Comparison of Vegetation Sampling Procedures in a Disturbed Mixed-Grass Prairie

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A fundamental principle of landscape ecology is that overall resolution of a study can be changed by varying the grain and extent of sampling. However, sampling methods yielding a desirable resolution may not be the most efficient in terms of data gathered per unit of effort. We tested three methods simultaneously to select the optimum sampling method and resolution for a vegetation survey at Fort Sill, Oklahoma. The military's standard sampling method, the Land Condition Trend Analysis Program, uses a modified point-intercept method to inventory vegetation. The point-intercept method may not adequately assess effects of disturbance on species richness in grasslands, so we tested it against contiguous quadrats and modified Whittaker plots. The point-intercept method, low resolution, was completed in the shortest time; however, it produced the least species richness. Contiguous quadrats, high resolution, required the greatest time investment, but had the highest species richness. Species richness in modified Whittaker plots (four levels of resolution) produced data quality similar to contiguous quadrats, but in less time. Modified Whittaker plots were most efficient because they detected the greatest number of species per unit of sampling effort and provided data at different spatial scales. ***© 2003 Oklahoma Academy of Science***

INTRODUCTION

Researchers currently use many different vegetation sampling methods in grassland systems (Shmida 1984, Stohlgren and Bull 1998, Barbour et al 1999). Each method examines the landscape at a slightly different grain (unit of observation) and extent (total area under study). Variation of study resolution (grain and extent together) and sampling frequency influences estimates of species richness and requires careful consideration to achieve an optimum sampling strategy (Turner 1989, Wiens 1989, Pickett and Cadenasso 1995, Whittaker et al 2001). The objective of sampling a plant community is generally to gain an accurate representation of the entire community; however, methods must balance increases in accuracy at a desired resolution with the available sampling resources to develop a feasible and efficient sampling strategy.

At Fort Sill, Oklahoma, we tested the point-intercept, contiguous quadrat, and modified Whittaker sampling procedures to determine the optimum vegetation sampling strategy for species richness in this mixed-grass system. Species richness was chosen because it is commonly used to measure effects of disturbance in grasslands. The point-intercept method (i.e., low resolution) has been used as a part of the military's Land Condition Trend Analysis (LCTA) standard, nationwide vegetation sampling procedure (Diersing et al 1992). Land Condition Trend Analysis surveys use a belt-transect approach in conjunction with the point-intercept method. Although point-intercept sampling is rapid and appropriate for some objectives, data resolution can be low in grassland systems (Dale et al 2002). A second method, contiguous quadrats (i.e., high resolution), allows users to ascertain spatial attributes of vegetation (Gillison and Brewer 1985, Ludwig and Tongway 1995). The contiguous quadrat method is quite robust in that it allows the researcher to ask many different questions about the data, but it is time consuming. Finally, the modified Whittaker approach (i.e., four levels of resolution; Fig. 1) provides a relatively robust data set, potentially in less time (Shmida 1984). Strengths of the modified Whittaker include detection of rare species and of spatial autocorrelation (Stohlgren et al 1995, Stohlgren et al 1998, Stohlgren et al 2002), however, we limit our discussion, here, to species richness measured by number of species encountered in each sampling unit, regardless of rarity.

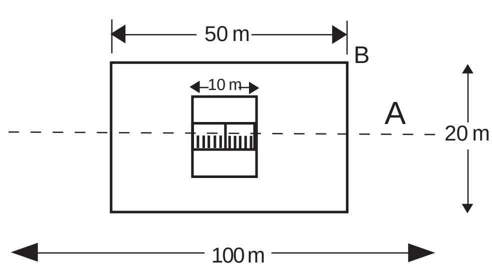

Figure 1. Contiguous quadrat and point-intercept data were collected along the 100-m transect A), and the modified Whittaker plot B) is bisected by the transect. The modified Whittaker plot was composed of ten 1-m^2, two 10-m^2, one 100-m^2, and one 1,000-m^2 sampling units.

