COENOSES 5 (1): 45-49, 1990

# RELATIVE INFLUENCE OF OBSERVER ERROR AND PLOT RANDOMIZATION ON DETECTION OF VEGETATION CHANGE

Neil E. West, Department of Range Science, Utah State University, Logan, Utah 84321-5230, U.S.A. and
Thomas J. Hatton, C.S.I.R.O., Div. Water Resources, Canberra A.C.T. 2601, Australia

**Keywords**: Cover, Estimation, Monitoring, Nonmetric Multidimensional scaling, Ordination, Sampling, Vegetation change

**Abstract.** A study was conducted in sagebrush-steppe vegetation, near Kemmerer, Wyoming, U.S.A., to separate the effects of observer error and plot randomization on the estimation of interannual changes in plant species richness, evenness, diversity and total cover. Multiple observers of the same set of quadrats produced significantly different estimates of diversity due to differences in the length and composition of species lists and cover estimates. A single observer's estimates of different sets of quadrats had equivalent diversities and reflected the same community. Changing observers, introduced less variability in floristic richness, in a relative sense, than did plot randomization. However, when species presence was combined with ocular estimates of cover, changing observers introduced more error into the estimation of diversity incorporating evenness and the characterization of the trajectory of change than did spatial randomization of plots. The desirability of using permanent plots and the same competent observer over time to detect vegetation change was reconfirmed as was the need to objectify estimates of abundance.

## Introduction

Vegetation changes over time are especially difficult to reliably detect on sparsely vegetated, but strongly patterned landscapes in arid to semi-arid climates (Friedel and Shaw 1987a, 1987b). In order to separate the contributions to variation due to space from those due to time, use of permanent plots has frequently been proposed (*e.g.*, Austin 1981). Sequential observation of permanent plots (as opposed to randomized plots) has costs, however, in loss of statistical power due to the consideration of autocorrelation (Gurevitch and Chester 1986), and in the restriction to nondestructive sampling techniques in order to allow resampling on the same spot.

A second, less tractable source of variation in vegetation data is observer error (Lamacraft 1978, Sykes et al. 1983). Multivariate approaches which can consider multiple characteristics of many species are increasingly used to summarize observed changes in community composition (Hopkins 1968, Van der Maarel 1969, Austin 1977, Austin et al. 1981, Hacker 1983, 1984, Foran et al., 1986, Hatton and West 1987, Wester and Wright 1987), but a disadvantage of multiple variable and multispecies estimation is that the identification and evaluation of a number of characteristics of all species present increases the opportunity for observer error.

Recent literature on island biogeography suggests that much of what was estimated to be real species turnover may be an artifact arising from sampling errors among observers (Nilsson and Nilsson 1982, 1983, 1985), raising serious doubts about the validity of many studies of compositional turnover. Kirkby et al. (1986) found large differences in the number of species recorded by observers along the same transect in woodland vegetation. Both Nilsson and Nilsson (1985) and Kirkby *et al.* (1986) recommended having the same observer (s) over time when trying to characterize the change in species presence/absence. The presumed increase in precision may, however, be countered by reductions in accuracy if the chosen observer does not consistently obtain a complete list of species really present.

The incorporation of abundance estimates further complicates observer error. Nondestructive estimation of abundance, whether allometric or ocular, involves a non-zero error term which may bias or cloud real differences in vegetation over time. Bannister (1966), however, recommended the use of ocular estimates of plant cover as the basis for ordination and it remains a widely employed method of evaluating plant abundance. Cover is complicated by variations in life forms, surface contrasts, canopy relationships and actual magnitude (Holm et al. 1984, Hatton et al. 1986; Friedel and Shaw 1987a, 1987b). These complications may be expected to increase differences among observers' characterizations of plant communities in addition to the differences among their lists and respective abundances of species present.

This study evaluated the *relative* importance of observer error and plot randomization on the characterization of a stand of sagebrush-steppe vegetation. Given multiple observers of the same plots, do their estimates of species diversity significantly differ? If so, is the varying value due to differences in their estimates of richness and/or evenness. Were observer's plant lists subsets of one another or did they indicate different plant communities? Given the same observer of different sets of random plots, are the diversity estimates for the various sets equivalent? If so, do they represent the same parent population? When expressed as the average of each set of observations, do the values for richness, evenness, diversity and total cover differ between the observers' estimates of the same set of plots and those made by a single observer on a different set of plots? The answers to these questions have implications in the design of any vegetation study intended to monitor change.

