Evaluation of five methods for measuring desert vegetation

Richard C. Etchberger and Paul R. Krausman

Abstract We obtained a complete census of vegetation in a 30- x 1,900-m plot in the Sonoran Desert (Tumamoc Hill, Pima County, Ariz.). We then evaluated the accuracy of 5 sampling techniques commonly used to sample vegetation in deserts: step-point, point-quarter, and 3 line-intercept methods. We compared presence and percent occurrence for each method with the census. The line-intercept (method 3) most closely estimated the census: it was closer for all species occurring on >1% of the site, revealed the least variability relative to sample size for dominant species, and accounted for more (20 of 23) plant species on the study site than the other methods.

Key words Arizona, line-intercept, point-quarter, step-point, vegetation sampling

Vegetation composition is one of the most often sampled attributes of wildlife habitat (Morrison et al. 1992). The results of vegetation sampling are often used to construct models that predict habitat use by wildlife (Capen 1981) or as correlative evidence of the importance of certain species of vegetation (Krausman and Leopold 1986, Etchberger et al. 1989).

In studies of the relationship between wildlife and vegetation it is usually not possible to count all vegetation because of time and financial constraints. Hence, there are many techniques (Mueller-Dombois and Ellenberg 1974, Cook and Stubbendieck 1986) used to sample vegetation. The degree of accuracy required in a sample of vegetation composition depends on study objectives. The results obtained usually are assumed to represent the composition of the study area. Unless one actually compares the accuracy of various techniques for specific studies and objectives (e.g., Block et al. 1987), it is impossible to comment on the desirability of one technique over another (Morrison et al. 1992).

Some quantitative vegetation sampling techniques have been evaluated relative to other techniques (Evans and Love 1957, Hanley 1978, Floyd and Anderson 1987) or with artificial vegetation (Cottam et al. 1953). Other techniques have been compared and their accuracy evaluated using a complete census of vegetation in a forested ecosystem (James and Shugart 1970). However, few studies have used a complete census of vegetation to evaluate the accuracy of vegetation sampling techniques commonly used in desert ecosystems (Phillips and Mac Mahon 1978,1981). Our objective was to evaluate the accuracy of the step-point, point-quarter, and 3 variations of line-intercept methods for measuring relative percent occurrence of Sonoran Desert plant species.

Study area

We selected a 5.7-ha study area west of Tumamoc Hill, Pima County, Arizona. We chose this site because it was representative of desert vegetation in the Sonoran Desert, easily accessible, and relatively level. Tumamoc Hill was part of the Carnegie Desert Laboratory and has been fenced since 1907 for protection from external influences (e.g., livestock). Although much of the Sonoran Desert has been exposed to grazing by livestock, we wanted to sample an area not influenced by livestock with a complete array of plants. Elevations ranged from 672 to 680 m. To-

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pography consisted of gentle slopes (<10%) intersected by several dry washes. Soils were mainly the Pinaleno-Palos Verdes association and were loamy in texture (D. Post, Univ. Arizona, Tucson, unpubl. data). The major vegetation association on the study area was creosote bush (*Larrea tridentata*) and triangle leaf bursage (*Ambrosia deltoidea*). Mean seasonal temperatures ranged from 16 to 30°C in winter and summer, respectively. Mean annual precipitation in Tucson was 28.3 cm.

Methods

We delineated a study plot (30 x 1,900 m) in which all plants could be counted within 3 months. From June through August 1990 (approx 1,000 human-hours) we counted all individual plants within the plot. We walked along a compass bearing, counted each plant and, as we counted individuals, marked a 6-m-wide strip with flagging to maintain accuracy. This complete census represented the known composition of perennial vegetation on the plot. We calculated percent occurrence of each species by dividing the total number of plants on the area into the number of plants of each species.

We evaluated the accuracy of 5 sampling techniques commonly used to sample vegetation in deserts: step-point (Evans and Love 1957), point-quarter (Cottam et al. 1953), and 3 line-intercept methods (Canfield 1941). We compared the presence and percent occurrence of species calculated by each method against the known presence and percent occurrence of perennial plant species. We collected random samples by gridding the study area and selecting starting points for transects from a random numbers table. We used perennial vegetation because it was the dominant vegetation, and there were few forbs and grasses present. Most studies classify species that occur with a frequency of <1% as trace species, and we limit out discussion to species that comprised >1% of the census.

For the step-point method, we randomly selected the starting points for 4 step-point transects across the study area. We recorded the number of times any part of each species touched a thin line (<1 mm) drawn on the toe of a boot placed in 1,200 steps. The total number of hits for each species was divided by the total hits for all species to yield the percent occurrence.

