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STATISTICAL ANALYSIS OF INTRASEASONAL HERBAGE DYNAMICS IN A VARIETY OF GRASSLAND COMMUNITIES

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ABSTRACT

Intrasite comparisons of aboveground plant biomass were made using data from the 1970 field season. Ordinations were made using analysis of variance and principal component analysis in an attempt to reveal the structural components of the herbage biomass across the grasslands. The nine sites analyzed were Bison, Bridger, Dickinson, Cottonwood, Hays, Jornada, Pantex, Pawnee, and Osage.

ABOVEGROUND BIOMASS ANALYSES

This report presents a series of statistical analyses performed on the 1970 field season aboveground biomass data from nine field sites in the U.S. IBP Grassland Biome. Two types of analyses were performed and interpreted: analysis of variance and principal component analysis. It is hoped that the results of these analyses will give some insight into the structure of the herbage biomass across the grasslands.

The following table gives a listing of the sites for which analyses were performed, along with some vital information.

Site	No. Sampling Dates	Treatment[1/] Codes	No. Replicates Per Treatment
Bison	9	1, 5	2
Bridger	6	1, 3	2
Cottonwood	12	1, 5	2
Dickinson	7	1, 4	2
Hays	9	1, 5	2
Jornada	5	1, 5	2
Osage	11	1, 5	2
Pantex	9	1, 3, 5	2
Pawnee	11	1, 2, 3, 4	2

[1/] Treatment code 1 = ungrazed; 2 = lightly grazed; 3 = moderately grazed; 4 = heavily grazed; 5 = grazed 1969, ungrazed 1970.

ANALYSIS OF VARIANCE

A series of five analyses of variance were performed on the aboveground biomass data from each site. For a given site the five variables analyzed were:

i. Total biomass

ii. Total live

iii. Total dead

iv. Recent dead

v. Old dead

For each of the five variables analyzed, the following linear model was used:

$$Y_{ijklm} = \mu + \alpha_i + \beta_j + \gamma_k + \delta_{l(j)} + \alpha\beta_{ij} + \beta\gamma_{jk} + \alpha\delta_{il(j)} + \gamma\delta_{kl(j)} + \varepsilon_{ijklm}$$

where

μ = overall mean response

α_i = deviation due to plant category i

β_j = deviation due to treatment j

γ_k = deviation due to date k

$\delta_{l(j)}$ = deviation due to replicate l within treatment j

$\alpha\beta_{ij}$ = deviation due to interaction between plant category i and treatment j

$\beta\gamma_{jk}$ = deviation due to interaction between treatment j and date k

$\alpha\delta_{il(j)}$ = deviation due to interaction between plant category i and replicate l within treatment j

$\gamma\delta_{kl(j)}$ = deviation due to interaction between date k and replicate l within treatment j

Due to program limitations, however, the following components were eliminated from the model for the given sites:

Dickinson	$\gamma\delta_{kl(j)}$
Pantex	$\gamma\delta_{kl(j)}$
Pawnee	$\gamma\delta_{kl(j)}$ and $\alpha\delta_{il(j)}$

In addition, analysis of variance could not be performed across sites due to the fact that there would be too many nested factors to get any meaningful results (i.e., both treatments and dates would have to be nested within sites, and replicates would have to be nested within treatments within sites).

Table 1 gives a summary of all of the ANOVA's performed.

The following table gives the nine plant categories used as levels of the first factor in all of the ANOVA's.

i	Plant Category
1	Cool season grass
2	Warm season grass
3	Cool season shrub
4	Warm season shrub
5	Cool season forb
6	Warm season forb
7	Warm season succulent
8	Cool season succulent
9	Other

Before the analyses of variance are discussed, a few comments should be made about the structure of the data input.

At the onset of the analyses it was assumed that each site would be categorized by the nine given plant categories. An absence of all species in any of the chosen categories simply meant that the biomass of that category was zero. This assumption overrode the fact that the plant species comprising that category were nonexistent on the particular site. The result was a true representation of anywhere from three to nine of the plant categories, per site, with the data of the remaining categories being zero-filled. Table 2 lists the plant categories prevalent on each of the sites.

A second consideration is the separation of the total biomass into the other four categories--total live, total dead, recent dead, and old dead. The separations are not consistent across sites. For example, for the Pawnee data the aboveground live and the aboveground dead were not separated from the total; consequently, the recent dead and the old dead were not distinguished. Some of the other sites which did separate the aboveground live and dead from the total biomass did not consistently separate the recent and old dead, across time. That is, this separation may not have occurred until the latter part of the sampling year. For this reason, discussion of the analyses of variance will focus on the total, live, and dead biomasses. The results of the recent dead and old dead analyses are presented, however, for what information they may offer.

Although discussion of the results of the analyses of variance will be by sites, it is interesting to note some main effect trends across the sites, as illustrated by Table 1:

(*i*) Each of the nine sites demonstrates highly significant differences between the plant categories for total, live, and dead biomasses, except for the Jornada-Dead analysis.

(*ii*) Each of the nine sites demonstrates significant differences between treatments for the total biomass, except for the Pawnee Site. For the most part, the significant difference between treatments still exists when the total biomass is separated into live and dead.

(*iii*) Each of the nine sites demonstrates significant difference between sampling dates for total, live, and dead biomasses except for the Bridger-Total and Jornada-Dead analyses.

(*iv*) Most of the nine sites do not show any replicates within treatment differences.

Each individual site analysis discussion will include the results of the Tukey's Q test (Snedecor and Cochran 1967), a multiple range test which detects where significant differences lie, should they exist. This test is performed for the date main effect for each site and for the treatment × date interaction when significant for the total biomass. Tukey's Q is calculated by:

$$Q = q(a,df)\sqrt{\frac{EMS}{n_o}}$$

where:

a = number of means being compared

df = degrees of freedom in the error team

$q(a,df)$ = a tabular value, Snedecor and Cochran (p. 568) $\alpha = .05$

EMS = Error Mean Square used in testing the main effect or interaction

n_o = a pooled estimate of the sample size making up each mean being compared, where

$$n_o = \frac{a}{\frac{1}{n_1} + \frac{1}{n_2} + \ . \ . \ . \ + \frac{1}{n_a}}$$

The results of the Q test are presented graphically in Fig. 1 to 13. On a given graph, two means are significantly different from each other if the two lines through the means do not overlap.

The Q-test graphs are also useful in illustrating trends within the main effect or interaction. That is, in the following graphs, the means across time will be shown. The means used in the graphs are least squares estimates, adjusted for the unbalanced design. The adjusted means are not much different from the actual means.

The dates are coded in Fig. 1 to 13. See Table 3 for the coding scheme.

Table 4 shows the calculated Q values.

Bison

The analysis of variance on the aboveground biomass at the Bison Site indicates highly significant category, treatment, and date differences for each of the three responses. In addition, for each of the three responses, there are highly significant category × treatment, treatment × date, and category × replicate within treatment differences. The replicate effect, however, shows an interesting effect in that the replicates within treatment 2 (lightly grazed 1969, ungrazed 1970) are significantly different for both total and dead. These differences may be due to varying aspects and/or slopes between the two plots of this treatment.

The results of the Q tests are presented in Fig. 1 and 2.

Fig. 1 illustrates the date trends and differences. There tends to be a general parabolic trend across time (from early May through late September) except for the decrease in the total biomass at the end of May. The most abundant biomass, for both total and live, occurs in early July and the least abundant in early May, at the beginning of the sampling. Significant differences between dates occur throughout the sampling year for these two responses. The most outstanding differences, for the total aboveground biomass, are that the dates from middle June through early August are significantly different from all of the other dates. For the live aboveground biomass, the dates between late May and early August are significantly different from each other.

The means across time for the dead biomass show no specific trend. The most unusual observation is the sudden decrease in dead biomass late in May. This late May reading tends to be significantly different from each of the other dates, except for early May.

Fig. 2a to 2c show the Bison treatment × date interaction for the total, live, and dead biomasses, respectively. The first figures of each graph are drawn with respect to treatments and the second figures with respect to dates.

Fig. 2a, the treatment × date interaction for total biomass, maintains the parabolic trends across time. The first treatment, no grazing, however, generally indicates greater biomass than the second treatment, light grazing. The second chart of Fig. 2a reinforces this view in that on only one sampling date (early May) does the lightly grazed pasture report a greater total biomass than the ungrazed pasture. The most noticeable significant differences center around the middle June through early August periods for the ungrazed pastures in that these four periods tend to be significantly different from each of the lightly grazed periods and several of the other ungrazed periods.

Fig. 2b, the treatment × date interaction for the live biomass, maintains the same basic trends as those of the total biomass. That is,

i. the general parabolic trends across time,

ii. the general increase in biomass for the ungrazed over the lightly grazed pastures except for the early May sampling date,

iii. the tendency for the ungrazed periods from middle June through early August to be significantly different from each of the lightly grazed periods and several of the remaining ungrazed periods.

Fig. 2c, the treatment × date interaction for the dead biomass at the Bison Site, illustrates a scattering of effects across time. When viewed with respect to treatments (upper graph) there seems to be an overall increase in dead biomass across time for the ungrazed treatment, while there is a rather constant dead biomass across time for the lightly grazed treatment. For the most part, the ungrazed pastures again have a greater biomass than the lightly grazed pastures.

Bridger

The analysis of variance on the total aboveground biomass at the Bridger Site shows significant differences between the category and treatment effects, but no differences between sampling dates or replicates within treatments. As previously noted, the nonsignificant date effect is inconsistent with the other sites. This nonsignificance is due to the error term used to test the date effect. For the Bridger Site there is a highly significant date × replicate within treatment interaction. If this interaction is significant in the ANOVA, it is used to test the variability of the date effect; if it is nonsignificant ($\alpha = .25$) it is pooled into the residual and this pooled error is used to test the date effect. Since the magnitude of the date × replicates within treatment interaction is more than four times that of the residual, the calculated F value of the date effect is more than four times smaller than it would be should it be tested over the residual, in which case it (date) would be significant. Thus, the date × replicates within the treatment is of such variability that it causes the date effect to be nonsignificant.

For the total aboveground biomass at the Bridger Site, the category × treatment interaction is also highly significant. This might change if only the categories with biomass greater than zero were used in the analysis. The two remaining interactions, treatment × date and category × replicates within treatment, are nonsignificant.

The live biomass analysis at Bridger differs from the total biomass analysis in the significance of the date effect. The dead biomass analysis differs by the significances of the date, treatment × date, and date × replicates within treatment effects.

Fig. 3 illustrates the results of Tukey's Q test. Again, for the total biomass, there are no differences between dates. The date trend is parabolic, with the peak being in late July and the least amount in late June.

The live biomass graph of Fig. 3 does not reveal any significant differences even though the analysis of variance does. Because the design is not completely balanced and because there are a total of 10 comparisons being made $({}_2C_5)$[1/] the true α-level is distorted. Thus, no exact probability

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[1/] ${}_2C_5$ = number of combinations of five things taken two at a time = $\binom{5}{2}$ =

$$\frac{5!}{2!\,(5-2)!} = 10.$$

statements can be made, and the test becomes rather conservative. The trend, however, is still increasing with the greatest live biomass occurring in late July and the least amount in late June.

The dead biomass at the Bridger Site follows a decreasing parabolic trend with the first and last sampling dates (late June and late August) each being significantly different from the other four dates. The greatest amount of dead biomass occurs in late June, and the least amount in middle August.

Cottonwood

The analysis of variance on the total aboveground biomass at the Cottonwood Site indicates highly significant category, treatment, and date effects as well as highly significant category × treatment, treatment × date, and category × replicates within treatment interactions. The remaining effects, replicates within treatment and date × replicates within treatment, are nonsignificant.

Similar significant trends are viewed for the live and dead biomasses except for: (*i*) the level of significance of the category × replicates within treatment interaction (α = .01, α = .10 for total and live, respectively) for the live aboveground biomass, and (*ii*) the significance, at α = .10, of the replicates within treatment effect for the no grazing treatment on the dead biomass.

Fig. 4 and 5 illustrate the date and treatment × date interaction for the total, live and dead biomasses at the Cottonwood Site.

Fig. 4 graphs a sampling span from early May through early December, thus extending farther into the winter months than most of the other sites.

The parabolic trend across time for total biomass is somewhat distorted by the three periods from early August through early September in that there is a significant decrease in biomass from the late July to the early August period followed by a gradual increase through early September. The late September sampling then shows a significant decrease in the total biomass collected. Significant differences in sampling dates tend to be caused by the fact that the very early and very late sampling dates (early May and early October, November, and December) tend to be significantly different from the middle sampling dates (middle June through early September, except for the early August collections).

The parabolic trend across time for the live biomass at the Cottonwood Site is interrupted only by the relatively low biomass during the early July and early August collections. Similar to the total biomass, the very early and very late sampling dates tend to be significantly different from each other. (In this case, the two May collections and the November and December collections are significantly different from each of the remaining dates.)

The dead biomass also displays a cyclic effect, although not as pronounced. As might be expected, the amount of dead biomass is relatively low at the beginning of the summer and relatively high through the winter and early spring months. Significant differences between dates tend to center around the break from spring to summer.

Fig. 5a, 5b, and 5c graph the treatment × date interaction for the total, live, and dead biomasses, respectively. The two graphs of each figure again show the interaction with respect to treatment and with respect to date.

The same trends are evident for the total and live aboveground biomasses of Fig. 5a and 5b. That is, the ungrazed treatment collections produced greater biomass, for each sampling date, than did the grazed 1969-ungrazed 1970 treatment. Further, for both total and live biomasses, the parabolic trend across time is more evident for the grazed-ungrazed treatment than for the strictly ungrazed treatment. These trends, for the ungrazed treatment, in fact, more nearly resemble a random scattering of points across time for the total biomass and a sharp linear decline across time (save for the May samplings) for the live biomass.

The random scattering across time is also pronounced for the treatment × date interaction for the dead biomass. For the most part (save for the early July and late August samplings) there is greater dead biomass for the ungrazed than for the grazed-ungrazed treatment. Significant differences exist between treatment-date throughout the year. The ungrazed treatments for late May and early November, however, tend to be significantly different from most of the other treatment-date combinations.

Dickinson

The analysis of variance on the aboveground biomass at the Dickinson Site shows different results for each of the three responses--total, live, and dead biomasses.

The analysis of variance on the total biomass gives significant category, treatment, date, and category × treatment effects. Further, the replicates within the ungrazed treatment show significant differences, possibly due to physical characteristics of the watersheds.

Significant differences for the live biomass exist between categories and dates and all first order interactions included in the model. Thus, the only similarities between this analysis and the previous one for the total biomass are the high significances of the category, date, and category × treatment effects.

The third analysis of variance (dead biomass) on the Dickinson Site indicates highly significant differences between categories, treatments, and dates as well as significant category × treatment and treatment × date interactions. The replicate effects were all nonsignificant, contrary to the two previous analyses.

The results of the Q tests are presented in Fig. 6. Although the treatment × date interaction is significant for both the live and dead biomasses, individual comparisons of the interaction means are not made because of the nonsignificance of this interaction for the total biomass.

Sampling at the Dickinson Site extended from late May through middle October. The total biomass graph of Fig. 6 shows tendencies at the parabolic trend across time. The most noticeable outlier is the middle September collection. This September collection tends to be significantly higher than all other collections, except for late July.

Measurements of live biomass show irregular fluctuations across time. Increases very early in the summer months are interrupted by gradual decreases through the middle summer months. The month of August starts another gradual increase, with the amount of live biomass again dropping off in mid-October. The September readings are again significantly different from many of the other dates.

Patterns for the dead biomass at the Dickinson Site are also irregular across time. No significant differences are detected by the Q test, possibly due to adjusted α-levels introduced by unequal sample sizes.

Hays

The analysis of variance on the total aboveground biomass at the Hays Site indicates significant differences between categories, treatments, and dates while there are no differences between replicates within treatments. Further, the treatments interact significantly with both categories and dates whereas the replicates within treatments do not interact with these other two main effects. These significances are similar to the dead biomass significances except for the α levels of the treatment (total: $\alpha = .10$, dead: $\alpha = .01$) and treatment × date (total: $\alpha = .01$, dead: $\alpha = .05$) effects. For the total aboveground biomass, significant differences differ from those of the live biomass in that the treatment effect and the category × treatment and treatment × date interactions are nonsignificant for the latter.

The results of the Q tests are presented in Fig. 7 and 8.

Fig. 7 illustrates the trends and differences across time. The sampling started in middle January and ended in middle November, thus producing the unusual pattern of total aboveground biomass. The total biomass (mostly dead) increases from middle January to middle February and then decreases to middle May where it once again starts to increase (now mostly live). The total biomass in middle May is significantly smaller than all other dates, except for the March, April, and November samplings.

The live biomass is quite small in middle January, increasing until middle July when it again starts to decrease. Further, the months from January through May are all significantly different from the months June through August.

The dead biomass reverses the trend from the live biomass. The dead biomass is relatively high in January, increasing to middle February and then decreasing until middle May. From May through August there is little fluctuation in the amount of dead biomass present at Hays. Increases in dead biomass begin to show in September. These sampling dates from May through August are significantly different from each of the remaining sampling dates, save for late September.

Fig. 8a and 8b illustrate the treatment × date interactions for the Hays Site. Again, the first figures of each graph are drawn with respect to treatments and the second figures with respect to dates. The graphs for the live biomass treatment × date interaction are omitted because of non-significance. The treatment × date graph of Fig. 8a (total biomass) hints at the same dual parabolic trend across time as shown in Fig. 7. There is, however, quite a difference in the effects between the two treatments (ungrazed and grazed 1969-ungrazed 1970). There is more total biomass in the early part of the year on the ungrazed soil than on the grazed-ungrazed soil, quite obviously due to the effects of grazing in 1969, which resulted in the reduction of standing dead for 1970. These early year differences are sometimes significant (i.e., middle February ungrazed is significantly different from middle May ungrazed and middle January through middle June grazed-ungrazed).

The date × treatment illustration of Fig. 8a shows that, except for the middle May, early July, and middle October collections, the ungrazed soil consistently produced more total aboveground biomass than the grazed-ungrazed soil. On a given date, however, the middle February collections are the only ones which are significantly different between the two grazing treatments.

Fig. 8b, the treatment × date graph for the dead biomass, suggests that the significant differences lie between the January-March collections on the ungrazed soil and the May-August collections on both soils. Both grazing treatments show little fluctuation in the amount of dead biomass present from this May through August period.

The date × treatment illustration shows a similar separation between treatments in middle February for the dead biomass as for the total biomass. Increases in biomass from the ungrazed to the grazed-ungrazed soil this time occurs during middle July.

Jornada

The analysis of variance on the aboveground biomass at the Jornada Site shows similar trends for the total and live biomasses. That is, there are significant differences between categories, treatments, and dates, with a highly significant category × treatment interaction. The remaining effects and interactions are nonsignificant.

The analysis of variance on the dead biomass appears quite different from all of the other analyses in that each of the four main effects are nonsignificant. The explanation is similar to that used in interpreting the nonsignificance of the date effect at the Bridger Site. The variabilities of the category × replicates within treatment and date × replicates within treatment interactions are great enough to prevent pooling into the error term. These interactions become the error terms for the category and date main effects, respectively. The interaction variability overrides the main effect variability and, thus, the nonsignificance. Similar to the Bridger-date effect, the Jornada category and date effects would be highly significant if they were tested over the residual.

