.
3C= Taxon proven to be more widespread and/or abundant than originally believed.
CU= Candidate Undetermined (Federal status review).
NL= Not Listed.

**State Status**
E= Endangered.
T= Threatened.
R= Rare.
EE= Endangered/Extirpated.
C= Candidate to be listed.
SC= Special Concern.
V= Exploitably vulnerable

**Natural Heritage Inventory Rank**
--STATE RANK--
S1= Critically imperiled in state with 5 or fewer occurrences or very few remaining individuals or because of some factor(s) making it especially vulnerable to extirpation from that state.
S2= Imperiled in state because of rarity with 6 to 20 occurrences or few remaining individuals or because of some factor(s) making it very vulnerable to extirpation from that state.
S3= Rare or uncommon in state with 21 to 100 occurrences in that state.
S4= Apparently secure in state, with numerous occurrences.
S5= Demonstrably common and secure in that state.
SH= Historically known from state.
SX= Extirpated.

--GLOBAL RANK--
G1= Critically imperiled globally because of extreme rarity with 5 or fewer occurrences or very few remaining individuals or because of some factor(s) making it especially vulnerable to extinction.
G2= Imperiled globally because of rarity with 6 to 20 occurrences or few remaining individuals or because of some factor(s) making it very vulnerable to extinction.
G3= Either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range; or because of other factors making it vulnerable to extinction throughout its range. Typically 21 to 100 occurrences.
G4= Apparently secure globally, though it may be rare in parts of its range, especially at the periphery.
G5= Very common and demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.

**A state or global rank followed by a "Q" indicates that the taxonomic status of the species is questionable. A rank followed by "?" indicates unranked or rank uncertain. A "T" following a global rank denotes the rank of that subspecies. Two ranks together (i.e. S1S2 or G3G4) indicate that the species is borderline between the ranks.

WL=Watch List
HR=Highly Rare

On Presque Isle, Pennsylvania, Cambell et al. (1989) reported that nearly three-fourths of the hairy puccoon (*Lithospermum caroliniense*) population's reproductive potential was lost to grazing by deer in 1988, threatening the plant's survival. Patrick (pers. comm. 1991) reported that deer ate the flowering stalk of the only purple pitcher plant (*Sarracenia purpurea*) to flower in a population in Tom's Swamp, Rabun County, Georgia, thus destroying the reproductive potential for that population during the 1989 season. An exclusion fence had to be erected on the Big Lazer Wildlife Management Area, Talbot County, Georgia in order to save a small population of croomia (*Croomia pauciflora*) from excessive damage from deer (Patrick pers. comm. 1991). In Kentucky, deer ate all the flowering stems of the only known population of Loesel's twayblade (*Liparis loeselii*) in 1984, while in 1989 deer ate all the flowering stems of the only known population of white fringeless orchid (*Platanthera integrilabia*) (MacGregor pers. comm. 1991). Deer browsing on the inflorescences caused a reduction or elimination of seed set in many populations of swamp pink (*Helonias bullata*) (Sutter 1984). In South Carolina, the perennial Canby's dropwart (*Oxypolis canbyi* ) is being browsed back to its base, which will eventually kill the plant (Rayner pers. comm. 1991). The bark and stems of two rare shrubs, pondspice (*Litsea aestivalis*) in South Carolina (Rayner pers. comm. 1991) and Florida torrey (*Torreya taxifolia*) in Florida (Gordon pers. comm. 1991), are damaged by antler rubbing in areas of high deer densities. Although they are not rare in some areas of their range, bellwort (*Uvularia grandiflora*), trout lily (*Erythronium americanum*), Adam and Eve

orchid (*Aplectrum hyemale*), showy orchis (*Orchis spectabilis*), and buttercup (*Ranunculus harveyi*) are very rare on Curley's Ridge, Arkansas (Tucker pers. comm. 1991). Tucker suggests that these scattered individual plants are isolated from other populations and eventually may be extirpated from Curley's Ridge by deer grazing activity.

Grazing has been shown to not only severely disturb a rare plant population, but to have secondary effects on species further up the food chain as well. Ecologists with the New Hampshire Natural Heritage Inventory Program have observed deer damage on wild lupine (*Lupinus perennis*), an obligate larval food source for the karner blue butterfly (*Lycaeides melissa samuelis*). (A proposal to add the butterfly to the federal list of endangered and threatened species is currently being prepared [Ameral pers. comm. 1991].) In this case an organism is dependent on the survival and reproduction of a plant species possibly threatened by deer.