For the point-quarter method, we randomly located 100 points in the study area. Using a compass, we then divided the area around each point into 4 equal parts. Next, we located any part of an individual plant within each quadrant that was nearest the center point and recorded the species. We determined percent occurrence by dividing the number of points at which a species occurred by the total for all species.

We used 3 variations of the line-intercept method described by Canfield (1941). For line-intercept methods 1 and 2, we measured vegetation that intercepted the line to the nearest 5 cm. Where crowns overlapped in layered vegetation, we measured each species separately. We calculated the percent occurrence for each perennial vegetation species by dividing the accumulated length for each species by the accumulated length for all species. The difference between line-intercept methods 1 and 2 was the random placement of the lines. For line-intercept method 1, we randomly chose a starting point and then ran 30 30-m transects end-to-end in a straight line. For line-intercept method 2, we randomly selected 12 starting points. We positioned 4 30-m transects starting at each point, and radiating in randomly selected directions away from the points.

For line-intercept method 3, we randomly positioned 4 30-m transects at 12 points similar to method 2, again for a total of 48 transects. However, instead of measuring the length of vegetation canopy intercept, we counted each plant that intercepted the line as a hit. We calculated the percent occurrence by dividing the total number of hits for each plant species by the total number of hits for all species.

We compared the 5 techniques to see how close each was to the census by plotting the means and 95% confidence intervals for the means for several species of vegetation. We then plotted the running mean for the percent occurrence of several species against sampling effort (Kershaw 1964) to examine the effects of sample size on accuracy of each method.

Results

There were 23 species of perennial vegetation on the study area. Six species each comprised >1% of the plants on the study area, and together comprised 92.7% of the vegetation composition (Table 1). Triangle leaf bursage plants occurred in greatest numbers (80.4% of total). No other species comprised >6% of the vegetation (Table 1).

The number of species observed with the 5 methods (Table 1) were: 15 with step-point (n = 1,200 steps); 15 with line-intercept method 1 (n = 30 transects); 9 with line-intercept method 2 (n = 50 transects); 20 with line-intercept method 3 (n = 40 tran-

Table 1. Percent occurrence of vegetation species comprising >1% of the census[a] and estimated with the step-point,[b] point-quarter,[c] and 3 line-intercept[d] sampling techniques, Tumamoc Hill, Arizona, 1990.

	$\bar{x}$ % occurrence by sampling technique					
Species	**Census**	**Step-point**	**Line-intercept 1**	**Line-intercept 2**	**Line-intercept 3**	**Point-quarter**
Triangle leaf bursage	80.4	32.6	24.2	73.2	76.5	37.4
Range ratany	6.0	3.0	9.2	8.0	7.3	1.0
Creosote bush	3.4	4.8	20.5	10.8	2.7	18.7
Cholla (*Opuntia* spp.)	1.7	0.7	2.7	0.0	4.5	1.3
White thorn (*Acacia constricta*)	1.2	4.1	8.6	2.5	2.1	0.8
Prickly pear (*Opuntia* spp.)	1.1	4.4	2.6	0.2	2.2	4.7
Total						
% occurrence	93.8	49.6	67.8	94.7	95.3	63.9
No. species	23	15	15	9	20	16

[a] Actual enumeration.
[b] Evans and Love (1957).
[c] Cottam et al. (1953).
[d] Canfield (1941).

sects); and 16 with point-quarter (n = 100 plots). In all 5 techniques the same 6 species were found to comprise >1% of the census. The plants of these 6 species totaled, respectively, 78.2, 67.8, 94.7, 95.3, and 63.9% of the vegetation in the 5 methods listed above.

When we plotted percent occurrence of triangle leaf bursage against sampling effort, line-intercept method 3 was closest to the census overall (Fig. 1). All of the other sampling methods underestimated the amount of bursage, regardless of sampling effort.

The means did not stabilize with increasing sample size with line-intercept methods 1 and 2, even after 30 and 50 transects, respectively (Fig. 1). They did stabilize with the point-quarter and step-point methods. However, both methods underestimated the amount of bursage. When we plotted the means and 95% confidence intervals for triangle leaf bursage, results from transect methods 2 and 3 were closest to the census (Fig. 2). Transect method 1, the point-quarter method, and the step-point method underestimated the amount of bursage (Fig. 2).