We were interested in finding the most efficient sampling technique for Fort Sill grasslands because plant species composition is one of the most time-consuming field measurements. Grassland phenology often limits the acceptable amount of time for completion of vegetation sampling. The three methods described above were tested at a heavily disturbed site and a moderately disturbed site at Fort Sill to determine the most efficient sampling strategy with the greatest resolution for these disturbed grasslands. We hypothesized that the point-intercept method would yield the least species richness, but would require the least amount of time. We predicted species richness to be greatest in the modified Whittaker plots and that sampling time would be less in the modified Whittaker plots than in the contiguous quadrats. We also predicted that the modified Whittaker plots would be the most efficient sampling method (i.e., most species encountered per unit sampling effort) for this environment.

METHODS

We sampled two sites of varying disturbance levels located in mixed-grass prairie (Mobley and Brinlee 1967) at Fort Sill, Oklahoma (34° 38' N, 98° 30' W). Military disturbance on the Fort Sill range results from tracked and wheeled vehicle traffic, bivouacking activities, and mission-related wildfires. Fort Sill contains a variety of habitats including tallgrass prairie, mixed-grass prairie, mesquite (*Prosopis glandulosa*) savannah, wetlands, crosstimbers, and riparian. The LCTA program stratified sites by vegetation type throughout the base then randomly designated 100-m transects in each type. Site 1, a heavily eroded area, was established as a LCTA special use plot in 2000. Recent heavy disturbance at this site resulted in 70% bare ground. Site 2, a moderately disturbed site, contained dense mixed-grass vegetation with bare ground coverage of only 2.5%. The 100-m transect was randomly placed within the site and recorded as a 2002 LCTA special use plot.

TABLE 1. Resolution of three sampling methods; taken together the grain (smallest sampling unit) and extent (total area sampled) dictate resolution.

Method	Grain	Extent	Resolution
Point-intercept	1 point	100 m	Low
Contiguous quadrats	1 m^2	100 m^2	High
Modified Whittaker plot	1 m^2, 10 m^2, 100 m^2, 1000 m^2	1000 m^2	Varied

We tested the point-intercept, contiguous quadrats, and modified Whittaker plot vegetation sampling methods within each site (Table 1) by overlaying the sampling schemes. Contiguous quadrat and point-intercept sampling began at 0.5 m from the end-point. A pole (2 m tall x 1.25 cm diameter) was placed at 1-m intervals along the tape to measure intercept vegetation. All species touching the pole were recorded (Diersing et al 1992). After the intercept data were recorded, a 1-m^2 (1 m x 1 m) quadrat was placed along the tape at 1-meter intervals. Species richness was recorded resulting in data from 100 intercept points and 100 m^2. Finally, a modified Whittaker plot as described by Shmida (1984) was established with the 100 m transect bisecting it (Fig. 1). The modified Whittaker plot method was composed of ten 1-m^2, two 10-m^2 (5 m x 2 m), one 100-m^2 (10 m x 10 m), and one 1,000-m^2 (50 m x 20 m) nested sampling units. All sampling was completed by the author during July 16-20, 2002.

RESULTS

Larger sampling units produced greater species richness than point data alone. The point-intercept method yielded the least number of species detected, while contiguous quadrats yielded the greatest. Richness from modified Whittaker plots was similar to that of contiguous quadrats (Table 2). Although the mean richness per unit in the contiguous quadrats equaled 10, there was greater variability between quadrats at both ends of the transect (Fig. 2). Location of observed vehicular disturbance may explain this variability. The modified Whittaker plots exhibited a continual increase in species richness (Fig. 3). Contiguous quadrats had the greatest number of species, followed by the modified Whittaker plots.

Analysis of the actual species detected by each method explained differences in overall richness. Seventy-six total species were recorded; however, a slightly different

