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Cost Comparison of Vegetation Monitoring Techniques Used to Assess White-tailed Deer Herbivory

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ABSTRACT

Many studies investigating the effects of white-tailed deer (*Odocoileus virginianus*) herbivory on herbaceous communities have utilized plots set along browse transects or exclosures. We compared the costs (i.e., labor and construction) of using browse transects and associated 1-m^2 plots versus paired small exclosures (1.4 m diameter x 1.6 m height) and 1-m^2 control plots to monitor the effects of deer herbivory in suburban Chicago, Illinois. During May–July 2008–2009, we sampled vegetation in 2,560 quadrats along browse transects and 600 exclosed and control quadrats on eight Lake County forest preserves. Within both vegetation sampling regimes, we quantified herbivory impacts on vegetation in each sample quadrat using plant community metrics and indicator species. Using a standardized cost per sampling unit, the cost of conducting a single browse transect (i.e., 10 1-m^2 quadrats) was US $72.80 and the cost of sampling five pairs of exclosures and controls (i.e., 10 1-m^2 quadrats) using the exclosure method cost $230.60; thus, for the same amount of data, the browse transect method cost 68.4% less than the exclosure method. Managers should consider using browse transects over exclosures to assess deer herbivory when deer are not restricted from specific areas or plants. The advantages of reduced cost, increased sample size, and ability to assess large areas may outweigh the use of exclosures in these situations.

INTRODUCTION

White-tailed deer (*Odocoileus virginianus*) herbivory can have detrimental effects on ecosystems, including those vertebrates and plants that serve as indicators of major ecological changes (Casey and Hein 1983; Anderson 1990; Flowerdew and Ellwood 2001; Smit et al. 2001; Frankland and Nelson 2003; Greenwald et al. 2007). Compared to woody vegetation investigations, few studies have assessed the impacts of deer herbivory on herbaceous plant communities (Anderson 1994) and limited vegetation monitoring methods exist. Several studies have monitored structural components of sole indicator species (Anderson 1994; Augustine et al. 1998; Augustine and Frelich 1998; Knight 2003; Farrington et al. 2004; Webster et al. 2005) or a few select species of interest (Englund and Meyer 1986; Augustine and Jordan 1998; Webster and Parker 2000; Webster et al. 2001; Frankland and Nelson 2003; Rurhen and Handel 2003). Fewer studies have broadly monitored all browsed species and plant community metrics such as species richness and species evenness to assess widespread impact of deer herbivory on plant communities (Anderson et al. 2001; Frankland and Nelson 2003; Anderson et al. 2005; Webster et al. 2005). Regardless of which plant community metrics or species are monitored, most deer herbivory studies utilize exclosures or browse transects to collect data in sample plots.

Exclosures are broadly described as fenced areas and are often used in white-tailed deer herbivory studies (Englund and Meyer 1986; Anderson 1994; Augustine et al. 1998; Anderson et al. 2001; Rurhen and Handel 2003; Anderson et al. 2005; Webster et al. 2005). Researchers assess deer herbivory by comparing structural aspects (e.g., stem height, number of flowering stems, leaf width) of floral communities observed in the control plots exposed to herbivory versus those within exclosures. Sampling methods within large exclosures include single large (3.7–10m^2) sample plots (Englund and Meyer 1986; Augustine et al. 1998; Rurhen and Handel 2003; Webster et al. 2005) or use of transects or randomized sampling within exclosures to delineate small (25cm^2–1m^2) sample plots (Anderson 1994; Anderson et al. 2001; Anderson et al. 2005).