For range ratany (*Krameria parvifolia*) frequency of occurrence by line-intercept method 3 most closely estimated the known population value throughout the range of sampling effort (Fig. 3). Line-intercept method 1 underestimated ratany at small sample sizes and overestimated ratany at larger sample sizes (Fig. 3). Line-intercept method 2 overestimated ratany regardless of sample size. However, the sample was closer to the census as sample size increased (Fig. 3). We did not record range ratany with the point-quarter technique until 75 plots had been sampled and then underestimated the amount (Fig. 3). The step-point method stabilized the mean as sampling effort increased but underestimated the

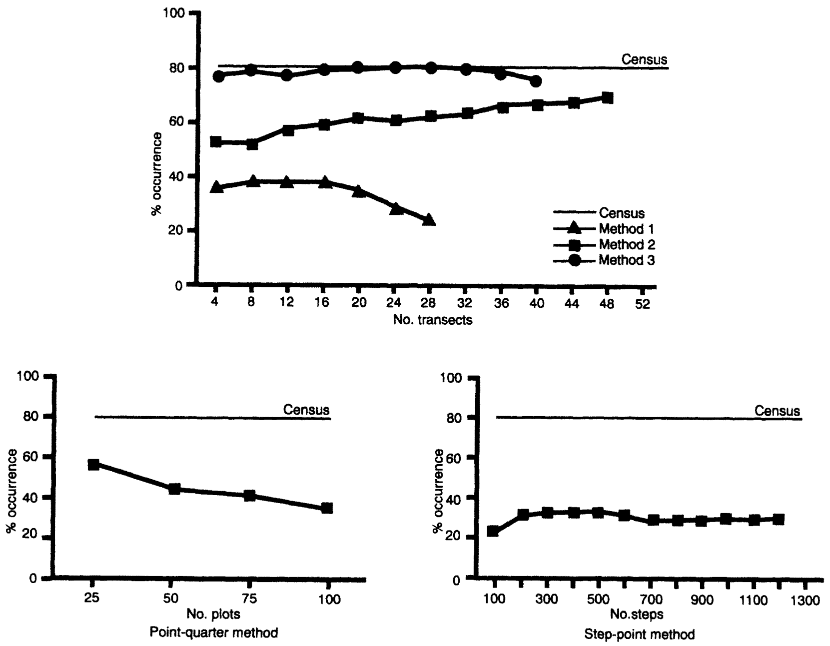

Fig. 1. Percent occurrence versus sampling effort for triangle leaf bursage as sampled by 3 methods of line-intercept transects, the point-quarter method, and the step-point method, Tumamoc Hill, Arizona, 1990.

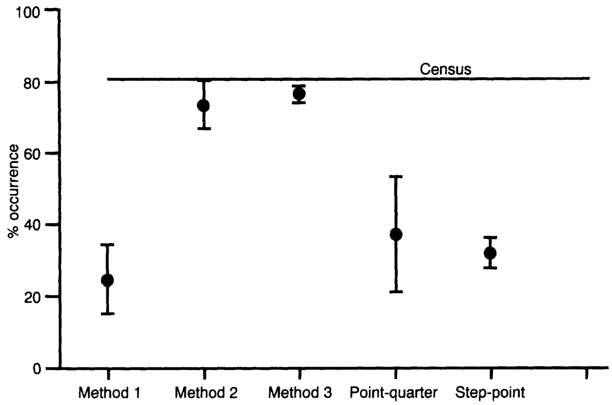

Fig. 2. Mean percent occurrence (running $\bar{x}$) and 95% confidence intervals for triangle leaf bursage as sampled by 3 line-intercept transect methods, the point-quarter method, and the step-point method, and compared to a census, Tumamoc Hill, Arizona, 1990.

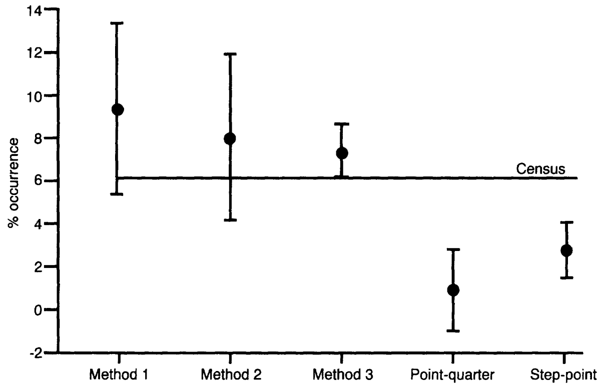

Fig. 4. Mean percent occurrence (running $\bar{x}$) and 95% confidence intervals for range ratany as sampled by 3 line-intercept transect methods, the point-quarter method, and the step-point method, and compared to a census, Tumamoc Hill, Arizona, 1990.

amount of range ratany (Fig. 3). When we plotted the means and 95% confidence intervals for range ratany, estimates from transect methods 1, 2, and 3 were closest to the census (Fig. 4). The point-quarter and step-point methods underestimated the amount of ratany (Fig. 4).

