Evaluation of Sampling Techniques on Tall-Grass Prairie

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Highlight: An evaluation of sampling techniques was conducted on a tall-grass prairie in eastern Oklahoma. The point transect, a modified point transect, line transect, angle order, quarter, and wandering methods were used. Relative and total density values were determined and compared with actual values obtained by hand count. The above methods, with the exception of the angle order, underestimated the relative density of splitbeard bluestem (Andropogon ternarius), a dominant and densely cloned species, and overestimated switchgrass (Panicum virgatum), a subdominant, single-stalked species. Relative and total density values obtained by the point transect were significantly less accurate than those obtained by the other methods; no method was significantly more accurate. With recalculus excluding splitbeard bluestem data, relative densities obtained by most of the methods agreed more closely with actual values, and the quarter method was again significantly less accurate. Results indicated that degree of clone density of the dominants and subdominants, as well as sampling time, should be noted prior to the selection of a sampling method in a highly aggregated grassland type. The modified point transect or quadrant methods are considered to be most applicable if the dominants are densely cloned as in splitbeard bluestem; however, the point transect or line transect methods may be adequate if the dominants are sparsely-cloned as in big bluestem (Andropogon gerardi) or little bluestem (Andropogon scoparius).

The point transect is one of the oldest and most widely used methods for grassland analysis. Other methods, however, have been developed to avoid much of the sampling time needed to obtain statistically reliable results. These methods include the meter-line transect (Weaver and Clements, 1929); point transect (Levy and Madden, 1933); loop (Parker, 1951); and quarter (Dix, 1961). Whitman and Siggeirsson (1954) compared the line and point transect methods in a mixed grassland type in North Dakota and considered both to be equally reproducible. Johnston (1957) compared the point transect, line transect, and loop methods in a mixed grassland type in Alberta. The loop method was found to be the least reproducible and a preference was indicated for the point transect method. Crockett (1963) compared the line transect, point transect, and wandering methods in a tall grassland type in Oklahoma and indicated a preference for the point transect method. More recently, density data obtained by the point transect method was compared to quadrat data for tall grassland types in Wisconsin (Risser and Zedler, 1968) and in Minnesota (Good and Good, 1971). In these studies the quadrat method results did not closely agree with those of the point transect method, particularly in aggregated stands.

The above studies were somewhat limited in scope in that only a few methods were compared in a stand, and sampled and actual counts were not made to determine accuracy. Nor were methods for non-random populations, the angle order (Morisita, 1957) and wandering quarter (Catana, 1963) compared with those best adapted for random populations (quarter, point transect, quadrant). The objectives of this study were to compare the field adaptability of methods in a highly aggregated tall-grass prairie, to determine accuracy by comparing actual and sampled data for the various methods; and to determine if accuracy of methods for non-random populations was greater than those for random populations.

Methods

The study site was located in an upland prairie, approximately 11 km west of Stillwater, Okla. By visual inspection the stand appeared homogeneous and contained as a dominant splitbeard bluestem (Andropogon ternarius), and as subdominants switchgrass (Panicum virgatum), little bluestem (A. scoparius), big bluestem (A. gerardi), and broomsedge (A. virginicus). The vegetation was approximately 30-60 cm high when sampled in July of 1970, and a 4-8 cm mulch layer was present. Four plots, each 1.2 x 5 m, were systematically established and numbered 1-4. Each was subdivided at 20 cm intervals by imaginary coordinates projected from stakes on the plot margins. Four sampling methods were used on these plots: the point transect (10 pins), the meter-line transect, the quarter, and the angle order. On plots 3 and 4 three other methods were used: a modification of the point transect whereby all basal contacts made by each pin were counted; a 10 x 10 cm open-ended quadrant; and the wandering quarter. Relative density (percentage composition) for each major species was determined by all of the above methods, relative frequency (frequency value of a species divided by total of frequency values for all species) by all except the wandering quarter, and total density by all except the point transect and wandering quarter methods.

The sampling units were randomized on each of the plots by the selection of a series of numbers, each of which represented a particular coordinate intersection. Sampling on each plot was terminated when approximately 400 shoots were encountered. A hit or contact by the point transect method was determined when a shoot was hit within 0.5 cm of ground level, and by the line transect method when a shoot was found within a 0.5 cm strip on either side of a 1 mm cord stretched tightly between two pins. After sampling, vegetation was removed from the plot and all shoots counted to determine the actual relative
and total density.