The results of Tukey's Q test on dates are shown in Fig. 9. The total and live biomass illustrations look very much alike in their trends in the gradual increase in biomass from middle July through early September. The significant differences between dates are not clearly shown for total biomass and are barely detected for live biomass. This is again due to the α level. The analysis of variance detects a difference only at the $\alpha = .10$ level, whereas all of the Q tests were made at the $\alpha = .05$ level. As with the live biomass, one would suspect the differences of the total biomass to be between the first and last sampling dates.

The dead biomass illustration shows a gradual decrease in biomass from early July through middle August and a gradual increase from middle August through early September. Similar to the analysis of variance, no differences between dates are detected.

Osage

The analysis of variance on the total aboveground biomass at the Osage Site shows three of the four main effects (category, treatment, and date) and two of the interactions (category × treatment and category × replicates within treatment) to be highly significant. It is interesting to note here that the category effect is still highly significant, in spite of the high variability of category × replicates within treatment. The analyses on the live and dead biomasses are similar to this analysis on total biomass except for the nonsignificance of the treatment effect for the live biomass. The levels of significance do vary slightly between the three analyses.

Fig. 10 illustrates the results of the Q test on dates. There is a gradual increase in total biomass except for a few fluctuations in early August and late September. Further, the collections from late March to early May tend to be significantly different from the collections from early July through the end of the sampling.

The live biomass date graph indicates a parabolic effect with the peak being in middle July and low point late in March. The first two and last one sampling periods tend to be significantly different in amount of live biomass.

Dead biomass trends seem to be slightly higher from late March through early June than they are from middle June through September. These differences between the early and middle parts of the year, however, are nonsignificant. The increase in dead biomass in October and November does tend to be significantly different from the preceding months.

Pantex

The three analyses of variance for the total, live, and dead biomasses at the Pantex Site are quite similar. With the exception of the treatment effect for the dead biomass, the category, treatment, and date main effects show significant differences (at varying levels of significance). For the three responses, there is consistently a category × treatment significance with the two remaining interactions being nonsignificant.

Because there are more than two treatments, Tukey's Q test is also considered on the treatments for this site (Fig. 11). The three treatments are ungrazed, moderately grazed, and grazed 1969-ungrazed 1970. The Q test indicates a significant difference between the grazed-ungrazed treatment and the other two treatments for both total and live biomasses. For these two variables the ungrazed and moderately grazed treatments are not significantly different from each other. For the dead biomass there are no significant differences between any of the grazing treatments, as indicated by the analysis of variance. Simultaneously, the three graphs of Fig. 11 show that the most total and live biomasses occur on the grazed-ungrazed soil, whereas the most dead biomass occurs on the ungrazed soil.

Fig. 12 shows the results of the Q test for dates on the Pantex Site. The most noticeable trend is the slight decrease in total biomass from middle June-middle August to late August-early October and then the slight increase late in October. The fact that the graph does not indicate any significant differences while the analysis of variance does, can again be attributed to a change in the α level (.05 for the graph and .10 for the analysis of variance). The graph for the live biomass exhibits the same decrease-increase trends in biomass as does the graph for the total biomass. A total of 36 comparisons ($_2C_9$) probably distorts the α level enough to not distinctly display any differences. (Middle July and early October are almost significantly different.)

The graph for the dead biomass at the Pantex Site displays an unusual trend in the significant increase in biomass from middle June to late June, the significant decrease in middle July, and then another significant increase in late July. The sampling of late July and the dates that follow do not show significant differences from one another.

Pawnee

The analysis of variance of total aboveground biomass at the Pawnee Site indicates significant differences between the categories and between the dates with no difference between treatments. It is interesting to note that Pawnee is the only site that has no significant differences between treatments. A further significance peculiar to the Pawnee Site is the replicate within the heavy grazing treatment. Physical conditions about the watersheds within this treatment may explain the significant difference. The slopes, steepnesses, and positions on the slopes of these watersheds (1 and 3) vary somewhat, as follows:

Watershed	Slope	Steepness	Position
1	Faces NE	More steep	Lower on slope
3	Faces S	Less steep	Higher on slope

Of the two interactions tested, the category × treatment effect is highly significant while the treatment by date effect is nonsignificant enough to pool it into the error term.

Fig. 13 shows the results of Tukey's Q test on dates for the Pawnee Site. Generally, the means follow a parabolic trend with the greatest biomass occurring in middle June and the least occurring in middle April. These two sampling periods tend to be the only ones significantly different from each other.

Conclusions

The analyses of variance presented offer only a limited amount of analysis information on the structure of the aboveground biomass at each of the nine sites in the U.S. IBP Grassland Biome. The information is limited in two respects.

First, program limitations prevent a complete view of the analysis of variance. There are four factors (category, treatment, date, and replicate) considered in the model, so the complete analysis should be extended to include up to the third-order interactions. The present analyses are limited to first-order interactions. The result is that the remaining interactions are all included in the error term. As a result, the error term presented may not be a valid representation of the true error. If significant second- and third-order interactions are in fact a part of the residual, then the error mean square will be greater than it truly should be. The result is that if the analysis, as is, detects a significant difference, then you can be sure that the difference exists. However, if the analysis does not detect a difference, there is that chance that a difference still does exist and was masked by the inflated error term.

The second limitation involves the interpretative power of these analyses of variance: analyses of variance and Tukey's Q tests simultaneously detect "treatment" differences and indicate the location of these differences. The nature of the experimental study, a growing season dependent on external factors--climate, moisture, soil, vegetation, etc., might a priori suggest category, treatment, or date differences. For the most part, the preceding tests only confirm these suspicions. The question still remains as to the structure of the ecosystems and explanations of the variability within these systems. The principal component technique of analysis attempts these explanations.

PRINCIPAL COMPONENT ANALYSIS

Since the analyses of variance had relatively little information content in terms of revealing possible sources of intraseasonal variation which serve to distinguish the various plant communities being studied, both within and between sites, it was decided to attempt a series of principal component analyses on the aboveground biomass data collected in 1970 at each of the study sites. For a given site it was of interest to determine if the selected components revealed the plant-structural dynamics which served to separate either treatments or replicate sampling plots within treatments.

Suppose that one has a series of n simultaneous measurements on p variates $(X_1, \ldots, X_p)$, all taken in the same units. Let Σ refer to the variance-covariance matrix generated. Then p, principal components of the form

$$Z_j = a_{1j}x_1 + a_{2j}x_2 + \ldots + a_{pj}x_j; \; j = 1, \ldots, p,$$

can be generated. The first principal component of the observations is that linear combination of the X's

$$Z_1 = a_{11}X_1 + a_{21}X_2 + \ldots + a_{p1}X_p$$

whose sample variance, $S^2_{z_1}$, is maximized over the choice of $\{a_{11}, \ldots, a_{p1}\}$, subject to the constraint $\sum_{i=1}^{p} a_{ij}{}^2 = 1$. In addition, $S^2_{z_1}$ is the greatest eigenvalue (characteristic root) of Σ, and the vector of multipliers

$$\underline{a_1} = \begin{pmatrix} a_{11} \\ \cdot \\ \cdot \\ \cdot \\ a_{p1} \end{pmatrix}$$

is the normalized eigenvector associated with the above-mentioned eigenvalue.

The second principal component is that linear combination of the X's

$$Z_2 = a_{12}X_1 + a_{22}X_2 + \cdot \cdot \cdot + a_{p2}X_2$$

whose sample variance, $S^2_{Z_2}$, is maximized over the choice of $\{a_{12}, \cdot \cdot \cdot, a_{p2}\}$, subject to the constraint that Cov $(Z_1, Z_2) = 0$ (i.e., the components are independent). Likewise, $S^2_{Z_2}$ is the second largest eigenvalue of Σ, and the vector of multipliers

$$\underline{a_2} = \begin{pmatrix} a_{12} \\ \cdot \\ \cdot \\ \cdot \\ a_{p2} \end{pmatrix}$$

is the eigenvector associated with that eigenvalue.

In general the k^th principal component is that linear combination of the X's

$$Z_k = a_{1k}X_1 + a_{2k}X_2 + \cdot \cdot \cdot + a_{pk}X_p$$

with the following properties:

(*i*) $S^2_{z_k} = \lambda_k = k^{th}$ largest eigenvalue of Σ

(*ii*) $\underline{a_k} = \begin{pmatrix} a_{1k} \\ \cdot \\ \cdot \\ \cdot \\ a_{pk} \end{pmatrix}$ = eigenvector associated with λ_k

(*iii*) $\underline{a}_k^T \underline{a}_k = 1$

(*iv*) Cov $(Z_j, Z_k) = 0;\ j(\neq k) = 1, \ldots, p.$

A complete description of principal component analyses can be found in Morrison (1967).

Thus, the first principal component is that linear combination of the original variables $(X_1, \ldots, X_p)$ with maximum variance. The second principal component is that linear combination of the original variables, independent of the first component, with maximum variance. The k^{th} principal component is that linear combination of the original variables, independent of the first k-1 components, with maximum variance. Thus, a set of principal components breaks the total variance-covariance structure of the system being studied into independent segments, the most important (i.e., maximum variance) of which hopefully lead to interpretation as to the structural dynamics of the original system. Principal components become especially useful when the first two or three components account for upwards of 80% of the total variability-covariability in the original system. In many cases, biological meaning can be assigned to the significant components in terms of the relative magnitudes and signs of the multipliers associated with those components. Goodall (1954) gives some meaningful interpretations of principal components for the classification of vegetation.

Four principal component analyses were performed on the 1970 Pawnee Site aboveground biomass data. The four analyses are distinguished by the original p variates used. The first analysis used eight functional groupings as original variates: cool season grass (CSG), warm season grass (WSG), cactus (CACT), cool season forb (CSF), warm season forb (WSF), shrub (SHRB), other (OTH) and litter (LITR). The second analysis used 66 plant species groups as original variates. The third analysis used the same functional groupings as the first with the exclusion of cactus and litter. The fourth analysis used 63 plant species groups (same as analysis 2) with the exclusion of the two cactus species (OPPO and MAVI) and litter. Overall mean values for each of the species groups and each of the functional groups are given in Table 5. The data were collected on two watersheds within each of four treatments (no, light, moderate, and heavy grazing) on 11 sampling dates. The results of the analyses are presented in Tables 6 to 9. Each of the tables has the following form:

(*i*) Coefficients, variances, and percentage of total variance for each of the first three components.

The component coefficients for the j^{th} component are expressed in the tables in the following form:

$$\text{Let } \lambda_j = j^{th} \text{ largest eigenvalue of } \Sigma$$

$$= \text{variance of } j^{th} \text{ component}$$

$$\underline{a_j} = \begin{pmatrix} a_{ij} \\ \cdot \\ \cdot \\ \cdot \\ a_{pj} \end{pmatrix} = \text{normalized eigenvector associated with } \lambda_j$$

Thus $\underline{a}_j^T \underline{a}_j = 1.$

Then

$$\underline{a}_j' = \begin{pmatrix} a_{ij}' \\ \cdot \\ \cdot \\ \cdot \\ a_{pj}' \end{pmatrix} = \frac{1}{\lambda_j} \begin{pmatrix} a_{ij} \\ \cdot \\ \cdot \\ \cdot \\ a_{pj} \end{pmatrix}$$

The vector $\underline{a}_j'$ refers to the component coefficients expressed in the tables. Thus the absolute magnitude of each principal axis is inversely proportional to the variance of the associated component.

The variances given in the tables are the first three eigenvalues of Σ, and, thus, are equal to the variances of the first three normalized components.

(*ii*) Analyses of variance of original observations along each of the first three principal axes over the design

$$Z_{ijkl} = \mu_l + \alpha_{il} + \beta_{jl} + \alpha\beta_{ijl} + \varepsilon_{ijkl}$$

where

Z_{ijkl} = value of the l^{th} principal component for the k^{th} observation within watershed i on date j.

μ_l = overall sample mean of component l

α_{il} = deviation from μ_l due to watershed i

β_{jl} = deviation from μ_l due to sampling date j.

$\alpha\beta_{ijl}$ = deviation from μ_l due to intersection between watershed i and sampling date j.

Note that the factor due to watersheds (7 df) is broken down into two independent sources--treatments (3 df) and watersheds within treatments (4 df)--in the ANOVA tables.

(*iii*) Plots of the summed total response for each watershed on each of the first three principal axes. Means which are not significantly different ($\alpha = .05$), employing Tukey's Q statistic for multiple comparisons (Snedecor and Cochran 1967) are connected by straight lines below each of the three principal axes. Within a given treatment, the two watershed mean responses are found above the principal axes.

Let us now attempt to interpret the results of the four analyses presented in Tables 6 to 9.

Analysis 1

The first component (Table 6), which accounts for 50% of the total variance inherent in the system, is a reflection of the total biomass of cactus and litter (the component coefficients for cactus and litter are an order of magnitude greater than any other coefficient and are both of the same sign). The biomass of litter is dominant in this component. There is no separation of treatments along the first principal axis, as is reflected in the first ANOVA of part (b) of Table 6; however, there are significant differences between watersheds within treatments. This is especially true for the heavy and no grazing treatments, as is reflected in part (c) of Table 6.

The second component, which accounts for 28% of the total variance, is a reflection of the difference in biomass between cactus and the combination of litter and warm season grasses. Once again, treatments do not separate out in this axis, whereas there are substantial differences between watersheds within treatments.

The third component, which accounts for 13% of the total variance, is a reflection of the biomass of warm season grasses. It appears from part (c) of Table 6 that the heavy grazing treatment has a distinctive response from the rest of the treatments along this principal axis, due to a relatively low biomass of warm season grasses.

Analysis 2

The results of this analysis (Table 7) (employing 66 species groups as original variables) are almost identical to the results of Analysis 1. The first two components of both analyses are virtually identical, both in explained variability and in interpretation. The third component of Analysis 2, which accounts for 6% of the total variance, is a reflection of the difference in biomass between *Bouteloua gracilis* (BOGR) and *Muhlenbergia torreyi* (MUTO), both warm season grasses. Watershed 8 is significantly different from all other watersheds along this principal axis. It has a high biomass of *Bouteloua gracilis* relative to *Muhlenbergia torreyi*.

Due to the fact that cactus and litter played such an important role in the interpretation of the first two principal component analyses, it was decided to rerun the analyses with cactus (OPPO and MAVI) and litter (LITR) excluded. It can be determined from inspection of the computer output for the analyses, that exclusion of cactus and litter reduces the total amount of variability and covariability in the system by approximately 50%.

Analysis 3

The first component, which accounts for 59% of the total variability inherent in the system, is a reflection of the total biomass of warm season grasses (Table 8). Again, treatments are not significantly different along this axis, whereas watersheds within treatments are significant. This component appears to be quite similar to component 3 of Analysis 1. The heavy grazed treatment appears to separate out from the other three treatments due to its low biomass of warm season grasses. However, the two watersheds within the heavy grazed treatment are not significantly different from watersheds 2 (no grazing) and 6 (moderate grazing).

The second component, which accounts for 30% of the total variability in this limited system, is a reflection of the total shrub biomass. It is interesting to note that treatments do separate out at the $\alpha = .10$ level of significance in the ANOVA (part (b) of Table 8). It appears that shrub biomass tends to decrease with long-term grazing.

The third component, which accounts for 8% of the total variability in the limited system, is a reflection of the warm season forb biomass. Although there are some significant differences between watersheds along the axis, these differences cannot be partitioned into either significant differences between treatments or between watersheds within treatments.

Analysis 4

The first component, which accounts for 24% of the total variability inherent in the limited system, reflects the differences in biomasses between the two warm season grasses *Bouteloua gracilis* (BOGR) and

Muhlenbergia torreyi (MUTO). The only distinct separation of watersheds along this axis is watershed 8 (no grazing) from the rest of the watersheds due to a high biomass of *Bouteloua gracilis* relative to *Muhlenbergia torreyi*.

The second component, which accounts for 20% of the total variability, appears to primarily reflect the total biomass of *Bouteloua gracilis* (BOGR) and *Muhlenbergia torreyi* (MUTO) and secondarily the difference in biomass between the above-mentioned two warm season grasses and *Aristida longiseta* (ARLO), a third warm season grass. With the exclusion of the no grazing treatment there appears to be some separation between the other three treatments along this axis. However, most of the differences, on a watershed basis, are nonsignificant.

The third component, which accounts for 17% of the total variability, reflects the total biomass of *Aristida longiseta* (ARLO), *Bouteloua gracilis* (BOGR), and *Muhlenbergia torreyi* (MUTO). However, there is very little separation along this axis, based upon grazing treatments. This axis appears to be quite close in composition and watershed pattern to the first principal axis of Analysis 3. Thus, the heavy grazed treatment does exhibit some distinction from the other treatments due to a relatively low biomass of warm season grasses, the most important species of which are reflected in this third component of Analysis 4.

Several things become quite apparent in the interpretations of these four analyses.

(*i*) There was very little relationship between the major components of variability in the aboveground biomass on the Pawnee Site in 1970 and the long-term grazing history of the plots sampled.

(*ii*) It appears that the biomass of cactus (mainly *Opuntia polyacantha*) and litter dominate the aboveground herbage dynamics on the Pawnee Site. The biomass of warm season grasses, in particular *Bouteloua gracilis*, *Aristida longiseta*, and *Muhlenbergia torreyi*, seem to be of secondary importance in determining the aboveground herbage dynamics at Pawnee.

(*iii*) There is some indication that the biomass of shrubs tends to decrease with long-term grazing pressure.

Subsequent sets of principal component analyses were performed on the 1970 field season aboveground biomass data from the following Comprehensive Network Sites: Bison, Jornada, Osage, Pantex, Hays, Cottonwood, Bridger, and Dickinson. For the first six sites mentioned above, two analyses were performed for each site: one on functional groupings of total aboveground live plus standing dead plant material (litter excluded) and one on all aboveground plant species (live plus standing dead) appearing on the sites. For the last two sites mentioned above (Bridger and Dickinson) standing dead determinations were not made by species. Thus, three analyses were performed for each of these sites: one on functional groupings of the total aboveground live plant material (all standing dead included in the "other" category) and two on all aboveground plant species (live only) appearing on the sites (with and without standing dead as a species group). The analyses are presented in Tables 10 through 29. Each of the tables has the following form:

i. Means and standard deviations for each of the original variables.

ii. Coefficients, variances, and percentage of total variance for each of the first three components.

iii. Plots of the mean response for each replicate plot within each treatment on each of the first three principal axes. Within a given treatment the two replicate plot means are joined above the principal axes.

Analyses of variance on the principal axes, along with individual comparisons between plots, were not attempted due to the difficulty in generating the data files for analysis.

Bison

Analysis 1. The first component (Table 10), which accounts for 55% of the total variability, is a reflection of the biomass of cool season grasses plus the "other" category. There appears to be a distinct separation of treatments along this axis. The second component, which accounts for 32% of the total variability, is a reflection of the difference in biomass between the "other" category and the combination of cool season grasses and cool season forbs. No separation of treatments is evident along this axis. The third component, which accounts for 13% of the total variability, is a reflection of the difference in biomass between cool season grasses and the combination of cool season forbs and the "other" category. Again, it is doubtful whether there are significant differences between treatments along this axis.

Analysis 2. The first component (Table 11), which accounts for 58% of the total variability inherent in the system, is a reflection of the total biomass of the "miscellaneous" category plus *Festuca scabrella* (FESC), a cool season grass. There appears to be a highly significant difference between grazing treatments along this axis. The grazed treatment reflects a low biomass of these two species groups relative to the ungrazed treatment. The second component, which accounts for 28% of the total variability, is a reflection of the difference in biomass between the "miscellaneous" category and *Festuca scabrella*. It is doubtful whether there are significant differences between treatments along this axis, although the sampling plots do order themselves by treatment. The third component, which accounts for 5% of the total variability, appears to reflect the difference in biomass between *Lupinus sericeus* (LUSE), a cool season forb, and *Festuca scabrella* (FESC), a cool season grass. Again, the treatments do not appear to be significantly different along this axis, although the sample plots do order themselves by treatment.

