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Impacts of White-Tailed Deer Grazing on Spring Wildflower Communities

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Impacts of white-tailed deer grazing on spring wildflower communities

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Faye Frankland

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EFFECTS OF DEER GRAZING ON SPRING WILDFLOWERS AT BEALL WOODS NATURE PRESERVE

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Master's Thesis

Eastern Illinois University

Charleston, Illinois

ABSTRACT

High deer densities on state forests and nature preserves throughout Illinois have prompted concerns that deer are impacting the growth, survival, and reproduction of spring-flowering herbaceous plants. I investigated the impacts of white-tailed deer (Odocoileus virginianus) on the herbaceous vegetation, particularly spring wildflowers, at Beall Woods Nature Preserve (BWNP). BWNP was selected as the site for this study because it supports a diverse community of spring wildflowers and a large deer population. The objectives for this study were to: (1) quantify the extent of deer foraging on representative spring-flowering plant species at Beall Woods Nature Preserve, (2) investigate the effects of this foraging on the growth, survival and reproduction of these species, and (3) develop an inexpensive, practical method for Illinois Department of Natural Resources (IDNR) Natural Heritage biologists to monitor the impact of deer on these species on nature preserves throughout Illinois.

The effects of grazing by deer were monitored using a series of 90 1-m^2 plots. Deer were excluded from grazing in 30 of these by 1-m^3 exclosures constructed of PVC frames enclosed with 2.54 cm wire mesh. Weekly monitoring of the herbaceous vegetation in the 30 exclosures and the 60 open plots began in mid-February and ended in mid-July 1999. I monitored plant species richness and abundance, number of plants grazed, heights of grazed and ungrazed individuals, number flowering, and number producing seed in all plots.

A total of 63 plant species were recorded in the plots including 36 perennials, 6 annuals and 21 woody species. No federal or state endangered or threatened species

were present; however, several species of concern such as Jack-in-the-pulpit (Arisaema triphyllum), green dragon (Arisaema dracontium), and goldenseal (Hydrastis canadensis) were found within the study plots. Species richness did not differ among exclosed, adjacent open and distant open plots. Spring beauty (Claytonia virginica) was the most widespread species. Toothwort (Dentaria laciniata) and red trillium (Trillium recurvatum) were also common.

Exclosures did not affect deer grazing in the treatment plots adjacent to them either by repelling or attracting deer. Some grazing on spring herbs was recorded in the open plots in every week from 22 February through 7 June. Grazing peaked during the first week of April then declined gradually through May with the emergence of foliage on woody plants.

Among all species, 49% were grazed to some extent. The intensity of grazing on individual species ranged from 63% on Jacob's ladder (Polemonium reptans) to 1% on Virginia knotweed (Polygonum virginianum). In addition to Jacob's ladder, other species that were grazed heavily included goldenseal, false Solomon's seal (Smilacina racemosa), red trillium, dwarf larkspur (Delphinium tricorne), and spring cress (Cardamine bulbosa). Forty percent of the unprotected trillium were grazed. The 2% that flowered were grazed before reaching the seed production stage. All of the Jacob's ladder that flowered were grazed resulting in no seed production. In contrast, 38% of the protected Jacob's ladder flowered and produced seed. Generally, spring wildflowers did not recover from herbivory during the season they were grazed. No regrowth of reproductive organs or leaves occurred.

Not all wildflowers were grazed heavily. Those species that were affected minimally by deer included wild ginger (Asarum canadense), Dutchman's breeches (Dicentra cucullaria), green dragon, toothwort, and spring beauty. Many of these species emerged after the peak of grazing by deer and reproduced more successfully than species that were heavily grazed. Others, such as toothwort and spring beauty, were available during the peak of grazing but may have escaped heavy grazing by numerically swamping herbivores during the brief critical period of growth and reproduction. For example, only 4% of the toothwort and 10% of the spring beauty were grazed.

There were significant differences in height between the protected and unprotected plants of several species. Often larger, more vigorous plants were grazed leaving smaller, non-reproducing individuals. The mean height of ungrazed red trillium on open plots was 9.8 cm compared to 12.7 cm for those located in the exclosures. Jacob's ladder averaged 20.6 cm in height outside exclosures but 33.3 cm inside exclosures.

This study corroborates previous research showing that continual grazing by white-tailed deer has negative effects on forest herbs. Selective foraging results in species such as Jacob's ladder, trillium, and goldenseal being grazed heavily resulting in reduced leaf area, height, flowering, and seed production. The extent of grazing on many forest herbs warrants reducing the density of deer on BWNP to protect these species. The IDNR should consider a deer management program to reduce and

maintain the population at a sufficiently low density to allow for the recovery of these sensitive herbaceous species.

Trillium, dwarf larkspur, false Solomon's seal, and Jacob's ladder appear to be useful indicator species of the impact of deer on forest herbaceous vegetation. These species are widely distributed in Illinois and are easy to identify. Furthermore, these species were heavily grazed in early spring when deer densities are high on BWNP and there are noticeable differences in flower production and stem height between protected and unprotected individuals of these species. Finally, this study suggests that small exclosures are a viable, inexpensive alternative to large, permanent exclosures for monitoring the impacts of deer on the forest herbaceous vegetation.

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INTRODUCTION

High densities of white-tailed deer (Odocoileus virginianus) on state forests and nature preserves throughout Illinois have prompted concerns that deer are impacting the growth, survival, and reproduction of spring-flowering herbaceous species. Observations by biologists with the Illinois Department of Natural Resources (IDNR) suggest that some wildflower species have declined locally on preserves during the past decade, coincidental with the rapid increase in deer populations (W. McClain, IL Dept. Nat. Resour., pers. comm.). Local extirpation of spring woodland wildflowers such as the white-flowered trillium (Trillium grandiflorum) has been documented in several nature preserves (Anderson 1997).

The purpose of this study was to investigate the impacts of white-tailed deer on the herbaceous vegetation, particularly spring wildflowers, at Beall Woods Nature Preserve (BWNP). BWNP was selected as the site for this study because it supports a diverse community of spring wildflowers and an expanding deer population. While BWNP currently supports a relatively diverse community of spring wildflowers, there is growing concern that the extent of grazing on these plants by resident deer may impact their growth and reproduction, and ultimately threaten the survival of local populations. Botanists familiar with BWNP have noted a decline in spring wildflowers, such as red trillium (Trillium recurvatum) (J. Ebinger, Eastern IL Univ., pers. comm.), since BWNP was dedicated as a nature preserve in 1966. In addition, recent spring floral surveys by IDNR biologists have reported the absence of white-flowered trillium, a species that was present on the area when Ashby and Ozment

(1967) conducted their floral survey of BWNP. While these declines in herbaceous vegetation could be attributed to other environmental factors, they coincide with an increasing deer population at BWNP and appear to be consistent with observations made on other nature preserves throughout the state.

My objectives for this research were to: (1) quantify the extent of deer foraging on representative spring-flowering plant species at Beall Woods Nature Preserve, (2) investigate the effects of this foraging on the growth, survival and reproduction of these species, and (3) develop an inexpensive, practical method for IDNR Natural Heritage biologists to monitor the impact of deer on these species on nature preserves statewide.

LITERATURE REVIEW

The effects of deer on the regeneration and growth of woody vegetation has been investigated frequently by biologists concerned with forest regeneration. Overabundant deer populations can alter the species composition of forests, slow regeneration, and impact the quality and diversity of habitat available to other wildlife species by reducing or eliminating young tree seedlings, shrubs and herbaceous plants (Graham 1954, Webb et al. 1956, Beals et al. 1960, Marquis 1974, Tierson et al. 1966, Ross et al. 1970, Alverson et al. 1988, Tilghman 1989, Strole and Anderson 1992, DeCalesta 1994).

Selective browsing on preferred woody species shifts the composition of the forest to less palatable species or to those species that can tolerate browsing. As browsing increases on preferred woody species, the density of these species decreases

(Beals et al. 1960) allowing less preferred species such as sugar maple (Acer saccharum) and browse-tolerant species such as multiflora rose (Rosa multiflora) to increase (Strole and Anderson 1992). Indirect changes to the ground cover as a result of overbrowsing also affect tree regeneration. In areas of high deer density, Tilghman (1989) recorded a negative correlation between blackberry (Rubus sp.) and hay-scented fern (Dennstaedtia punctilobula). As deer populations increased, blackberry cover decreased; whereas, the hay-scented fern increased in density. This increase in ground cover appeared to prevent shade-intolerant species such as white oak (Quercus alba) seedlings from becoming established.

Browse-intolerant species show signs of recovering when released from intense browsing pressure (Ross et al. 1970, Anderson and Loucks 1979, Tilghman 1989, Anderson and Katz 1993). Tilghman (1989) concluded that deer populations should be maintained at ≤ 7 deer/km^2 to allow for tree regeneration and desired tree species composition.

Effects of deer foraging on woodland herbaceous vegetation has been studied less frequently. Within the past decade, studies on deer herbivory have documented reductions in herb frequency, abundance, richness and evenness (Anderson 1994, Balgooyen and Waller 1995, Rooney and Dress 1997, Augustine and Frelich 1998). Rooney and Dress (1997) attributed declines in the herbaceous vegetation in an old-growth forest located in Pennsylvania to the herbivory of an overabundant deer population. Species richness, abundance and evenness of the herbaceous understory had decreased since the original survey was conducted 66 years earlier.

Spring-flowering herbaceous plants may be particularly vulnerable to grazing by deer because these species emerge and reproduce before the leaves of woody plants and agricultural crops are available as forage. Kelly (1994) reported that foraging by deer was more intense in forests in early-spring than in summer in part because deer tend to disperse out of forests and into crop fields once the latter begin to provide food and cover in summer (Nixon et al. 1991).

The removal of plant tissue by herbivores affects a plant's abilities to survive. The loss of foliage and photosynthetic tissue and the subsequent loss of roots and stored energy reduces the vigor of the plant, its ability to compete, and its reproductive effort (Smith and Smith 1998). Anderson (1994) found that when the leaves of white-flowered trillium were removed by deer, these plants had lower energy reserves and consequently less energy available for reproduction during the next growing season. Growth was also impacted by the cumulative effects of grazing over several years reducing the height of trillium. However, stem height increased when these plants were protected by exclosures. Based on the stem height of white-flowered trillium and the percentage of individuals flowering, Anderson recommended that deer densities should be maintained at 4-6/km^2.

Augustine and Frelich's (1998) study on deer herbivory on trillium in old-growth forest fragments in Minnesota supported Anderson's findings of decreased stem height and flowering percentages as a result of high deer densities. Grazing during a single growing season did not affect the growth the next year, but continuous grazing over several years did reduce the height of the individual plants. When deer herds

were reduced or individual plants were protected from herbivory for two growing seasons, flowering rates and leaf area increased in these plants. Such results have led several researchers to suggest that trillium may serve as a potential indicator species of the impact of deer grazing on the herbaceous vegetation of a forest (Anderson 1994, Augustine and Frelich 1998). Balgooyen and Waller (1995) measured the frequency and percent cover of bluebead lily (Clintonia borealis) on numerous sites in Wisconsin that varied in deer density and reported that both measures decreased as deer density increased leading them to conclude that this species also has the potential to be an indicator species of the impact of grazing within its range.

Forest fragmentation may exacerbate the detrimental effects of deer on understory species by concentrating deer in small forest patches particularly during winter and spring when agricultural fields provide little cover (Nixon et al. 1991). Local extirpation of forest herbs is possible when deer and other herbivores eliminate local seed sources and recolonization via seed dispersal is restricted by the isolation often associated with fragmentation (Alverson et al. 1988, Strole and Anderson 1992).

MATERIALS AND METHODS

Study Area

This study was conducted at BWNP, located within Beall Woods State Park in Wabash County (T2S,R13W,sec11) in the Wabash border natural division of southeastern Illinois (Schwegman 1973). This 257-ha property was acquired by the state in September 1965. In January 1966, a 133-ha parcel of old-growth forest on the

site was dedicated as a nature preserve. Listed in the National Register of Natural Landmarks as the "Forest of the Wabash," Beall Woods is the best remaining example of the immense forest that once grew along the Wabash River (McFall and Karnes 1995). The property was owned by the Beall family from the mid-1800's until 1961. Tenants farmed the property from prior to 1911 until 1961 (Esary, pers. comm., 1999). Cattle and hogs grazed the woods and whereas there was selective harvesting of timber, no major cutting occurred (Ashby and Ozment 1967). No major disturbance has occurred since coming under the jurisdiction of the Illinois Nature Preserves Commission.

Soils in the study area are of the Alford-Iona and Haymond-Allison associations (Walker and Fehrenbacher 1964). The Alford-Iona soils are light-colored, moderately to well-drained, upland soils. With additional fertilization, they can be highly productive. Haymond-Allison soils are bottomland soils bordering the Wabash River. They are light and moderately dark-colored soils that are poorly to well-drained. These soils need drainage in order to be farmed.

