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Sensitivity of Frequency Plots for Detecting Vegetation Change

Abstract

Field procedures that will monitor vegetation changes are required to assess the effects of management activities on rangelands. The more sensitive the monitoring methodology, the earlier any evaluation of management programs may be accomplished.

As a vegetation attribute that can be sampled, frequency has many desirable qualities: it is stable over time, easily measured, and the resulting data is readily analyzed. While frequency is not suitable for vegetation description, it does offer the potential for detecting vegetation change with successive measures over time.

Studies were undertaken to compare the relative sensitivities to vegetational change of three frequency plot sizes (10x25, 15x33.5 and 20x50 cm). The testing was carried out in four different range communities. At each site, frequency of occurrence by species was obtained with each of the frequency plots. Known percentages of vegetation were then excluded from further sampling, thus simulating changes in the vegetation over time. The transect was then resampled. The plot size detecting the smallest amount of change with a given number of samples was deemed to be the most sensitive for a given site.

Results show that each of the frequency plots was very sensitive to successional change. Of the three frequency plot sizes tested, an increase in plot size brought about a corresponding improvement in sensitivity to vegetational change in the particular types of vegetation sampled. In the vegetation sampled in this study, the plot sizes were not large enough to produce frequencies that were less sensitive than the smaller plot sizes.

Introduction

Since effective evaluation of range management programs requires proper assessment of vegetational change, the need for efficient monitoring of range trend has long been recognized (Pickford and Reid 1942, Ellison 1949). Without early detection of trend, it becomes difficult to reverse vegetational change not meeting management goals, since the change is usually well advanced by the time it is detected. In addition, current monitoring techniques often require prohibitively long time spans to note any change due to the implementation of management actions.

Successional trend, as an indicator of change in condition, is expressed by a change in species composition (Costello 1956). This change in composition can be theoretically measured by corresponding changes in cover, yield, density or frequency. However, some of these attributes are more sensitive to successional change than others. For efficient detection of trend, it is preferable to select an easily measured attribute that is sensitive to small changes in species composition, yet insensitive to weather-induced fluctuations. Although cover and yield data are useful

in applications such as production studies, they are not desirable for detecting range trend. Seasonal and yearly weather fluctuations greatly affect yield and cover (basal and foliar); hence their levels are too transient for effectively measuring successional change. Density, as opposed to cover and yield, is an essentially stable attribute, particularly with perennial vegetation. Unfortunately, measuring and recording density can be very time consuming, particularly if the plants are small and numerous, or if they reproduce vegetatively (Strickler and Stearns 1963). For these reasons, frequency (species presence or absence) is a more desirable attribute for measuring range trend. Since it is partially determined by density, it is stable over periods of time. In addition, frequency is easily and quickly measured, requiring only species' presence in a plot, and data are readily analyzed statistically (Brown 1954).

Frequency's requirement for different plot sizes according to vegetation type sampled (Kershaw 1973) makes it a poor choice for describing vegetation; it is difficult, without one standardized plot size, to conceptualize frequency

data. However, frequency has the potential for use in trend studies where the data desired represents a difference between two sampling dates rather than a single absolute measurement. Therefore, the objective of this study was to determine if frequency plot data would be more sensitive to detecting small levels of range trend. The greatest benefit of a more sensitive method of measuring trend would be the earlier detection of vegetational change resulting from management practices.

Methods

Field Methods

During the summer of 1981, four sites located within 70 km of Salmon, Idaho, were studied. These sites were selected to test the procedures in a variety of vegetational types. Listed as habitat types (Hironaka *et al.* 1983, Steele *et al.* 1981), the sites are:

1. *Pinus ponderosa*/*Festuca idahoensis*. Located at an elevation of 1500 m, this site exhibited a typical (Morris and Mowat 1958) fire-maintained *P. ponderosa* stand structure. It combined an uneven-aged stand overstory with a grass-dominated understory.
2. *Artemisia tridentata* subsp. *vaseyana*/*Festuca idahoensis*. Several *Pseudotsuga menziesii* trees were present on this site, although there was no indication of previous occupation by this species. The elevation was 1975 m.
3. *Artemisia tridentata* subsp. *vaseyana*/*Festuca idahoensis*. Located at an elevation of 2250 m, this site had been prescribed burned three years prior to sampling.
4. *Artemisia tridentata* subsp. *vaseyana*/*Festuca idahoensis*. This site was located on an exposed high elevation (2725 m) with an abundance of small forbs and few shrubs. The few *Artemisia* individuals present were small and stunted.