Few researchers have used small exclosures to assess white-tailed deer herbivory (Augustine and Frelich 1998; Augustine et al. 1998; Frankland and Nelson 2003). With large exclosures, bias exists because plants are associated with one another and large exclosures may not contain browsed species from a different portion of the study site (Frankland and Nelson 2003). Additionally, researchers risk simple pseudoreplication if they are only comparing one exclosure and one control (Hulbert 1984). Thus, smaller (≤1m^2), but more abundant, exclosures are preferable to increase sample size and reduce bias. In addition, small exclosures are less expensive, may be collapsible for storage and transport, and allow for greater coverage of study sites (Frankland and Nelson 2003). Small exclosures have been used to fence individual plants (Augustine and Frelich 1998) or enclose small populations of a specific species (Augustine et al. 1998). Alternatively, Frankland and Nelson (2003) used 30 1-m^2 exclosures with paired controls to monitor portions of entire vegetation communities.

Browse transects also have been used to assess white-tailed deer herbivory on woody vegetation (Pitt and Schwab 1990; Doenier et al. 1997), yet this technique is scarcely applied to assess the effects of deer herbivory in herbaceous communities outside of exclosures. In general, this method involves sampling vegetation along multiple transects. When browse transects have been employed, several methods have been utilized to assess the impacts of deer herbivory. Augustine and Jordan (1998) examined the percent browsed, percent unbrowsed, and percent flowering of seven early-summer forb and seven late-summer forb species using 6-m^2 circular plots spaced 25–50 m apart along transects. Augustine and Frelich (1998) used 2-m and 4-m strip transects to investigate browse damage on trillium (*Trillium* spp.) communities. Similarly, Knight (2003) used 1-m^2 plots randomly placed along transects through trillium populations to assess browse damage. Alternatively, Webster and Parker (2000) and Webster et al. (2001) used three 10-m long transects to quantify percent cover of herbaceous forbs.

The quality of data gained from either vegetation sampling method can be variable, if not questionable. Many researchers rely on exclosures and paired controls because they believe it results in higher quality data due to its experimental setup. However, comparisons of individual species and plant community metrics found in exclosure and control plots may not indicate the overall effect of deer herbivory at a site. Observations inside an exclosure do not necessarily depict how the plant community would appear in the absence of deer herbivory but rather contain vegetation that is in a stage of recovery (Suzuki et al. 2008). Further, it may take several years after the construction of exclosures to see significant differences between exclosure and control plots due to the legacy effects of chronic deer browsing (Russell et al. 2001; Banta et al. 2005; Royo et al. 2010; Urbanek et al. 2012*a*). In addition, researchers must consider the effects of light depletion on plants within exclosures due to exclosure material creating shadows. Hence, researchers must be cautious when drawing conclusions from observed differences between exclosures and control plots.

Similarly, researchers must be equally cautious when using data collected from browse transects. Without control plots, multiple sites or years are required to gain any valuable data. When multiple sites are involved, researchers should be aware that differences in abiotic factors may conflate results. However, if researchers are only interested in overall differences between sites over time, data on stem heights or plant community metrics can be assessed as indices to monitor trends. Thus, obstacles exist for both vegetation monitoring methods, but both exclosures and browse transect methods can provide the same quality data if studies are well designed.

We assessed white-tailed deer herbivory on eight Lake County forest preserves near Chicago, Illinois (Urbanek and Nielsen 2010, Urbanek et al. 2012*a*,*b*). We compared the advantages, disadvantages, and cost of using browse transects and exclosures in four different plant communities. The objective of this study was to provide managers with information regarding which technique is most beneficial to use given a situation when both deer herbivory monitoring methods are applicable (i.e., no need to restrict deer from an area).

STUDY AREA

Lake County, Illinois, is located approximately 40 km northwest of downtown Chicago, has >703,462 inhabitants, and is <1,200 km^2 in area (USCB 2010). The Lake County Forest Preserve District (hereafter, the District), created in 1958, consists of >10,800 ha in 57 preserves that provide a combination of natural, recreational, educational, and cultural resources for county residents and tourists. The District identifies separate plant communities within its preserve system as characterized by the Chicago Wilderness Terrestrial Classification System (CRBC 1999): forests contain >50% canopy cover, savannas have 10–50% canopy cover, and prairies and wetlands consist of canopy cover <10%.