## Methods

The study was conducted in a mesic variant of the sagebrush-steppe vegetation type (West 1983) near Kemmerer, Wyoming (41:50 N 110:30 W). Further details on the vegetation and environment of that area can be found in Hatton and Carpenter (1986) and Hatton and West (1987).

Plot centers of twenty, round 1 $m^2$ quadrats were randomly located within a 20 m by 50 m area of apparently homogeneous vegetation and were permanently marked with a metal rod in each plot center.

Percent cover by species, based on a vertical projection within the quadrat boundary (Hatton et al. 1986), was estimated for the permanent quadrats in 1984 and 1985 by the junior author. Sampling was timed to correspond to the onset of senescence among winter annuals and peak vegetative growth of perennials (usually early July).

In addition to the above, in 1985, four other trained observers estimated plant cover by species on these same 20 permanent quadrats. These observers were given simultaneous instruction in the technique, had gained familiarity with local plant taxonomy on adjacent plots, and worked independently for six weeks in the study area prior to obtaining the data used here. A more experienced field taxonomist was present to help in species identification, but only if requested by an observer. Thus, any error arising in identification among observer estimates was unlikely to be due to differences in taxonomic prowess. Differences in lengths of the species list are probably due to time and care spent in searching out smaller species underneath larger ones and inherent powers of observation that may be sharpened by experience. Finally, five sets each of twenty randomly located quadrats were estimated by the junior author in 1985 within the same study area. All estimations in 1985 were made within a one week period in July.

All observers attempted to estimate cover directly to the nearest 1%. Use of cover scales was avoided because of the interactions between cover classes and the precision with which estimates can be made (Hatton et al. 1986). Diversity and compositional similarity among the observers' estimates and among the junior author's estimates was assessed via a technique developed by Pielou (1986). Pielou's method avoids problems arising from the lack of independence among calculated similarity coefficients and reflects the richness as well as the evenness of the vegetation. Pielou recognized that while the data produced by her technique were independent, they were not suitable for nonparametric inference based on tests of rank and therefore we applied an exact test (Pielou 1977) based on a 2×2 contingency table. Our inferential procedure was based on the randomization t-test (Romesburg 1985), which requires only independence among samples. This nonparametric procedure may be expected to be more powerful than the contingency test alternative since it requires no arbitrary division of the data into classes.

From among the set of observers of the same set of quadrats, two mutually independent pairs were randomly chosen to test the null hypothesis that their diversity estimates were equivalent. Given that they were not, the hypothesis that the less diverse of the pair was a subset of the more diverse set of estimations was tested, and randomization paired t-tests were employed to determine if the differences in diversity were due to differences in the estimates of richness and/or evenness. Evenness was expressed as the quotient of the inverse of Simpson's (1949) index of concentration over the number of species.

Pielou's method, as modified above, was also used to test the effect of randomizing sets of quadrats to test the null hypothesis that the diversity estimates by the same observer for 2 mutually independent pairs of random sets of 20 quadrats were equivalent. Given that they were, the hypothesis that the estimates for these pairs were sampled from the same community was tested via the randomized t-test.

Because inferences regarding vegetation change are often made on the basis of all variables observed in the entire sample and not individual observations, the data for each observer and each set of quadrats were com-

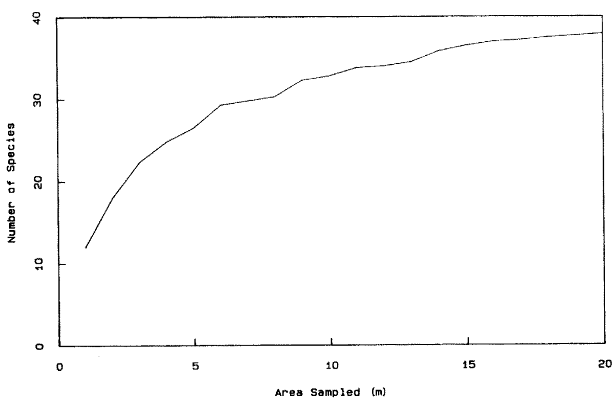

**Fig. 1. Species-area curve for sagebrush-steppe vegetation in study area.**

bined into a single record, representing a cumulative sampling area of 20 $m^2$ by each observer. A species-area curve, developed by the iterative method (Hatton and Carpenter 1986), based on information from all of the sets of quadrats, was constructed to demonstrate that the sample size was adequate to characterize the richness of the vegetation (Figure 1). The iterative method has been found (Hatton and Carpenter, 1986) to be more reliable than traditional, graphical presentations of such data because misidentifications of rarer species do not cause exaggeration of nominal diversity.