Vegetation data reported in this study consist of the herbaceous component only. Use of scientific names except for *Artemisia* follows Hitchcock and Cronquist (1973).

The sampling process consisted of three phases, designed to simulate trend sampling over a period of years. In phase 1, frequency and cover

baseline measurements were taken. Phase 2 consisted of randomly excluding known amounts of vegetation from further sampling, simulating a known compositional change over time. In phase 3, the plots sampled in phase 1 were resampled after the vegetation change had been created. Phases 2 and 3 were completed three times, since three different levels of change were studied.

The sampling unit consisted of a series of successively larger metal plot frames arranged in a nested configuration. The frequency plot sizes were 10x25, 15x33.5, and 20x50 cm, representing areas of 250, 500, and 1000 cm², respectively. The nested configuration allowed for direct comparison of any one plot size to another, since a plant located in a particular plot would also be included in all plots of a larger size.

At each site, ten 10-m transects were located within a uniform area. The transects were usually placed parallel to each other at a distance of two to three meters. Along each transect, 40 of the nested configurations were uniformly spaced, for a total of 400 samples per site.

At each of the 400 nested configurations, frequency of occurrence for individual species within each of the three frequency plots was recorded. A plant was defined as being present if any portion of the rooted crown occurred within the quadrat. In addition, 120 systematically located point measurements were made along each transect (1200 points per site) to measure foliar cover. These frequency and cover measurements comprise the aforementioned phase 1. Next, phase 2 was conducted. Changes in species number and abundance were created to simulate successional trend. To do this, randomly located sections of the transect, each 20-cm long, were marked off. Each section also extended perpendicularly from the transect 50 cm to include all sizes of the sample plots. Any plant located within these "exclusion areas" was considered to have disappeared, thus simulating a vegetation change over time. To achieve the desired levels of change (10, 20, and 30 percent reduction in vegetation) 5, 10, and 15 exclusion areas, respectively, were located. By superimposing the randomly located exclusion areas over the uniformly spaced sample plots, varying amounts of vegetation change within a single sample plot could be created, from complete exclusion to no change. Neither of these extremes occurred frequently. Instead, varying

amounts of partial overlap occurred between the sample plots and the exclusion areas. Following each of the three levels of change, phase 3 was accomplished by resampling the original sample plots and the exclusion areas. Following each of the three levels of change, phase 3 was accomplished by resampling the original sample plots, minus the exclusion areas, for frequency and cover.

In summary, the field sampling consisted of:

1. a) recording the initial frequency data for the three plots within each of the 400 concentric configurations per site;
b) recording foliar cover generated by 1200 points per site;
2. creating a change in the vegetation;
3. resampling the original frequency plots and cover points after the change had been made.

Steps 2 and 3 were done three times, once at each level of change introduced (10, 20, and 30 percent). While this study considered "change" to be a reduction in species variety and abundance, a reversal of the data could be used to discuss the effects of species increase. With the same set of data, however, the results of an increase were not tested. Since this study was testing various plot sizes for sensitivity to small levels of change, the amount of change induced was limited to a maximum of 30 percent.

The objective of this study was to compare changes in frequency levels detected by different plot sizes. Without a reference standard, it would be impossible to determine if the frequency changes detected by one plot size were more precise than any other plot size. Frequency itself could not be used as a reference for two reasons: 1) it is the value being tested, and 2) its results are highly related to plot size. For these reasons a vegetation measurement other than frequency had to be established as a reference. Density, yield and cover were considered. For practical reasons, cover was the attribute chosen. It was found, however, that basal cover levels at the sites studied, were too small to be useful. Foliar cover was thus chosen as the reference standard. It was determined that sampling foliar cover at such an intensive level (1200 points per site), would give an accurate assessment of change (Table 1). The sole purpose of the foliar cover data was to determine whether a significant vegetation change had

occurred as a result of the exclusion process. No attempt was made to relate cover to frequency. Normally, foliar cover is not used to determine trend; it is subject to yearly and seasonal environmental fluctuations. However, it was used as a parameter in this study since all sampling on a site was done in a few days' time, during which vegetation changes were insignificant.