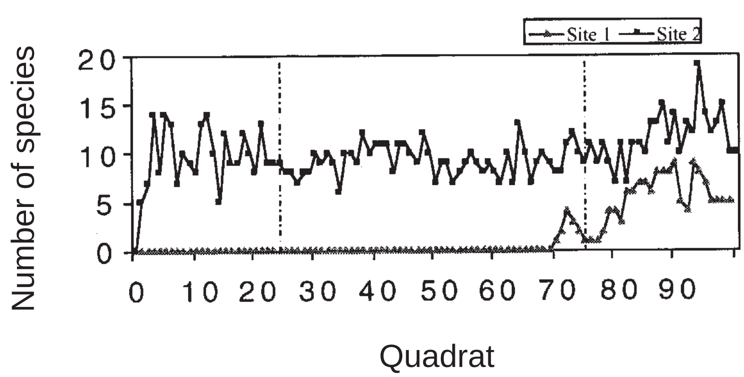

Figure 2. Total number of species per quadrat in contiguous quadrats method; points indicate total species richness per quadrat along the 100-m transects; arrows across the bottom and top axes indicate observed vehicular disturbance at Site 1 and Site 2, respectively; dotted vertical lines are the extent of the modified Whittaker plots along the transect.

TABLE 2. Species richness, sampling time, and sampling efficiency (species detected per hour of effort) for three sampling methods, Fort Sill, Oklahoma.

	Species richness		Sampling time (h)		Sampling efficiency	
Method	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
Pont intercept (n=100)	5	24	0.33	2.0	15	12
Contiguous quadrats (100 m^2)	25	56	2.0	23.0	13	2
Modified Whittaker plot (1000 m^2)	21	48	1.0	3.5	21	14

suite of species was detected between methods and sites (Appendix). Although we found more species in the contiguous quadrats (Table 2), some species detected by other methods were not found using the contiguous quadrats (Site 1-3 species, Site 2- 5 species). In Site 2, the lowest resolution method (point-intercept) detected five species not detected in the highest resolution method (modified Whittaker plot). Aside from those five species, the point-intercept method consistently detected the most common species as observed from cover estimates in each sampling unit. The modified Whittaker plot also detected species at each site that were not found by the contiguous quadrats method.

Time required to complete all sampling procedures (Table 2) varied between the two sites because of the large difference in bare ground (70% versus 2.5%); however, point-intercept data were quickly attained. Only the last 30 m of the transect at Site 1 contained vegetation cover. At Site 2, vegetation cover was dense throughout the transect.

The modified Whittaker plot was the most efficient of the three methods tested, as calculated by using the number of species detected per unit of sampling effort (Table 2). Despite the high species richness rating, contiguous quadrats was the least efficient method (i.e. the method that allowed the observer to collect accurate data in the least amount of time). Furthermore, rate of species accumulation with the point-intercept method suggested that beyond 50 samples, the amount of data collected did not continue to increase with the effort expended. Richness in the other two methods continued to increase steadily throughout the sampling area.

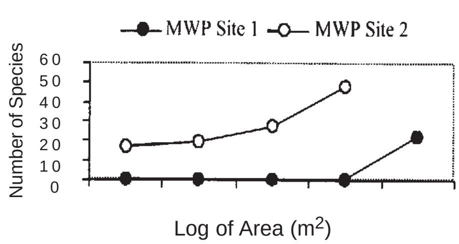

Figure 3. Accumulation of new species in modified Whittaker plots. Species richness varied across the two modified Whittaker plots due to disturbance level. The 1-m^2 value represents an average of the 10 measurements of the smallest grain in each plot, and the 10-m^2 value is an average of two measurements of the next largest grain size per plot (refer to Fig. 1 for sampling scheme).

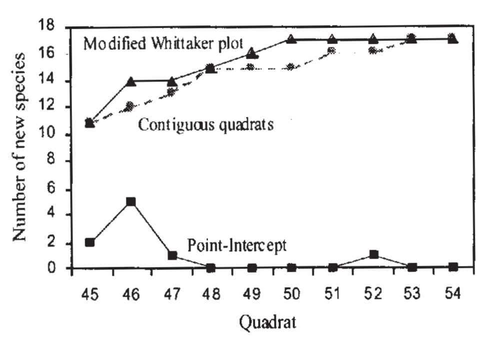

Figure 4. Cumulative addition of new species in 10 contiguous 1-m^2 quadrats at Site 2. The modified Whittaker's smallest sampling unit is a block of ten 1-m^2 quadrats; that same block of 10 quadrats was measured by using contiguous quadrats. Even though the blocks of 10 were offset by 0.5 m, similar results were achieved.