The climate for Wabash County is continental with warm, humid summers and moderately cold winters (Walker and Fehrenbacher 1964). The warmest month is July and the coldest is January with mean temperatures of 24.3° and -3.6°C, respectively. Average annual precipitation for the area is approximately 100 cm with heaviest monthly precipitation falling from March to June.

Past surveys of the woody and herbaceous vegetation have been conducted at BWNP. Lindsey (1962) classified the upland forest as oak-hickory-maple and the

floodplain as oak-gum-elm-hickory forest. Ashby and Ozment (1967) in their survey identified 340 plant species and eight different forest communities, four on the upland and four in the floodplain. Oaks (Quercus sp.) were the dominant trees in the upland forests. The floodplain forests were characterized by American elm (Ulmus americana) and silver maple (Acer saccharinum). A recent survey by Ebinger (1997) noted that sugar maple has replaced oaks as first in importance in the upland forests. American elm and silver maple remain first in importance in the floodplain forests.

Aerial deer censuses conducted by IDNR biologists during the period 1996-1999 reported an average minimum deer density of 22 deer/km^2 on site (T. Esker, IL Dept. Nat. Resour., pers. comm.). Vegetation surveys conducted annually on BWNP since 1996 to document the extent of deer browsing on woody plants have indicated that woody plant species have been severely impacted. An average of 41% of the total stems were browsed (T. Esker, IL Dept. Nat. Resour., pers. comm.). Ebinger (1997) attributed seedling and sapling mortality of several species to deer browse.

Methods

I conducted my research in BWNP using a series of 30 deer exclosures measuring $1m^3$ in size. These structures were constructed using polyvinyl chloride (PVC) frames enclosed with 2.54 cm wire mesh. Deer and rabbits (Sylvilagus floridanus) were excluded and although smaller herbivores such as rodents were not, the size of wire mesh likely deterred them from freely entering the study area.

The exclosures were placed on the upland portion of the nature preserve (Figs. 1-3). The bottomland area was not surveyed due to the fact that flooding occurs during the spring and this area is inaccessible when species such as red trillium and Jack-in-the-pulpit (Arisaema triphyllum) are emerging.

During the spring of 1998, patches of forest herbs were located. Exclosures were established so that these patches were divided between the exclosure and an unprotected $1m^2$ plot. On the chance that the exclosures influenced foraging by either attracting or repelling deer, an additional 30 unprotected $1m^2$ plots were established away from the exclosure areas. I attempted to select these additional plots so that they were at least 9 m away from the associated exclosure and contained species similar to those in the exclosure.

Weekly monitoring of the herbaceous vegetation in the 30 exclosures and the 60 open plots began in mid-February and ended in mid-July 1999. Species richness and abundance as well as the number of plants grazed, the number of flowering and the number producing seed were documented. Identification and naming of all plant species followed Mohlenbrock (1986). Plant heights of Jack-in-the-pulpit, green dragon (Arisaema dracontium), spring cress (Cardamine bulbosa), dwarf larkspur (Delphinium tricorne), toothwort (Dentaria laciniata), Jacob's ladder (Polemonium reptans), false Solomon's seal (Smilacina racemosa), and red trillium were measured to note any possible difference between the exclosures and open plots.

Grazing of individual leaves was recorded for species, such as, spring beauty (Claytonia virginica) and white trout lily (Erythronium albidum). The number of

individual plants that were grazed was recorded for species such as red trillium, Jack-in-the-pulpit, green dragon, goldenseal (Hydrastis canadensis), and mayapple (Podophyllum peltatum). Clusters or clumps of leaves and stems were counted for species such as dwarf larkspur, Dutchman's breeches (Dicentra cucullaria), Jacob's ladder, and the grasses and sedges (Leersia/Carex sp.).

The percentage of grazing that occurred in the open plots immediately adjacent to the exclosures and the distant open plots was compared to determine whether or not the exclosures influenced deer foraging in these plots. To verify that deer (not rabbits) were responsible for the grazing, an automatic IR-triggered camera system was placed in two plots to photograph animals as they foraged. The extent of grazing on each species was analyzed as was the timing of grazing. Differences in species richness among exclosed plots and the two types of unprotected plots were tested using ANOVA.

RESULTS

A total of 63 plant species were recorded in the plots including 36 perennials, 6 annuals and 21 woody species (Appendices A, B). No federal or state endangered or threatened species were present; however, species of concern such as Jack-in-the-pulpit, green dragon, spring cress, dwarf larkspur, toothwort, white trout lily, goldenseal, Jacob's ladder, and red trillium were found within the study plots.

Species richness did not differ among the exclosed, the adjacent open and the distant open plots ($F = 0.72$; $p = 0.49$). Exclosures averaged of 10.1 species/plot while

adjacent open and distant open plots averaged 9.8 and 9.3 species/plot, respectively.

Spring beauty was the most widespread species (Table 1) occurring in 86 of the 90 plots. Toothwort and red trillium was also fairly common occurring in 62% and 54% of the plots, respectively. The tendency of certain forest herbs to occur in patches limited the frequency of occurrence. For example, Jacob's ladder and false Solomon's seal were each present in only 3% of the plots, but they were abundant in these few plots.

During 21 days of monitoring plots with the IR cameras, I recorded six incidents of deer foraging in open plots. No rabbits or other vertebrate herbivores were recorded using these plots.

There was little difference in the extent of deer grazing between the two different types of unprotected plots. This suggests that the exclosures did not affect deer grazing in the open plots adjacent to them, either by repelling or attracting deer. Grazing was recorded in 28 of the 30 (93%) plots located adjacent to the exclosures and in 29 of the 30 (97%) plots situated ≥9 m away from the exclosure site. The only evidence of grazing within the exclosures was by invertebrates, particularly snails and insects. Grazing by these groups was most evident on grasses and sedges and spring beauty.

Grazing on spring herbs was recorded in the open plots in every week from 22 February through 7 June (Fig. 4). Grazing increased through March, peaked during the first week of April when grazing was documented in 62% of the open plots, then declined gradually through April and May until less than 15% of the plots were grazed

during mid-May. This decline in grazing on forest herbs coincided with the emergence of agricultural crops and the foliage on woody plants.

Of all species present, 49% were grazed to some extent (Table 2). Sample sizes were small for many of these species making analysis of the effect of grazing on these plants unreliable. Consequently, I focused most of my analyses on the 24 species which had >25 individuals in my study plots.

The intensity of grazing on individual plant species ranged from 63% on Jacob's ladder to 1% on Virginia knotweed (Polygonum virginianum). Other species that were grazed heavily included goldenseal, false Solomon's seal, red trillium, dwarf larkspur, and spring cress. Red trillium, present in 54% of the plots, had 40% of the 328 unprotected plants grazed. Only 2% of red trillium flowered and none went to seed due to grazing (Table 3). Jacob's ladder while present in only 2% of the open plots was grazed intensely at 63%. All plants of this species that flowered were grazed resulting in zero seed production. In contrast, 38% of the protected Jacob's ladder flowered and produced seed. Goldenseal was also grazed heavily; 45% of the individuals on open plots were grazed. Only 8% of this species reached the flower and seed production stages. Dwarf larkspur was also impacted heavily by deer; 37% of the unprotected plants were grazed. Of the individuals that avoided grazing, 32% flowered and 23% produced seed. Spring cress, an early emerging species, was found in 20% of the plots and 31% were grazed. Only 37% of the unprotected plants of this species produced seed; whereas, 83% of the plants present in the protected plots flowered and produced seed. Those species which emerged and were readily available in March and

early-April tended to be heavily grazed and their reproduction was impaired (Figs. 5-8; Table 3).

Not all wildflower species were grazed heavily. Those that were affected minimally by deer included wild ginger (Asarum canadense var. reflexum), Dutchman's breeches, green dragon, toothwort, and spring beauty (Table 3). Some species appear to have escaped heavy herbivory by emerging after the peak of grazing such as green dragon and Jack-in-the-pulpit; grazed 3% and 14%, respectively (Figs. 9, 10). However others, such as toothwort and spring beauty, were available early but were not heavily grazed (Figs. 11, 12). Only 4% of unprotected toothwort were grazed and 10% of the spring beauty were grazed (Table 3).

Generally, spring wildflowers did not recover from herbivory during the season they were grazed. Regrowth of reproductive parts or foliage did not occur even though some species, such as false Solomon's seal and Jacob's ladder, persisted through mid-July. However, a few species such as lopseed (Phryma leptostachya) and enchanter's nightshade (Circaea lutetiana) that were grazed later in the spring (early to mid-May) had regrowth of stems and leaves, flowered, and produced seed.

There were noticeable height differences between the protected and unprotected plants of several species (Table 4). The mean height of the remaining red trillium that avoided grazing in the open plots was 9.8 cm compared to the average height of 12.7 cm for those located in the exclosures. Jacob's ladder had an average height of 20.6 cm on the open plots but 33.3 cm within the exclosures. Grazing impacted the height

of dwarf larkspur. The mean height of those in the open plots was 8.8 cm and 12.4 cm within the exclosures.

DISCUSSION

Previous research conducted on white-flowered trillium and nodding trillium (T. cernuum) and white trillium (T. flexipes) has shown that cumulative grazing by white-tailed deer has negative effects on these species (Anderson 1994, Augustine and Frelich 1998). Trilliums are grazed in greater proportions than would be expected based on their availability, suggesting that deer select for these species while foraging. Stem height and leaf area decrease as grazing increases. Anderson (1994) concluded that the percentage of the plants flowering and mean stem height could serve as indicators of overgrazing by deer. He speculated that the herbaceous vegetation of a forest can sustain itself when deer populations are maintained at densities which allow trilliums to reach a mean stem height of $\geq$ 12 cm. My research supports his hypothesis. The average stem height of unprotected red trillium in my study was 9.8 cm while plants protected by exclosures for a single season averaged 12.7 cm. Large, unprotected plants usually were grazed, while smaller, non-reproducing individuals were largely ignored. Reproduction was very low for protected trilliums; only 1% flowered and 1% produced seed. I speculate this low rate of reproduction is a consequence of the cumulative effect of grazing on these plants over several years prior to the initiation of this study. Two years of protection may be necessary in order to see an increase in flower and seed production (Augustine and Frelich 1998).

The timing of emergence also appears to be an important factor influencing deer grazing pressure. While deer exhibit a "generalist" foraging behavior in the winter months, they forage more selectively during early spring and summer (Nudds 1980). Consequently, those species which emerged early in the spring before other preferred foods were available tended to be grazed the most heavily and their reproduction was most impaired. Grazing of herbaceous plants increased through March, peaked during the first week of April, and subsequently declined through May. In contrast, plants such as green dragon and Jack-in-the-pulpit which did not become readily available until late-April and May were not grazed as heavily. The limiting factor of late-emerging forest herbs is likely to be competition with the developing foliage of trees and shrubs for available sunlight. These plants must balance the threats of grazing pressure early in the spring and shade later in the spring if they are to survive and reproduce successfully. Those herbs that are relatively shade-tolerant may benefit from a delayed emergence in order to avoid the peak of grazing.

Plants may defend themselves against herbivory by using an array of defense mechanisms including chemical defenses (toxins or chemicals that inhibit digestion), reproductive inhibitors, structural defenses such as thorns or spines, absence of chemical attractants used as cues by herbivores, and "masting," the synchronized emergence and reproduction of large numbers of individuals so as to swamp the herbivores during a brief critical season (Stiling 1996). In this study, species such as toothwort and spring beauty appear to use a "masting" (herbivore swamping) strategy to reduce losses to herbivory. They emerged early but were not heavily grazed and

were so abundant during the brief critical period of growth and reproduction that deer foraging had relatively little impact on these species. Others that were available during the peak of grazing but were not heavily grazed, such as wild ginger, may incorporate chemical defenses to discourage herbivores, although it was beyond the scope of this study to test this hypothesis.

Based on my results, red trillium, dwarf larkspur, false Solomon's seal, and Jacob's ladder may also be suitable indicator species for gauging the effects of deer on the health of forest herbaceous vegetation. These species were readily abundant and heavily grazed at BWNP, with noticeable differences in flower production and stem height between the protected and unprotected plants. They are also species that are widely distributed throughout Illinois and can be easily identified by a resource manager.

As previously mentioned, Anderson (1994) and Augustine and Frelich (1998) also recommended trilliums as good indicators of grazing pressure. Parker (1999) identified Jack-in-the-pulpit as an indicator species of deer damage in Indiana. My research does not support this suggestion. Only 14% of Jack-in-the-pulpit were grazed in this study in spite of high grazing intensity by deer. Possible reasons for this difference in results could be due to regional variations in emergence of species which seems unlikely since one of Parker's study sites was located within 20 miles of BWNP. Another factor that might influence the use of this late-emerging herb may be the availability of other forage species, particularly agricultural crops, in the landscape surrounding the study site.