METHODS

Exclosure Methods

The following are modified methods from Urbanek et al. (2012*a*) and Urbanek and Nielsen (2010). During 2007-2009, we used exclosures to compare the effects of deer herbivory in two forest and three savanna sites with known overwintering deer densities (Urbanek et al. 2012*a*). In 2008 and 2009, we sampled vegetation in a 1-m^2 quadrat in

150 exclosures and 150 control plots each year, thus 600 1-m^2 quadrats were sampled via this method during the course of study.

On each site, we constructed 30 small (1.4 m diameter x 1.6 m height) deer exclosures during June–August 2007 with 5.4 x 1.6-m rectangular pieces of fixed-knot 12.5-gauge (ga) wire STAY-TUFF® horse fencing (Stay-Tuff Fence Manufacturing, Inc., New Braunfels, Texas, USA) by bending the pieces to form circular exclosures with approximately 1.4-m diameters. This size allowed for a 1-m^2 quadrat to fit within the exclosure with a 0.2-m unbrowsed buffer to allow deer browsing in the periphery of the exclosure. The horizontal spacing between stay wires gradually diminished from 18 cm at the bottom to 8 cm at the top and the vertical distance between line wires remained constant at 15 cm. This design allowed for smaller browsing animals (***e.g.***, eastern cottontails [*Sylvilagus floridanus* Allen], woodchucks [*Marmota monax* L.]) to enter the exclosure in the larger spacing at ground level while deterring deer from browsing at the top. Exclosures were tied with 16-ga wire to three 1.2-m posts staked at angles from each other for stability.

Exclosures were spaced in each site in a grid design approximately 60 m from any neighboring exclosure and 30 m from any road, path, railroad or habitat edge. A 1-m^2 control plot was located 30 m away from each exclosure at an azimuth of 225° to accommodate all control plots within the designated study area. Control plots were also ≥30 m from any other exclosure, road, path, railroad or habitat edge.

We collected plant measurements within exclosures and control plots during 1–30 June, 2008–2009. We began collecting data in the southernmost preserve and worked in a northernly direction among preserves. This accounted for the approximate 2-week temporal difference in plant growth among similar species in preserves on opposite sides of the county (K. Klick, Lake County Forest Preserve District botanist, pers. comm.). We used similar deer browse measurements as found in the literature (Anderson 1990, 1994; Augustine and Frelich 1998; Webster and Parker 2000; Frankland and Nelson 2003). All herbaceous plants found within the control quadrats were identified and number of individual ramets (hereafter, plants) of each species was tallied. The number of plants browsed by deer was quantified per species and height (cm) was recorded for each individual. We only included browsed plants that we were 100% confident were browsed by deer and not by any other animal. Plants browsed by deer were identified by jagged edges as opposed to rodent browse which tends to be angled and clean-cut (Anderson 1969; Hygnstrom et al. 1994). Stem height was measured as the distance from the ground to the apical meristem or end of the remaining stem. We identified and quantified the number of individual plants of all species in exclosure quadrats. The stem height of all species browsed in the control quadrats were measured in the exclosure quadrats. In both exclosures and control quadrats, we estimated percent cover of non-vegetated soil, grass and sedge.

Browse Transect Methods

The following are modified methods from Urbanek et al. (2012*b*) and Urbanek and Nielsen (2010). During the study, we sampled 256 browse transects in two forest, two savanna, two prairie, and two wetland sites with known overwintering deer densities

(Urbanek et al. 2012*b*). On each browse transect, we sampled vegetation in 10 1-m^2 quadrats, thus 2,560 1-m^2 quadrats were sampled via this method during the course of study.

Eight browse transects were conducted in each community type during 1–31 May and 1–31 July of 2008 and 2009, resulting in 128 transects monitored each year. Transects conducted in May were used to assess spring ephemerals and early-stages of other forbs and July transects were used to assess herbaceous plants growing throughout the summer season. We created polygons that encompassed the respective plant community for each preserve using ArcMap software (ESRI Corporation, Redlands, California, USA) and used Hawths Tools to randomly place 100-m-long transects throughout the polygons in each preserve. All transects were placed ≥30 m away from any road, path, railroad or other transect.