Analysis of overlapping areas at Site 2 showed equivalent estimates of richness for contiguous quadrats and the modified Whittaker plot within 10 m^2 (Fig. 4). Because sampling of the transect began at 0.5 m and the modified Whittaker was set up on the meter mark, the methods overlapped but were offset by 0.5 m.

DISCUSSION

Sampling methods must be chosen in accordance with the particular type of vegetation being studied, i.e., plant density, size, and height are important considerations (Barbour et al 1999). Other important considerations include number of samples necessary to represent the community and time needed to collect data. Researchers most often choose quadrat methods for sampling grasslands (Sorrells and Glenn 1991), but transects are more suitable for some purposes especially when time is the limiting factor. Quadrat methods are favored in grasslands because a single observation represents several species, rendering quadrats a more efficient sampling tool than point methods. Linear sampling methods allow an observer to recognize gradients more readily than with other methods (Brown 1954). Length of transect is also important; several short transects can be read more quickly than a single long transect but with the same accuracy (Jorgensen et al 2000). After reviewing 96 vegetation sampling technique papers, Sorrells and Glenn (1991) also concluded that point methods tend to underestimate diversity in grassland systems.

The military has inventoried Fort Sill by using the LCTA-recommended method, point-intercept (Diersing et al 1992, Harris 1997) with the goal of producing nationwide comparisons of vegetation change. However, the point-intercept method has low resolution in mixed-grassland systems, so we tested additional sampling methods. The modified Whittaker method detected the greatest number of species per hour at both heavily disturbed and moderately disturbed sites even though the overall species list was greater for the contiguous quadrats. Observer fatigue also may have been a factor in the modified Whittaker at Site 2. The point-intercept method showed a high species per hour rating, but yielded lower species richness than either alternative method. We predict that at least 200 points would be needed for species richness to approach that of other methods.

A possible explanation for lower levels of species richness in the modified Whittaker plots than in the contiguous quadrats, despite their greater area, may be a result of the 100-m transects crossing environmental gradients. Disturbance defined by the presence of vehicular tracks was observed at Site 2 in the portion of the transect outside the modified Whittaker plots. The area where the three methods overlapped had lower variability in species richness per quadrat, suggesting that the ends of the transect may have crossed environmental gradients. These gradients can include soil variability, topographic features, disturbance, and other biotic and abiotic factors (Gillison and Brewer 1985, Shmida and Wilson 1985). Traversing these gradients coupled with the presence of disturbance may help to explain the higher species richness in the contiguous quadrats.

Another possible explanation for a difference in richness between modified Whittaker plots (1000 m^2) and contiguous quadrats (100 m^2) may simply lie in the fact that the methods differ in the area, not necessarily the amount, of space sampled. This is evidenced by the similarity in richness estimates in the overlapping quadrats at Site 2. That is, when sampling the same area, the two methods provided equivalent richness estimates. It seems likely that a 1-m^2 quadrat may be searched more accurately than a 1000-m^2 plot to find all the species present. Although we cannot calculate actual species richness from this study, the greatest number of species was encountered in the contiguous quadrats method.

Modified Whittaker plots were most efficient because they detected the greatest number of species per unit of sampling effort at both sites and provided the greatest interpretive power because observations included different spatial scales. By using this method, the study's grain could be varied without sacrificing resolution. For example, at the smallest unit (1 m^2) results for the modified Whittaker plot and contiguous quadrats were equivalent, even though blocks of quadrats were offset by 0.5 m. In conclusion, we recommend species richness studies in mixed-grass prairie at Fort Sill use the modified Whittaker approach when appropriate, because this study has demonstrated that it allows observers to collect species richness data accurately and efficiently. The modified Whittaker plot allows researchers to detect rare species at a higher rate than does point-intercept and at a similar rate to contiguous quadrats.

ACKNOWLEDGMENTS

This research was funded by the Oklahoma Agricultural Experimental Station and by the Construction Engineering Research Laboratory, US Army Corps of Engineers and administered through the Oklahoma Cooperative Fish and Wildlife Research Unit (Oklahoma State University, Oklahoma Department of Wildlife Conservation, US Geological Survey's Biological Resources Division and Wildlife Management Institute cooperating). Additional support was provided by the Department of Plant and Soil Sciences, Oklahoma State University. James Furlo and Veronique Martin were instrumental in selecting study sites by analyzing maps of Fort Sill. The guidance of Dr. Samuel Fuhlendorf was also greatly appreciated. Finally, we thank two anonymous reviews for their helpful comments.