## DISCUSSION

Verifying white-tailed deer impacts on threatened and endangered plants is difficult. Direct observation of deer grazing on the plants is obviously the best evidence; however, this rarely occurs. Signs of browsing on the plant may be the next best evidence available; but unless the plant or plant populations are checked frequently, browsing can often be overlooked or mistaken for browsing by other herbivores such as rabbit or woodchuck. Rumen and fecal content analysis are two common techniques used to determine white-tailed deer diets. Most threatened and endangered flora utilized by deer are herbaceous. Since most such material is highly digestible (Torgerson and Pfander 1971, Anthony and Smith 1974, Short 1975, Blair et al. 1977, Dublin 1980, Vangilder et al. 1982), individual species can be underrepresented and often unidentifiable in rumen and fecal samples (Anthony and Smith 1974, Dublin 1980, Mengak 1982, Mengak and Wood 1983). Validation is further complicated because the typically small mass of threatened and endangered flora consumed may not be detected in rumen and fecal samples. In many cases only the flower heads are eaten, and these may be virtually unidentifiable in fecal samples (Anthony and Smith 1974).

The fact that no graminoid species were reported damaged by deer may reflect the ease with which damage is observed on broad-leaved forbs as opposed to grasses, which possibly is related to graminoids' greater tolerance for herbivory and ability to recover after grazing. The high number of lilies and orchids on the list may reflect dietary preferences or a bias created by the interest and focus many plant specialists have for these flowering plants.

Regulatory mechanisms created to protect threatened and endangered species recognize the need to conserve the habitat in which such species are found. But simply setting land aside as protected areas is insufficient. Successful conservation of rare species depends on an understanding of the interactions of many elements within ecological communities, as well as knowledge of how the relationships within natural communities determine the size, configuration, and land-use patterns typical of reserve areas. Recent studies demonstrate that the size and shape of reserves, the nature and distribution of habitats within them, the composition of their ecological communities, and the kinds and extent of physical connections between reserves and other areas are significant factors influencing community interactions (Diamond 1975, Ranney et al. 1981, Schonewald-Cox 1988). Where high edge-to-interior ratios and early successional composition of forests result from decisions about how reserves are created and maintained, the distribution and abundance of species such as white-tailed deer will be affected (Clark and Gilbert 1982, Williamson and Hirth 1985). The success that deer might enjoy by utilizing such human-influenced habitats may result in highly adverse impacts to populations of threatened and endangered plants. Such highly complex relationships will influence future conservation efforts and it is essential that we begin to define the monitoring tasks that will provide us with some of the answers.

If the rare plant species listed here have been subjected to deer predation throughout evolution, why are deer dangerous to them now? Although these plant species may have a long history of interaction with deer, some aspects of these interactions may have changed in recent years. First, a number of these rare plant species have lost habitat to human development and disturbance; reduced populations may be less able to recover after disturbance by deer. Furthermore, deer populations in many areas are higher than they have been historically. Because the amount of forest edge has greatly increased and many habitats have been fragmented, deer encounter rare plant species more easily. Once a plant species has been locally extirpated in one fragment, dispersal and recolonization from another fragment is uncertain. Plants may be especially vulnerable to depredation on the outer limits of their range where plant populations are typically smaller or more scattered. Nature reserves often prohibit hunting and other human activities that limit deer populations and consequently deer populations may increase in these areas, which may also support rare plant species.

Information on white-tailed deer impacts on threatened and endangered plant species is lacking because of (1) the way wildlife food habits data are collected, (2) the infrequency of reports of endangered plant consumption, and (3) the lack of an interstate network for assembling such information. The limitations of stomach content and fecal analyses suggest that long-term monitoring of the rare plant populations is the best means of verifying possible disturbance by deer. The following questions should be addressed:

1. How are threatened and endangered plant species being monitored now for deer impacts?
2. What strategies are needed to ensure that potential impacts will be adequately documented and monitored so that the data from different reserves can be compared?
3. What effect does the size and configuration of a reserve have on impacts by deer to threatened and endangered plants? This includes not only the direct effect of deer population density, but also the effect on distribution of plant populations.



For the period of one year, John Hadidian and Susan P. Bratton will be accepting and pooling further observations regarding white-tailed deer impacts on threatened and endangered plants. Information may be sent to the address listed for John Hadidian. Future pooling of information should be arranged through a conservation organization or a federal agency.