TABLE 1. Percent foliar cover before and after each exclusion level, high elevation *Artemisia tridentata* subsp. *vaseyana*/*Festuca idahoensis* habitat type.

Exclusion Level (%)	Foliar Cover	Percent Change in Foliar Cover From Original (0% Exclusion) Level
0	38	
10	34	10
20	31	18*
30	28	26**

*Significant at the alpha = 0.20

**Significant at the alpha = 0.10

Significance determined by separate 't' test between the control level and each of the three "exclusion" levels.

Data Analysis

Sampling 400 plots is usually considered to be too time consuming for most management requirements. Therefore, to enhance the usefulness of this study, the original 400 nested configurations were considered to be a population, from which a random sample of 200 was drawn. The 600 foliar cover points associated with these 200 samples were also used in the analysis. All results shown here are from the smaller (200) sample size. Data from each of the four sites were analyzed independently; no attempt was made to combine information from different sites.

Individual 't' tests were used with the foliar cover data to determine, as a reference standard, if the exclusion process had indeed made significant changes in the vegetation. With alpha = 0.10 or 0.20, tests were made on differences in percent foliar cover between the control (original) level and each of the three separate "exclusion levels." Each of the 10 transects (40 nested configurations each) within a site was considered a sample.

A Chi-square test with Yates' correction factor (Mueller-Dombois and Ellenberg 1974) was

used to determine, for each plot size, if significant changes in frequency had occurred between the control and any of the exclusion levels. The data used in these tests were the number of occurrences of each species per plot size at the control and each "exclusion level." With the total number of samples taken also known, the frequency data were arranged in a presence-absence form, utilized in the Chi-square analysis. For all species, the number of occurrences in each plot size at the control level was tested against the three exclusion levels. For the Chi-square test, each species-plot size combination was considered a sample. Results were compared at alpha levels of 0.20 and 0.10.

While placing the three plot sizes in a nested arrangement helps ensure that any plants found in a given plot size are subsequently located in all larger plot sizes, statistical comparisons between plot sizes would be inappropriate, since the nesting procedure violates the rule of independence.

Results and Discussion

Foliar Cover

Except as noted, only the results from the exposed high elevation *Artemisia tridentata* subsp. *vaseyana*/*Festuca idahoensis* habitat type will be reported. Results from the other three sites are similar to this one, and are being excluded only for brevity.

Results of the separate t-test procedures using the foliar cover data from the *Artemisia tridentata* subsp. *Vaseyana/Festuca idahoensis* showed the following: It was not possible to detect a significant difference ($\alpha = 0.20$) in foliar cover when only 10 percent of the vegetation was excluded (Table 1). However, at the 20 percent "exclusion level," a statistical ($\alpha = 0.20$) difference in foliar cover was noted. After 30 percent of the vegetation was excluded, a statistically valid change ($\alpha = 0.10$) occurred when compared to the control level. Considering the intensity of the foliar cover sampling, this information provides a standard against which the frequency data can be compared; without the foliar cover results, it would be impossible to validate the frequency results. In addition, at all sites, the percent changes in foliar cover from the control levels nearly equalled the percent changes made based on the exclusion level (Table 1).

Frequency

The results of the Chi-square test on species occurrence are shown in Table 2. It is apparent that two factors are interacting to determine if a given plot size can detect a change in any species. One factor is the initial frequency of the species, the other is the magnitude of change in frequency. To further reveal these effects on detecting trend, the lowest level at which a change in species frequency became significant ($\alpha = 0.20$ or 0.10) in any plot size is plotted against the control frequency level (Fig. 1). This graph shows that in order to detect a relatively small change in species occurrence, there had to be a large initial frequency value. With smaller initial frequency values, it was more difficult for the frequency plots to detect small changes in the vegetation. Therefore, to detect as small a change in the vegetation as possible, a plot size must be used that will give optimum frequency values. Curtis and McIntosh (1950) state that for frequency sampling, plot size should be adjusted so that the most prevalent species receives a frequency value of 63 to 86 percent. This study supports that view. Additionally, for trend detection, plot sizes that give higher frequency values than these should be avoided. If a species becomes more prevalent over time to the point where it reaches 100 percent frequency, its usefulness for detecting change is lost, since at this level, there is no way to compare relative differences with previous values. Figure 1 also shows that as an increasing amount of change is created, the frequency plots become more effective at detecting that change; detection of large changes in the vegetation can be accomplished with smaller initial frequencies.