One of the objectives of this research was to develop an inexpensive method to monitor impacts of deer on the forest herbaceous vegetation. Based on my results, the 1-m^3 exclosures used in my study are a viable alternative to the large exclosures typically used in previous studies. Large exclosures are expensive to build and require considerable manpower to construct. The exclosures I used are relatively inexpensive to build and require 1-2 individuals to transport and set up in the field. In addition, they are collapsible and easy to store, if necessary. Once established and staked into the ground on the study site they prove to be durable and stable. Further, the small size allows the researcher to divide small, often ephemeral patches of herbaceous plants into protected and unprotected sample areas.

This study corroborates previous research showing that the persistent grazing of forest herbs by white-tailed deer reduces the growth and reproduction of these species, in some cases threatening their survival. On Illinois' nature preserves, these plants are an important aesthetic and ecological component of the natural ecosystem that the preserve system seeks to conserve. The extent of grazing on many herbs at BWNP warrants reducing the density of deer to protect these species. The IDNR should consider implementing a deer management program to reduce and maintain the population at sufficiently low densities to allow for the recovery of sensitive herbaceous species.

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Table 1. Species occurrence in 90 1-m^2 study plots at Beall Woods Nature Preserve, Illinois, February - July 1999.

Scientific Name	Common Name	No. of Plots	% of Occurrence in Plots
Claytonia virginica	Spring beauty	86	96%
Dentaria laciniata	Toothwort	56	62%
Trillium recurvatum	Red trillium	49	54%
Polygonum virginianum	Virginia knotweed	45	50%
Viola sp.	Violet	42	47%
Impatiens capensis	Spotted touch-me-not	39	43%
Pilea pumila	Clearweed	35	39%
Phryma leptostachya	Lopseed	34	38%
Arisaema triphyllum	Jack-in-the-pulpit	32	36%
Parthenocissus quinquefolia	Virginia creeper	31	34%
Leersia/Carex sp.	Grass/sedge	28	31%
Dicentra cucullaria	Dutchman's breeches	27	30%
Fraxinus sp.	Ash	26	29%
Arisaema dracontium	Green dragon	25	28%
Podophyllum peltatum	Mayapple	23	26%
Delphinium tricorne	Dwarf larkspur	19	21%
Sanicula gregaria	Common snakeroot	19	21%
Cardamine bulbosa	Spring cress	18	20%
Toxicodendron radicans	Poison ivy	18	20%
Circaea lutetiana	Enchanter's nightshade	17	19%
Eupatorium rugosum	White snakeroot	17	19%
Asarum canadense var. reflexum	Wild ginger	16	18%
Sanguinaria canadensis	Bloodroot	16	18%
Cystopteris protrusa	Fragile fern	12	13%
Lindera benzoin	Spicebush	12	13%
Nyssa sylvatica	Black gum	12	13%
Asimina triloba	Pawpaw	11	12%
Galium sp.	Bedstraw	11	12%
Erythronium albidum	White trout lily	10	11%
Carya sp.	Hickory	6	7%
Liriodendron tulipifera	Tuliptree	6	7%
Cryptotaenia canadensis	Honewort	5	6%
Sassafras albidum	Sassafras	5	6%
Ulmus sp.	Elm	5	6%
Galium sp.	Wild licorice	4	4%
Geum canadense	White avens	4	4%
Phlox divaricata	Phlox	4	4%
Prunus serotina	Wild black cherry	4	4%

Table 1. Species occurrence in 90 1-m^2 study plots at Beall Woods Nature Preserve, Illinois, February - July 1999.

Scientific Name	Common Name	Plots	% of Occurrence in Plots
Blephilia hirsuta	Pagoda plant	3	3%
Cynoglossum officinale	Hound's tongue	3	3%
Polemonium reptans	Jacob's ladder	3	3%
Smilacina racemosa	False Solomon's seal	3	3%
Acer sp.	Maple	2	2%
Corydalis flavula	Pale corydalis	2	2%
Phytolacca americana	Pokeweed	2	2%
Sambucus canadensis	Elderberry	2	2%
Agrimonia sp.	Agrimony	1	1%
Botrychium virginianum	Rattlesnake fern	1	1%
Dioscorea villosa	Wild yam	1	1%
Hydrastis canadensis	Goldenseal	1	1%
Hydrophyllum virginianum	Virginia waterleaf	1	1%
Liquidambar styraciflua	Sweet gum	1	1%
Osmorhiza longstylis	Anise-root	1	1%
Ostrya virginiana	Hop hornbeam	1	1%
Oxalis sp.	Oxalis	1	1%
Polygonum hydropiper	Smartweed	1	1%
Quercus sp.	Oak	1	1%
Rosa multiflora	Multiflora rose	1	1%
Rubus flagellaris	Dewberry	1	1%
Smilax hispida	Bristly catbrier	1	1%
Symphoricarpos orbiculatus	Coralberry	1	1%
Triphora trianthophora	Nodding pogonia	1	1%
Vitis sp.	Grape	1	1%

Table 2. Extent of grazing on 55 species located in the 60 1-m^2 open plots at Beall Woods Nature Preserve, Illinois, February - July 1999.

Scientific Name	Common Name	Total No.	% Grazed
Oxalis sp.	Oxalis	1	100%
Cryptotaenia canadensis	Honewort	3	67%
Polemonium reptans	Jacob's ladder	19	63%
Leersia/Carex sp.	Grass/sedge	59	56%
Hydrastis canadensis	Goldenseal	65	45%
Trillium recurvatum	Red trillium	328	40%
Smilacina racemosa	False Solomon's seal	54	39%
Delphinium tricorne	Dwarf larkspur	71	37%
Viola sp.	Violet	150	33%
Cardamine bulbosa	Spring cress	103	31%
Sanguinaria canadensis	Bloodroot	17	29%
Phryma leptostachya	Lopseed	53	26%
Galium sp.	Bedstraw	8	25%
Nyssa sylvatica	Black gum	21	24%
Circaea lutetiana	Enchanter's nightshade	55	16%
Impatiens capensis	Spotted touch-me-not	129	16%
Arisaema triphyllum	Jack-in-the-pulpit	234	14%
Podophyllum peltatum	Mayapple	162	14%
Erythronium albidum	White trout lily	136	13%
Phlox divaricata	Phlox	19	11%
Claytonia virginica	Spring beauty	4,063	10%
Cystopteris protrusa	Fragile fern	59	10%
Parthenocissus quinquefolia	Virginia creeper	56	7%
Sanicula gregaria	Common snakeroot	28	7%
Asarum canadense var. reflexum	Wild ginger	292	6%
Dicentra cucullaria	Dutchman's breeches	252	6%
Dentaria laciniata	Toothwort	970	4%
Pilea pumila	Clearweed	258	4%
Arisaema dracontium	Green dragon	138	3%
Toxicodendron radicans	Poison ivy	43	2%
Polygonum virginianum	Virginia knotweed	83	1%
Asimina triloba	Pawpaw	6	0%
Blephilia hirsuta	Pagoda plant	5	0%
Botrychium virginianum	Rattlesnake fern	1	0%
Carya sp.	Hickory	5	0%

Table 2. Extent of grazing on 55 species located in the 60 1-m^2 open plots at Beall Woods Nature Preserve, Illinois, February - July 1999.

Scientific Name	Common Name	Total No.	% Grazed
Corydalis flavula	Pale corydalis	9	0%
Cynoglossum officinale	Hound's tongue	3	0%
Eupatorium rugosum	White snakeroot	26	0%
Fraxinus sp.	Ash	40	0%
Galium sp.	Wild licorice	3	0%
Geum canadense	White avens	1	0%
Hydrophyllum virginianum	Virginia waterleaf	9	0%
Lindera benzoin	Spicebush	24	0%
Liquidambar styraciflua	Sweet gum	1	0%
Liriodendron tulipifera	Tuliptree	17	0%
Ostrya virginiana	Hop hornbeam	2	0%
Phytolacca americana	Pokeweed	2	0%
Polygonum hydropiper	Smartweed	2	0%
Prunus serotina	Wild black cherry	4	0%
Rubus flagellaris	Dewberry	1	0%
Sambucus canadensis	Elderberry	2	0%
Sassafras albidum	Sassafras	3	0%
Smilax hispida	Bristly catbrier	1	0%
Triphora trianthophora	Nodding pogonia	1	0%
Ulmus sp.	Elm	3	0%

Table 3. Extent of grazing and impact of grazing on the reproduction of 24 herbaceous plant species at Beall Woods Nature Preserve, Illinois, during February - July 1999.

		Plants outside exclosures				Plants inside exclosures			
Scientific Name	**Common Name**	**N**	**% Grazed**	**% Flwr**	**% Producing Seeds**	**N**	**% Grazed**	**% Flwr**	**% Producing Seeds**
Arisaema dracontium	Green dragon	138	3%	1%	0%	79	0	1%	0%
Arisaema triphyllum	Jack-in-the-pulpit	234	14%	0%	0%	131	0	2%	0%
Asarum canadense var. reflexum	Wild ginger	292	6%	*		97	0	*	
Cardamine bulbosa	Spring cress	103	31%	43%	37%	46	0	83%	83%
Circaea lutetiana	Enchanter's nightshade	55	16%	29%	27%	13	0	8%	8%
Claytonia virginica	Spring beauty	4,063	10%	46%	46%	2,300	0	68%	68%
Cystopteris protrusa	Fragile fern	59	10%	*		61	0	*	
Delphinium tricorne	Dwarf larkspur	71	37%	32%	23%	52	0	58%	58%
Dentaria laciniata	Toothwort	970	4%	8%	8%	550	0	13%	13%
Dicentra cucullaria	Dutchman's breeches	252	6%	2%	1%	206	0	1%	1%
Erythronium albidum	White trout lily	136	13%	0%	0%	31	0	0%	0%
Hydrastis canadensis	Goldenseal	65	45%	8%	8%	0	0		
Impatiens capensis	Spotted touch-me-not	129	16%	36%	36%	47	0	47%	47%
Phlox divaricata	Phlox	19	11%	63%	53%	12	0	100%	100%
Phryma leptostachya	Lopseed	53	26%	30%	28%	21	0	62%	57%
Pilea pumila	Clearweed	258	4%	14%	14%	107	0	17%	17%
Podophyllum peltatum	Mayapple	162	14%	2%	2%	63	0	3%	0%
Polemonium reptans	Jacob's ladder	19	63%	11%	0%	8	0	38%	38%
Polygonum virginianum	Virginia knotweed	83	1%	29%	29%	39	0	26%	26%
Sanguinaria canadensis	Bloodroot	17	29%	0%	0%	16	0	6%	6%
Sanicula gregaria	Common snakeroot	28	7%	29%	29%	3	0	67%	67%

Table 3. Extent of grazing and impact of grazing on the reproduction of 24 herbaceous plant species at Beall Woods Nature Preserve, Illinois, during February - July 1999.

		Plants outside exclosures				Plants inside exclosures			
Scientific Name	Common Name	N	% Grazed	% Flwr	% Producing Seeds	N	% Grazed	% Flwr	% Producing Seeds
Smilacina racemosa	False Solomon's seal	54	39%	0%	0%	49	0	0%	0%
Trillium recurvatum	Red Trillium	328	40%	2%	0%	220	0	1%	1%
Viola sp.	Violet	150	33%	29%	15%	107	0	26%	26%

*Flowering not documented

Table 4. Comparison of average heights between protected and unprotected plants of 8 species at Beall Woods Nature Preserve, Illinois, during February - July 1999.