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## LITERATURE CITED

Alverson, W.S., D.M. Waller, and S.L. Solheim. 1988. Forests too deer: edge effects in northern Wisconsin. Conservation Biology 2(4):348-358.

Ameral, M. Pers. comm. 1991. U.S. Fish and Wildlife Service, Concord, N.H.

Anthony, R.G. and N.S. Smith. 1974. Comparison of rumen and fecal analysis to describe deer diets. Journal of Wildlife Management 38(3):535-540.

Beals, E.W., G. Cottam, and R.J. Vogl. 1960. Influence of deer on vegetation of the Apostle Islands, Wisconsin. Journal of Wildlife Management 24(1):68-80.

Blair, R.M., H.L. Short, and E.A. Epps, Jr. 1977. Seasonal nutrient yield and digestibility of deer forage from a young pine plantation. Journal of Wildlife Management 41(4):667-676.

Bratton, S.P. 1979. Impacts of white-tailed deer on the vegetation of Cades Cove, Great Smoky Mountains National Park. Proceedings of the Annual Conference of the Southeastern Association of Game Fish Commissions 33:305-312.

Campbell, J.M., W.C. Fenton, and J.F. Majewski. 1989. Pollinators of some rare and endangered plants of Presque Isle. Unpublished report for The Commonwealth of Pennsylvania Department of Environmental Resources Bureau of Forestry. 30 p.

Causey, M.K. 1964. Nutritional analysis and seasonal variation of some herbaceous deer browse plants in the pine-hardwood areas of Winn and Union Parishes, Louisiana. M.S. hesis, Louisiana State University, Shreveport, Louisiana. 46 p.

Chamrad, A.D. and T.W. Box. 1968. Food habits of white-tailed deer in South Texas. Journal of Range Management 21(3):158-164.

Clark, T.P. and F.F. Gilbert. 1982. Ecotones as a measure of deer habitat quality in central Ontario. Journal of Applied Ecology 19:751-758.

Crawford, H.S. 1982. Seasonal food selection and digestibility by tame white-tailed deer in central Maine. Journal of Wildlife Management 46(4):974-982.

Diamond, J.M. 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. Biological Conservation 7:129-146.

Dublin, H.T. 1980. Relating deer diets to forage quality and quantity: The Columbian White-tailed Deer (*Odocoileus virginianus leucurus*). M.S. thesis, University of Washington, Seattle. 135 p.

Ehrlich, P.R. 1988. The loss of diversity: causes and consequences. Pp. 21-27 *in*. E.O. Wilson, ed., Biodiversity. National Academy of Sciences Press, Washington, D.C.

Ehrlich, P.R. and A.H. Ehrlich. 1981. Extinction: the causes and consequences of the disappearance of species. Random House, New York. 305 p.

Everitt, J.H. and D.L. Drawe. 1974. Spring food habits of white-tailed deer in the South Texas plains. Journal of Range Management 27:15-20.

Gordon, D. Pers. comm. 1991. The Nature Conservancy, Florida Museum of Natural History, Gainesville, Fla.

Healy, W.M. 1967. Forage preferences of captive deer while free ranging in the Allegheny National Forest. M.S. thesis, Pennsylvania State University, University Park. 93 p.

Hosley, N.W. and R.K. Ziebarth. 1935. Some winter relations of the white-tailed deer to forests in north central Massachusetts. Ecology 16(4):535-553.

Korschgen, L.J., W.R. Porath, and O. Torgenson. 1980. Spring and summer foods of deer in the Missouri Ozarks. Journal of Wildlife Management 44(1):89-97.

MacGregor, J. Pers. comm. 1991. U.S. Forest Service, Daniel Boone National Forest, Berea, Kentucky.Marquis, D.A. 1981. Effect of deer browsing on timber production in Allegheny hardwood forests of northwestern Pennsylvania. Northeastern Forest Experiment Station, Broomall, Penn. 10 p.

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

McCullough, D.R. 1985. Variables influencing food habits of white-tailed deer on the George Reserve. Journal of Mammalogy 66(4):682-692.

McIlwain, J.P. 1965. The relationship of browse production and availability to the physical condition of deer. M.S. thesis, Louisiana State University, Shreveport. 63 p.