Determination of total density in the
quarter and angle order methods followed
Dix (1961) and Morisita (1957), respec-
tively. In the latter method two estimates
are determined, \( \bar{m}_1 \) and \( \bar{m}_2 \). If \( \bar{m}_1 \) is
greater than \( \bar{m}_2 \), \( \bar{m}_2 \) is considered as the
best density estimate; if \( \bar{m}_1 \) is less than
\( \bar{m}_2 \), the average of the two estimates \( \bar{m}_0 \)
is determined, and \( \bar{m}_0 \) is considered as the
best estimate of density.

Since both sampled and actual data
were collected, the sampled and actual
counts of the populations could be com-
pared by the chi-square statistic given by
the formula:

\[
\chi^2 = \sum \frac{(X_{obs} - X_{exp})^2}{X_{exp}}
\]

where

\( \chi^2 = \) the chi-square value
\( \sum = \) the summation of the ratios ob-
tained when observed and actual data
for each species or group of species
(i.e., forbs and miscellaneous grasses)
were compared. Since there were
seven species or groups of species (in-
cluding splitbeard bluestem) and six
species or groups of species exclud-
ing it, seven or six ratios were summed
to obtain the respective chi-square value.

\( X_{obs} = \) the number of shoots of a species on
a particular plot encountered by the
sampling method.

\( X_{exp} = \) the sum total of shoots of all species
encountered in that plot multiplied
by the actual relative density of that
species.

The chi-square values for each method
on all four plots were compared for
significance by nonparametric proce-
dures: the Friedman statistic (Bradley,
1968), or the Kruskal-Wallis statistic
(Siegel, 1956).

Two indices of aggregation were calcu-
lated to determine vegetation pattern.
These included the index of non-
randomness (Pielou, 1959) and the var-
iance: mean ratio (Blackman, 1942). The
former is determined from the relation
\( \alpha = \pi D \omega \), where \( \omega \) is the mean square
of the point to plant distances of the
quarter method and \( D \) is the density of
plants determined by actual counts. The
latter index was calculated from quadrat
data, and could be determined on plots
3 and 4 only. In both indices, values
in excess of 1.0 indicate aggregation.

Results

Density

Sampled values of relative density did
not closely approximate actual values for
the major species by the methods used
(Table 1). On all plots most of the
methods, but particularly the quarter,
derived the relative density of splitbeard bluestem, a densely-cloned
species, and overestimated switchgrass, a
single-stalked species. The latter was best
estimated by the quadrat method.

Loosely-cloned species such as little blue-
stem and big bluestem were under-
estimated by the quarter method but not
by the point transect, line transect, or
angle order methods. Other species or
groups such as broomsedge bluestem,
miscellaneous grasses, and forbs were not
at all or only slightly underestimated by
the point transect, line transect, and angle
order techniques; however, the quarter
method grossly overestimated the single-
stalked miscellaneous grasses and forbs.

Chi-square values calculated for the point
transect, line transect, and angle order
methods were approximately equivalent,
while those of the quarter method were
much higher (Table 2). Only the chi-
square value of 11.59 on plot 4 with the
line transect method indicated a good fit
between actual and sampled data (\( P = .05 \)).

Table 1. A comparison of sampled and actual density values (%) obtained by the sampling methods.\(^1\)

<table>
<thead>
<tr>
<th>Species</th>
<th>Plot</th>
<th>Actual relative density</th>
<th>Point transect</th>
<th>Line transect</th>
<th>Angle(^2) order</th>
<th>Quarter</th>
<th>Modified point transect</th>
<th>Quadrat</th>
<th>Wandering quarter</th>
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\(^1\)The quadrat, modified point transect, and wandering quarter methods were used on plots 3-4 only.
\(^2\)n=3; k=4 (see Morisita, 1957).
Table 2. Chi-square values determined from actual and sampled density data. Values for each method on each plot are given as well as average and overall values.1

<table>
<thead>
<tr>
<th>Plot</th>
<th>Point transect</th>
<th>Line transect</th>
<th>Angle order</th>
<th>Modified point transect</th>
<th>Quadrat</th>
<th>Wandering quarter</th>
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<td>175.1</td>
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<td>56.2</td>
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<td>78.1</td>
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1The overall chi-square value for plots 1-4 or 3-4 is indicated by 0X².

Table 3. Comparison of total density values (plants/m²) obtained from some sampling techniques.

<table>
<thead>
<tr>
<th>Plot</th>
<th>Actual density</th>
<th>Line transect</th>
<th>Angle order</th>
<th>Quadrat</th>
</tr>
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<td>1</td>
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</table>

*\( \overline{m_{lex}} \) was calculated by excluding distance measurements 1 cm or less.