This study noted several other interrelated points. First, as would be expected, plot size was positively correlated with frequency. Thus frequency, in turn (along with the magnitude of change), determined the sensitivity of that plot size to detecting change. The largest plot size tested was generally most sensitive to detecting change in the vegetation, due to the optimum frequency values it provided.

Second, the largest plot size tested usually showed a change in a larger number of species than did the smaller plot sizes. These additional species are important, since they improve the sensitivity of detecting change in species composition.

TABLE 2. Results of the Chi-square analysis on frequency for the *Artemisia tridentata* subsp. *vaseyana*/*Festuca idahoensis* habitat type. The first row for each plot size contains the initial frequency and the three subsequent frequencies resulting from the exclusion process. The second row is the percent change from that original frequency. This list includes only species in which a change was detected.

Species	Initial cover (%)	Plot size	Exclusion Level (%)			
			0	10	20	30
Phlox multiflora	7.8	10x25	62	58	54	47
				6	13*	24**
		15x33.5	82	79	72	66
Festuca idahoensis	7.5			5	12**	20**
		20x50	90	87	83	79
				3	8**	12**
Antennaria microphylla	4.7	10x25	64	60	55	52
				6	14**	19**
		15x33.5	87	82	78	73
Agoseris glauca	3.2			6*	10**	16**
		20x50	95	92	90	86
				3	5**	9**
Poa sandbergii	2.0	10x25	60	56	52	48
				7	13*	20**
		15x33.5	77	72	67	62
Carex xerantica	1.7			6	13**	19**
		20x50	86	82	78	74
				5	9**	14**
Erigeron compositus	1.2	10x25	42	37	35	31
				12	17	26**
		15x33.5	53	50	47	43
Arnica sororia	1.5			6	11	19*
		20x50	62	58	56	51
				6	10	18**
Phlox multiflora	7.8	10x25	36	34	32	30
				6	11	17*
		15x33.5	52	48	45	41
Festuca idahoensis	7.5			8	13	21**
		20x50	68	63	60	56
				7	11*	18**
Antennaria microphylla	4.7	10x25	18	16	15	14
				11	17	22
		15x33.5	28	25	24	21
Agoseris glauca	3.2			11	14	25*
		20x50	38	36	34	31
				5	11	18
Poa sandbergii	2.0	10x25	36	30	28	25
				17	22*	31**
		15x33.5	48	44	41	39
Carex xerantica	1.7			8	15	19*
		20x50	63	58	55	52
				8	13*	17**
Erigeron compositus	1.2	10x25	30	28	27	24
				7	10	20*
		15x33.5	39	36	34	32
Phlox multiflora	7.8			8	13	18*
		20x50	50	47	46	42
				6	8	16*

TABLE 2 continued.

Species	Initial cover (%)	Plot size	Exclusion Level (%)			
			0	10	20	30
Arenaria congesta	1.2	10x25	46	43	39	36
				6	15*	22**
		15x33.5	66	60	56	54
	20x50	77	72	68	67	
			6	12**	13**	
Eriogonum acuminata	1.0	10x25	20	18	16	13
				10	20	35*
		15x33.5	29	26	25	23
	20x50	44	41	38	37	
			7	14	16*	
Phlox longifolia	0.7	10x25	26	23	20	18
				12	23	31**
		15x33.5	34	30	28	26
	20x50	46	42	40	38	
			9	13	17*	
Draba densifolia	0.2	10x25	13	12	11	9
				8	15	31
		15x33.5	22	20	18	14
	20x50	33	9	18	36**	
			32	30	26	
			3	9	21*	

*Significant at alpha = 0.20

**Significant at alpha = 0.10

Third, with only one exception, a change created by excluding 10 percent of the plants along the transect could not be detected by any of the frequency plot sizes. When exclusion levels reached 20 and 30 percent, the resulting changes in frequency could regularly be detected, especially with the larger plot sizes. Examination of Figure 1 can provide estimations, for those sites studied, of the minimum initial frequencies needed to detect a particular change in frequency. For example, at this site (a high elevation *A. tridentata* subsp. *vaseyana*/*F. idahoensis* habitat type), a plot size providing an initial frequency of at least 60 percent would be necessary to detect a subsequent 15 percent change in frequency. This figure also shows that it was difficult for any single frequency plot, of the sizes tested, to consistently detect changes in frequency less than about 10 percent. As the change became greater than 10 percent, frequency plots became quite useful for detecting that change.