Similar to the exclosure methods, we began collecting data in the southernmost preserve and worked in a northernly direction among preserves. A measuring tape was used to mark the center of each transect and at every 10-m mark (e.g., 0 m, 10 m, 20 m) a random 4-digit number was chosen to locate where the 1-m^2 sample quadrat was placed. The first two digits determined the direction and distance (m) the observer moved along the transect. Even numbers specified forward progress and odd numbers indicated the observer went backwards along the transect. The second two digits determined the perpendicular distance (cm) the center of the quadrat was placed away from the right of the transect.

All herbaceous species were identified and number of plants were tallied within each quadrat. For each browsed species, average height (cm) was collected using methods similar to Webster and Parker (2000) and Webster et al. (2001). The 10 largest flowering plants closest to the center of the quadrat were measured from the ground to the apical meristem. If 10 flowering individuals could not be found within the quadrat, the 10 largest plants closest to the center were measured. If <10 plants were found within the quadrat, all plants were measured. We also quantified the total number of plants browsed per species and approximate percent cover of non-vegetated soil, grass, and sedge within each quadrat. After data collection, the observer walked to the next 10-m mark and repeated this procedure, but placed the quadrat on the left of the transect to ensure that each quadrat was placed on alternating sides along the transect until 10 quadrats were sampled.

Cost Comparison

We recognize survey costs and hourly labor costs may change over time; thus, we were more interested in the difference in cost between the 2 techniques which we reasoned would remain similar over time. We used an hourly wage of $10/people-hour for the cost calculations of both vegetation monitoring techniques. For browse transects, costs included only labor to sample the vegetation because no specialized equipment (i.e., items not typically readily available at an agency) was required. For exclosures, costs included specialized equipment (Table 1), construction labor, and sampling labor. We adjusted the people-hours required for sampling the exclosures and control quadrats to the average time it took to sample a quadrat using the browse transect methods (19 min/observer) to correct for differences in stem height measurement methods. We then standardized costs per 1-m^2 quadrat for each vegetation sampling regime to facilitate direct comparisons between techniques. Finally, we calculated the total cost and standardized costs for each technique over a 1, 2, 3, 4, 5, and 10-year study to determine if and when the costs would merge (Table 2). For these calculations, we kept labor costs constant (i.e., $10/hr) and did not include any maintenance charges for the exclosures.

RESULTS

Conducting 256 browse transects cost US $18,650 (1,865 people-hours at $10/hr). For exclosures (Table 1), we spent $3,127 on equipment and $10,710 in labor costs, which brought the grand total cost to $13,837. Using a standardized cost, a single 1-m^2 quadrat via the exclosure study design ($13,837/600 quadrats) was $23.06, whereas the cost to sample a single 1-m^2 quadrat via the browse transect method ($18,650/2,560 quadrats) was $7.28. Accordingly, sampling five pairs of 1-m^2 quadrats (i.e., 10 1-m^2 quadrats) using the exclosure method cost $230.62, whereas the cost of sampling a single browse transect (i.e., 10 1-m^2 quadrats) was $72.80. Given a 10-year study, the standardized per-quadrat cost of the browse transect method would still be 32% less expensive than using the exclosure method (Table 2).

DISCUSSION

Exclosures and browse transects are both useful vegetation monitoring techniques for assessing white-tailed deer herbivory and both methods have advantages and disadvantages. We found that for the same quantity of data (i.e., 10 1-m^2 quadrats) the browse transect method cost 68% less than the exclosure method. Exclosures studies can be more expensive due to the initial construction and labor expenses. Proper fencing material (e.g., large gauge wire) must be sturdy enough to withstand local weather and any damage deer may cause from pushing against the structure. In contrast, browse transect costs are substantially lower because this method has no initial building expenses and the necessary equipment (i.e., a meter tape) is usually already available. Even given a long-term study, the initial costs of exclosures incur a legacy effect on total costs for over a decade.