In conclusion, the information content of both analyses on the 1970 Bison data is fairly low due to the large biomass of unidentifiable plants. These are delegated to the "other" category in Analysis 1 and the "miscellaneous" category in Analysis 2. It appears that some of these unidentifiable plant species, along with *Festuca scabrella*, may play a primary role in the separation of grazing treatments on this site. Of secondary importance, it appears that the no grazing treatment could be partially categorized by a stronger dominance of *Festuca scabrella*, the predominant cool season grass on the site, over *Lupinus sericeus*, the predominant cool season forb on the site, than on the grazed treatment.

Jornada

Analysis 1. The first component (Table 12), which accounts for 50% of the total variability inherent in the system, is primarily influenced by the total biomass of cool season shrubs. There appears to be a distinct separation of treatments along this axis due to a greater biomass of cool season shrubs on the ungrazed than on the grazed treatment. The second component, which accounts for 27% of the total variability, appears to be a reflection of the difference in biomass between warm season grasses and warm season forbs. There is a pronounced difference between treatments along this axis. It appears that the relation of the biomass of warm season grasses to warm season forbs is almost a complete reversal between the two treatments sampled. The forbs dominate the grasses on the grazed treatment, and the grasses dominate the forbs on the ungrazed treatment. The third component, which accounts for 18% of the total variability, is a reflection of the total biomass of warm season grasses and warm season forbs. Again, the two treatments appear to separate on this axis.

Analysis 2. The first component (Table 13), which accounts for 49% of the total variability inherent in the system, is predominantly influenced by the biomass of *Yucca elata* (YUEL), a cool season half shrub. It can be seen that this component is almost identical to the first component of Analysis 1. However, the separation between treatments is not as distinct on this axis as it is on the first principal axis of Analysis 1. There appears to be significant variability within treatments along this axis. The second component, which accounts for 21% of the total variability, is a reflection of the difference in biomass between *Bouteloua eriopoda* (BOER), a warm season grass, and *Gutierrezia sarothrae* (GUSA), a warm season half-shrub. A distinct separation of treatments occurs along this axis. Again, this axis is almost identical to the second principal axis of Analysis 1, both in total variance and in interpretation. The third component, which accounts for 18% of the total variability, is a reflection of the total biomass of *Bouteloua eriopoda* and *Gutierrezia sarothrae*. Again, a distinct separation between the two treatments sampled occurs along this axis.

In conclusion, it appears that the grazing treatments on the Jornada Site are distinguishable primarily in terms of the biomass of *Bouteloua eriopoda*, a warm season grass and *Gutierrezia sarothrae*, a warm season half-shrub. The no grazing treatment is distinguished by a relatively high biomass of the two species, with the grass dominant over the shrub. The grazed 1969-ungrazed 1970 treatment is characterized by a relatively low biomass of the two species, with the shrub dominant over the grass. The species demonstrating the greatest degree of variability in the system is *Yucca elata*, a cool season half-shrub. However, it appears that substantial variability of this species occurs both within and between the two treatments sampled. In addition, warm season forbs dominate warm season grasses on the grazed treatment, with the reverse occurring on the grazed 1969-ungrazed 1970 treatment.

Osage

Analysis 1. The first component (Table 14), which accounts for 94% of the total variability inherent in the system, is primarily influenced by the biomass of warm season grasses. Treatments appear to separate out fairly distinctly along this axis. The other two components examined appear to have very little information content. The second component is strongly influenced by the "other" category, and the third component accounts for less than 1% of the total variability in the system.

Analysis 2. The first component (Table 15), which accounts for 69% of the total variability inherent in the system, is primarily influenced by the total biomass of *Andropogon scoparius* (ANSC), a warm season grass. The treatments appear to separate into distinguishable units along this axis. The second component, which accounts for 17% of the total variability, is a reflection of the biomass of *Sporobolus asper* (SPAS), another warm season grass. The sampling plots within treatments order themselves by treatment on this axis; however, it is doubtful whether the treatment differences are significant. The third component, which accounts for 5% of the total variability, is primarily influenced by the biomass of *Panicum virgatum* (PAVI), another warm season grass. Again, it is doubtful whether any treatment differences are significant on this axis. It is interesting to note that the mean values of the two sampling plots within the ungrazed treatment are virtually identical on the second principal axis, whereas the mean values of the two sampling plots within the grazed 1969-ungrazed 1970 plot are virtually identical on the third principal axis. This might indicate that the ungrazed treatment is partially categorized by a relatively low biomass of *Sporobolus asper*, whereas the grazed-ungrazed treatment is partially categorized by a relatively high biomass of *Panicum virgatum*. Note that the sign of the component coefficient associated with a particular species must be taken into account in order to make the above inferences.

In conclusion, it is rather obvious that the aboveground plant biomass dynamics on the Osage Site are dominated by warm season grasses, in particular by *Andropogon scoparius*. The no grazing treatment is characterized by a relatively high biomass, and the grazed 1969-ungrazed 1970 treatment is characterized by a relatively low biomass of *Andropogon scoparius*. In addition, it appears that two warm season grasses, *Sporobolus asper* and *Panicum virgatum*, have a secondary influence on the biomass dynamics of the Osage Site.

Pantex

Analysis 1. The first component (Table 16), which accounts for 96% of the total variability, is solely a reflection of the biomass of warm season succulents. It appears that the three treatments do separate to some degree on this axis with warm season succulent biomass increasing with grazing level. The other two components examined appear to have very little information content. The second component reflects the biomass of warm season grasses. There is certainly no separation of treatments along this axis. This component accounts for only 3% of the total variability inherent in the system. The third component accounts for less than 1% of the total variability.

Analysis 2. The results of this analysis (Table 17) are almost identical to those of Analysis 1 (Table 16). The first component, which accounts for 94% of the total variability, is almost entirely a reflection of the biomass of *Opuntia polyacantha* (OPPO), a warm season succulent. As in the case of Analysis 1, the treatments appear to separate out along this axis, with an apparent trend of increasing *Opuntia* biomass with increased grazing level. The second component, which accounts for 5% of the total variability, appears to be influenced by the biomass of *Bouteloua gracilis* (BOGR), a warm season grass. However, no treatment (or plot) separation is readily apparent along this axis. It is of little use to try to garnish information from the third component.

In conclusion, it is rather obvious that the aboveground plant biomass dynamics on the Pantex Site are dominated by warm season succulents, in particular *Opuntia polyacantha*, whose biomass is an increasing function of grazing level. In addition, the biomass of *Bouteloua gracilis*, a warm season grass of equal overall biomass to *Opuntia polyacantha*, shows little tendency to vary either within or between grazing treatments.

Hays

Analysis 1. The first component (Table 18), which accounts for 85% of the total variability inherent in the system, is a reflection of the total biomass of warm season grasses. The two treatments sampled appear to distinguish themselves along this axis. As at previous sites, the biomass of warm season grasses is lower on the grazed treatment than on the ungrazed treatment. The second component, which accounts for 11% of the total variability, is a reflection of the biomass of warm season forbs. It is quite evident that the treatments do not separate out on this axis. The third component, which accounts for 4% of the total variability, is a reflection of the biomass of cool season grasses. Again, treatments do not appear to separate out on this axis.

Analysis 2. The first component (Table 19), which accounts for 43% of the total variability inherent in the system, is a reflection of the difference in biomass between *Andropogon gerardi* (ANGE) and *Bouteloua curtipendula* (BOCU), both warm season grasses. There appears to be a distinct separation of treatments along this axis, with the biomass of *Andropogon gerardi* being relatively more dominant over *Bouteloua curtipendula* on the ungrazed treatment than on the grazed treatment. The second component, which accounts for 22% of the total variance, is a reflection of the difference in biomass between *Bouteloua curtipendula* and *Andropogon scoparius* (ANSC), both warm season grasses. Again, treatments appear to separate along this axis, with *Bouteloua curtipendula* being relatively more dominant over *Andropogon scoparius* on the grazed than on the ungrazed treatment. The third component, which accounts for 14% of the total variance, is a reflection of the biomass of the three dominant warm season grasses on the site: *Andropogon gerardi*, *Bouteloua curtipendula*, and *Andropogon scoparius*. It is rather doubtful whether treatments are significantly different along this axis, although the sample plots do order themselves by treatment. There appears to be a lower total biomass of these three species on the grazed than on the ungrazed treatment.

In conclusion, it is apparent that the aboveground herbage dynamics on the Hays Site are dominated by warm season grasses, in particular by three species: *Andropogon gerardi*, *Bouteloua curtipendula*, and *Andropogon scoparius*. Treatments appear to be distinguishable by the differences in biomass between these three species as well as by the total biomass of warm season grasses. The grazed 1969-ungrazed 1970 treatment is characterized in three ways relative to the ungrazed treatment.

i. A relatively low biomass of warm season grasses.

ii. Relatively less dominance of *Andropogon gerardi* over *Bouteloua curtipendula*.

iii. Relatively more dominance of *Bouteloua curtipendula* over *Andropogon scoparius*.

Cottonwood

Analysis 1. The first component (Table 20), which accounts for 83% of the total variability inherent in the system, is a reflection of the difference in biomass between cool season grasses and warm season grasses. It is rather doubtful whether the treatments are significantly different along this axis; however, the sample plots do order themselves according to treatment. The second component, which accounts for 15% of the total variability, is a reflection of the total biomass of grass, warm season and cool season. In this case there is definitely no separation of treatments along this axis. The third component is not worth consideration since it accounts for less than 1% of the total variation in the system.

Analysis 2. The first component (Table 21), which accounts for 79% of the total variability, is primarily controlled by the biomass of *Agropyron smithii* (AGSM), a cool season grass. Secondarily, it reflects the difference in biomass between *Agropyron smithii* and *Buchloe dactyloides* (BUDA), a warm season grass. It should be noted that these two species are the two dominant plant species on the site. It is quite obvious (part c) that treatments separate out along this axis. The biomass of *Agropyron smithii* is larger relative to the biomass of *Buchloe dactyloides* in the ungrazed treatment than in the grazed treatment. The second component, which accounts for 14% of the total variability in the system, is a reflection of the total biomass of *Agropyron smithii* and *Buchloe dactyloides*. Treatments do not separate along this axis. The third component, which accounts for 4% of the total variability in the system, is a reflection of the biomass of *Bouteloua gracilis* (BOGR), a warm season grass. Again, treatments do not separate out along this axis.

In conclusion, it appears that the aboveground herbage dynamics on the Cottonwood Site are characterized primarily by the difference in biomass between *Agropyron smithii*, a cool season grass, and *Buchloe dactyloides*, a warm season grass. Grazing treatments appear to separate according to this difference, with *Buchloe dactyloides* being relatively more dominant over *Agropyron smithii* on the grazed 1969-ungrazed 1970 treatment than on the ungrazed treatment.

Bridger

Analysis 1. There are only two functional groupings which were identifiable on this site in 1970: cool season grasses and cool season forbs (Table 22). The rest of the plant species, including standing dead, were put into an "other" category. The first component, which accounts for 67% of the total variability, is a reflection of the total biomass of cool season grasses and cool season forbs. Grazing treatments appear to separate along this axis. The biomass of these two groups tends to be lower on the grazed than on the ungrazed plots. The second component reflects the difference in biomass between cool season grasses and cool season forbs. Of the total variability, 25% is accounted for by this component. A distinct separation of treatments is not evident along this axis. However, there is a trend for the no grazing treatment to have forbs dominant over grasses and the moderate grazing treatment to have grasses dominant over forbs. Of course, the interpretation is weak and relativistic in nature. The third component, which accounts for the balance (8%) of the variability inherent in the system, reflects the biomass of the "other" category, and thus defies interpretation.

One must be careful not to put too much weight on the results of the above analysis due to the fact that there were only three original variables to work with. In this case, an analysis of variance on the original variables might lend more information than the principal component analysis.

Analysis 2. This is an analysis of the Bridger Site data by species groups in which standing dead is included as a species group. The first component (Table 23), which accounts for 28% of the total variability in the system, is very hard to interpret. However, it appears to reflect the biomass of three of the predominant plant species on the site--*Festuca idahoensis* (FEID), a cool season grass, *Lupinus argenteus* (LUAR), a cool season forb, *Agropyron subsecundum* (AGSU), a cool season grass--and their abundance in relation to standing dead. Treatments appear to separate along this axis. The ungrazed treatment has a higher biomass of the above plant species relative to standing dead than the grazed treatment. The second component, which accounts for 22% of the total variability, is, again, quite incomprehensible to me. The third component, which accounts for 16% of the total variability, appears to reflect the difference in biomass between two forb categories--*Lupinus argenteus* and a miscellaneous forb category (MIFB)--and the combination of standing dead and the most prevalent cool season grass species on the site--*Festuca idahoensis*. It is quite apparent that treatments do not separate along this axis.

Analysis 3. This is an analysis of the Bridger Site data by species groups in which standing dead is excluded from the analysis. Due to the relatively low mean biomass of the standing dead category, the results of the analysis are quite similar to those obtained from Analysis 2. The first component, which accounts for 31% of the total variability of the system under study, is a reflection of the biomass of four predominant plant species groups on the site: *Festuca idahoensis* (FEID), a cool season grass, *Lupinus argenteus* (LUAR), a cool season forb, *Agropyron subsecundum* (AGSU), a cool season grass, and the miscellaneous forb (MIFB) category. As in the case of Analysis 2, the two treatments appear to separate along this axis. The second component, which accounts for 24% of the total variability, appears to partially reflect the difference in biomass between *Festuca idahoensis* and *Agropyron subsecundum*, the two predominant cool season grasses on the site. Of secondary importance appears to be the magnitude of the biomass of *Lupinus argenteus*, a cool season forb, and *Danthorra intermedia*, a cool season grass. The treatments do not appear to be significantly different along this axis; however, the sampling plots do order themselves by treatment. The third component, which accounts for 18% of the total variability, is primarily a reflection of the difference in biomass between *Festuca idahoensis*, the predominant cool season grass on the site, and the combination of *Lupinus argenteus*, the predominant cool season forb on the site, and the miscellaneous forb category. Treatments do not separate along this axis.

In conclusion, it appears that the standing dead compartment as a whole plays a relatively minor role in the determination of variability in the aboveground herbage dynamics on the Bridger Site. It appears that the primary sources of variability in the system are two cool season grass species--*Festuca idahoensis* and *Agropyron subsecundum*. Grazing treatments tend to distinguish themselves based upon these two species, along with the biomass of *Lupinus argenteus*, a cool season forb, and some other miscellaneous forbs. There appears to be considerable variability within the grazing treatments due to relative differences within the cool season grass compartment and between the cool season grass and cool season forb compartment.

Dickinson

Analysis 1. The first component (Table 25), which accounts for 73% of the total variability in the system, is primarily a reflection of the biomass in the "other" category, which is predominantly made up of standing dead. There appear to be significant differences between treatments along this axis. The second component, which accounts for 13% of the total variability in the system, is primarily a reflection of the biomass of cool season grasses and secondarily of warm season grasses and cool season forbs. Treatments do not appear to separate along this axis. The third component, which accounts for 8% of the total variability, is a reflection of the difference in biomass between cool season grasses and warm season grasses and forbs. Again, the treatments do not separate along this axis.

Analysis 2. This analysis is performed on the Dickinson Site data by species groups with standing dead included as a species group. Note that (Table 26, Part a) the standing dead compartment accounts for a considerable proportion of the total mean aboveground biomass on the site. The first component (Table 26), which accounts for 73% of the variability in the system, is primarily a reflection of the biomass of standing dead. The treatments appear to separate distinctly along this axis, with the no grazing treatment having a significantly higher biomass of standing dead than the heavy grazing treatment. The second component, which accounts for 9% of the variability in the system, is primarily a reflection of the biomass of *Stipa comata* (STCO), the predominant plant species on the site and a cool season grass. Secondarily, the biomass of *Bouteloua gracilis* (BOGR), the predominant warm season grass at Dickinson and *Artemisia ludoviciana* (ARLU), the predominant warm season forb, are reflected in this component. Treatments do not appear to be significantly different along this axis, although the sampling plots do order themselves by treatment. The third component, which accounts for 5% of the total variability, is primarily a reflection of the biomass of *Bouteloua gracilis* and *Artemisia ludoviciana*, a warm season grass and forb, respectively. Secondarily, it is a reflection of the relative difference between the above two warm season species and *Stipa comata*, a cool season grass. Again, treatments do not appear to be significantly different along this axis, although the sample plots do order themselves by treatment. The grazed plots tend to have a higher biomass of the two warm season species relative to the cool season species than the ungrazed plots.

Analysis 3. This analysis is performed on the Dickinson Site data by species groups with standing dead excluded. The first component (Table 27), which accounts for 34% of the total variability in the system, is primarily a reflection of the biomass of *Stipa comata* (STCO), a cool season grass. Secondarily, it is a reflection of the biomass *Artemisia ludoviciana* (ARLU), a warm season forb. Treatments appear to be significantly different along this axis with a larger biomass of these species occurring in the ungrazed treatment. The second component, which accounts for 18% of the total variability in the system, is primarily a reflection of the biomass of *Bouteloua gracilis* (BOGR), a warm season grass. Again, treatments appear to be significantly different along this axis with a larger biomass of this species appearing on the grazed treatment. The third component, which accounts for 15% of the variability in the system, is a reflection of the difference in biomass between *Stipa comata*, the predominant cool season grass on the site, and *Artemisia ludoviciana*, the predominant warm season forb on the site. Treatments do not distinguish themselves along this axis.

In conclusion, it appears that grazing treatments on the Dickinson Site can be distinguished independently by examining the biomass of either standing dead, *Stipa comata*, a cool season grass, or *Bouteloua gracilis*, a warm season grass. Overall, the interpretation is rather weak due to the rather small amount of the total variability inherent in the system which is accounted for by the first two or three components.

Conclusions

It is interesting to note that the pairs of sites which Grant (1971) found most similar using Sharon and Weavers index of similarity, at one date in the year, also appear to be similar as a result of ordination by principal component analysis.

Hays and Osage had the highest similarity index in Grant's analysis. Hays is a mixed grass site, whereas Osage is a tallgrass site. However, both sites are dominated by the biomass of warm season grasses. In addition, at both sites the warm season grasses have a higher biomass on the ungrazed treatment than on the grazed treatment.

Bison and Bridger had practically as high a similarity index in Grant's analysis as Hays and Osage. Bison is a Palouse site, whereas Bridger is a mountain site. Grazing treatments on the two sites can be distinguished based upon the relative biomass of cool season grasses and cool season forbs. On both sites cool season grasses dominate cool season forbs. However, at Bison the dominance is stronger on the no grazing treatment, and at Bridger the dominance is stronger on the moderately grazed treatment. In addition, at Bridger the grazing treatments can be separated on the basis of the total biomass of cool season grasses and cool season forbs, with the higher biomass of the two occurring on the ungrazed treatment.

The third pair of sites with a high index of similarity in Grant's analysis is Pawnee, a shortgrass site and Jornada, a desert grassland site. From the analyses presented in this paper it appears that the similarity between the two sites is keyed to the shrub biomass and the way that it relates to grazing treatments. At Pawnee, shrub biomass tends to decrease with grazing. In addition, it appears that the biomass of warm season grasses decreases with grazing. At Jornada the biomass of both warm season grasses and warm season shrubs is relatively high on the ungrazed treatment, with the grasses dominant over the shrubs; and the biomass of both warm season grasses and warm season shrubs is relatively low on the grazed treatment, with the shrubs dominant over the grasses. Thus, on both sites a decrease in shrub biomass is apparent with increased grazing pressure.