Species	N	x	SE	t-value	Prob>t	
Green dragon (Arisaema dracontium)						
Exclosure	26	16.3	1.5	1.20	0.210	Not Significant
Open plots	83	14.4	0.7			
Jack-in-the-pulpit (Arisaema triphyllum)						
Exclosure	91	15.2	0.6	2.80	0.006	Significant
Open plots	83	12.7	0.6			
Spring cress (Cardamine bulbosa)						
Exclosure	37	22.6	0.8	5.90	0.001	Significant
Open plots	43	15.7	0.8			
Toothwort (Dentaria laciniata)						
Exclosure	19	16.9	1.0	0.60	0.600	Not Significant
Open plots	80	16.4	0.4			
Dwarf larkspur (Delphinium tricorne)						
Exclosure	29	12.4	0.8	2.60	0.010	Significant
Open plots	19	8.8	1.2			
Jacob's ladder (Polemonium reptans)						
Exclosure	3	33.3	2.4	5.20	0.030	Significant
Open plots	8	20.6	0.3			
False Solomon's seal (Smilacina racemosa)						
Exclosure	25	24.7	1.4	7.00	0.001	Significant
Open plots	38	13.8	0.9			
Red trillium (Trillium recurvatum)						
Exclosure	91	12.7	0.5	3.88	0.0002	Significant
Open plots	52	9.8	0.4			

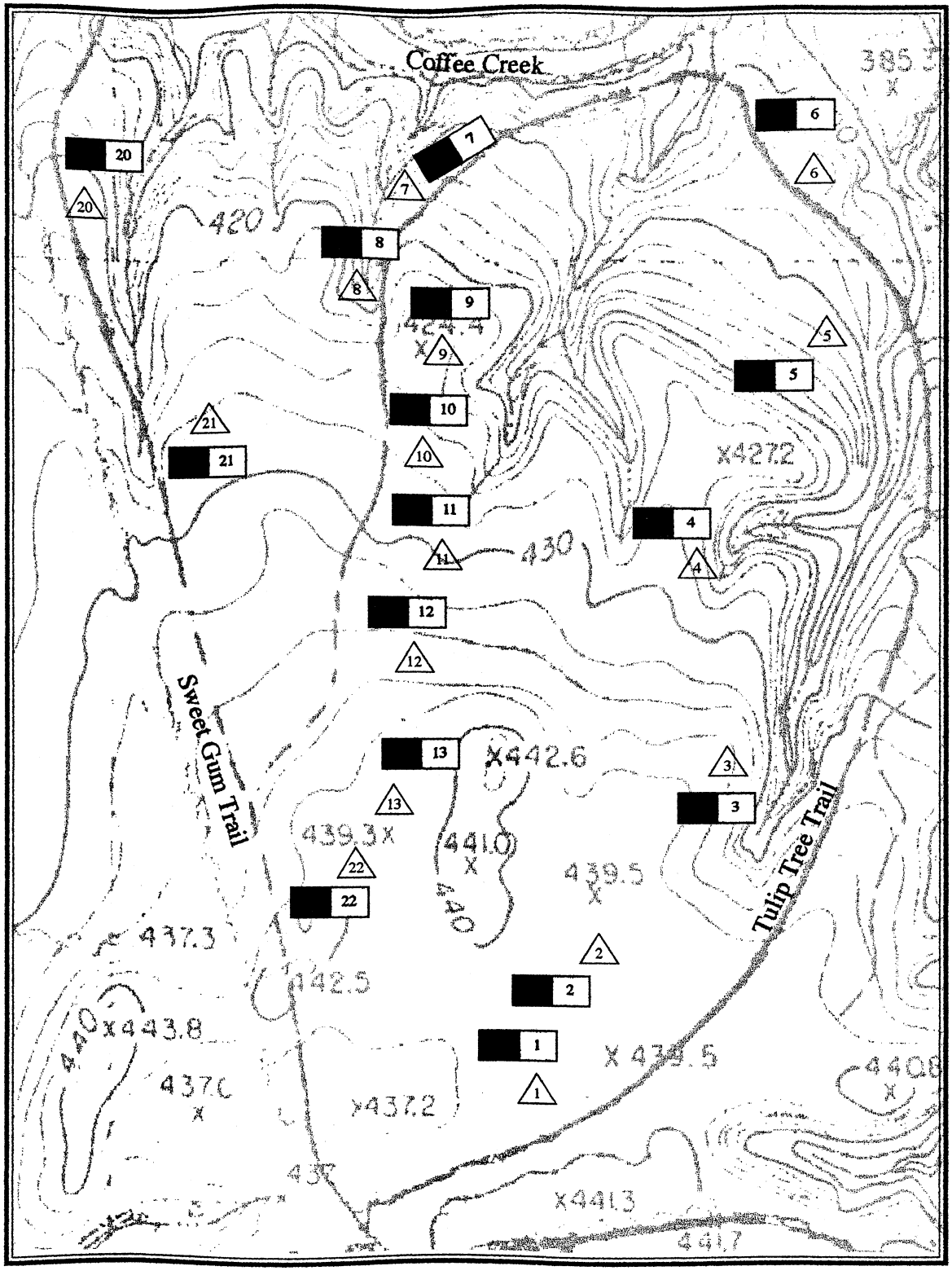

Figure 1. Locations of 90 1-m^2 study plots at Beall Woods Nature Preserve, Illinois, February - July 1999, Plots 1-13; 20-22.

Exclosure ("A" Plot)
Adjacent Open Plot ("B" Plot)
Distant Open Plot ("C" Plot)

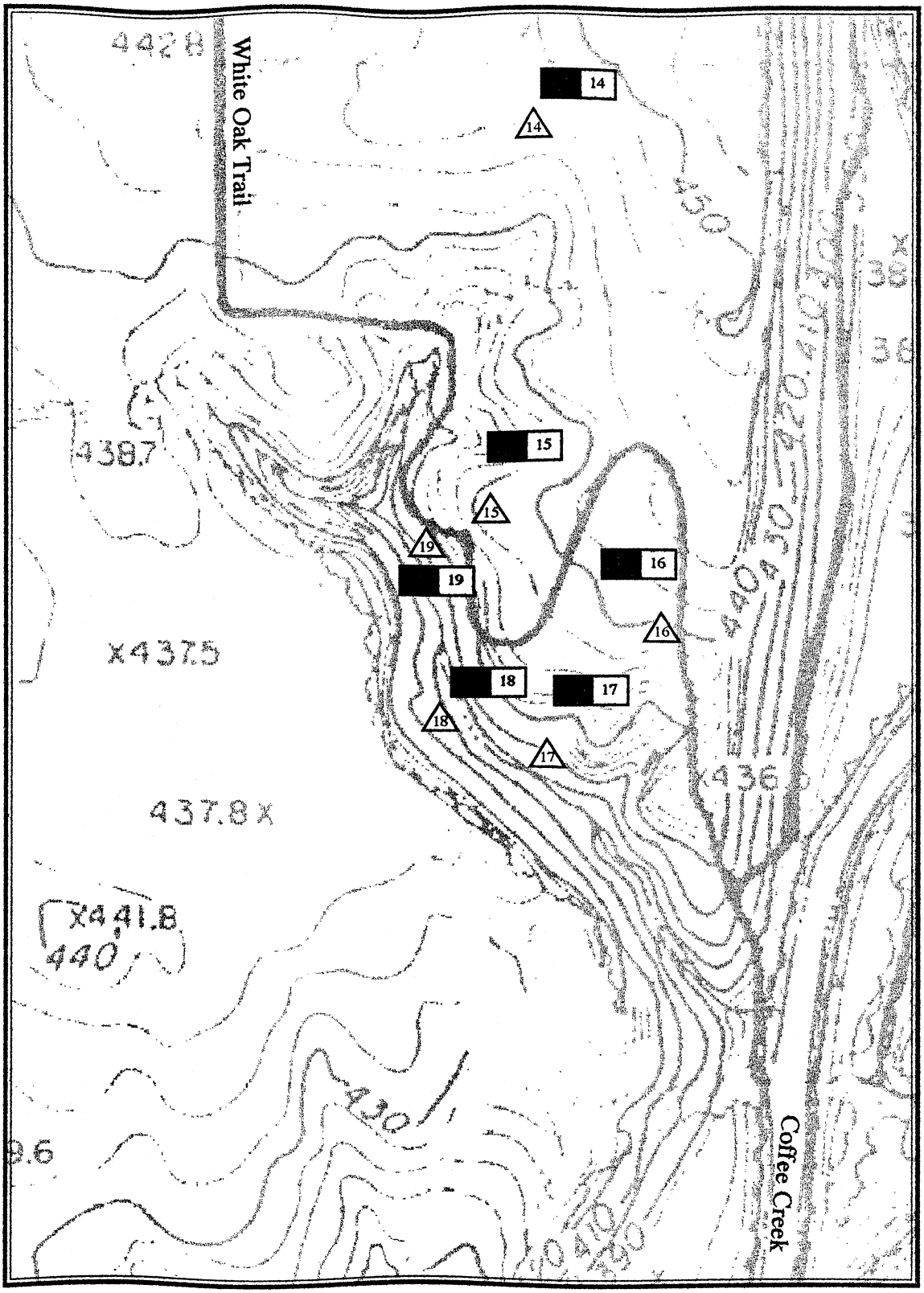

Figure 2. Locations of 90 1-m^2 study plots at Beall Woods Nature Preserve, Illinois, February - July 1999, Plots 14-19.

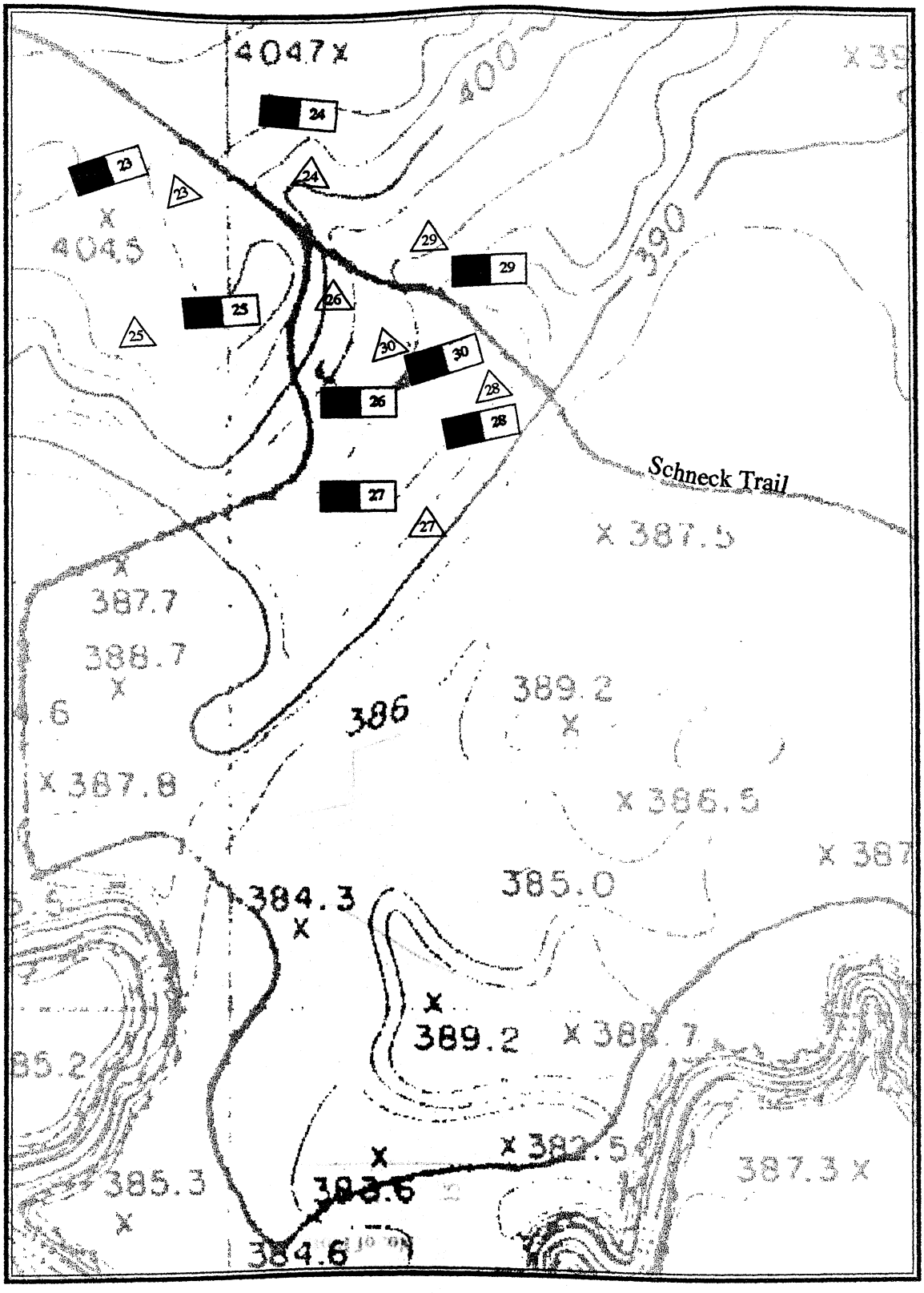

Figure 3. Locations of 90 1-m^2 study plots at Beall Woods Nature Preserve, Illinois, February - July 1999, Plots 23-30.