Given the average values for the estimates of each of the observers of the same set of quadrats and for each of the random sets of quadrats estimated by the junior author, the null hypotheses that the estimates of species richness, evenness, diversity and total cover were the same between the set of different observers and the set of different plots were tested by means of randomization t-test.

The averaged estimates for four observers (01-04) of the same plots in 1985, for one observer's averaged estimates for 5 random sets of plots (R1-R5) in 1985, and for one observer's averaged estimates of the permanent plots over two years (84, 85) were combined into a data matrix of 11 samples by 70 "species". (Some of these "species" were due to different names applied to the same plant by different, less-experienced observers. The "real" number of taxa, as judged by the most experienced observer, was a maximum of about 47 but a mean near 40.).

These samples were ordinated by nonmetric multidimensional scaling (Faith et al. 1987) employing the Bray-Curtis (1957) dissimilarity metric for presence/absence analysis and the Kulczynski (1928) dissimilarity metric for cover-weighted estimates. Ordinations along the first two ordinal axes were used to demonstrate the relative similarity among observers and among different sets of quadrats as compared with that between the same set of quadrats estimated by the same observer over two years.

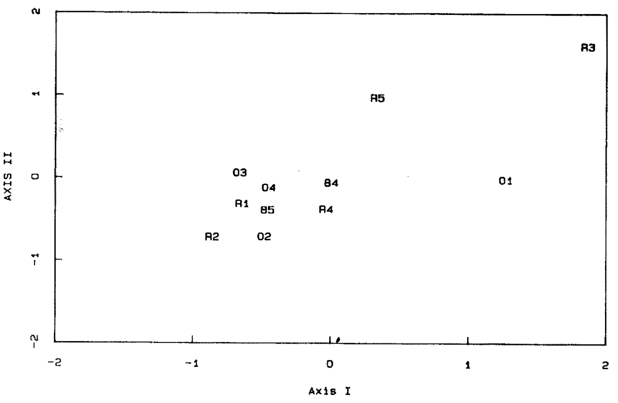

**Fig. 2. Nonmetric multidimensional scaling ordination of four observers' estimates in 1985 of species presence/absence in the same set of quadrats (01-04), five sets of estimates in 1985 by the same observer of different sets of quadrats (R1-R5), and the estimates by a single observer of the same set of quadrats over two years (84, 85).**

## Results

Both of the pairs of observers' estimates of diversity of the same set of quadrats differed significantly ($p < 0.01$), and in both cases the shorter list was a subset of the longer list compiled by the other observer ($p = 0.12$ and 0.16, respectively). The differences in diversity within these contrasted pairs were due to differences in both the richness ($p < 0.01$) and evenness ($p < 0.01$) of the species.

Both pairs of different set of quadrats estimated by the same observer had similar diversities ($p = 0.94$ and 0.58, respectively), and were sampled from the same plant community ($p = 0.58$ and 0.93, respectively).

When estimates for each observer or set of plots were combined (Table 1), the estimates of richness by observers of the same set were not significantly different from the richness estimates of different sets by the same observer ($p = 0.52$), but the estimated of evenness, diversity and total cover differed significantly ($p = 0.04$, 0.03 and 0.05, respectively).