It is interesting to note that Grant inferred a lack of similarity between the two shortgrass sites: Pawnee and Pantex. One would think them to be quite similar due to the fact that both are dominated by *Opuntia polyacantha*, a warm season succulent and *Bouteloua gracilis*, a warm season grass. However, at Pawnee the biomass of *Opuntia polyacantha* does not appear to vary in direct response to grazing. However, at Pantex it seems to increase in biomass with grazing pressure. It is interesting to note that at both sites the biomass of *Bouteloua gracilis*, the dominant warm season grass, does not appear to vary in direct response to grazing.

Finally, some degree of similarity can be inferred between the two northern mixed grass sites: Cottonwood and Dickinson. On the average, Cottonwood is dominated by the biomass of warm season grasses and Dickinson by cool season grasses. At Cottonwood the dominance of warm season grasses over cool season grasses is more pronounced on the grazed treatment. At Dickinson warm season grasses demonstrate a higher biomass on the grazed treatment and cool season grasses a higher biomass on the ungrazed treatment. Thus, it appears that the similarity between the two sites occurs in the relative biomass of warm season and cool season grasses.

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Table 1. Summary of within site analysis of variance significances.

	Bison	Bridger	Cottonwood	Dickinson	Hays	Jornada	Osage	Pantex	Pawnee	
Category	***	***	***	***	***	***	***	***	***	
Treatment	**	**	***	**	*	***	***	***	NS	
Date	***	NS	***	***	***	*	***	*	***	
Replicates (Treatment 1)	NS	NS	NS	**	NS	NS	NS	NS	NS	
Replicates (Treatment 2)	**	NS	NS	NS	NS	NS	NS	NS	NS	
Replicates (Treatment 3)								NS	NS	Total
Replicates (Treatment 4)									***	
Category × Treatment	***	***	***	***	***	***	**	***	***	
Treatment × Date	***	NS	***	NS(p)	***	NS	NS(p)	NS(p)	NS(p)	
Category × Replicates (Treatment)	**	NS(p)	***	NS	NS(p)	NS(p)	***	NS(p)		
Date × Replicates (Treatment)	NS(p)	***	NS(p)		NS(p)	NS	NS(p)			
Category	***	***	***	***	***	***	***	***		
Treatment	**	**	*** NS	NS	***	NS	***			
Date	***	**	***	***	***	*	***	**		
Replicates (Treatment 1)	NS	NS	NS	NS	NS	NS	NS	NS		Live
Replicates (Treatment 2)	NS	NS	NS	NS	NS	NS	NS	NS		
Replicates (Treatment 3)								NS		
Category × Treatment	***	***	***	***	NS(p)	***	*	***		
Treatment × Date	***	NS	***	***	NS(p)	NS(p)	NS(p)	NS(p)		
Category × Replicates (Treatment)	**	NS(p)	*	**	NS(p)	NS(p)	**	NS(p)		
Date × Replicates (Treatment)	NS(p)	***	NS(p)		NS(p)	NS	NS(p)			

Table 1. Continued.

	Bison	Bridger	Cottonwood	Dickinson	Hays	Jornada	Osage	Pantex	Pawnee	
Category	***	***	***	***	***	NS	***	***		Dead
Treatment	**	**	**	***	***	NS	***	NS		
Date	***	***	***	**	***	NS	***	***		
Replicates (Treatment 1)	NS	NS	*	NS	NS	NS	NS	NS		
Replicates (Treatment 2)	**	NS	NS	NS	NS	**	NS	NS		
Replicates (Treatment 3)								NS		
Category × Treatment	***	***	***	***	***	*	***	***		
Treatment × Date	***	***	***	**	**	*	NS	NS(p)		
Category × Replicates (Treatment)	***	NS(p)	***	NS(p)	NS(p)	*	*	NS(p)		
Date × Replicates (Treatment)	NS(p)	NS(p)	NS(p)		NS(p)	NS	NS(p)			
Category	***	***	***	***	***	NS	***	***		Recent Dead
Treatment	**	***	*	*** **	NS	***	*			
Date	***	***	***	***	***	NS	***	***		
Replicates (Treatment 1)	NS	NS	**	*	NS	NS	NS	NS		
Replicates (Treatment 2)	NS	NS	NS	NS	NS	**	NS	NS		
Replicates (Treatment 3)								NS		
Category × Treatment	***	***	***	***	***	*	***	***		
Treatment × Date	***	***	***	***	**	*	***	NS(p)		
Category × Replicates (Treatment)	NS(p)	NS(p)	***	NS(p)	NS(p)	*	NS(p)	NS(p)		
Date × Replicates (Treatment)	NS(p)	NS(p)	NS(p)		NS(p)	NS	NS(p)			

Table 1. Continued.

	Bison	Bridger	Cottonwood	Dickinson	Hays	Jornada	Osage	Pantex	Pawnee	
Category	***	***	***	***	***	0	***	***		
Treatment	*	NS	**	NS	**	0	***	NS		
Date	***	***	***	***	***	0	***	***		
Replicates (Treatment 1)	NS	NS	NS	NS	NS	0	NS	NS		Old Dead
Replicates (Treatment 2)	NS	NS	NS	NS	NS	0	NS	NS		
Replicates (Treatment 3)						0		NS		
Category × Treatment	***	NS(p)	***	***	***	0	***	NS(p)		
Treatment × Date	***	NS(p)	***	*	**	0	**	NS(p)		
Category × Replicates (Treatment)	NS(p)	NS(p)	**	NS(p)	NS(p)	0	NS	NS(p)		
Date × Replicates (Treatment)	NS(p)	NS(p)	NS(p)		NS(p)	0	NS(p)			

*** = Significance for α = .01

** = Significance for α = .05

* = Significance for α = .10

NS = Nonsignificance for α = .10

NS(p) = Nonsignificance for α = .25
(Sum of squares pooled into error)

Table 2. Plant categories present on the U.S. IBP sites, 1970.

Site	CSG	WSG	CSSH	WSSH	CSF	WSF	CSSU	WSSU	OTH
Bison	x			x	x	x			x
Bridger	x				x				x
Cottonwood	x	x		x	x	x	x		x
Dickinson	x	x		x	x	x	x		x
Hays	x	x	x	x	x	x			x
Jornada		x	x	x	x	x			x
Osage	x	x		x					x
Pantex	x	x			x	x	x	x	x
Pawnee	x	x		x	x	x	x		x

Table 3. Sampling-date codes used in Fig. 1 to 13.

	Jornada
1.	14-7-70, 15-7-70
2.	30-7-70, 31-7-70
3.	10-8-70, 11-8-70
4.	20-8-70, 21-8-70
5.	1-9-70, 2-9-70

	Pantex
1.	15-6-70
2.	29-6-70
3.	13-7-70
4.	27-7-10
5.	10-8-70
6.	24-8-70
7.	5-9-70
8.	2-10-70
9.	31-10-70

	Bridger
1.	30-6-70, 29-6-70
2.	8-7-70
3.	20-7-70, 21-7-70
4.	3-8-70
5.	17-8-70
6.	31-8-70

	Bison
1.	2-5-70
2.	15-5-70
3.	30-5-70
4.	17-6-70
5.	2-7-70
6.	16-7-70
7.	4-8-70
8.	24-8-70
9.	26-9-70

	Hays
1.	16-1-70
2.	15-2-70, 16-2-70
3.	20-3-70, 24-3-70, 15-3-70
4.	15-4-70, 16-4-70
5.	15-5-70
6.	16-6-70, 15-6-70
7.	6-7-70, 1-7-70, 2-7-10
8.	21-7-70, 16-7-70
9.	3-8-70, 4-8-70
10.	(16-19)-8-70
11.	(15-28)-9-70
12.	(15-17)-10-70
13.	(15-18)-11-70

Table 3. Continued.

Osage	Cottonwood
1. 27-3-70, 11-4-70	1. 6-5-70
2. 1-5-70, 2-5-70	2. 20-5-70
3. 1-6-70, 2-6-70	3. 6-6-70
4. 17-6-70, 18-6-70	4. 20-6-70
5. 1-7-70, 2-7-70	5. 6-7-70
6. 16-7-70	6. 20-7-70
7. 3-8-70, 4-8-70	7. 6-8-70
8. 17-8-70	8. 20-8-70
9. 26-9-70	9. 6-9-70
10. 18-10-70	10. 6-10-70
11. 14-11-70	11. 6-11-70
	12. 6-12-70

Pawnee	Dickinson
1. 9-9-70, 14-4-70, 10-4-70, 11-4-70	1. 25-5-70
2. 5-5-70, 7-5-70, 6-5-70	2. (8-11)-6-70
3. 19-5-70	3. (22-24)-6-70
4. 1-6-70	4. (6-8)-7-70
5. 16-6-70, 18-6-70, 17-6-70	5. (22-28)-7-70
6. 29-6-70, 1-7-70	6. (3-6)-8-70
7. 15-7-70, 16-7-70, 19-7-70	7. (17-18)-8-70
8. 29-7-70, 28-7-70	8. (15-17)-9-70
9. 11-8-70, 12-8-70	9. 17-10-70
10. 24-8-70, 25-8-70	
11. 8-9-70, 12-9-70	

Table 4. Calculated Q values for individual comparisons.

Site	Date			Treatment			Treatment × Date		
	Total	Live	Dead	Total	Live	Dead	Total	Live	Dead
Bison	5.87	4.36	3.90				9.34	6.94	6.20
Bridger	7.67	8.07	0.90						
Cottonwood	4.92	3.17	3.44				7.55	4.86	5.28
Dickinson	14.56	8.80	14.20						
Hays	9.28	8.70	10.87				14.05		16.46
Jornada	5.62	5.62	0.37						
Osage	18.66	12.98	13.24						
Pantex	15.56	15.34	2.47	5.61	5.06	1.90			
Pawnee	5.04								

Table 5. Mean biomass values for 1970 Pawnee Site aboveground sampling.

Variable	Mean	Standard Deviation
a. Species		
1AGSM	.136051	.883573
2ARLO	2.316619	5.701806
3BOGR	11.288040	6.381911
4BUDA	.731804	2.691311
5CAFI	.063821	.486852
6CAHE	.696136	.944711
7FEOC	.067656	.215665
8MUTO	1.017628	6.418283
9SCPA	.019077	.390588
10SIHY	.052926	.403029
11SPCR	.177017	.810501
12STCO	.105511	1.196836
13ARIN	.000028	.000754
14ALDR	.006051	.055792
15ASTA	.011108	.078390
16ASTR	.122287	.986254
17BAOP	.230994	1.022336
18CHAL	.000043	.001131
19CHLE	.004560	.035940
20CHVI	.091946	1.657825
21CIUN	.041989	.516802
22CRYP	.004560	.034325
23CYMO	.003807	.062980
24EREF	.268068	1.456261
25EUGL	.000085	.001921
26EVNU	.008139	.127631
27GACO	.027656	.134879
28GILA	.009460	.066317
29HASP	.012145	.134625
30HEPE	.000114	.002664
31HYFI	.024148	.373704
32LARE	.002827	.019418
33LEDE	.025540	.071290
34LEMO	.008494	.069773
35LIIN	.004375	.071719
36LIPU	.011037	.186846
37LOOR	.007955	.041182
38LUPU	.000455	.005776
39LYJU	.006932	.066281
40MAVI	.229602	1.835976
41MILI	.012216	.101280
42MUDI	.002344	.040369

Table 5. Continued.

Variable	Mean	Standard Deviation
a. (Continued)		
430ECO	.138551	1.216046
440PPO	6.237628	15.543008
450RLU	.007216	.101444
46PEAL	.010298	.149731
47PLPU	.017997	.060077
48PSTE	.126662	2.233024
49SAKA	.006477	.058051
50SCBR	.018509	.180351
51SETR	.059176	.501541
52SPCO	.327926	.596459
53STPA	.004645	.123243
54TAPA	.000199	.003410
55THME	.028835	.265764
56THTR	.051293	.267646
57TOGR	.021406	.170576
58TROC	.009389	.068740
59UNKF	.000114	.001765
60GRSQ	.000270	.007161
61ARFR	1.098253	4.654369
62ATCA	.155156	1.938022
63CHNA	.652045	4.273627
64EULA	.008068	.214073
65GUSA	.281264	1.788593
66LITR	20.569020	18.196108
b. Functional Groups		
1CSG	1.122102	1.898873
2WSG	15.550185	9.851070
3CACT	6.467230	15.622374
4CSF	.744105	1.271347
5WSF	.994602	3.580712
6SHRB	2.194787	7.006197
7OTH	.034972	.381880
8LITR	20.569020	18.196108

Table 6. 1970 Pawnee Site--Principal Component Analysis 1--eight aboveground functional groups.

a. Component Coefficients.

Variable	Component Coefficients		
	1	2	3
1CSG	-.00033	-.00131	-.00295
2WSG	-.00196	-.01001	-.10133
3CACT	-.02504	.06022	-.01084
4CSF	-.00016	-.00011	-.00025
5WSF	-.00081	-.00168	.00129
6SHRB	-.00035	-.00332	.00819
7OTH	-.00002	.00001	-.00004
8LITR	-.04544	-.03270	.01028
Variance	370.80055	207.82987	94.62782
Percentage of Total Variance	50.14	28.11	12.80

Table 6. Continued.

b. ANOVA's on first three principal axes.

Source	df	ss	ms	F	
		Component 1			
W	7	46.76910	6.68130	7.19	***
T	3	23.13812	7.71271	1.31	NS
W(T)	4	23.63098	5.90775	6.36	***
Date	10	18.70623	1.87062	2.01	**
W × D	70	48.74229	.69639	.73	NS(p)
Error	616	588.77760	.95581		
Pooled Error 1	686	637.52489	.92934		
Total		703.00025			
		Component 2			
W	7	34.25196	4.89314	5.11	***
T	3	14.05840	4.68613	.93	NS
W(T)	4	20.19356	5.04839	5.27	***
Date	10	11,64503	1.16450	1.22	NS
W × D	70	70.93948	1.01342	1.07	NS(p)
Error	616	586.16365	.95156		
Pooled Error 1	686	657.10313	.95788		
Total	703	703.00012			
		Component 3			
W	7	80.10285	11.44326	13.55	***
T	3	40.04838	13.34946	1.33	NS
W(T)	4	40.05447	10.01362	11.86	***
Date	10	43.52082	4.35208	5.15	***
W × D	70	65.20371	.93148	1.12	NS(p)
Error	616	514.17232	.83470		
Pooled Error 1	686	579.37603	.84457		
Total	703	702.99970			

** = Significant for $\alpha = .05$

*** = Significant for $\alpha = .01$

NS = Nonsignificant for $\alpha = .10$

NS(p) = Nonsignificant for $\alpha = .25$

Table 6. Continued.

c. Total responses for each replicate on first three principal axes.

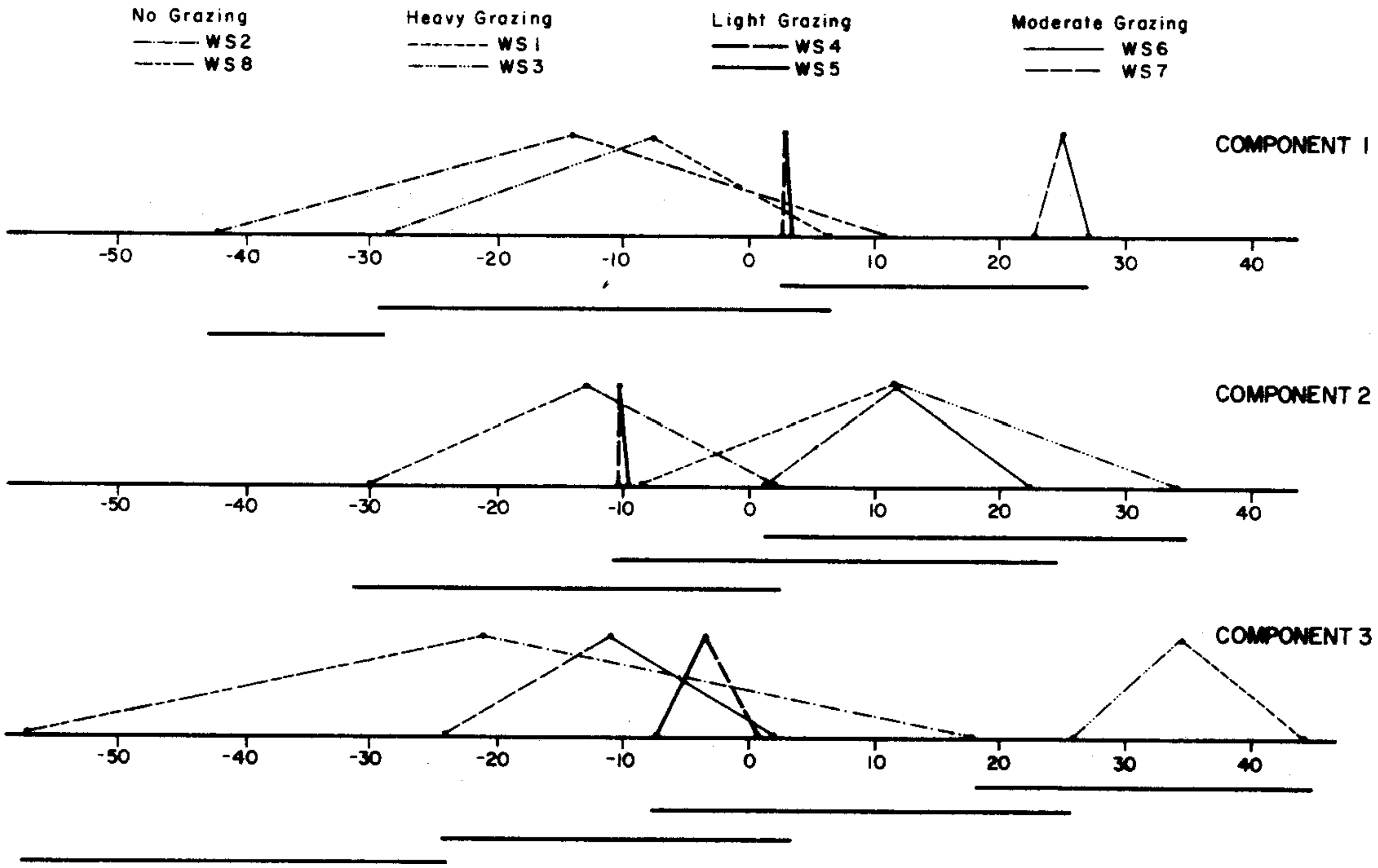

Table 7. 1970 Pawnee Site--Principal Component Analysis 2--66 aboveground species groups.

a. Component Coefficients.