Line-intercept method 3 most closely and consistently estimated the census of creosote bush (Fig. 5), but the running mean did not stabilize as quickly as for ratany and bursage. Line-intercept methods 1 and 2 overestimated the amount of creosote bush regardless of sampling effort (Fig. 5). The mean did not stabilize with line-intercept method 1 regardless of sampling effort (Fig. 5). The point-quarter method overestimated the amount of creosote bush and the mean did not stabilize (Fig. 5). The mean stabilized with increasing sample size with the step-point method. However, this technique overestimated the amount of creosote bush (Fig. 5). The means and 95% confidence intervals for creosote bush estimated from transect method 3 and the step-point method most closely approximated the census (Fig. 6).

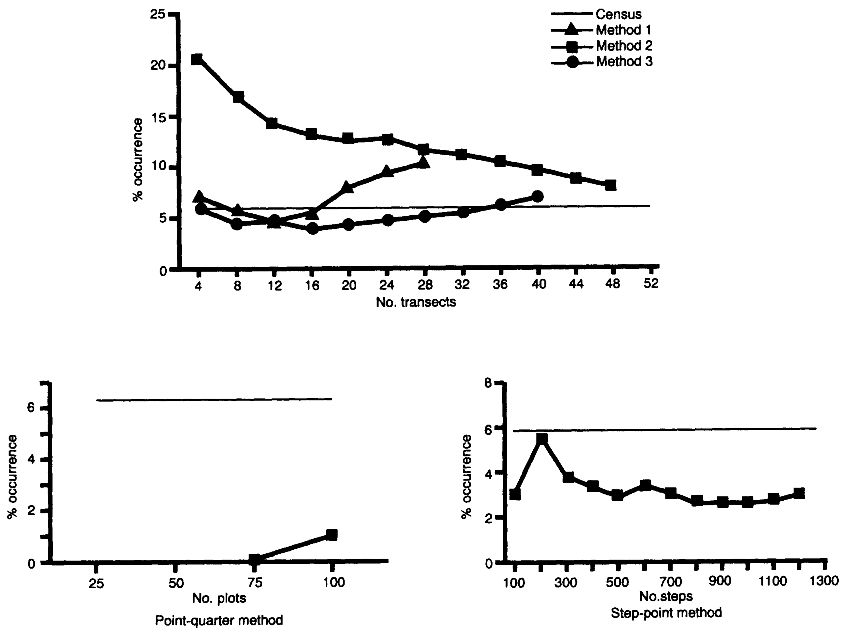

Fig. 3. Percent occurrence versus sampling effort for range ratany as sampled by 3 methods of line-intercept transects, the point-quarter method, and the step-point method, Tumamoc Hill, Arizona, 1990.

Discussion

Line-intercept method 1 was the least accurate of the line-intercept techniques. This technique has been used to sample large study areas in a minimum amount of time. Triangle leaf bursage and creosote bush were underestimated and overestimated, respectively (Table 1). This method identified only 15 of the 23 plant species on the site and did not result in an accurate sample of the vegetation; accuracy did not improve with increased sampling effort. Although the starting point of the transect was randomly located and the line covered the length of the study area, this method did not produce accurate results.