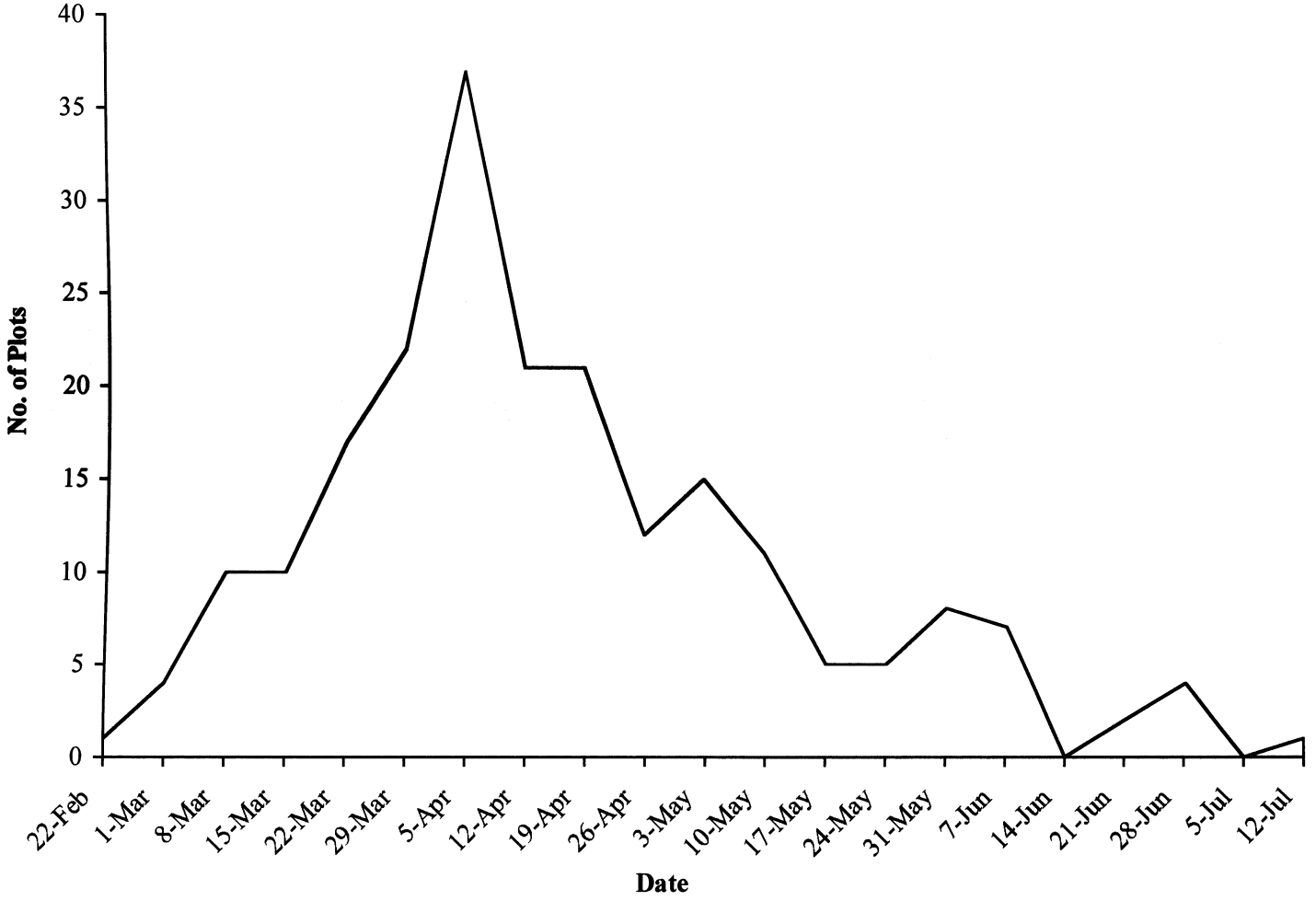

Figure 4. The timing and extent of grazing by white-tailed deer (Odocoileus virginianus) on all herbaceous plants in 90 study plots at Beall Woods Nature Preserve, Illinois, during the period from February 22 through July 12, 1999.

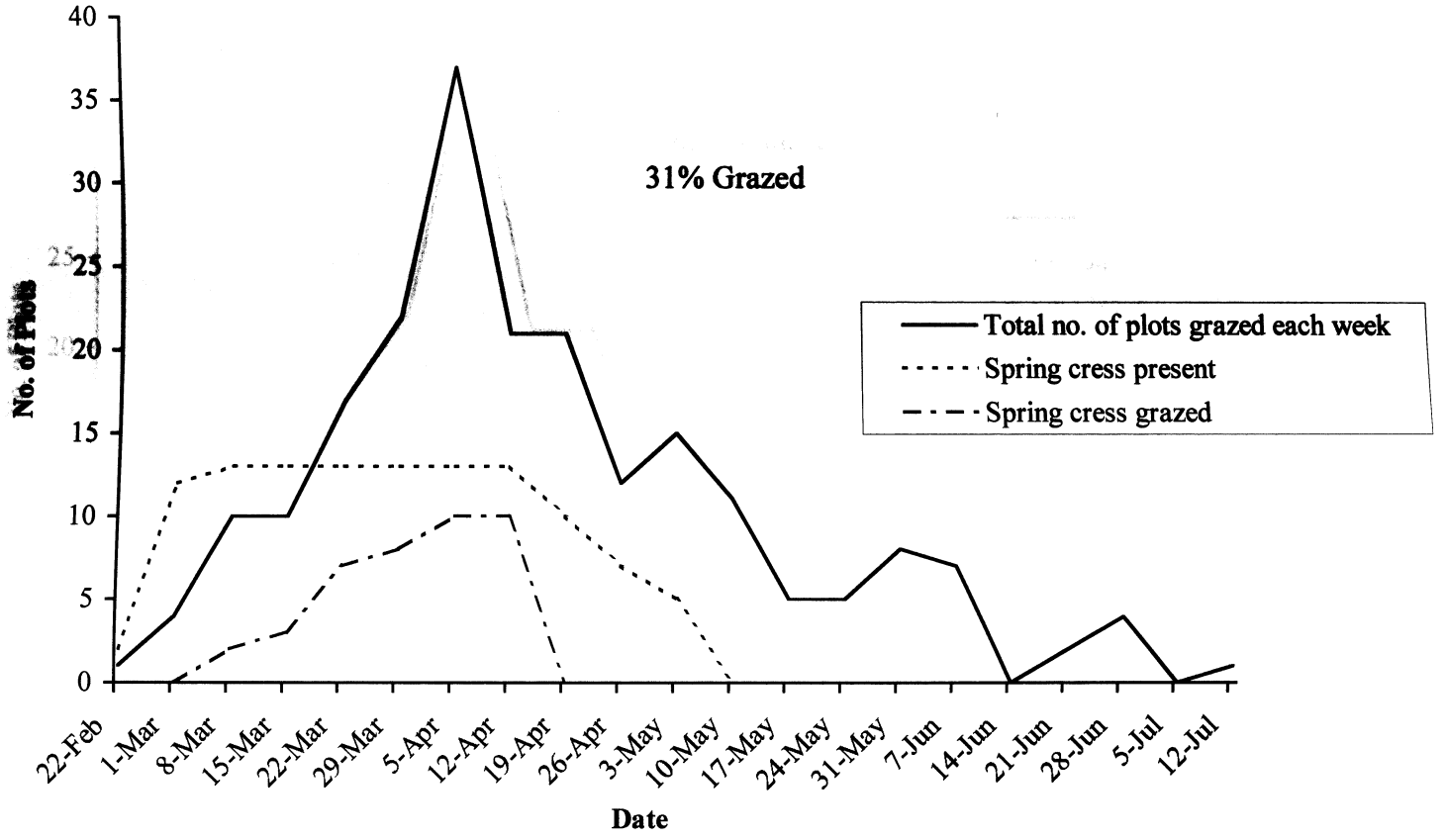

Figure 5. The frequency of plots containing spring cress (Cardamine bulbosa) and the timing of grazing of this species at Beall Woods Nature Preserve, Illinois, during the period from February 22 through July 12, 1999. The timing and extent of grazing by deer on all herbaceous plants in the 90 study plots is also shown.

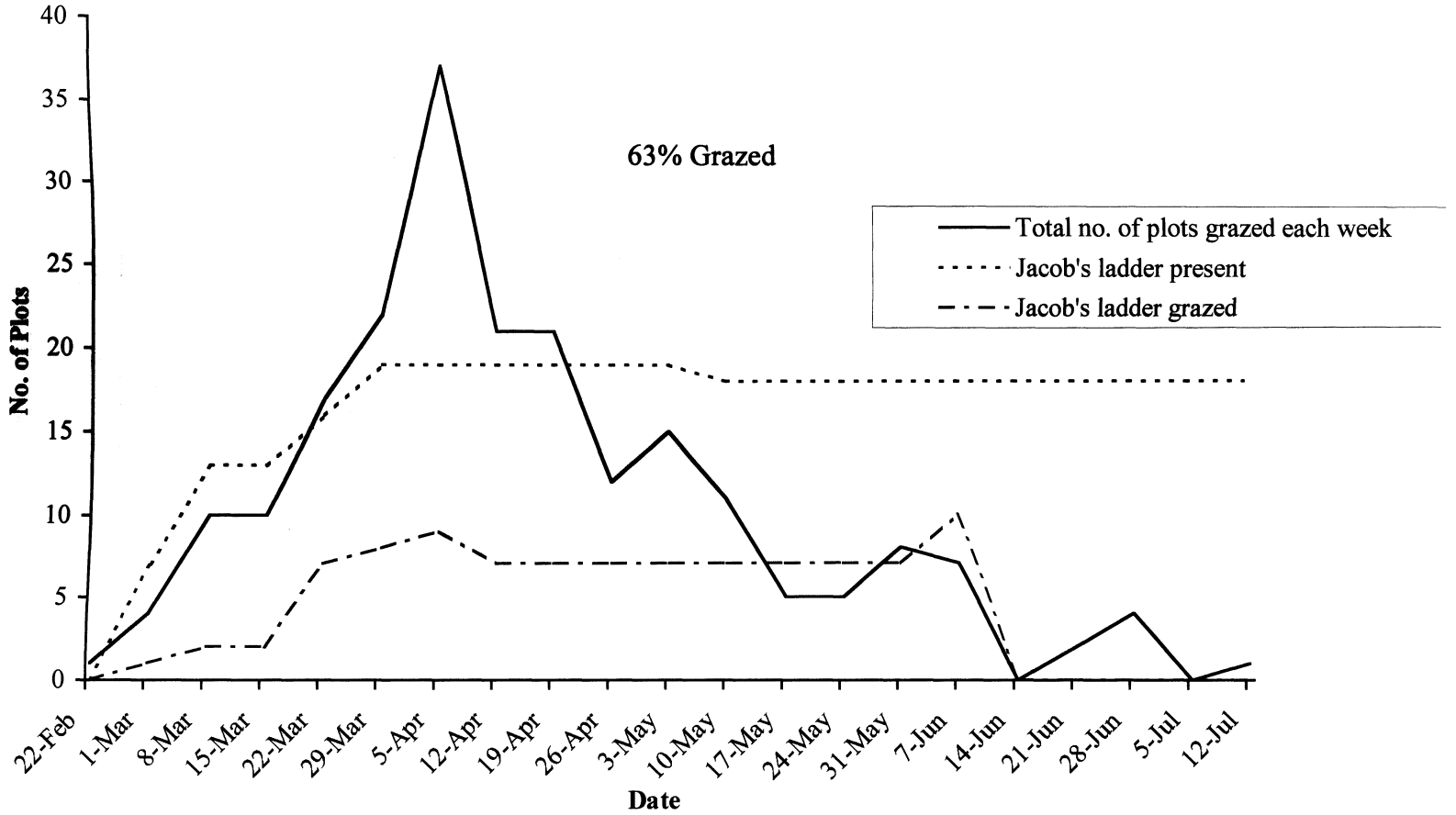

Figure 6. The frequency of plots containing Jacob's ladder (Polemonium reptans) and the timing of grazing of this species at Beall Woods Nature Preserve, Illinois, during the period from February 22 through July 12, 1999. The timing and extent of grazing by deer on all herbaceous plants in the 90 study plots is also shown.