Variable	Component Coefficients		
	1	2	3
1AGSM	.00014	.00020	.00045
2ARLO	.00097	.00448	.00760
3BOGR	.00186	.00309	-.10390
4BUDA	-.00001	-.00048	.00860
5CAFI	-.00003	.00008	.00048
6CAHE	.00018	.00048	.00277
7FEOC	.00000	.00003	-.00023
8MUTO	-.00153	.00027	.10660
9SCPA	.00031	-.00082	.00040
10SIHY	.00004	.00018	-.00111
11SPCR	-.00008	.00021	.00227
12STCO	-.00002	.00023	-.00314
13ARIN	-.00000	.00000	-.00000
14ALDR	.00000	-.00000	-.00009
15ASTA	.00000	-.00004	-.00001
16ASTR	.00003	-.00000	.00004
17BAOP	-.00003	.00035	-.00240
18CHAL	-.00000	-.00000	.00000
19CHLE	.00000	-.00001	.00001
20CHVI	.00038	.00072	.00121
21CIUN	.00007	.00018	-.00005
22CRYP	.00001	.00001	.00002
23CYMO	-.00000	-.00000	.00001
24EREF	-.00004	.00002	-.00115
25EUGL	-.00000	-.00000	.00000
26EVNU	-.00001	.00001	.00004
27GACO	-.00000	.00002	.00019
28GILA	-.00001	-.00002	-.00003
29HASP	-.00000	.00002	-.00002
30HEPE	.00000	.00000	-.00000
31HYFI	.00002	-.00001	.00006
32LARE	.00000	-.00000	-.00003
33LEDE	.00001	.00001	-.00002
34LEMO	-.00001	.00000	-.00000
35LIIN	-.00001	-.00000	.00001
36LIPU	-.00001	-.00001	-.00001
37LOOR	-.00001	-.00001	.00001
38LUPU	-.00000	-.00000	-.00000
39LYJU	.00000	.00001	.00004
40MAVI	-.00012	.00002	-.00062
41MILI	.00002	.00002	-.00013

Table 7. Continued.

a. (Continued)

Variable	Component Coefficients		
	1	2	3
42MUDI	-.00000	.00000	.00001
43OECO	.00005	-.00001	.00162
44OPPO	.02492	-.06132	-.00002
45ORLU	-.00000	.00001	.00000
46PEAL	-.00001	.00001	.00004
47PLPU	.00001	.00000	-.00004
48PSTE	.00034	.00071	.00153
49SAKA	.00000	.00001	.00011
50SCBR	-.00002	.00000	-.00019
51SETR	.00004	.00013	-.00034
52SPCO	.00015	-.00032	.00022
53STPA	-.00001	-.00000	-.00009
54TAPA	.00000	-.00000	-.00000
55THME	-.00001	-.00006	.00001
56THIR	-.00002	.00002	.00008
57TOGR	.00001	-.00002	.00002
58TROC	-.00000	.00002	-.00009
59UNKF	.00000	-.00000	-.00000
60GRSQ	.00000	.00000	.00001
61ARFR	.00036	.00101	.00206
62ATCA	-.00001	.00022	-.00183
63CHNA	-.00003	.00139	.00121
64EULA	-.00001	.00001	-.00005
65GUSA	.00000	.00047	.00097
66LITR	.04544	.03341	.00763
Sample Variance	371.26751	203.58704	44.64735
Percentage of Total Variance	48.61	26.65	5.85

Table 7. Continued.

b. ANOVA's on first three principal axes.

Source	df	ss	ms	F	
		Component 1			
W	7	47.61475	6.80211	7.33	***
T	3	24.48759	8.16253	1.41	NS
W(T)	4	23.12716	5.78179	6.23	***
Date	10	18.89165	1.88917	2.04	**
W × D	70	50.68323	.71833	.75	NS(p)
Error	616	586.21009	.95164		
Pooled Error 1	686	636.49332	.92783		
Total	703	702.99972			
		Component 2			
W	7	30.08138	4.29734	4.45	***
T	3	11.11628	3.70543	.78	NS
W(T)	4	18.96510	4.74128	4.91	***
Date	10	10.96467	1.09647	1.14	NS
W × D	70	71.80516	1.02579	1.07	NS(p)
Error	616	590.14904	.95803		
Pooled Error 1	686	661.95420	.96495		
Total	703	703.00025			
		Component 3			
W	7	73.93499	10.56214	12.17	***
T	3	35.14749	11.71583	1.21	NS
W(T)	4	38.78750	9.69688	11.18	***
Date	10	24.09524	2.40952	2.78	***
W × D	70	70.45832	1.00655	1.16	NS
Error	616	534.51152	.86771		
Total	703	703.00007			

** = Significant for α = .05

*** = Significant for α = .01

NS = Nonsignificant for α = .10

NS(p) = Nonsignificant for α = .25

Table 7. Continued.

c. Total responses for each replicate on first three principal axes.

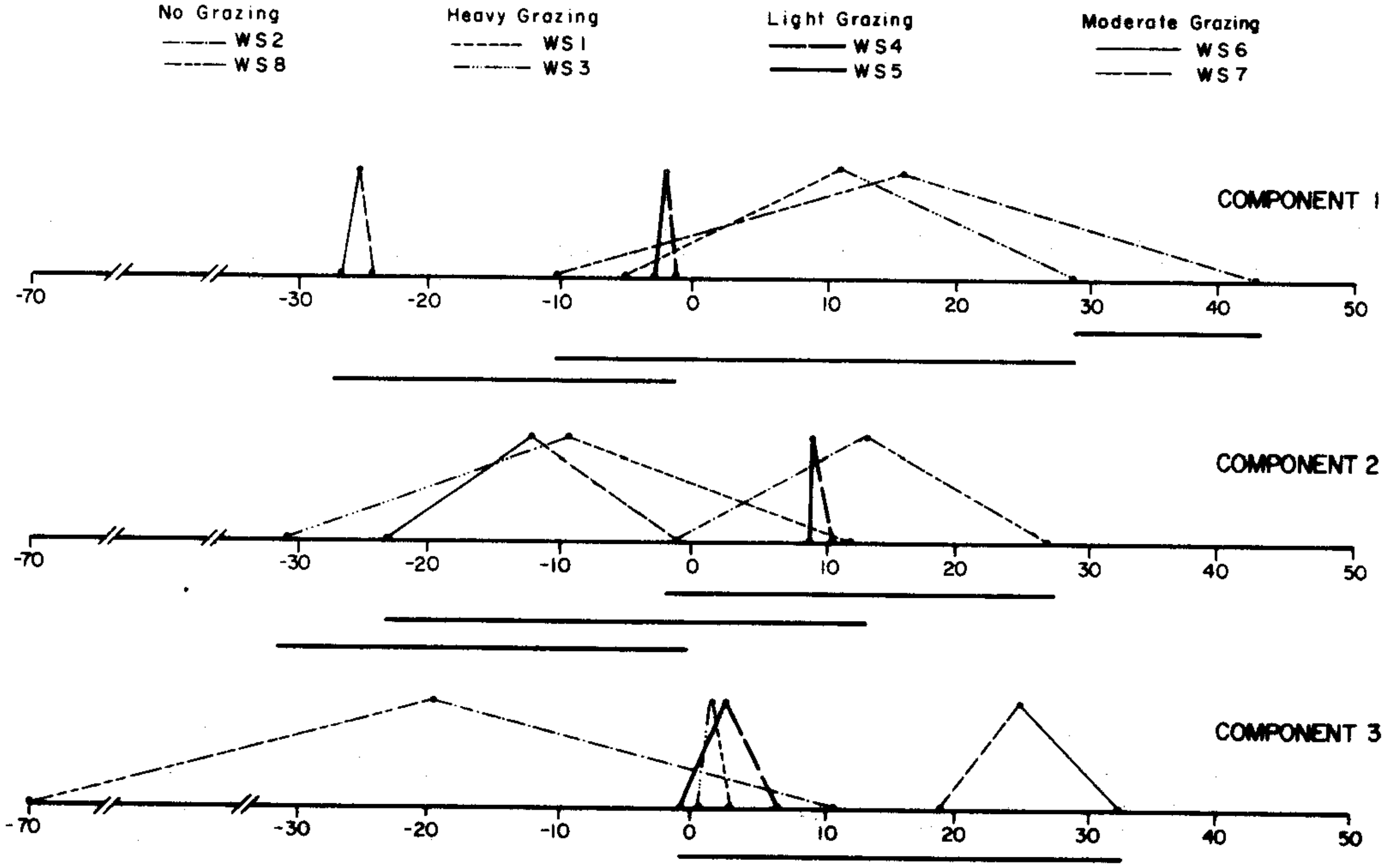

Table 8. 1970 Pawnee Site--Principal Component Analysis 3--six aboveground functional groups.

a. Component Coefficients.

Variable	Component Coefficients		
	1	2	3
1CSG	-.00348	.00034	-.03146
2WSG	-.10120	.00724	.00037
3CSF	-.00033	.00002	.00072
4WSF	.00018	-.00215	-.27622
5SHRB	.00515	.14270	-.00411
6OTH	-.00004	.00019	.00032
Sample Variance	97.28063	48.97049	12.93544
Percentage of Total Variance	59.20	29.80	7.88

Table 8. Continued.

b. ANOVA's on first three principal axes.

Source	df		ss	ms	F	
			Component 1			
W	7		86.35151	12.33593	14.74	***
T		3	44.60181	14.86727	1.42	NS
W(T)		4	41.74970	10.43743	12.46	***
Date	10		42.38996	4.23900	5.06	***
W × D	70		63.39330	.90562	1.09	NS(p)
Error	616		510.86505	.82933		
Pooled Error 1	686		574.25835	.83711		
Total			702.99982			
			Component 2			
W	7		53.92532	7.07362	7.95	***
T		3	42.50113	14.16704	4.96	*
W(T)		4	11.42419	2.85605	3.21	**
Date	10		13.63507	1.36351	1.52	NS
W × D	70		87.26215	1.24660	1.40	**
Error	616		548.17738	.88990		
Total	703		702.99992			
			Component 3			
W	7		22.10254	3.15751	3.28	***
T		3	15.79798	5.26599	3.34	NS
W(T)		4	6.30456	1.57614	1.64	NS
Date	10		19.59932	1.95993	2.02	**
W × D	70		66.17086	.94530	.98	NS(p)
Error	616		595.12728	.96612		
Pooled Error 1	686		661.29814	.96399		
Total	703		703.00000			

* = Significant for α = .10
** = Significant for α = .05
*** = Significant for α = .01

NS = Nonsignificant for α = .10
NS(p) = Nonsignificant for α = .25

Table 8. Continued.

c. Total responses for each replicate on first three principal axes.

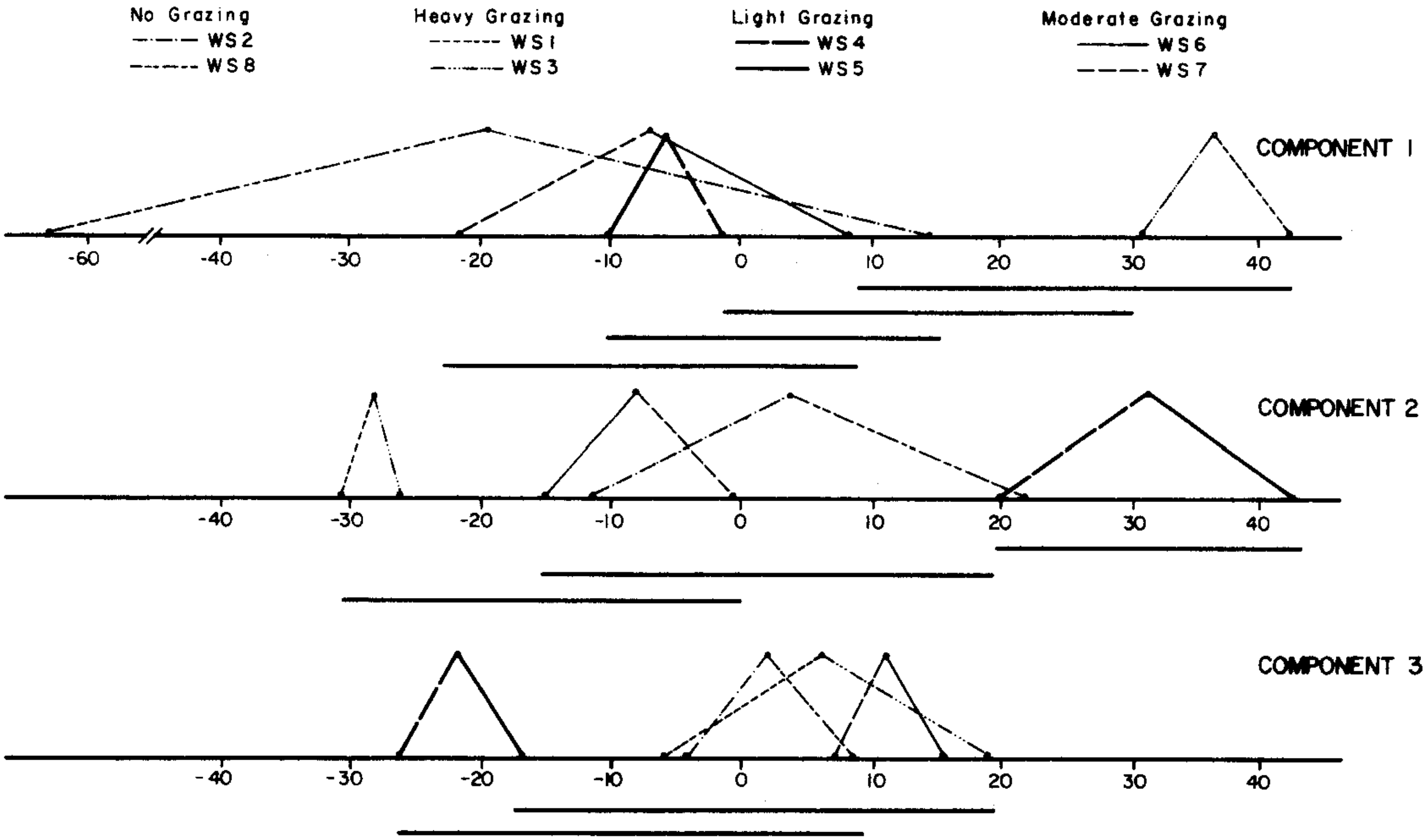

Table 9. 1970 Pawnee Site--Principal Component Analysis 4--63 aboveground species groups.

a. Component Coefficients.

Variable	Component Coefficients		
	1	2	3
1AGSM	.00023	-.00059	.00008
2ARLO	.00087	-.05842	-.16367
3BOGR	-.10474	.10467	-.04499
4BUDA	.00884	-.01287	.01532
5CAFI	.00046	-.00118	-.00041
6CAHE	.00233	.00007	-.00211
7FEOC	-.00022	.00027	.00028
8MUTO	.10453	.10672	-.04519
9SCPA	.00026	-.00036	.00039
10SIHY	-.00124	.00040	-.00330
11SPCR	.00222	.00039	-.00125
12STCO	-.00321	.00238	-.00496
13ARIN	-.00000	.00000	.00000
14ALDR	-.00009	.00010	.00000
15ASTA	-.00000	-.00001	.00012
16ASTR	.00005	-.00043	.00142
17BAOP	-.00242	.00155	-.00153
18CHAL	.00000	-.00000	.00000
19CHLE	.00001	.00002	.00003
20CHVI	.00058	-.00121	.00022
21CIUN	-.00015	.00008	.00039
22CRYP	.00001	.00007	.00003
23CYMO	.00002	-.00003	.00007
24EREF	-.00106	.00019	.00039
25EUGL	.00000	-.00000	.00000
26EVNU	.00004	-.00019	-.00021
27GACO	.00018	-.00001	-.00022
28GILA	-.00002	.00000	.00006
29HASP	-.00002	-.00002	.00010
30HEPE	-.00000	.00000	.00000
31HYFI	.00002	-.00024	-.00047
32LARE	-.00003	.00003	.00002
33LEDE	-.00003	.00009	.00012
34LEMO	.00000	-.00003	-.00000
35LIIN	.00002	-.00004	.00005
36LIPU	.00000	-.00012	-.00014
37LOOR	.00002	-.00006	.00005
38LUPU	-.00000	-.00000	.00000
39LYJU	.00003	-.00011	-.00009
40MILI	-.00016	.00010	-.00011

Table 9. Continued.

a. (Continued).

Variable	Component Coefficients		
	1	2	3
41MUDI	.00001	-.00003	-.00001
42OECO	.00150	.00095	-.00093
43ORLU	.00000	-.00010	-.00001
44PEAL	.00005	-.00009	.00016
45PLPU	-.00005	.00003	.00002
46PSTE	.00082	-.00100	-.00314
47SAKA	.00010	.00009	-.00014
48SCBR	-.00017	.00029	-.00009
49SETR	-.00041	.00020	-.00001
50SPCO	.00012	-.00078	-.00038
51STPA	-.00008	.00009	.00002
52TAPA	-.00000	.00000	.00000
53THME	.00004	-.00028	.00009
54THTR	.00008	-.00049	-.00033
55TOGR	.00002	-.00008	.00027
56TROC	-.00009	.00005	-.00004
57UNKF	-.00000	-.00000	-.00000
58GRSQ	.00001	-.00000	.00001
59ARFR	.00071	-.01819	-.00991
60ATCA	.00192	.00083	-.00389
61CHNA	.00087	.00145	.00681
62EULA	-.00004	.00004	.00009
63GUSA	.00082	-.00311	.00176
Sample Variance	45.42659	38.04712	31.93672
Percentage of Total Variance	24.20	20.26	17.02

Table 9. Continued.

b. ANOVA's on first three principal axes.

Source	df		ss	ms	F	
			Component 1			
W	7		80.02143	11.43163	13.39	***
T		3	43.97551	14.65850	1.63	NS
W(T)		4	36.04592	9.01148	10.55	***
Date	10		26.56344	2.65634	3.11	***
W × D	70		70.31174	1.00445	1.18	NS
Error	616		526.10356	.85406		
Total	686		703.00017			
			Component 2			
W	7		57.22892	8.17556	9.28	***
T		3	28.23815	9.41272	1.30	NS
W(T)		4	28.99077	7.24769	8.23	***
Date	10		41.68196	4.16820	4.73	***
W × D	70		52.57953	.75114	.84	NS(p)
Error	616		551.50962	.89531		
Pooled Error 1	686		604.08915	.88060		
Total	703		703.00003			
			Component 3			
W	7		102.69165	14.67024	16.96	***
T		3	65.86893	21.95631	2.39	NS
W(T)		4	36.82272	9.20568	10.64	***
Date	10		6.77139	.67714	.78	NS
W × D	70		46.52743	.66468	.75	NS(p)
Error	616		547.00955	.88800		
Pooled Error 1	686		593.53698	.86521		
Total	703		703.00002			

*** = Significant for α = .01
NS = Nonsignficant for α = .10
NS(p) = Nonsignficant for α = .25

Table 9. Continued.

c. Total responses for each replicate on first three principal axes.