Mengak, M.T. 1982. A comparison of two diet analysis techniques applied to white-tailed deer in coastal South Carolina. M.S. thesis, Clemson University, Clemson, South Carolina. 71 p.

Mengak, M.T. and G.W. Wood. 1983. Comparison of two diet analysis techniques applied to white-tailed deer. Proceedings of the Annual Conference of the Southeastern Association of Game Fish Commissions 37:138-145.

National Science Foundation. 1989. Loss of biological diversity: a global crisis requiring international solutions. National Science Foundation, Washington, D.C. 19 p.

Patrick, T. 1991. Pers. comm. Georgia Natural Heritage Inventory, Georgia Department of Natural Resources, Social Circle, Ga.

Ranney, J.T., M.C. Bruner, and J.B. Levenson. 1981. The importance of edge in the structure and dynamics of forest islands. Pp. 67-95 *in* R.L. Burgess and D.M. Sharper, eds., Forest island dynamics in man-dominated landscapes. Springer-Verlag, New York.

Rayner, D.A. 1991. Pers. comm. Department of Biology, Wofford College, Spartanburg, S.C.

Sauer, P.R., J.E. Tanck, and C.W. Severinghaus. 1969. Herbaceous food preferences of white-tailed deer. N.Y. Fish and Game Journal 16(2):145-157.

Schonewald-Cox, C. 1988. Boundaries in the protection of nature reserves. Bioscience 38:480-486.

Shafer, E.L. 1965. Deer browsing of hardwoods in the northeast. U.S. Forest Service Research Paper NE-33. 37 p.

Shissler, B.P. 1985. White-tailed deer biology and management in Pennsylvania. Wildlife Managers, Conestoga, Penn. 78 p.

Short, H.L. 1975. Nutrition of southern deer in different seasons. Journal of Wildlife Management 39(2):321-329.

Simberloff, D. 1986. Are we on the verge of mass extinction in tropical rain forests? Pp. 165-180 *in* D.K. Elliot, ed., Dynamics of Extinction. John Wiley and Sons, New York.

Skinner, W.R. and E.S. Telfer. 1974. Spring, summer, and fall foods of deer in New Brunswick. Journal of Wildlife Management 38(2):210-214.

Stamps, J.A., M. Buechner, and V.V. Krishnan.

1987. The effects of edge permeability and habitat geometry on emigration from bounded habitats. American Naturalist 129:533-552.

Storm, G.L., R.H. Yanner, D.F. Cottam, and G.M. Vecellio. 1989. Population status, movements, habitat use, and impact of white-tailed deer at Gettysburg National Military Park and Eisenhower National Historic Site, Pennsylvania. National Park Service Technical Report NPS/MAR/NRTR-89/043. 123 p.

Sutter, R.D. 1984. The status of *Helonias bullata* L. (Liliaceae) in the Southern Appalachians. Castanea 49:9-16.

Tilghman, N.G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. Journal of Wildlife Management 53(3):524-532.

Torgerson, O. and W.H. Pfander. 1971. Cellulose digestibility and chemical composition of Missouri deer foods. Journal of Wildlife Management 35(2):221-231.

Tucker, G. 1991. Pers. comm. U.S. Forest Service, Ozark National Forest, Russellville, Ark.

Vangilder, L.D., O. Torgerson, and W.R. Porath. 1982. Factors influencing selection by white-tailed deer. Journal of Wildlife Management 46(3):711-718.

Warren, R.J. and C.R. Ford. 1990. Population and ecological characteristics of white-tailed deer on Catoctin Mountain Park. Final report. Contract No. CA-3500-8-0001 National Capital Region, U.S. National Park Service and Sub-agreement No. 19, Cooperative Agreement No. CA-5000-4-8005, U.S. Department of Interior and University of Georgia. 52 p.

Watts, C.R. 1964. Forage preferences of captive deer while free ranging in a mixed oak forest. M.S. thesis, Pennsylvania State University, University Park. 65 pp.

Webb, W.L., R.T. King, and E.F. Patrick. 1956. Effect of white-tailed deer on a mature northern hardwood forest. Journal of Forestry 54:391-398.

Whittington, R.W. 1984. Piedmont Plateau. Pp. 355-366 *in*: L.K. Halls, ed., White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Penn.

Williamson, S.J. and D.H. Hirth. 1985. An evaluation of edge use by white-tailed deer. Wildlife Society Bulletin 13(3):252-257.