**\( \overline{m_1} \) was calculated by including all distance measurements.

***\( \overline{m_0} \) is the average of \( \overline{m_1} \) and \( \overline{m_2} \) divided by \( \pi \).
The methods varied considerably in sampling time and could be ranked according to decreasing time requirements as follows: point transect, line transect, angle order, wandering quarter, quarter and quadrat. Approximately 400 shoots could be encountered by the quadrat method in one-half less time than in the point transect method. Sampling time for both the point and line transect methods was increased because of the mulch layer; in addition, the high density of splitbeard clumps (5-6 shoots/cm²) hampered sampling in the latter. In the angle order method much time was spent in locating the third nearest individual and calculating total density.

Discussion

The composition of an aggregated grassland community theoretically can best be determined by a single pin of infinitely small size as a sampling unit, which is repeatedly lowered into the vegetation, striking the shoots of each species. In a random sample the probability of hitting shoots of each species is proportional to their density. Since only sampling error would be present, the observed values should closely approximate the expected values. The chi-square values obtained by such a method should not exceed 12.59, with six degrees of freedom at P = .05 (Snedecor and Cochran, 1967). The poor agreement of sampled and actual data in this study indicates considerable bias in the sampling methods. High aggregation of some species is believed to contribute to much of the poor agreement. Splitbeard bluestem was an especially aggregated species; a decrease in its density coincided with a decrease in magnitude of Pielou’s index on plots 1-4. In addition, sampled values departed less from actual values for major species when splitbeard bluestem data were excluded. With its inclusion the chi-square value of 12.59 was not or was slightly exceeded only by the modified point transect method on plot 3 and 4, and by the line transect method on plot 4. With its exclusion, however, the maximum expected chi-square value of 11.07 (5 degrees of freedom at P = .05) was obtained on plot 3 by both of the point transect methods, and on plot 4 by the point transect, line transect, and quadrat methods.

Density data obtained by the quarter method were significantly less accurate than those obtained by the other methods. The quarter method was originally developed to sample dispersed forest vegetation, but subsequently was used in grasslands by Dix (1961). The reliability of this method for grasslands was evaluated in several studies in which quarter method density data were compared to either actual or quadrat counts. In the Arizona desert grassland and California grassland types, Morris (1962) found the quarter method grossly underestimated density. In Wisconsin, Kissler and Zedler (1968) found that density was grossly underestimated for stands dominated by aggregated species such as little bluestem, big bluestem, prairie dropseed (Sporobolus heterolepis), or hairy grama (Bouteloua hirsuta). In Minnesota, Good and Good (1971) found that the quarter method underestimated density in xeric stands dominated by grama grass (Bouteloua gracilis), needleleathread (Stipa comata), and in mesic stands dominated by big bluestem and Kentucky bluegrass (Poa pratensis).

In this study better results were obtained by distance methods other than the quarter method; for example, the wandering quarter for relative density, and the angle order for total density. The accuracy of the estimates of the latter, however, depended upon whether \( \frac{\hat{m}}{\pi} \) or \( \frac{\hat{m}_0}{\pi} \) was used. In this study the estimate \( \hat{m}_1 \) was greater than \( \hat{m}_2 \) in all plots, and according to Morisita (1957), \( \frac{\hat{m}_1}{\pi} \) should be used as the density estimate. However, only \( \frac{\hat{m}_\text{lex}}{\pi} \) gave a good density estimate; and it was significantly more accurate than \( \frac{\hat{m}_1}{\pi} \) or the line transect method. In a desert grassland type in Arizona, Morris (1967) compared angle order density data with that obtained by quadrat and actual counts. In that study, despite the fact that \( m_1 \) was greater than \( m_2, \frac{\hat{m}_0}{\pi} \) rather than \( \frac{\hat{m}_1}{\pi} \) gave the better density estimate.

The three additional methods used on plots 3 and 4, when compared with the other methods, were not significantly different. One of these, the modified point transect method, does appear to have less bias in this highly aggregated grassland type because, on the average, chi-square values calculated from the 10 subgroups of relative density data were lower. When splitbeard bluestem data were omitted, however, the modified point transect did not appear to have any advantage over the line transect and point transect methods. These latter methods may give accurate results when used to sample species with loose clones such as big bluestem and little bluestem.

The choice of a particular method for sampling grassland vegetation should be based not only on growth form, but also on the degree of aggregation of the dominant and subdominant species. Accuracy, as well as time and reproducibility, should also be considered. In this grassland type the quadrat method appeared to have advantages over the other methods when time was considered, but did not appear to be as accurate as the point transect method. The development of better techniques to assess density and percentage composition of highly aggregated species is needed to facilitate studies in aggregated grassland communities.