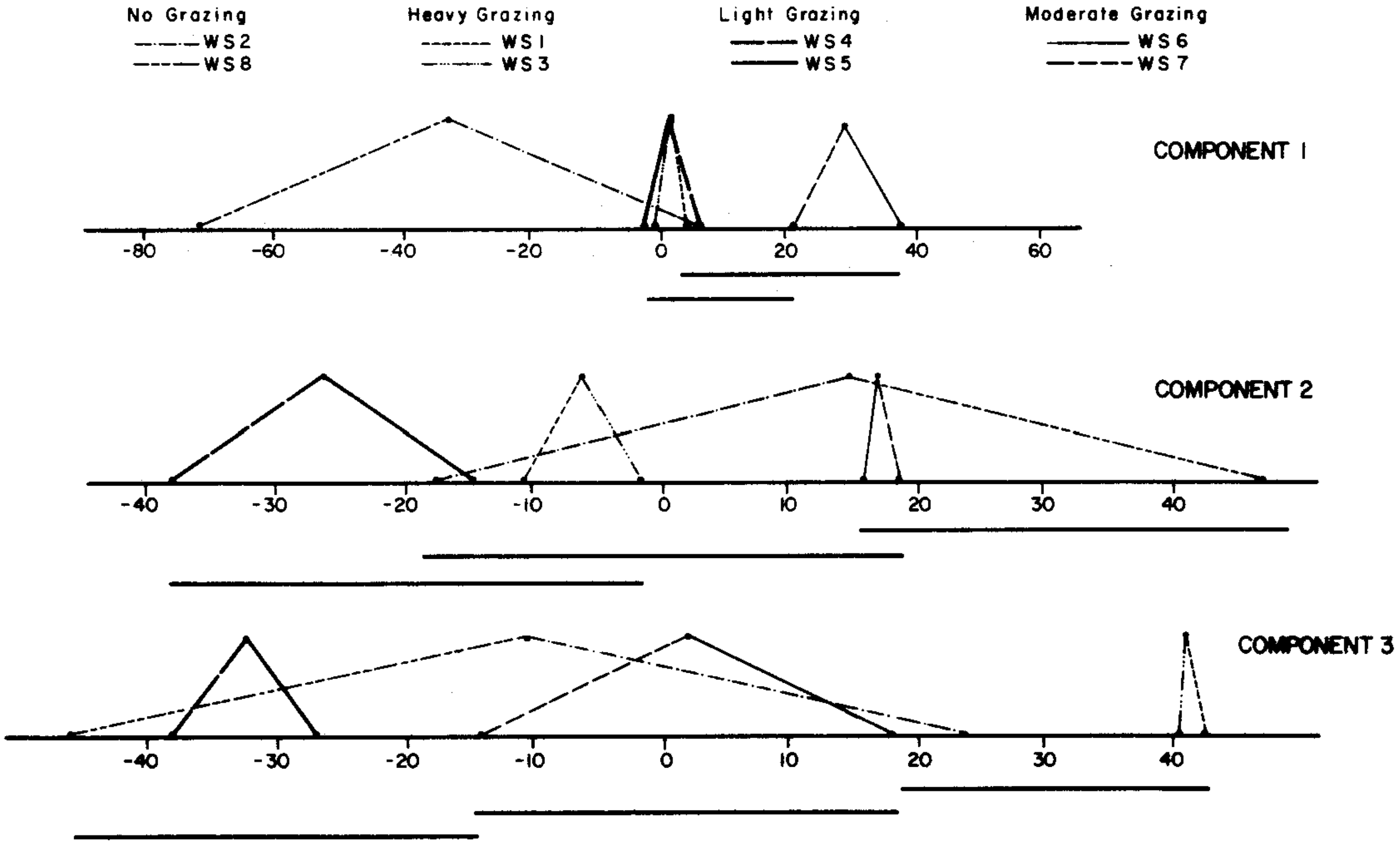

Table 10. 1970 Bison Site--Principal Component Analysis 1--five aboveground functional groups.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1CSG	61.370284	48.789740
2WSSH	.009968	.126307
3CSF	33.895457	33.590105
4WSF	.732744	3.242160
5OTH	62.971167	50.544271

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1CSG	.01205	-.01241	.03340
2WSSH	-.00000	.00000	-.00000
3CSF	.00377	-.01024	-.06259
4WSF	-.00012	-.00004	-.00006
5OTH	.01177	.01598	-.01417
Variance	3354.77613	1944.49511	764.36215
Percentage of Total Variance	55.23	32.01	12.59

Table 10. Continued.

c. Mean responses for each replicate on first three principal axes.

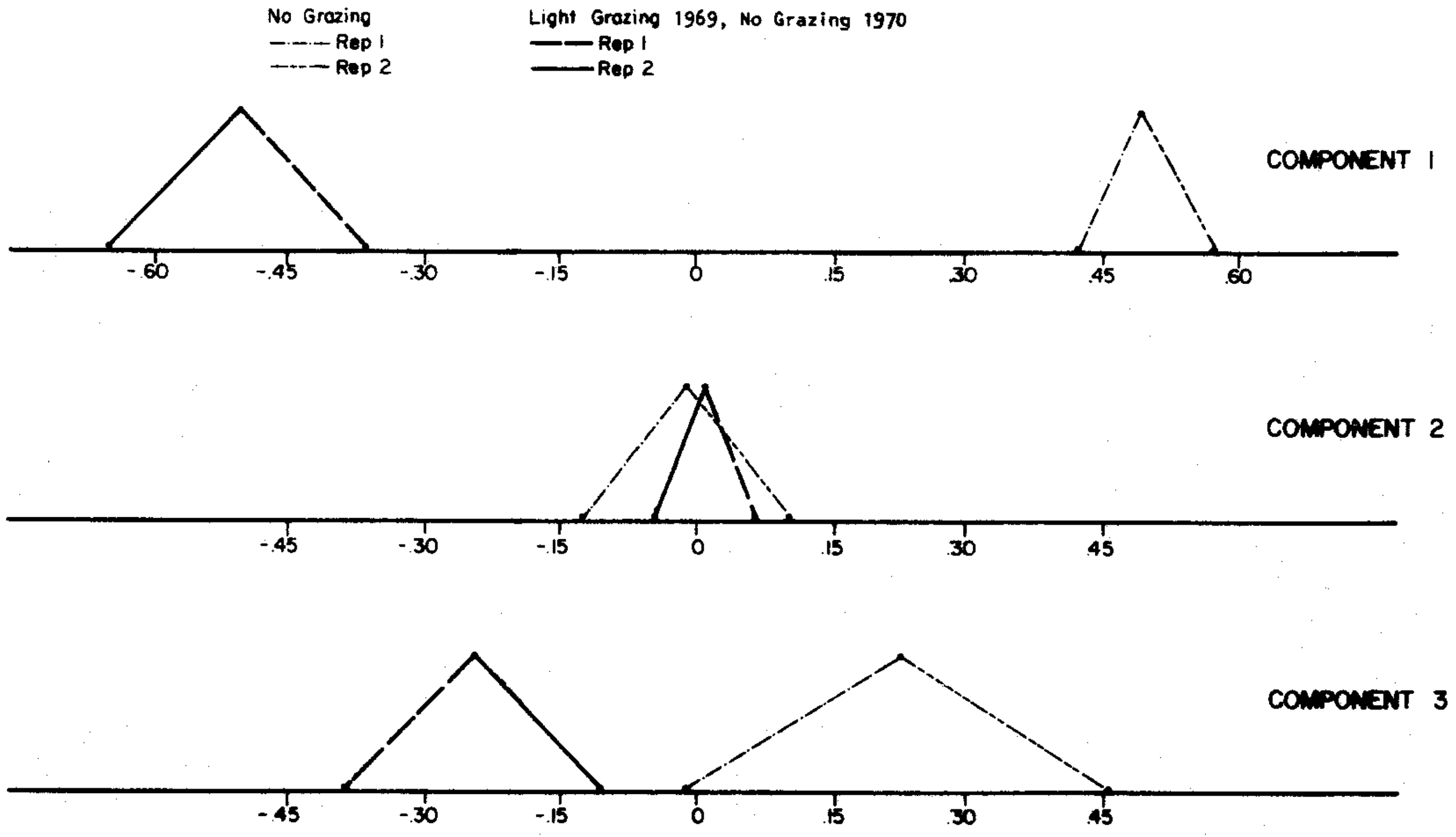

Table 11. 1970 Bison Site--Principal Component Analysis 2--43 aboveground plant species.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1MISC	62.978076	50.545579
2FESC	40.333502	54.627021
3FEID	10.958580	10.230728
4ACMI	4.446909	9.368101
5MISC1	4.652681	7.483114
6SARH	.038801	.347656
7FRPU	.021924	.188568
8ANRO	.231136	1.716570
9DOCO	.036278	.293241
10ZIPA	.428360	1.403218
11AGO	1.554511	3.787571
12LIRU	2.058833	8.884003
13GETR	.971104	4.355867
14ARFU	1.526151	2.950571
15ERI	.043817	.529595
16POPR	.270032	1.918730
17HECY	.062177	.641366
18AGSP	9.017382	14.187212
19KOCR	.453912	2.146880
20LUSE	11.423123	20.383717
21MISC2	4.192240	7.823204
22CRAC	.017508	.182352
23HIAL	.168675	.976738
24ARFR	.010032	.127094
25CASU	.787855	4.147266
26ANMA	.018801	.254584
27BRTE	.033785	.478630
28MINU	.261609	1.462054
29MISCA2	.666467	2.520526
30BASA	.179211	2.375611
31ASFA	.721577	3.238945
32AGGL	.035331	.629055
33TRDU	.133344	1.572841
34MISC3	.022713	.270469
35CRVI	.011987	.213429
36CIAR	.036593	.651521
37LUSC	.030284	.539190
38AGSP2	.025868	.460558
39GACO	.011987	.213429
40LAPU	.011356	.202196
41FIED	.107287	1.910192
42LIRR	.003785	.067399
43ASSP	.013281	.236457

Table 11. Continued.

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1MISC	-.00963	.01867	.00117
2FESC	-.01257	-.01354	-.00810
3FEID	.00094	.00105	.00455
4ACMI	-.00009	.00004	.00519
5MISC1	-.00013	-.00093	.00518
6SARH	.00001	-.00001	-.00006
7FRPU	.00001	-.00001	-.00003
8ANRO	.00002	-.00008	.00061
9DOCO	.00001	-.00001	-.00006
10ZIPA	.00008	-.00001	.00030
11AGO	.00003	-.00013	.00116
12LIRU	-.00064	-.00139	-.00323
13GETR	-.00030	-.00030	-.00042
14ARFU	.00001	-.00024	.00128
15ERI	.00001	.00001	.00000
16POPR	.00001	.00013	-.00022
17HECY	-.00001	.00000	-.00004
18AGSP	.00139	.00119	.00921
19KOCR	.00010	-.00003	.00002
20LUSE	-.00214	-.00283	.05147
21MISC2	.00034	-.00028	.00395
22CRAC	.00000	.00000	.00001
23HIAL	-.00004	-.00005	.00010
24ARFR	.00000	-.00000	-.00001
25CASU	-.00001	.00003	.00245
26ANMA	.00000	-.00002	-.00003
27BRTE	.00000	-.00003	.00003
28MINU	.00004	-.00016	.00042
29MISCA2	.00006	.00004	.00138
30BASA	.00013	.00018	-.00047
31ASFA	.00013	.00001	.00022
32AGGL	.00000	.00002	.00002
33TRDU	.00002	.00002	.00014
34MISC3	-.00001	-.00003	.00008
35CRVI	-.00000	.00002	.00001
36CIAR	.00000	-.00001	-.00006
37LUSC	-.00000	-.00001	-.00008
38AGSP2	-.00000	.00000	.00000
39GACO	.00000	.00001	-.00000
40LAPU	.00000	.00000	-.00000
41FIED	.00003	-.00002	-.00011
42LIRR	-.00000	.00000	-.00001
43ASSP	.00000	.00000	-.00002
Variance	3860.47167	1832.79114	343.29853
Percentage of Total Variance	58.04	27.56	5.16

Table 11. Continued.

c. Mean responses for each replicate on first three principal axes.

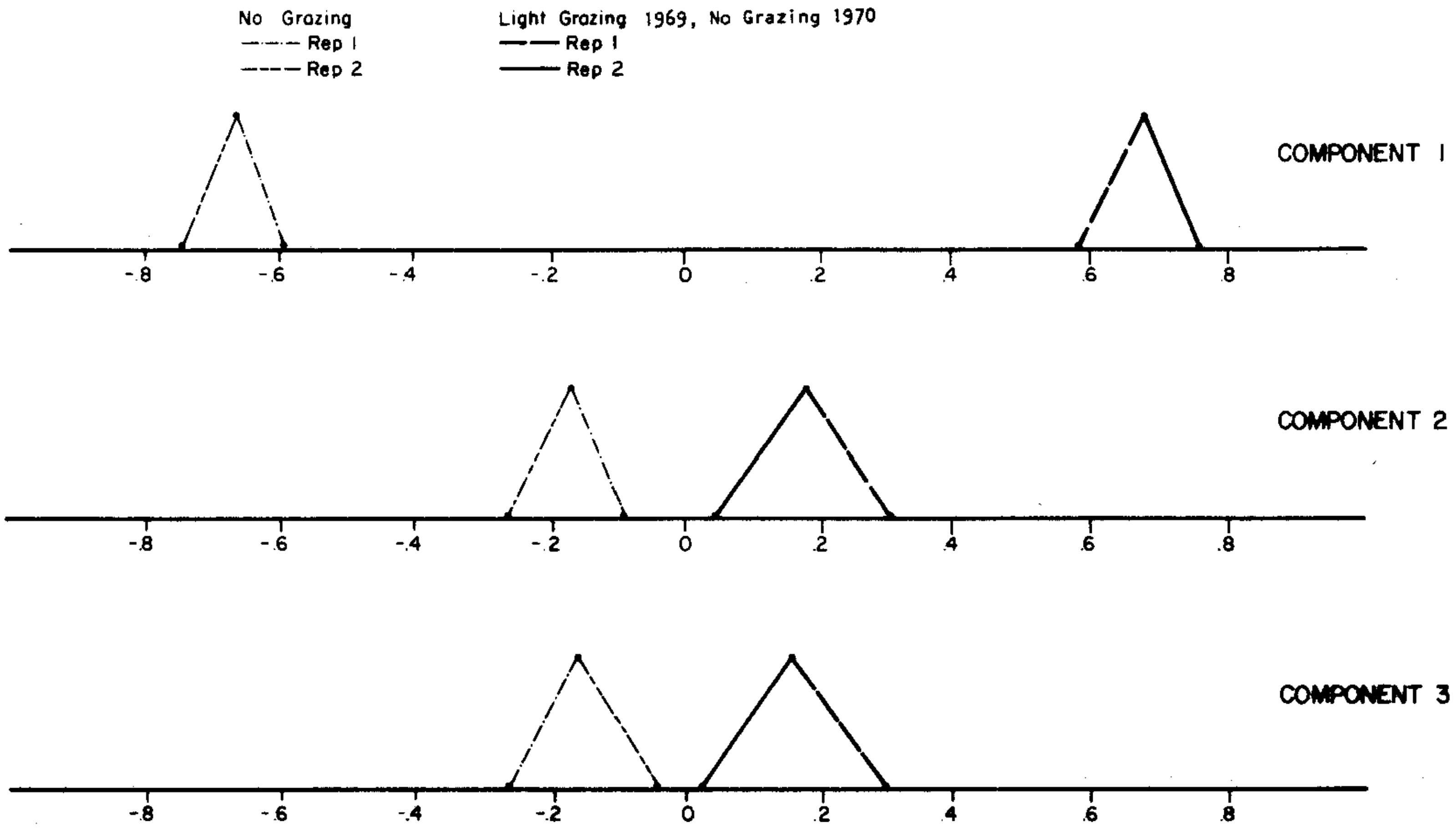

Table 12. 1970 Jornada Site--Principal Component Analysis 1--six aboveground functional groups.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1WSG	30.944099	36.202558
2CSSH	11.455198	52.538158
3WSSH	2.366089	17.699731
4CSF	1.151584	2.632043
5WSF	29.634604	34.978379
6OTH	.657129	1.887022

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1WSG	.00266	-.01913	.02040
2CSSH	.01865	.00417	-.00080
3WSSH	-.00005	-.00260	.00135
4CSF	.00001	-.00038	-.00030
5WSF	-.00163	.01650	.02405
6OTH	-.00006	.00010	-.00023
Variance	2796.15858	1509.67098	1002.70243
Percentage of Total Variance	49.77	26.87	17.85

Table 12. Continued.

c. Mean responses for each replicate on first three principal axes.

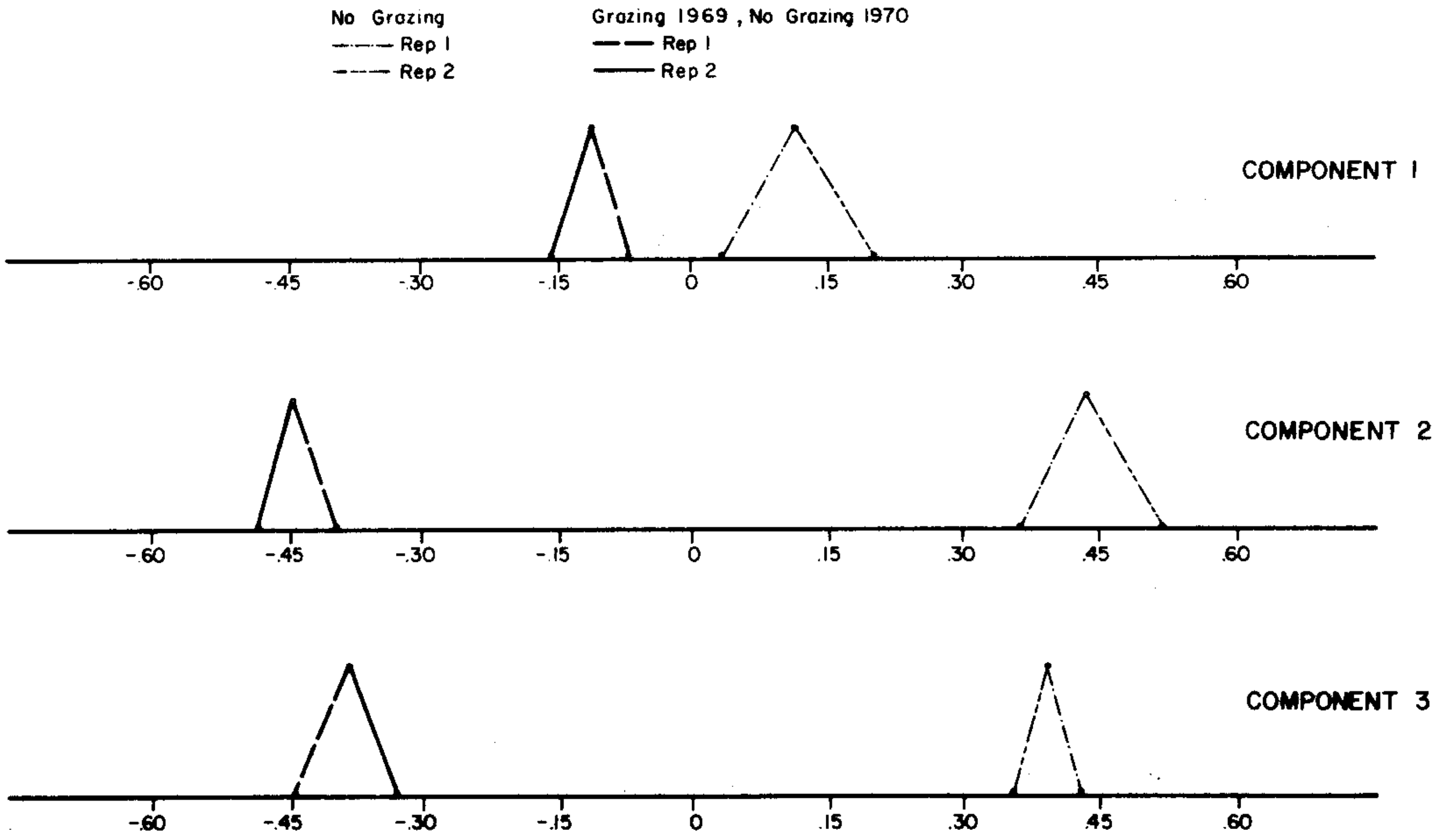

Table 13. 1970 Jornada Site--Principal Component Analysis 2--54 aboveground species.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1YUEL	11.455594	52.539096
2BOER	22.094307	32.910967
3GUSA	15.978663	32.978125
4SPFL	8.325842	16.307504
5CRCR	1.116535	2.634607
6APRA	.058317	.211065
7CABA	.533762	1.056783
8CHIN	1.102772	2.018432
9PSTA	.018020	.190302
10SAKA	8.235050	11.374139
11NAHI	.215743	.783166
12ERAB	.317525	1.001593
13DIWI	.096040	.484268
14EPTR	1.437970	14.495942
15ERPU	.636337	1.884246
16CRCO	1.438614	2.960998
17ASTA	.008218	.068863
18LEFE	.009604	.079356
19ARLO	.038020	.279723
20ZIGR	.078317	.677349
21KRSE	.054851	.418965
22ALIN	.093366	.306905
23LIAU	.046535	.507469
24HELI	.015446	.127209
25STEX	.002475	.025778
26SOEL	.070495	.426156
27BAAB	.005941	.084432
28APSP	.061188	.396801
29PRJU	.860545	10.283355
30KRSC	.005644	.080210
31GUSP	.012871	.095327
32EUAL	.014158	.116600
33CONI	.212871	.513698
34PORT	.433663	.862669
35MISC2	.038218	.153334
36TRTE	.005743	.033064
37MISC4	.159802	.419263
38COCR	.000198	.002814
39ERIO	.003564	.050659
40KAHI	.131386	.475421
41HODE	.072376	.514529
42ARIS	.064455	.916084
43AMAR	.000297	.004222