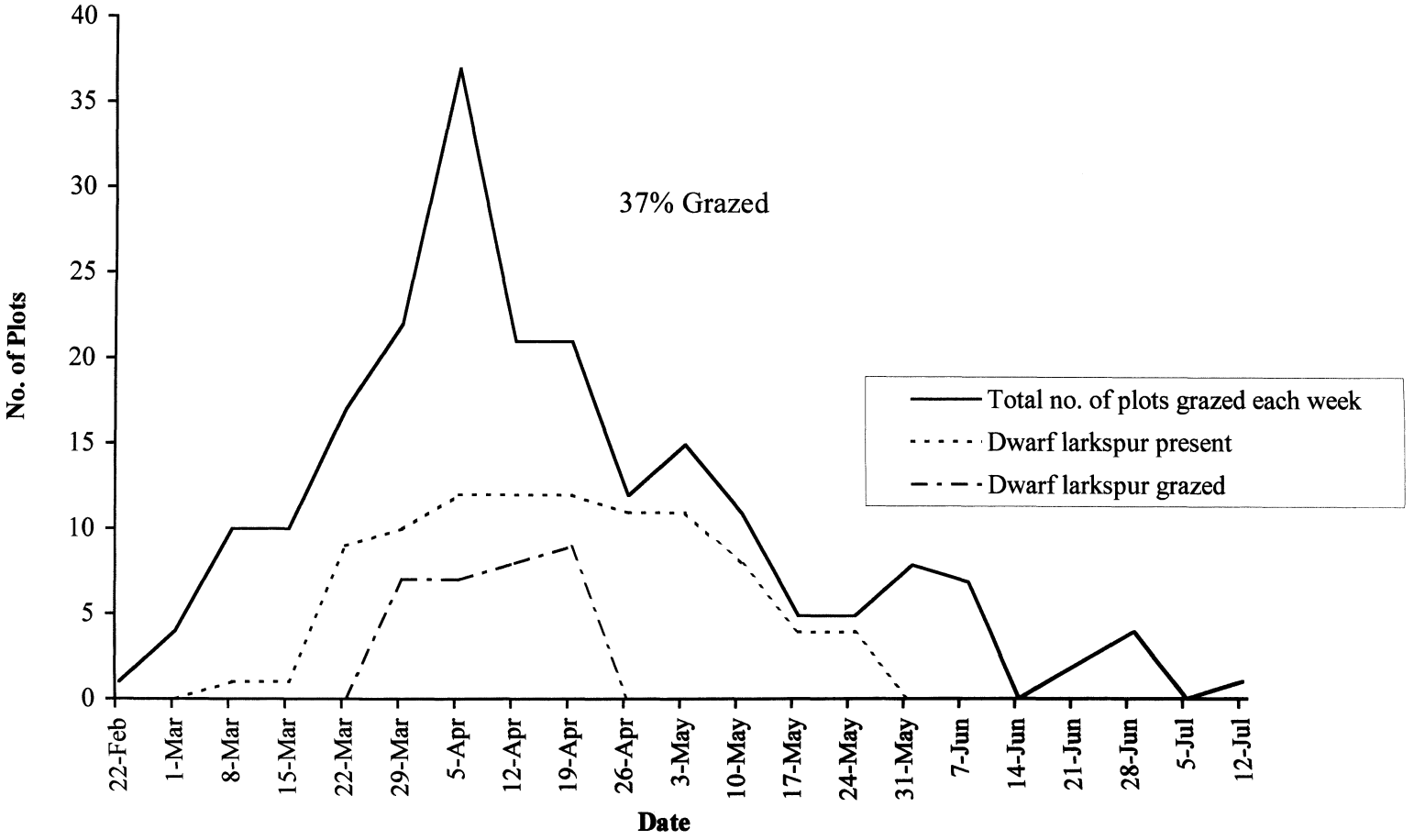

Figure 7. The frequency of plots containing dwarf larkspur (Delphinium tricorne) and the timing of grazing of this species at Beall Woods Nature Preserve, Illinois, during the period from February 22 through July 12, 1999. The timing and extent of grazing by deer on all herbaceous plants in the 90 study plots is also shown.

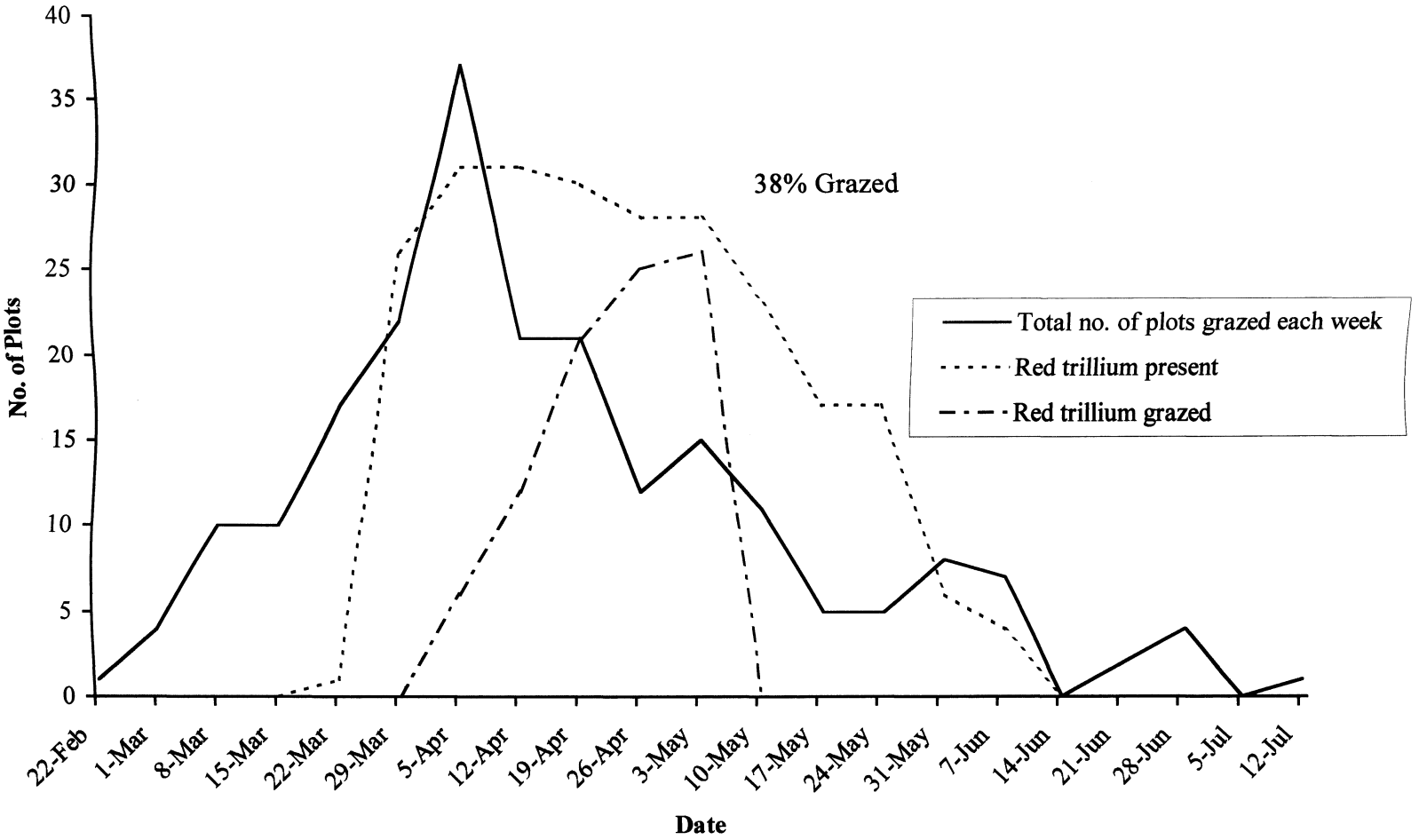

Figure 8. The frequency of plots containing red trillium (Trillium recurvatum) and the timing of grazing of this species at Beall Woods Nature Preserve, Illinois, during the period from February 22 through July 12, 1999. The timing and extent of grazing by deer on all herbaceous plants in the 90 study plots is also shown.

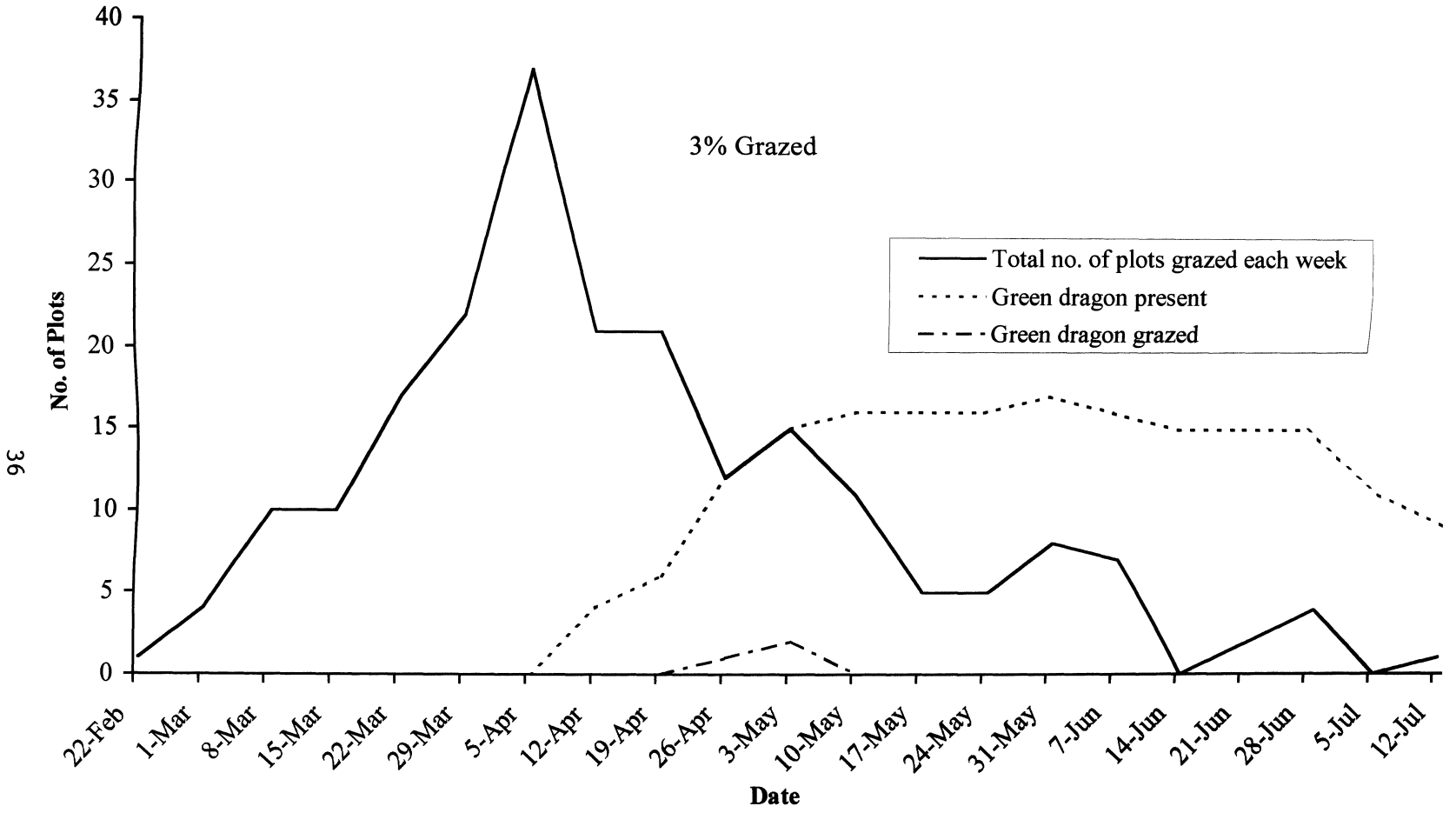

Figure 9. The frequency of plots containing green dragon (Arisaema dracontium) and the timing of grazing of this species at Beall Woods Nature Preserve, Illinois, during the period from February 22 through July 12, 1999. The timing and extent of grazing by deer on all herbaceous plants in the 90 study plots is also shown.

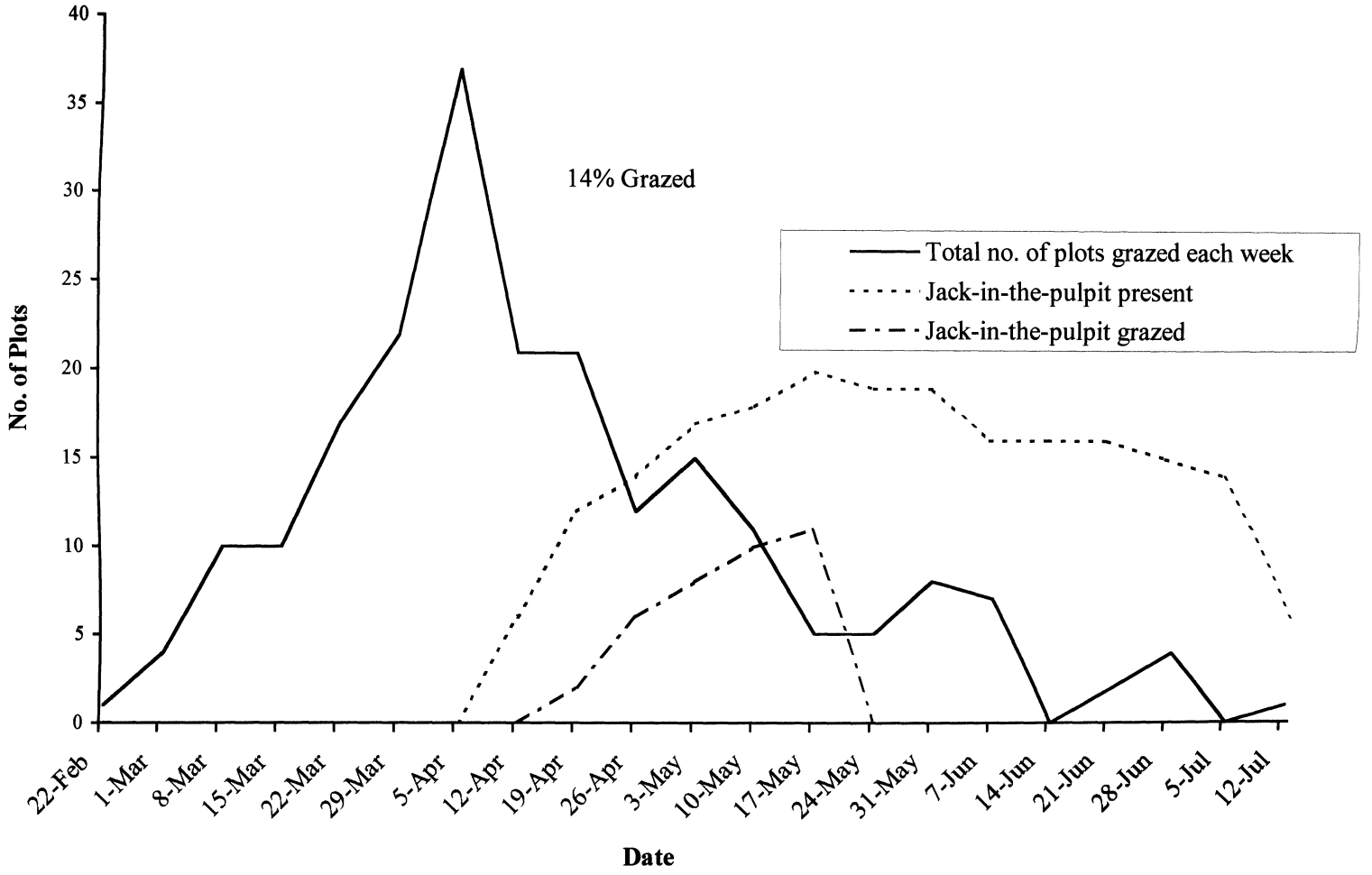

Figure 10. The frequency of plots containing Jack-in-the-pulpit (Arisaema triphyllum) and the timing of grazing of this species at Beall Woods Nature Preserve, Illinois, during the period from February 22 through July 12, 1999. The timing and extent of grazing by deer on all herbaceous plants in the 90 study plots is also shown.