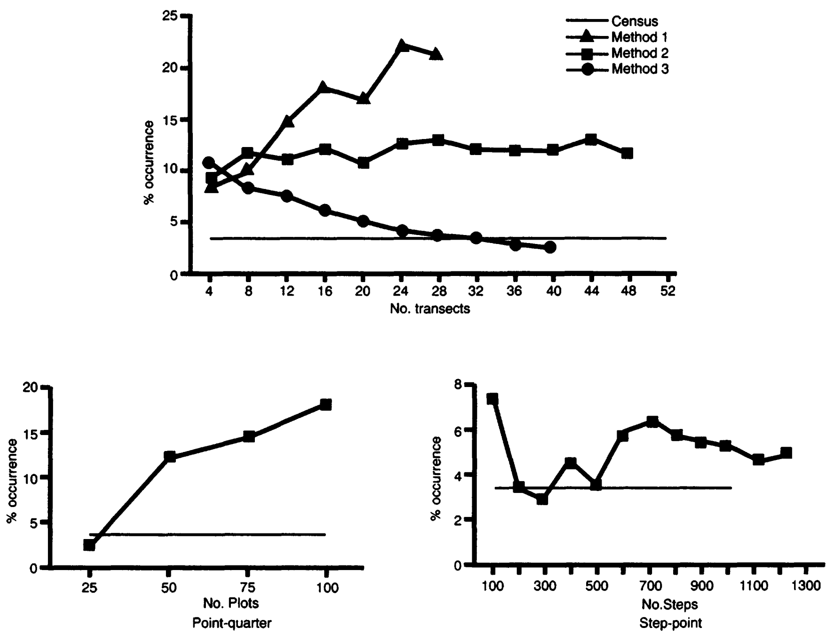

Fig. 5. Percent occurrence versus sampling effort for creosote bush sampled by 3 methods of line-intercept transects, the point-quarter method, and the step-point method, Tumamoc Hill, Arizona, 1990.

The running means of line-intercept method 2 stabilized with increasing effort for triangle leaf bursage, range ratany, and creosote bush, but the results were not accurate or consistent. Range ratany and creosote bush were overestimated and triangle leaf bursage was underestimated. Method 2 was an improvement over method 1, probably due to the placement of starting points for the transects. This method used the same random location technique as line-intercept method 3, but the measurement technique differed. Measuring crown-intercept length did not provide as close as estimate of the population values as method 3.

Line-intercept method 3 most closely estimated the population values. This method was the closest to the census for the 6 vegetation species occurring >1% on the site (Table 1). It also showed the least variability relative to sample size for triangle leaf bursage (Fig. 1), range ratany (Fig. 2), and creosote bush (Fig. 3). This sampling technique identified 20 of the 23 plant species on the study area (Table 1). Line-intercept method 3 used random placement of the starting points for each set of transects and allowed a greater probability of sampling all parts of the study area than line-intercept method 1.

Although we had a complete census (i.e., species composition and abundance) to compare the results of the 5 methods we tested, we did not measure cover. Cover is among the most widely used measures of abundance of plant species (Floyd and Anderson 1987), but we did not have time to accurately measure cover of individual species and compare the estimates made with the 5 methods used in the area.

Although often it is not possible to test the biases inherent in vegetation sampling, many conclusions may be drawn from the results. Multivariate analyses of data often are used to rank the importance of vegetation variables (Block et al. 1987). Our results indicate that the sampling technique used influences the results of these analyses. For example, line-intercept technique 1 measured creosote bush as occurring at nearly the same frequency as triangle leaf bursage, but, in fact, it occurred >20 times as frequently. This could have serious impacts on the management recommendations drawn from the data.

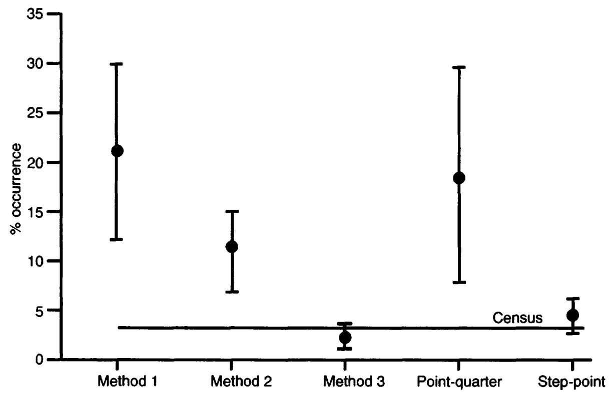

Fig. 6. Mean percent occurrence (running $\bar{x}$) and 95% confidence intervals for creosote bush sampled by 3 line-intercept transect methods, the point-quarter method, and the step-point method, and compared to a census, Tumamoc Hill, Arizona, 1990.

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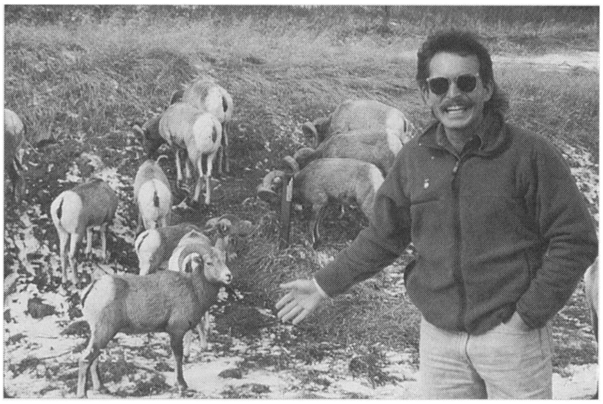

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