**Table 1. Estimated values for cumulative species richness, (20 $m^2$) and evenness, diversity and mean total cover (%) for the same set of twenty (1 $m^2$) quadrats observed by the junior author (JA) and four other observers (01-04) and for five independent sets of twenty quadrats estimated by the junior author (R1-R5).**

| | JA | 01 | 02 | 03 | 04 | R1 | R2 | R3 | R4 | R5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Species richness | 35 | 29 | 27 | 28 | 25 | 34 | 27 | 34 | 26 | 31 |
| Species evenness | 0.22 | 0.30 | 0.26 | 0.25 | 0.25 | 0.18 | 0.25 | 0.20 | 0.23 | 0.19 |
| Species diversity | 7.71 | 8.56 | 7.14 | 6.96 | 6.34 | 6.15 | 6.88 | 6.64 | 6.00 | 5.82 |
| Total cover | 55.0 | 54.9 | 82.0 | 72.8 | 37.3 | 43.8 | 49.5 | 40.8 | 45.1 | 37.8 |

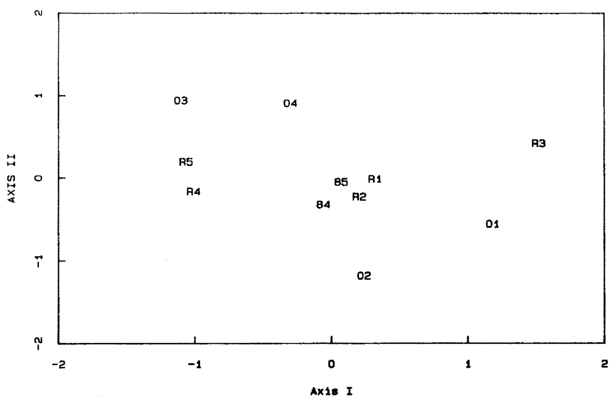

**Fig. 3. Nonmetric multidimensional scaling ordination of four observers' estimates in 1985 of cover by species in the same set of quadrats (01-04), five sets of estimates in 1985 by the same observer of different sets of quadrats (R1-R5), and the estimates by a single observer of the same set of quadrats over two years (84, 85).**

Presence/absence and cover-weighted ordinations had relatively low stresses in two dimensions (0.16 and 0.17, respectively). Kruskal (1964) considers stress a measure of goodness of fit. The presence/absence ordination shows that either changing observers or sets of quadrats sampled can overwhelm the change in vegetation detected by the same observer of the same set of quadrats (Figure 2). This effect is even more dramatic when cover-weighted values are included in the ordination (Figure 3).

## Discussion

Multiple observers, trained and sampling species presence and cover on an identical set of quadrats, simultaneously produced significantly different estimates of species diversity, richness and evenness. That some observers' estimates were subsets of others' rather than recording some different species indicates that error not only arose from differences in cover estimates (as reflected in evenness), but also arose from differences in their ability to detect the full set of species present in a given quadrat. Having one observer estimate different sets of quadrats randomly located in the same area produced no significant differences in the estimates of diversity, nor did it indicate that the samples were drawn from different populations. Evidence from the ordinations, however, suggests that re-randomizing plots each time data are taken does introduce noise into the system. In this case, the noise arising from plot randomization exceeded the difference in the same observer's estimates of the permanent quadrats over two years.

The contrasts between the averaged estimates for observers of the same set of quadrats and the averaged estimates for different sets of quadrats by the same observer indicate that given enough opportunities at detecting the presence of a species, observers will eventually produce similar species lists. The differences arising from the personal biases in ocular estimation of cover, however, persist and obscure real differences in composition and introduce artificial ones.

This study supports the observations by Lamacraft (1978), Nilsson and Nilsson (1985), Kirkby et al. (1986) and Friedel and Shaw (1987a, 1987b) that changing observers can lead to serious errors in vegetation data. In a *relative* sense, however, it would appear that in the case of this study, changing observers introduced comparatively less variability into the estimates of change in floristic richness than did plot randomization. However, when species presences were combined with ocular estimates of cover, changing observers introduced comparatively more relative error into the estimation of diversity and the characterization of trajectory than did randomizing the plots. Less subjective abundance determinations, as in Carpenter and West (1987), may reduce the noise associated with changing observers and allow a correction for biases. Given the ideal of permanent quadrats in the study of vegetation change and the concomitant requirement for nondestructive sampling, it is clearly desirable to either retain the same observer over time (if he or she consistently produces a full species list and reasonably accurate estimates of the variable (s) of interest in a time efficient fashion) or to somehow objectify the detection of species and the estimation of their abundances.

**Acknowledgements.** This study was supported by Grant DEB 81-01827 from the National Science Foundation. Authors wish to thank Dr. David Roberts for assistance in the analytical design.

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*Manuscript received: January 1989*