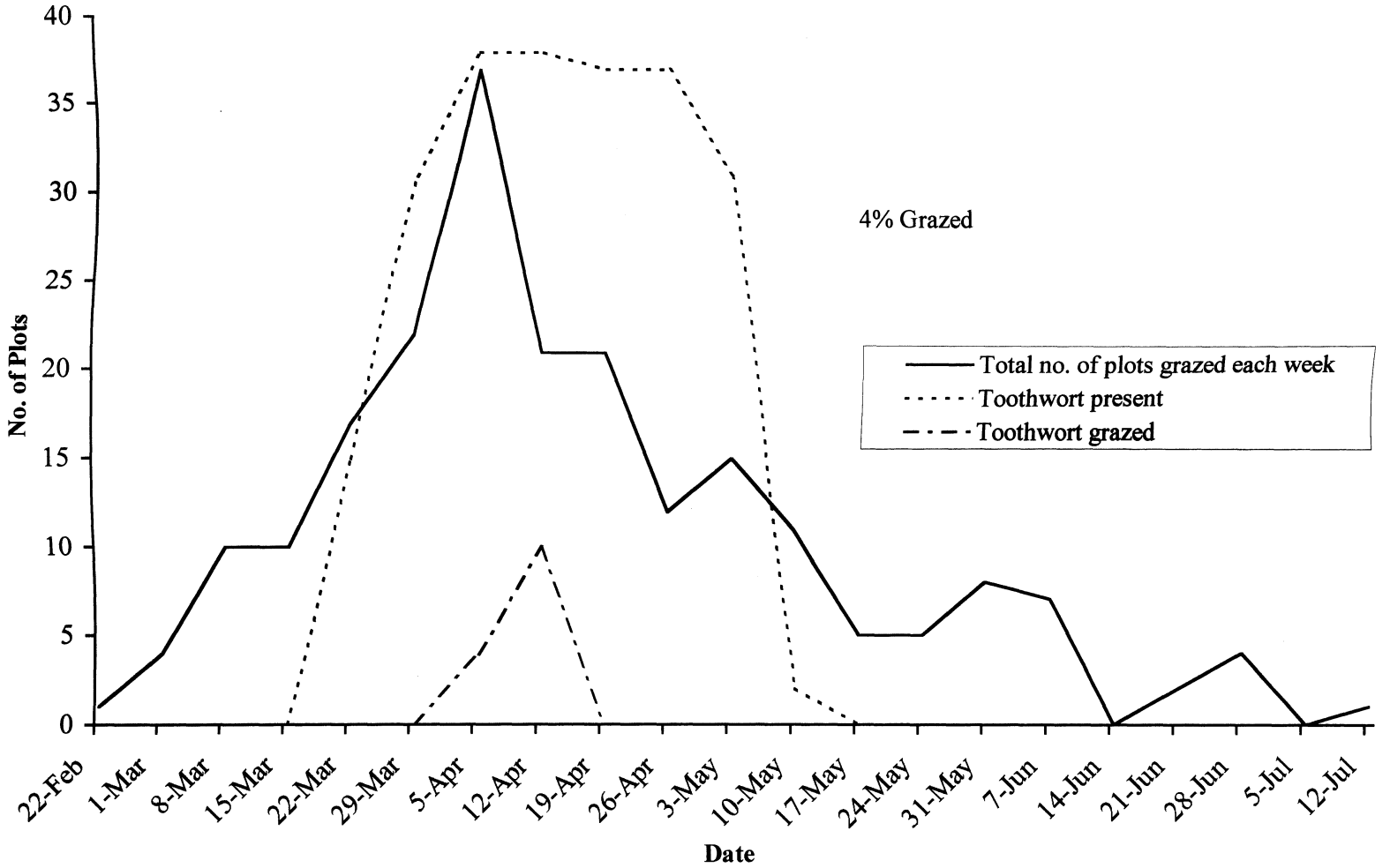

Figure 11. The frequency of plots containing toothwort (Dentaria laciniata) and the timing of grazing of this species at Beall Woods Nature Preserve, Illinois, during the period from February 22 through July 12, 1999. The timing and extent of grazing by deer on all herbaceous plants in the 90 study plots is also shown.

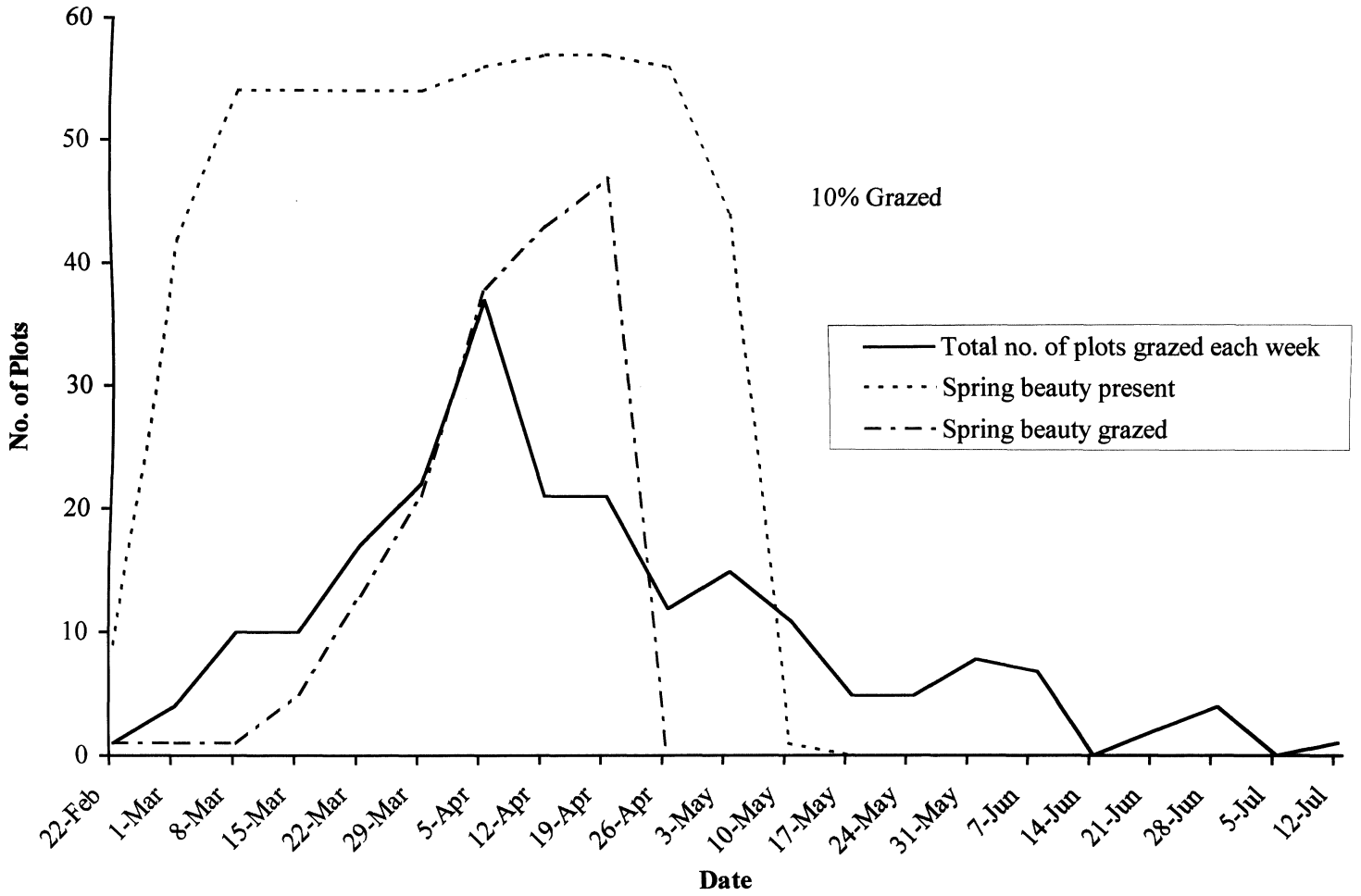

Figure 12. The frequency of plots containing spring beauty (Claytonia virginica) and the timing of grazing of this species at Beall Woods Nature Preserve, Illinois, during the period from February 22 through July 12, 1999. The timing and extent of grazing by deer on all herbaceous plants in the 90 study plots is also shown.

Appendix A. Plant species identified in 90 1-m^2 study plots at Beall Woods Nature Preserve, Illinois, February - July 1999.

Family	Scientific Name	Common Name
Aceraceae	*Acer* sp.	Maple
Rosaceae	*Agrimonia* sp.	Agrimony
Araceae	*Arisaema dracontium* (L.) Schott	Green dragon
Araceae	*Arisaema triphyllum* (L.) Schott	Jack-in-the-pulpit
Aristolochiaceae	*Asarum canadense* var. *reflexum* (Bickn.) Robins.	Wild ginger
Annonaceae	*Asimina triloba* (L.) Dunal.	Pawpaw
Lamicaeae	*Blephilia hirsuta* (Pursh) Benth.	Pagoda plant
Ophioglossaceae	*Botrychium virginianum* (L.) Sw.	Rattlesnake fern
Brassicaceae	*Cardamine bulbosa* (Schreb.) BSP	Spring cress
Juglandaceae	*Carya* sp.	Hickory
Onagraceae	*Circaea lutetiana* Aschers. & Magnus ssp. *canadensis* (L.) Aschers. & Magnus	Enchanter's nightshade
Portulacaceae	*Claytonia virginica* L.	Spring beauty
Papaveraceae	*Corydalis flavula* (Raf.) DC	Pale corydalis
Apiaceae	*Cryptotaenia canadensis* (L.) DC	Honewort
Boraginaceae	*Cynoglossum officinale* L.	Hound's tongue
Aspleniaceae	*Cystopteris protrusa* (Weatherby) Blasd.	Fragile fern
Ranunculaceae	*Delphinium tricorne* Michx.	Dwarf larkspur
Brassicaceae	*Dentaria laciniata* Muhl.	Toothwort
Papaveraceae	*Dicentra cucullaria* (L.) Bernh.	Dutchman's breeches
Dioscoreaceae	*Dioscorea villosa* L.	Wild yam
Liliaceae	*Erythronium albidum* Nutt.	White trout lily
Asteraceae	*Eupatorium rugosum* Houtt.	White snakeroot
Oleaceae	*Fraxinus* sp.	Ash
Rubiaceae	*Galium* sp.	Bedstraw
Rubiaceae	*Galium* sp.	Wild licorice
Rosaceae	*Geum canadense* Jacq.	White avens
Ranunculaceae	*Hydrastis canadensis* L.	Goldenseal
Hydrophyllaceae	*Hydrophyllum virginianum* L.	Virginia waterleaf
Balsaminaceae	*Impatiens capensis* Meerb.	Spotted touch-me-not
Poaceae	*Leersia/Carex* sp.	Grass/sedge
Lauraceae	*Lindera benzoin* (L.) Blume	Spicebush
Hamamelidaceae	*Liquidambar styraciflua* L.	Sweet gum
Magnoliaceae	*Liriodendron tulipifera* L.	Tuliptree
Nyssaceae	*Nyssa sylvatica* Marsh.	Black gum
Apiaceae	*Osmorhiza longstylis* (Torr.) DC	Anise-root
Corylaceae	*Ostrya virginiana* (Mill.) K. Koch	Hop hornbeam
Oxalidaceae	*Oxalis* sp.	Oxalis
Vitaceae	*Parthenocissus quinquefolia* (L.) Planch.	Virginia creeper
Polemoniaceae	*Phlox divaricata* L. ssp. *laphamii* (Wood) Wherry	Common phlox
Phrymaceae	*Phryma leptostachya* L.	Lopseed
Phytolaccaceae	*Phytolacca americana* L.	Pokeweed
Urticaceae	*Pilea pumila* (L.) Gray	Clearweed

Appendix A. Plant species identified in 90 1-m^2 study plots at Beall Woods Nature Preserve, Illinois, February - July 1999.