<table>
<thead>
<tr>
<th>Plot</th>
<th>Pielou’s index</th>
<th>Variance: mean</th>
<th>Rel. density of splitbeard bluestem (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.05</td>
<td>-</td>
<td>62.7</td>
</tr>
<tr>
<td>2</td>
<td>9.97</td>
<td>10.10</td>
<td>31.9</td>
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<tr>
<td>3</td>
<td>8.90</td>
<td>4.39</td>
<td>51.9</td>
</tr>
<tr>
<td>4</td>
<td>7.96</td>
<td>-</td>
<td>37.5</td>
</tr>
</tbody>
</table>

1 Quadrat data were obtained only for plots 3 and 4.

Table 4. Two measures of aggregation. All index values are significant at P = .01.

Literature Cited


A Comparison of Sampling Methods in Dense Herbaceous Pasture

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Highlight: Several methods of vegetation sampling were compared in a very homogeneous herbaceous vegetation: Needle points, double metre points, bayonet points, line transects, area measurements, and harvesting with sorting and weighing. Consistent curvilinear relationships were found between species frequencies, interceptions, and biomasses obtained by several methods. These constant relationships allow the estimation of yields from the double metre points by simple and fast observations. The shape of the curves suggests some ecological relationship between the vegetation attributes analyzed.

Many problems arise in quantitative sampling of dense herbaceous vegetation because of difficulties in delineating individuals or tillers and because of entanglement of species. The main problem is optimization of time and resources to attain sufficient accuracy. Another question is the kind of relations which exist between estimates obtained by different methods.

Many methods of measuring and surveying vegetation have been reviewed by Brown (1954). They differ by the attributes sampled, sampling techniques, sample numbers, and types of lay-out. Field observations may consist of species lists, frequency (in sub-units), cover (in sub-units), or with vertical, oblique, or horizontal levels of these lay-outs have also been compared by Hédin and Lefebvre (1951), mountier and Radcliffe (1964), and others.

Optimization of sample numbers with time has been discussed by Hyder et al. (1965) and Fisser and Van Dyne (1966). The distribution of samples may be entirely subjective (i.e. as applied by some phytosociologists), stratified (Gounot, 1960), at random, or regular. Numerous combinations at different levels of these lay-outs have also been used (Boyd and Bayens, 1963).

The present paper evaluates different sampling methods by very detailed observations on dense natural herbaceous pasture in Central France.

The Experimental Area

The 0.4 hectare, very homogeneous experimental plot is situated on a basaltic plateau, West of Castré in the Massif Central of France, at 950 m altitude. The climate is mesothermic with a short summer growing season. Precipitation (rain and snow) totals 1600 mm annually, and is regularly distributed all around the year. The soil is deep, brown, mull moder humus, very loamy (45%) and slightly stony; pH is 5.5. The vegetation consists mainly of perennial grasses and forbs. The three dominant species are Festuca rubra, Agrostis vulgaris and Trifolium repens.

The area was grazed 6 months a year with a stocking rate of 1-1.5 animal units/hectare/year. For more details, see Daget and Poissonet (1965).

Experimental Procedure

Methods Compared.

The following sampling methods were compared:

1) Needle points—Points were defined using a very thin needle, accurately located by a special frame (Long et al., 1972). The number of hits for each species was recorded at each point. This method gives the most accurate point estimates but is time-consuming; it is used as the "reference method" for further comparisons. 8 x 160 points were located at 7.5 cm intervals along 4 m lines.

2) Double metre points—Points were defined by vertical sighting on the edges of a 2 m ruler (Daget and Poissonet, 1971). This method is much faster than the previous one: 12 x 100 points were recorded at 4 cm intervals.

3) Bayonet points—Points were defined by the edge of the blade or a "bayonet" (Poissonet et al., 1972), which is convenient in tall herbage. Two hundred eighty-nine points were located randomly, 289 regularly, 256 regularly in 4 subplots of 64 x 1 x 1 m squares, or 0.5 x 0.5 m squares.

4) Line transects—Species presence was recorded in 25 cm segments of 4 lines of 64 m each.

5) Areas with species ranking—Species presence and their orders (De Vries and De Boer, 1959) were done at regular intervals of (a) "handfuls" (145 units) which were harvested, (b) 0.5 x 0.5 m squares (256), (c) 0.25 m² squares (12),