Table 13. Continued.

a. (Continued)

Variable	Mean	Standard Deviation
44HOJA	.006040	.085839
45APGR	.007129	.101318
46PAHI	.030594	.177906
47TILA	.250396	.594868
48MISC5	.035050	.255244
49BOTO	.059307	.283260
50SPCO	.026733	.379943
51BOTA	.005842	.083025
52MISC	.014950	.174197
53SPSC	.021980	.312397
54MUPO	.207475	2.948777

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1YUEL	.01895	-.00147	.00072
2BOER	.00043	.02114	.02114
3GUSA	-.00096	-.01960	.02317
4SPFL	.00046	.00007	-.00197
5CRCR	-.00000	.00046	.00007
6APRA	-.00000	-.00001	-.00002
7CABA	-.00002	-.00022	-.00007
8CHIN	.00007	.00002	-.00019
9PSTA	-.00000	.00002	.00001
10SAKA	-.00013	-.00182	-.00315
11NAHI	-.00001	-.00001	-.00014
12ERAB	-.00001	-.00001	-.00013
13DIWI	.00002	-.00000	-.00002
14EPTR	-.00010	.00207	.00132
15ERPU	-.00005	-.00012	-.00018
16CRCO	.00001	-.00010	-.00018
17ASTA	-.00000	.00000	-.00000
18LEFE	-.00000	-.00000	-.00001
19ARLO	-.00000	-.00000	.00003

Table 13. Continued.

b. (Continued)

Variable	Component Coefficients		
	1	2	3
20ZIGR	-.00001	.00001	-.00002
21KRSE	-.00000	-.00003	-.00001
22ALIN	.00000	-.00002	-.00002
23LIAU	-.00000	.00000	-.00003
24HFLI	-.00000	.00001	.00001
25STEX	-.00000	.00000	-.00000
26SOEL	.00000	-.00000	.00004
27BAAB	-.00000	-.00000	-.00000
28APSP	-.00001	-.00002	-.00001
29PPJU	-.00006	.00013	-.00055
30KRSC	-.00000	-.00000	-.00000
31GUSP	.00000	.00000	.00000
32EUAL	-.00000	-.00001	.00000
33CONI	-.00001	.00001	-.00005
34PORT	-.00001	.00000	-.00008
35MISC2	-.00000	.00001	.00001
36TRTE	-.00000	.00000	.00000
37MISC4	-.00001	.00005	-.00002
38COCR	-.00000	-.00000	-.00000
39ERIO	-.00000	.00000	.00000
40KAHI	-.00001	-.00004	-.00004
41HODE	-.00001	-.00002	-.00006
42ARIS	-.00001	-.00005	.00005
43AMAR	-.00000	-.00000	-.00000
44HOJA	.00000	-.00000	-.00001
45APGR	-.00000	-.00000	-.00001
46PAHI	.00001	.00003	.00003
47TILA	-.00000	-.00001	.00000
48MISC5	-.00000	.00003	.00001
49BOTO	-.00000	.00000	-.00001
50SPCO	-.00000	.00006	.00005
51BOTA	-.00000	-.00001	.00001
52MISC	-.00000	-.00001	-.00000
53SPSU	-.00000	.00005	.00005
54MUPO	.00067	-.00014	.00021
Variance	2770.51823	1188.84986	999.91252
Percentage of Total Variance	48.76	20.92	17.60

Table 13. Continued.

c. Mean responses for each replicate on first three principal axes.

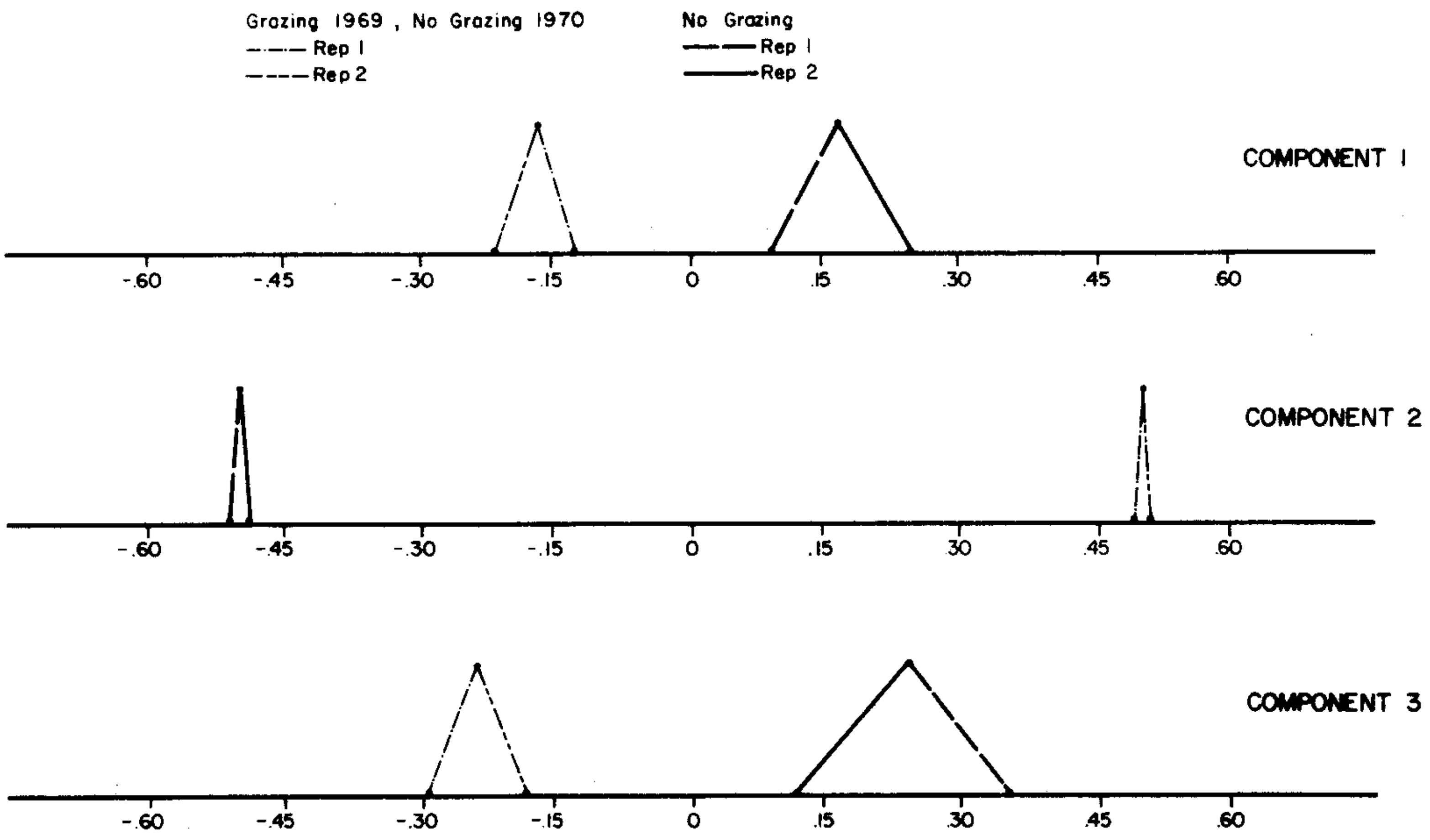

Table 14. 1970 Osage Site--Principal Component Analysis 1--four aboveground functional groups.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1CSG	17.682238	20.019929
2WSG	294.468252	209.505857
3WSSH	.014825	.250716
4OTH	48.316923	55.621881

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1CSG	.00009	-.00081	.05115
2WSG	-.00472	-.00209	.00073
3WSSH	.00000	.00001	-.00000
4OTH	.00050	-.01939	-.00221
Variance	44380.07737	2625.72302	381.49581
Percentage of Total Variance	93.65	5.55	0.80

Table. 14. Continued.

c. Mean responses for each replicate on first three principal axes.

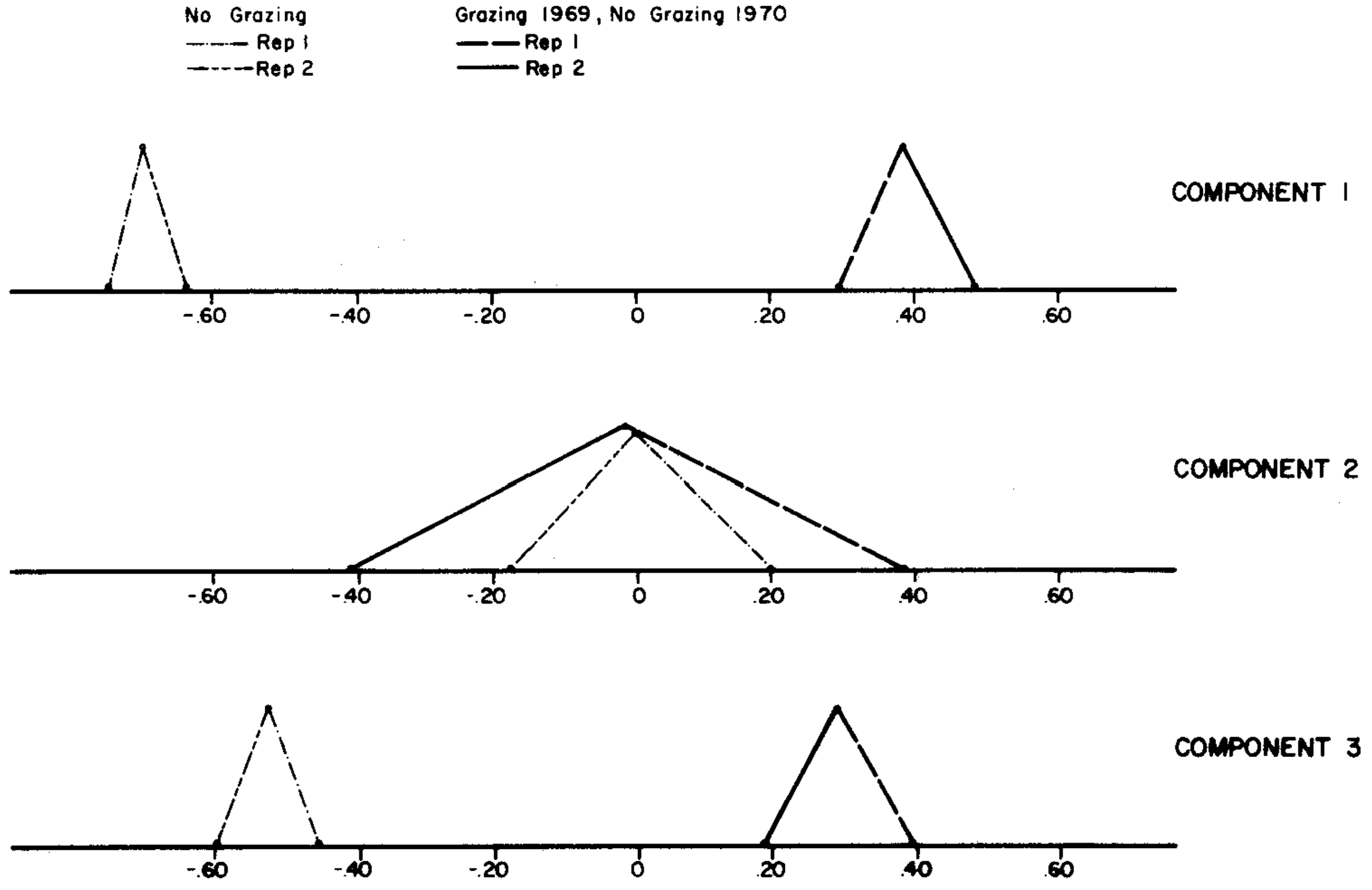

Table 15. 1970 Osage Site--Principal Component Analysis 2--29 aboveground species.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1ANGE	5.170210	22.358287
2ANSC	216.145035	187.738853
3SONU	17.008112	37.420315
4SPAS	34.484336	94.788355
5MISC	5.855524	21.486174
6PAVI	21.679161	51.901618
7FORB	1.084755	4.477941
8SEDG	.533706	2.297525
9POPR	1.858741	5.946989
10BRJA	13.928252	20.259030
11AMCO	.014825	.250716
12AMPS	1.599441	6.663662
13MISCB	5.760420	13.179530
14MISCA	19.265315	35.167259
15MISCC	5.334126	19.464515
16POAN	.014685	.241335
17FORBC	1.426294	7.448029
18FORBD	.439021	4.711668
19FORBA	3.668531	10.430283
20ForbB	.684615	4.128966
21MISCD	.455804	3.396231
22SEDGA	.911189	2.777094
23SEDGB	.426294	2.061410
24FORBF	.134406	.924501
25FORBE	.217483	1.843070
26SEDGC	.015385	.143885
27MISCG	2.393147	13.063361
28MISCF	.002657	.044940
29MISCE	.006434	.108801

Table 15. Continued.

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1ANGE	.00003	.00019	-.00064
2ANSC	-.00526	-.00075	.00049
3SONU	-.00014	.00029	-.00013
4SPAS	.00036	-.01055	-.00108
5MISC	.00007	.00006	.00006
6PAVI	.00018	-.00053	.01916
7FORB	.00001	.00004	-.00010
8SEDG	-.00000	.00002	-.00005
9POPR	-.00001	.00003	.00029
10BRJA	.00022	-.00029	.00100
11AMCO	.00000	.00000	-.00000
12AMPS	.00004	-.00006	-.00030
13MISCB	.00000	-.00002	.00033
14MISCA	.00038	.00018	-.00198
15MISCC	.00007	-.00005	-.00040
16POAN	.00000	.00000	-.00000
17FORBC	-.00002	.00000	-.00012
18FORBD	.00000	.00002	-.00006
19FORBA	-.00001	.00007	-.00033
20FORBB	-.00001	.00001	-.00005
21MISCD	.00001	-.00001	-.00009
22SEDGA	-.00001	.00000	-.00006
23SEDGB	-.00000	-.00000	-.00004
24FORBF	-.00000	.00000	-.00001
25FORBE	-.00000	-.00000	.00001
26SEDGC	-.00000	-.00000	.00001
27MISCG	.00003	-.00010	-.00000
28MISCF	-.00000	.00000	-.00000
29MISCE	-.00000	-.00000	.00000
Variance	35685.70355	8898.15506	2670.92509
Percentage of Total Variance	68.64	17.11	5.14

Table 15. Continued.

c. Mean responses for each replicate on first three principal axes.

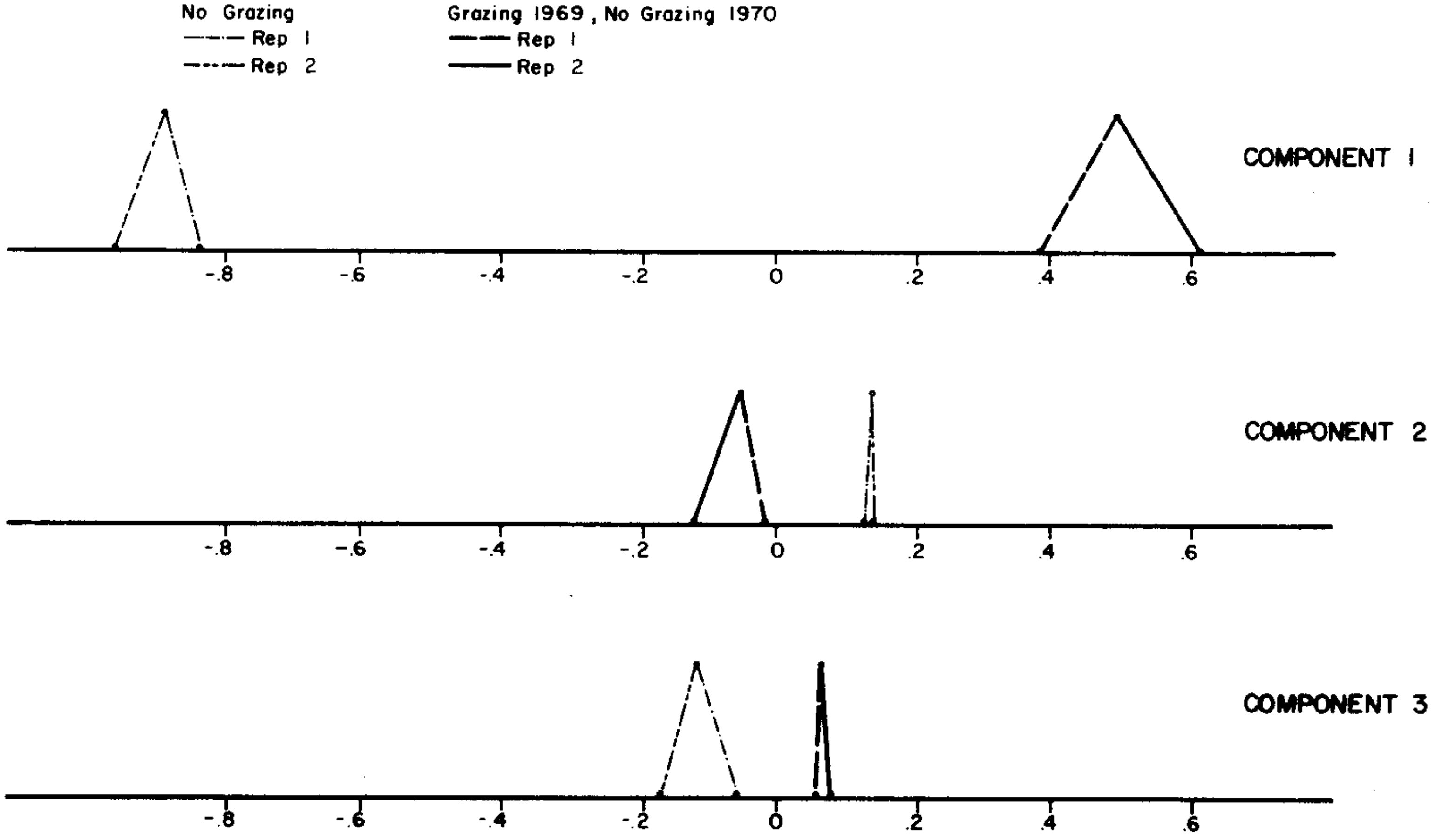

Table 16. 1970 Pantex Site--Principal Component Analysis 1--seven aboveground functional groups.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1CSG	10.508746	10.943566
2WSG	68.133823	36.024450
3CSF	10.021223	12.333778
4WSF	.244771	1.522527
5CSSU	.299664	4.167446
6WSSU	60.821988	192.980549
7OTH	1.046697	2.706485

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1CSG	-.00005	-.00295	.01399
2WSG	.00002	-.02746	-.00139
3CSF	.00001	-.00003	-.07915
4WSF	-.00001	.00002	.00030
5CSSU	.00000	.00000	.00123
6WSSU	-.00518	-.00007	-.00032
7OTH	-.00000	-.00016	-.00477
Variance	37246.22341	1311.118028	154.14345
Percentage of Total Variance	95.90	3.38	0.39

Table 16. Continued.

c. Mean responses for each replicate on first three principal axes.