In addition to a higher cost, there are several other disadvantages to using exclosures. First, managers often use large exclosures for their deer herbivory assessments which can lead to a strong bias (Frankland and Nelson 2003). Thus, smaller, but more abundant, exclosures are preferable to increase sample size and reduce bias (Frankland and Nelson 2003), yet this also increases costs. In addition, sample size may be limited with traditional metal or wood exclosures due to difficulty associated with constructing exclosures in rugged or remote terrain. Second, exclosures require maintenance to repair damage from factors like weather and vandalism; hence, further long-term costs may be incurred. Third, exclosures detract from the natural setting of the land, especially if left unmaintained. Large metal or wood exclosures are often laborious to move and manipulate regularly and are thus usually left in the same spot where they were originally constructed. In summary, exclosure studies are more expensive, may be biased if only large exclosures are used, and the structures could be an eyesore to visitors of natural areas.

Exclosures do have two primary advantages over browse transects. First, exclosures that are maintained (i.e., regularly fixed and checked for structural integrity) can support long-term studies that may provide stark comparisons between chronically browsed and unbrowsed sites. Second, exclosures provide means for two-way analyses if researchers seek to compare both the effect of different white-tailed deer densities (i.e., comparison of different sites) and the absence of deer browse (Urbanek et al. 2012*a*). Similarly, exclosures may also provide data for other analyses if deer herbivory research is conducted on a single site and in only one year whereas the browse transect method would require multiple years of data collection for a comparable analyses on a single site. However, if multiple sites with known deer densities are monitored in a given year, comparisons can be made among sites using browse transects to determine the effect of deer density and subsequent browse on plants (Urbanek et al. 2012*b*).

Comparatively, browse transects have some advantages over exclosures besides a reduced cost. Unlike exclosures, sample sizes are not limited with this method because transects can be laid anywhere in the study site including places that may be unsuitable for exclosures. Additionally, the browse transect method creates less disturbance to the natural setting because no unnatural structures are required.

IMPLICATIONS

Natural resource managers should be concerned with the advantages, disadvantages, and cost of browse transects and exclosures when considering which method to use to assess white-tailed deer herbivory. This is especially true given a situation where deer do not need to be restricted from an area and no prior exclosures have been constructed. In these cases, we recommended managers consider using browse transects due to the advantages of reduced cost, increased sample size, and ability to assess large areas.

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Table 1. Incurred costs of using exclosures to monitor white-tailed deer herbivory in Lake County, Illinois, 2007-2009.

Equipment and labor	Cost
Equipment	
Specialized fencing	$1,992.00
Fence cutters	$113.00
U-posts	$760.00
Wire for tying u-posts to fencing	$32.00
Equipment shipping and delivery	$230.00
Total equipment costs	$3,127.00
Labor ($10/people-hr)	
Construction labor (618 people-hours)	$6,180.00
Sampling labor (453 people-hours)	$4,530.00
Total labor costs	$10,710.00
Grand total	$13,837.00

Table 2. Projected costs (USD) of vegetation monitoring techniques to assess white-tailed deer herbivory in Lake County, Illinois 2007-2009. Labor costs were held constant ($10/hr) and no cost of maintenance to exclosures was included.

Years of study	Browse transect method			Exclosure method		
	Total cost	Total # of quadrats sampled	Standardized cost	Total cost	Total # of quadrats sampled	Standardized cost
1	$9,325	1,280	$7.28	$11,572	300	$38.57
2	$18,650	2,560	$7.28	$13,837	600	$23.06
3	$27,975	3,840	$7.28	$16,102	900	$17.89
4	$37,300	5,120	$7.28	$18,367	1,200	$15.31
5	$46,625	6,400	$7.28	$20,632	1,500	$13.75
10	$93,250	12,800	$7.28	$31,957	3,000	$10.65