Family	Scientific Name	Common Name
Berberidaceae	*Podophyllum peltatum* L.	Mayapple
Polemoniaceae	*Polemonium reptans* L.	Jacob's ladder
Polygonaceae	*Polygonum hydropiper* L.	Smartweed
Polygonaceae	*Polygonum virginianum* L.	Virginia knotweed
Rosaceae	*Prunus serotina* Ehrh.	Wild black cherry
Fagaceae	*Quercus* sp.	Oak
Rosaceae	*Rosa multiflora* Thunb.	Multiflora rose
Rosaceae	*Rubus flagellaris* Willd.	Dewberry
Caprifoliaceae	*Sambucus canadensis* L.	Elderberry
Papaveraceae	*Sanguinaria canadensis* L.	Bloodroot
Apiaceae	*Sanicula gregaria* Bickn.	Common snakeroot
Lauraceae	*Sassafras albidum* (Nutt.) Nees	Sassafras
Liliaceae	*Smilacina racemosa* (L.) Desf.	False Solomon's seal
Smilacaceae	*Smilax hispida* Muhl.	Bristly catbrier
Caprifoliaceae	*Symphoricarpos orbiculatus* Moench	Coralberry
Anacardiaceae	*Toxicodendron radicans* (L.) Kuntze	Poison ivy
Liliaceae	*Trillium recurvatum* Beck	Red trillium
Orchidaceae	*Triphora trianthophora* (Sw.) Rydb.	Nodding pogonia
Ulmaceae	*Ulmus* sp.	Elm
Violaceae	*Viola* sp.	Violet
Vitaceaae	*Vitis* sp.	Grape

Appendix B. Locations of plant species identified in 90 1-m^2 study plots at Beall Woods Nature Preserve, Illinois, February - July 1999.

Scientific Name	Common Name	Plot Locations
Acer sp.	Maple	1A, 10A,
Agrimonia sp.	Agrimony	25A
Arisaema dracontium (L.) Schott	Green dragon	3C, 5B, 9C, 10A-B-C, 11C, 12A-B-C, 13A-B, 14A-B, 15A, 17B, 18A-B-C, 20C, 21A-B-C, 22A-B-C
Arisaema triphyllum (L.) Schott	Jack-in-the-pulpit	1A-B, 2A-B, 3A, 5B, 11B-C, 12A, 13C, 14A-B-C, 15A-B-C, 16A-B-C, 17A-B-C, 18A-B-C, 19A-B, 20A-B, 22B, 25A-B
Asarum canadense var. reflexum (Bickn.) Robins.	Wild ginger	2C, 9C, 13B-C, 16A-B-C, 17A-B-C, 18A-B-C, 22A-B-C
Asimina triloba (L.) Dunal.	Pawpaw	3A-B, 8B, 11A-B, 12A-B, 14A, 17A, 19A, 29A
Blephilia hirsuta (Pursh) Benth.	Pagoda plant	1C, 2A-B
Botrychium virginianum (L.) Sw.	Rattlesnake fern	3B
Cardamine bulbosa (Schreb.) BSP	Spring cress	1A-B-C, 23A-B-C, 24C, 25A-B, 26C, 27A-B-C, 28A-B-C, 30B-C
Carya sp.	Hickory	15B, 21B, 23A-C, 24B, 26C
Circaea lutetiana Aschers. & Magnus ssp. canadensis (L.) Aschers. & Magnus	Enchanter's nightshade	1B, 2C, 5A, 10C, 12C, 13A-B, 14C, 15B, 22B, 23B, 24A, 25A-C, 26C, 27A, 29A
Claytonia virginica L.	Spring beauty	***Found in all plots except 13A-B-C and 16C
Corydalis flavula (Raf.) DC	Pale corydalis	26A-B
Cryptotaenia canadensis (L.) DC	Honewort	23A-B, 24B-C, 26A
Cynoglossum officinale L.	Hound's tongue	25A-B-C
Cystopteris protrusa (Weatherby) Blasd.	Fragile fern	14A-B-C, 16A-B, 17A-B-C, 18A-B, 19A-B
Delphinium tricorne Michx.	Dwarf larkspur	7B, 14A-C, 15A-B-C, 16B-C, 17A-B-C, 18A-B-C, 19A-C, 25A, 28A, 30C
Dentaria laciniata Muhl.	Toothwort	2A-B-C, 5A-B, 6A-B-C, 7A-B-C, 8A-B-C, 9A-B-C, 10A-C, 14A-B-C, 15A-B-C, 16A-B-C, 17B-C, 18B-C, 19A-B-C, 20A-B, 21A-B-C, 22C, 23B, 24A-B-C, 25B, 26A-C, 27C, 28A-B, 29A-B-C, 30A-B

A= Exclosure B= Adjacent open plot C= Distant open plot

Appendix B. Locations of plant species identified in 90 1-m^2 study plots at Beall Woods Nature Preserve, Illinois, February - July 1999.

Scientific Name	Common Name	Plot Locations
Dicentra cucullaria (L.) Bernh.	Dutchman's breeches	6A-B-C, 7A-B-C, 8A-B-C, 15A, 16A-B-C, 17A, 18A-B-C, 19A-B-C, 21A-B-C, 23C, 24A-B, 26C
Dioscorea villosa L.	Wild yam	6A
Erythronium albidum Nutt.	White trout lily	7A-B-C, 8A-B-C, 15C, 19C, 21A, 27C
Eupatorium rugosum Houtt.	White snakeroot	1A-C, 2A-B, 3C, 4B, 5B, 9C, 12A, 14B-C, 23A-B, 24A, 25B, 29B, 30C
Fraxinus sp.	Ash	4B-C, 5A-B-C, 7A-B-C, 8A-B, 9C, 10A, 12A, 13A-C, 20B-C, 21A-B-C, 26A-B, 28A, 29C, 30A-B
Galium sp.	Bedstraw	16C, 18A, 23A-B, 24A, 25C, 26A-C, 27B, 28A, 30A
Galium sp.	Wild licorice	1A, 6B-C, 28B
Geum canadense Jacq.	White avens	2A, 23A, 25B, 27A
Hydrastis canadensis L.	Goldenseal	15C
Hydrophyllum virginianum L.	Virginia waterleaf	25C
Impatiens capensis Meerb.	Spotted touch-me-not	1A-B-C, 2A-B-C, 4A, 6A-B, 8C, 9A-B-C, 10A-B-C, 11A-B, 21B, 22A-C, 23A-B-C, 24A-C, 25A-B-C, 26C, 27A-B-C, 28C, 29A-B, 30A-B-C
Leersia/Carex sp.	Grass/sedge	1B-C, 3A-B, 4C, 5B-C, 6B, 7A, 9A-C, 10B, 23A-B-C, 24A-B, 25A-B-C, 26B-C, 27A-B-C, 28B,29C, 30C
Lindera benzoin (L.) Blume	Spicebush	1A-B-C, 2B-C, 3B-C, 4C, 10C, 11C, 13C, 19A
Liquidambar styraciflua L.	Sweet gum	13B
Liriodendron tulipifera L.	Tuliptree	3A, 9A, 10B, 12C, 14C, 15B, 16A-B
Nyssa sylvatica Marsh.	Black gum	3B, 4B-C, 5C, 6A, 11C, 13B, 19B, 24A-B, 25C, 26C
Osmorhiza longstylis (Torr.) DC	Anise-root	3A
Ostrya virginiana (Mill.) K. Koch	Hop hornbeam	6C
Oxalis sp.	Oxalis	2C
Parthenocissus quinquefolia (L.) Planch.	Virginia creeper	1C, 2A, 5A, 6A-B-C, 7A-B, 9B, 10B, 12C, 13A, 14A, 19B, 20A, 21A, 23A-B-C, 25C, 26B-C, 27A-B-C, 28A-B, 29A, 30A-B-C

A= Exclosure B= Adjacent open plot C= Distant open plot

Appendix B. Locations of plant species identified in 90 1-m^2 study plots at Beall Woods Nature Preserve, Illinois, February - July 1999.

Scientific Name	Common Name	Plot Locations
Phlox divaricata L. ssp. laphamii (Wood) Wherry	**Common phlox**	**23C, 24C, 25A-B**
Phryma leptostachya L.	**Lopseed**	**2A-C, 3B-C, 4B-C, 5A-B-C, 6B, 10B-C, 12A-B-C, 13A, 14A-B-C, 15A-B, 16C, 18C, 19A-B-C, 20A-B, 23C, 25C, 26A, 27B, 28A, 29A**
Phytolacca americana L.	**Pokeweed**	**2B, 5C**
Pilea pumila (L.) Gray	**Clearweed**	**1A-B-C, 2A-B-C, 3C, 4A-B, 5B-C, 6A-B, 9C, 10B-C, 12A-B-C, 16A-B, 22C, 23B, 24A-B-C, 25A-B-C, 26A-B, 27A-C, 28A-B**
Podophyllum peltatum L.	Mayapple	**2A, 3A-B-C, 4A-B-C, 6A-B-C, 7B, 8A-B, 14A, 15A-B-C, 19A-C, 20A-B, 21A-B-C, 24B-C, 25C, 26A-B-C, 28A-B, 29C**
Polemonium reptans L.	Jacob's ladder	**23A-B-C**
Polygonum hydropiper L.	Smartweed	**6C**
Polygonum virginianum L.	Virginia knotweed	**1B-C, 2C, 3A-B-C, 4A-B-C, 5A-B-C, 6B-C, 7A, 9A, 10A-B-C, 11A-C, 12A-B-C, 13A-B-C, 14A-B, 19A-B, 20A-C, 21A, 22C, 24A, 25A-B-C, 27A-B, 28B-C, 30B-C**
Prunus serotina Ehrh.	Wild black cherry	**15B-C, 16A-B**
Quercus sp.	Oak	**23A**
Rosa multiflora Thunb.	Multiflora rose	**2A**
Rubus flagellaris Willd.	Dewberry	**4B**
Sambucus canadensis L.	Elderberry	**23C, 25A**
Sanguinaria canadensis L.	Bloodroot	**5A-B-C, 11C, 13B, 14A-B, 16A-C, 19B-C, 20A, 23B, 28A, 29A-B**
Sanicula gregaria Bickn.	Common snakeroot	**3B-C, 4C, 5B-C, 6C, 7B, 9B-C, 10A-C, 11C, 12A, 14B, 22C, 23A, 25C, 26B, 27C**
Sassafras albidum (Nutt.) Nees	Sassafras	**15A, 16A-B, 25B, 26C**
Smilacina racemosa (L.) Desf.	False Solomon's seal	**24A-B-C**

A= Exclosure B= Adjacent open plot C= Distant open plot

Appendix B. Locations of plant species identified in 90 1-m^2 study plots at Beall Woods Nature Preserve, Illinois, February - July 1999.

Scientific Name	Common Name	Plot Locations
Smilax hispida Muhl.	Bristly catbrier	6C
Symphoricarpos orbiculatus Moench	Coralberry	20A
Toxicodendron radicans (L.) Kuntze	Poison ivy	1A-B, 2A-B, 4A-B, 9A-B-C, 10A-B, 11C, 12C, 14A-B, 23A, 27A, 30C
Trillium recurvatum Beck	Red trillium	1A-B, 2A-B-C, 3A-B-C, 4A-B-C, 5A-C, 6A-B-C, 8A-B, 10-A-B-C, 11A-B-C, 12A-B-C, 13A-B-C, 14C, 15A-B-C, 16A-B-C, 17A-B-C, 18A-B-C, 19A 22A, 23C 24B, 25A-B
Triphora trianthophora (Sw.) Rydb.	Nodding pogonia	11B
Ulmus sp.	Elm	1A-C, 4C, 19B, 20A
Viola sp.	Violet	1B, 2A-B-C, 3A-C, 4B, 5A-B-C, 10C, 11A-B-C, 12A-B, 13A-B, 14A-B-C, 15A-B-C, 16C, 17A-B-C, 18A-B-C, 19A-B-C, 20A-B, 21B, 22A-B, 25A-B, 28C
Vitis sp.	Grape	2A

A= Exclosure B= Adjacent open plot C= Distant open plot