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Received: Oct 3, 2002; Accepted March 24, 2003

APPENDIX. Plant species recorded during sampling using contiguous quadrats, modified Whittaker plots, and point-intercept methods at Fort Sill, Oklahoma. Taxonomy follows the National Plants Database version 3.5, National Resource Conservation Service.

Species	Site 1			Site 2		
	CQ*	MWP	PT-INT	CQ	MWP	PT-INT
Acalypha monococca					x	
Achillea millefolium				x	x	
Ambrosia psilostachya	x	x		x	x	x
Amphiachyris dracunculoides					x	
Andropogon gerardii				x		
Apocynum cannabinum				x	x	x
Aristida sp.				x		x
A. purpurea var. *wrightii*	x	x	x			
Artemisia ludoviciana					x	
Asclepias asperula var. *capricornu*		x		x	x	
A. viridis				x		
Aster sp.				x		x
A. ericoides	x	x		x	x	x
Bothriochloa saccharoides var. *torreyana*	x	x		x	x	x
Bouteloua sp.				x		
B. curtipendula	x			x	x	x
B. hirsuta	x	x	x	x		
B. rigidiseta					x	
Bromus japonicus				x	x	
Centaurea americana				x	x	
Chrysopsis villosa	x					
Croton capitatus	x			x	x	
C. texensis				x	x	x
Dalea candida	x				x	
D. purpurea	x	x		x	x	
Desmanthus illinoensis	x			x	x	x
D. leptolobus	x	x		x	x	
Dichanthelium oligosanthes var. *scribnerianum*				x	x	x
Elymus canadensis				x	x	x
Eragrostis intermedia				x	x	x
E. secundiflora		x				
E. spectabilis				x		x
Erigeron annuus					x	
E. strigosus				x		
Euphorbia dentata				x	x	
Grindelia squarrosa		x		x	x	x
Hedyotis nigricans	x	x	x	x	x	
Helianthus annuus				x	x	
H. maximiliani				x	x	x
H. pauciflorus				x		

APPENDIX. (contd.) Plant species recorded during sampling using contiguous quadrats, modified Whittaker plots, and point-intercept methods at Fort Sill, Oklahoma. Taxonomy follows the National Plants Database version 3.5, National Resource Conservation Service.

Species	Site 1			Site 2		
	CQ*	MWP	PT-INT	CQ	MWP	PT-INT
Hypericum drummondii					x	
Krameria lanceolata				x		
Lactuca serriola				x	x	
Liatris punctata var. *nebraskana*	x	x		x	x	
Linum sulcatum	x			x		
Mimosa nuttallii				x	x	x
Monarda clinopodioides				x	x	
Nasserla leuotricha				x	x	
Neptunia lutea				x	x	
Oxalis violacea				x		
Panicun virgatum				x	x	x
Plantago sp.	x				x	
Poaceae sp.				x		
Polygala verticillata				x		
Psoralea sp.				x	x	x
Rudbeckia hirta				x	x	
Scheddonnardus paniculatus	x	x				
Schizachyrium scoparium	x	x		x	x	x
Sedum pulchellum	x					
Silphium laciniatum				x	x	
Solanum elaeagnifolium	x	x		x	x	x
Solidago missouriensis		x				
Sorghastrum nutans				x	x	x
Sorghum halepense				x	x	
Sporobolus sp.				x		x
S. compositus.	x	x	x	x	x	x
Thelesperma filifolium	x	x				
Tragia ramosa				x		x
Vernonia badlwinii					x	
Unknown #5	x	x	x	x		
Unknown #12				x		
Unknown #15				x		
Unknown #23					x	
Unknown #25		x			x	
Unknown #28	x					
Unknown #30	x	x				
Total	25	21	5	56	48	24

*CQ=Contiguous quadrats, MWP=Modified Whittaker plot, PT-INT=Point-intercept method.