Fourth, the species in Table 2 have been listed in descending order of initial (control) foliar cover. This was done to illustrate that foliar cover can be used as a guide for determining which species might be abundant enough to show significant changes when using frequency to detect trend. This is not to imply that there are direct relationships between frequency and cover. It is, however, very difficult to determine before sampling what a species' frequency will be. Simple ocular estimation of foliar cover can provide the land manager with a rough estimate of the various species' abundance and of the frequency plot sizes which might be successfully used on a given site for trend analysis. For example, on all sites, it was difficult to consistently detect trend, using frequency, in any species with an initial foliar cover less than about one or two percent. If management needs were considered for these four particular sites, frequency sampling of species with foliar covers less than about one

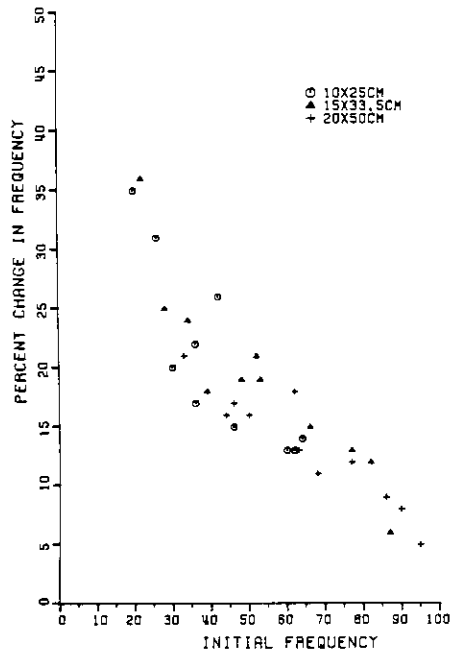


Figure 1. Initial frequency versus the smallest significant ($\alpha = 0.20$ or 0.10) percent change detected at any exclusion level, by plot size, (*Artemisia tridentata* subsp. *vaseyana*/*Festuca idahoensis* habitat type).

or two percent might not provide much additional information. Additionally, this level is a crude approximation and applies only to those sites covered in this study. There are, however, situations where this foliar cover generalization might not hold true. Species with large spreading leaves and small bases would tend to have high foliar cover levels, yet low frequency levels. Since the Chi-square analysis is based on species presence-absence, one would not expect the small frequency levels, in these cases, to be sensitive to change for such species with large foliar and small basal cover.

In summary, the specific results for the

Artemisia tridentata subsp. *vaseyana*/*Festuca idahoensis* habitat type are as follows. Density and dispersion characteristics combined to create high frequency levels. As a result, 12 of the 22 species found at this site reflected a statistical change (Table 2). Initial frequencies of any plot size-species combination showing a significant difference varied from 22 to 95 percent. At this site, either the 15x33.5-cm or 20x50-cm plot would be adequate for detecting small changes in the vegetation. They both detected about the same change (six and five percent, respectively), and they detected differences in the same number of species (11). This similarity is most likely due to the high frequency readings that both plot sizes developed. Although the 10x25-cm plot detected differences in a large number of species (10), the smallest change it could detect was 13 percent, more than twice that of either the 15x33.5-cm or 20x50-cm plots.

Conclusions

At four sites in Idaho, 10x25, 15x33.5, and 20x50-cm frequency plots were sensitive to known changes in the vegetation. Each of these larger frequency plots regularly detected small amounts of vegetation change at $\alpha = 0.20$ and 0.10 .

Initial frequency as well as the magnitude of change in frequency are primarily responsible for determining sensitivity to vegetational change. Those plot sizes giving higher initial frequency readings were more sensitive to detecting subsequent changes in frequency. The number of species in which a significant change was detected was positively related to plot size.

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