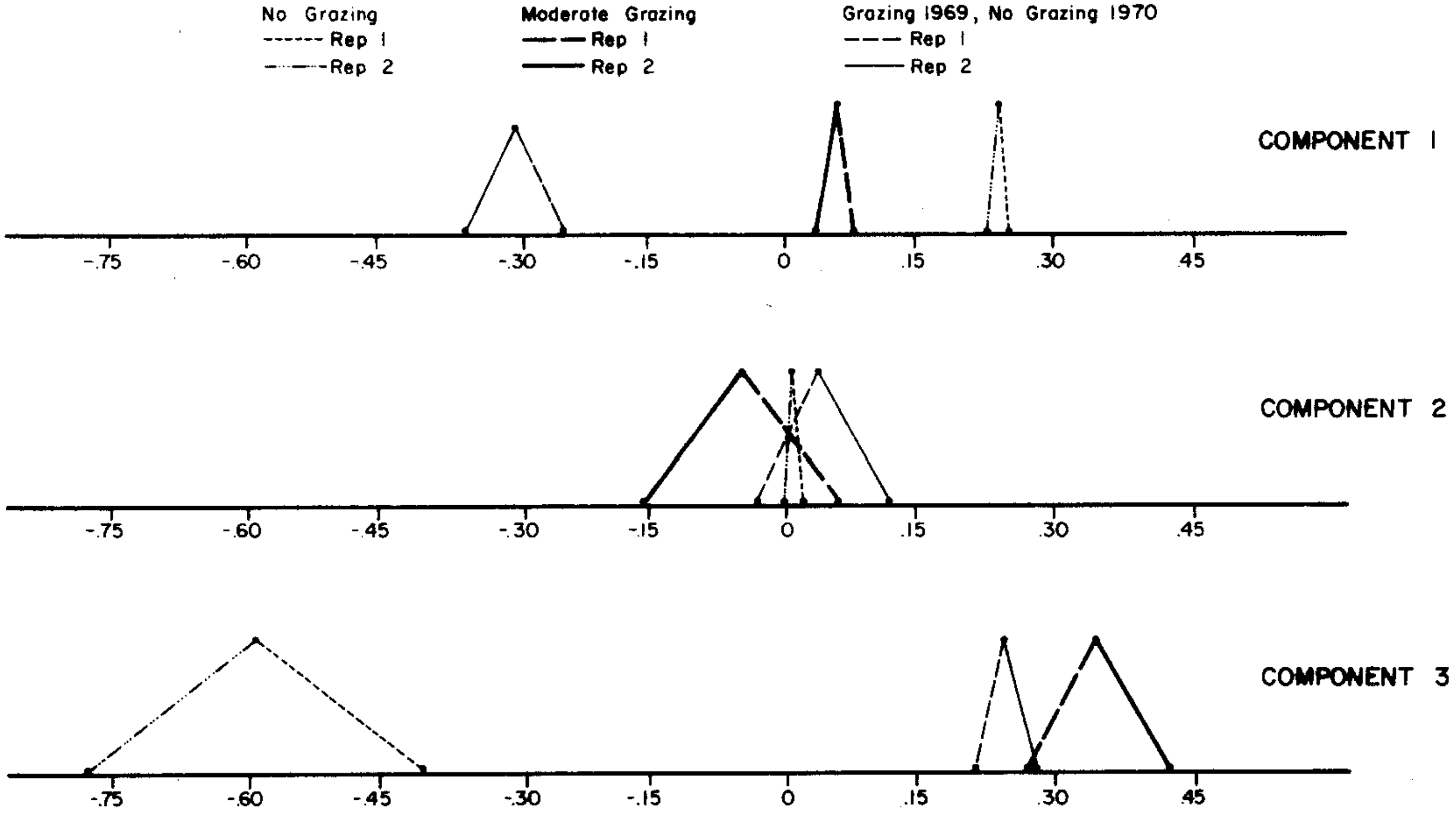

Table 17. 1970 Pantex Site--Principal Component Analysis 2--17 aboveground species.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1LEPI	1.540245	9.305867
2BOBU+	7.466483	23.909047
3HOPU	10.511560	10.945115
4FORB2	.135260	1.022993
5LEP2	.018012	.212347
6OPU	60.823394	192.981588
7FORB1	.476911	1.971536
8LEP	7.402813	10.117220
9SPCO	.244862	1.523261
10FORB3	.023945	.282373
11RAT	.104281	.930368
12PLPU	.062355	.500098
13BOGR	59.382783	40.716185
14BUDA	1.292813	5.316764
15PUPL	.004465	.080738
16FORB	.302202	1.442473
17MAM	.299755	4.168125

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1LEPI	-.00001	-.00013	-.00802
2BOBU+	-.00001	-.00779	-.04389
3HOPU	.00005	.00159	-.00730
4FORB2	.00000	-.00004	-.00018
5LEP2	-.00000	-.00002	-.00009
6OPU	.00518	-.00005	-.00003
7FORB1	-.00000	.00015	-.00034
8LEP	-.00000	-.00034	.00534
9SPCO	.00001	-.00002	-.00003
10FORB3	-.00000	-.00000	.00002
11RAT	-.00000	.00003	-.00012
12PLPU	.00000	.00001	-.00001
13BOGR	.00000	.02201	-.01496
14BUDA	-.00001	-.00027	.00202
15PUPL	-.00000	.00000	-.00001
16FORB	-.00000	-.00001	.00036
17MAM	-.00000	.00004	.00009
Variance	37246.42344	1825.29014	434.65439
Percentage of Total Variance	93.50	4.58	1.09

Table 17. Continued.

c. Mean responses for each replicate on first three principal axes.

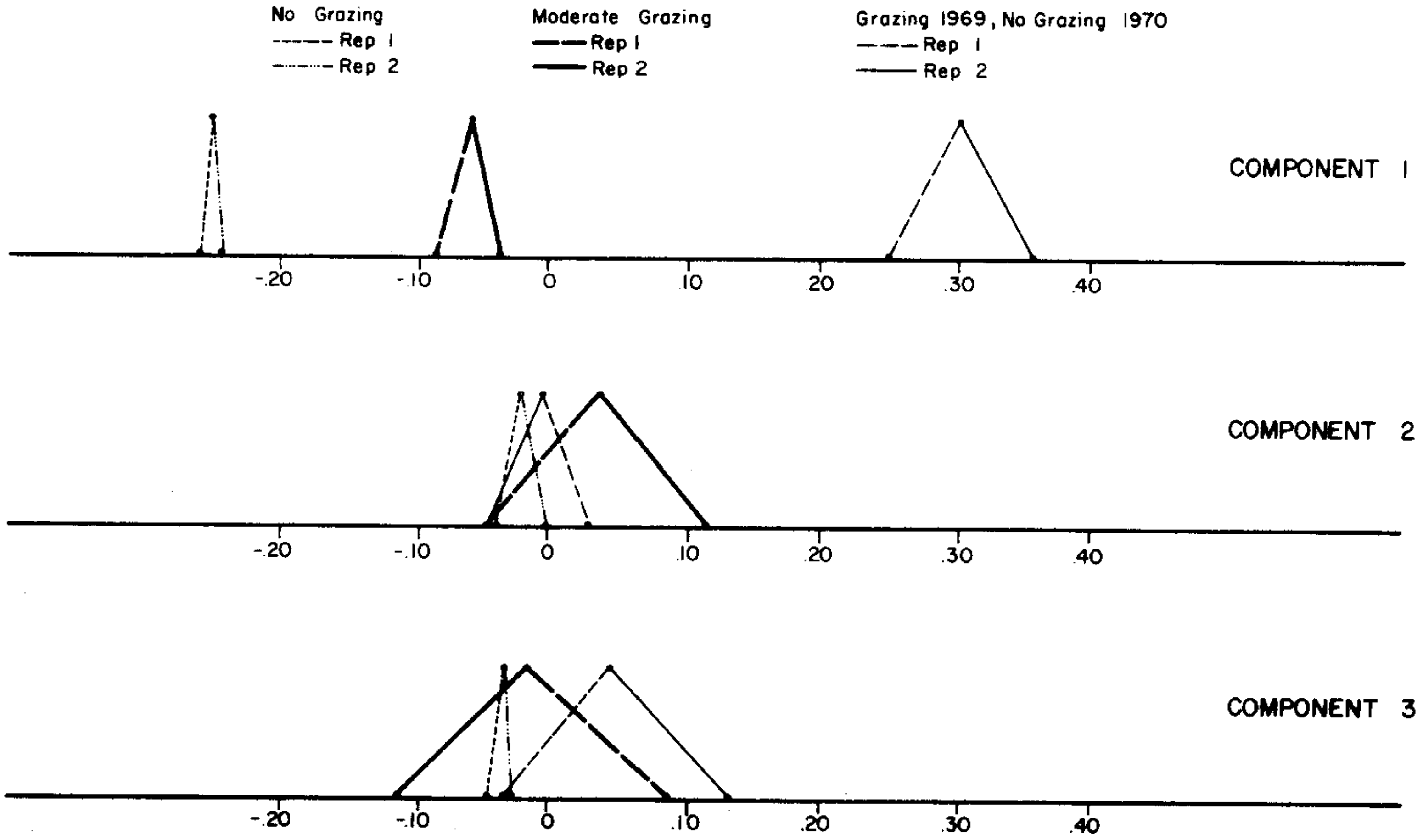

Table 18. 1970 Hays Site--Principal Component Analysis 1--eight aboveground categories.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1CSG	3.332901	17.556093
2WSG	148.731870	79.482027
3CSSH	.120916	.949603
4WSSH	1.990000	6.764728
5CSF	.884847	1.980667
6WSF	21.113588	28.028321
7CSSU	.011870	.192136
8OTH	.949466	3.856906

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1CSF	-.00011	-.00057	.11397
2WSG	-.01258	.00031	-.00099
3CSSH	-.00000	.00002	-.00004
4WSSH	.00002	.00068	-.00145
5CSF	-.00000	.00043	-.00102
6WSF	.00011	.03566	.00189
7CSSU	.00000	.00000	-.00001
8OTH	.00004	.00038	-.00110
Variance	6318.34140	786.78616	307.72630
Percentage of Total Variance	84.51	10.51	4.11

Table 18. Continued.

c. Mean responses for each replicate on first three principal axes.

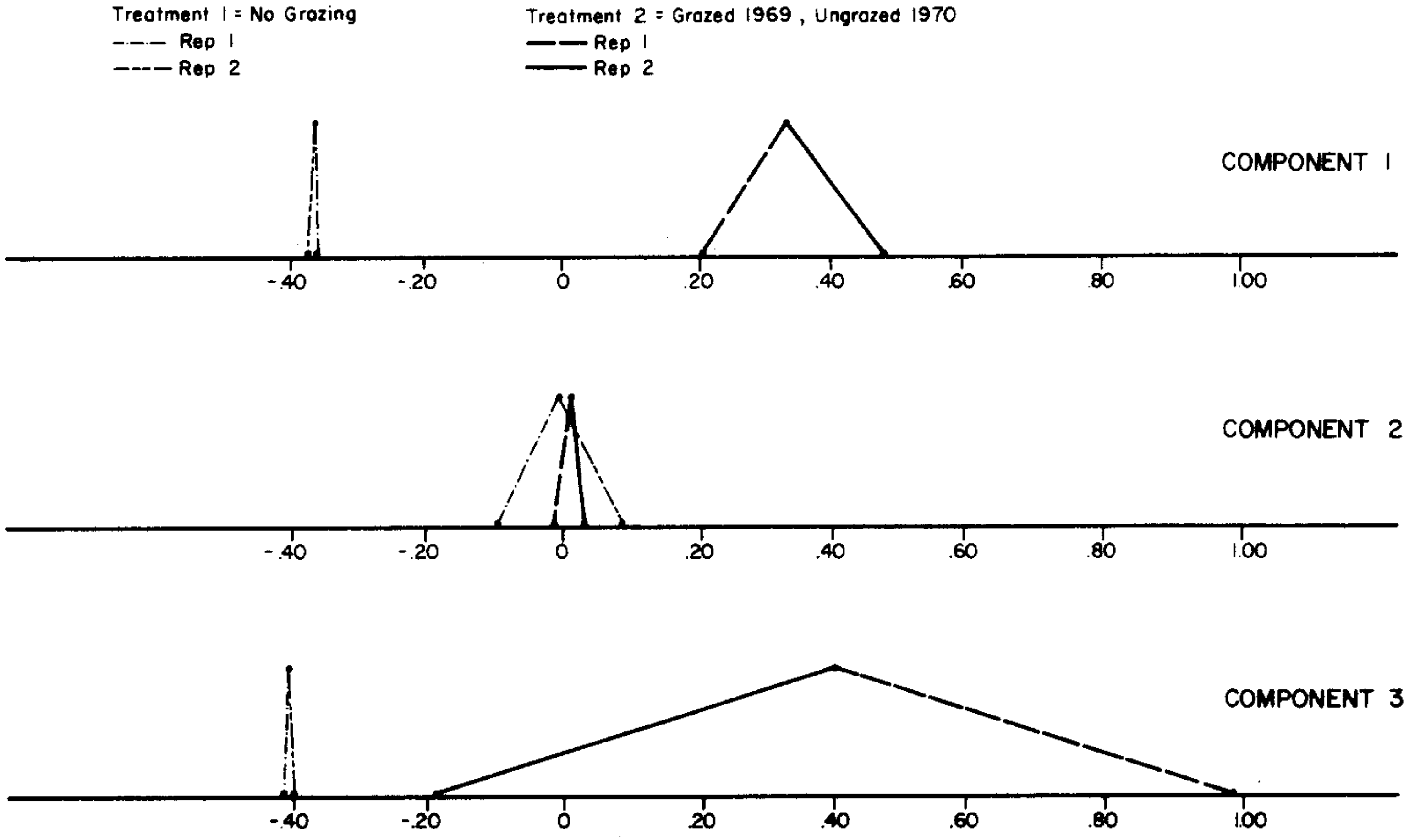

Table 19. 1970 Hays Site--Principal Component Analysis--92 aboveground species.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1ANGE	57.006374	69.689647
2BOCU	41.072023	46.362473
3SORI	1.430992	5.776380
4ANSC	21.832443	48.543423
5PAVI	2.777137	12.692180
6BOGR	11.558779	24.808782
7BUDA	4.573359	12.559663
8ARLO	4.136069	12.113454
9SONU	5.668969	24.683498
10OESE	.719504	2.297693
11SPAS	.108740	1.376141
12GUSA	1.041832	4.009062
13TEST	.057214	.696056
14HOAN	.311565	2.239032
15MOUN	.098015	.685262
16ECAN	.752481	1.828556
17CIUN	.604351	2.766061
18AMPS	1.602443	4.413438
19BRJA	2.414122	16.123973
20SOMI	.520496	1.758709
21ASAR	.189427	1.460892
22LIPU	.171412	1.074825
23SCRE	.187786	.960655
24AMCA	.949198	5.604295
25ASOB	.273092	1.407570
26CAGR	.003817	.061780
27RACO	.350611	1.150357
28SOMO	.227634	1.619258
29AGSM	.910687	5.336617
30ASMU	.576145	1.694054
31PSTE	10.505305	22.209733
32STLI	.188855	1.713249
33ASFE	.008893	.126706
34PSES	.000992	.016063
35THGR	.279389	1.186600
36SCUN	1.998206	5.527791
37ASVI	.006641	.093466
38SPPI	.209580	1.536301
39GACO	.019198	.145499
40CHVI	.107481	1.383781
41SIHY	.008473	.096831
42EUMA	.015153	.149491
43GRSQ	.297977	1.592765
44ARPU	.005382	.087110
45MEOF	.042786	.412228
46PEPU	.003626	.045882
47SEPL	.050649	.371167

Table 19. Continued.

a. (Continued)

Variable	Mean	Standard Deviation
48SEUN	.031565	.510922
49PAJA	.008969	.127069
50HOPU	.000153	.002471
51HEHI	.000153	.002471
52SPCR	.007557	.080302
53ERRA	.116527	1.016042
54MACO	.003779	.057508
55PSCU	.019542	.316315
56ASPU	.000687	.008986
57EVPI	.002061	.023948
58VEBI	.002366	.035908
59MEOP	.000076	.001236
60ASMO	.000687	.011120
61AMSA	.002786	.045100
62STLT	.000076	.001236
63AMEA	.001718	.027801
64STCI	.003893	.063016
65YUGL	.116908	.949214
66TRRA	.066260	.612813
67LYJU	.007328	.118618
68ONOC	.007023	.113676
69CASP	.016794	.243335
70CAIN	.013702	.156706
71VEST	.004427	.055821
72MEAL	.036947	.307090
73LEER	.234695	1.552939
74BOHI	.255229	2.475713
75SISP	.031565	.300349
76HEAN	.034198	.320480
77OEFR	.003817	.061780
78CIOC	.001450	.023476
79OXST	.007252	.116149
80LECA	.008855	.142095
81KYGL	.005420	.087728
82RHGL	.001374	.022241
83SEPL	.001069	.017298
84POAL	.004656	.075372
85SPSI	.007405	.118620
86OELA	.035534	.292973
87HEMA	.107824	1.745291
88OPMA	.015458	.250210
89MESP	.025573	.317134
90ARTE	.011870	.192136
91LEOV	.020534	.305176
92TRPR	.006221	.100702

Table 19. Continued.

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1ANGE	.01305	.00408	-.00547
2BOCU	-.00421	.00879	-.02038
3SORI	.00021	.00007	.00015
4ANSC	.00080	-.01662	-.01197
5PAVI	.00024	-.00001	.00034
6BOGR	-.00138	.00120	.00381
7BUDA	-.00050	.00049	.00153
8ARLO	-.00032	.00075	.00004
9SONU	.00005	-.00182	.00052
10OESE	.00003	-.00007	.00008
11SPAS	-.00002	.00003	-.00006
12GUSA	-.00006	.00015	.00012
13TEST	-.00000	-.00004	-.00000
14HOAN	-.00001	-.00001	.00001
15MOUN	.00000	-.00000	.00004
16ECAN	.00001	-.00012	-.00002
17CIUN	.00001	-.00015	-.00002
18AMPS	-.00009	.00029	-.00010
19BRJA	-.00046	.00099	-.00211
20SOMI	-.00000	.00002	.00004
21ASAR	-.00002	.00002	.00003
22LIPU	-.00000	-.00003	.00000
23SCRE	-.00000	-.00005	.00001
24AMCA	.00001	-.00052	-.00027
25ASOB	-.00000	-.00004	.00005
26CAGR	-.00000	.00000	.00000
27RACO	-.00003	.00006	.00001
28SOMO	-.00001	.00000	.00009
29AGSM	-.00009	.00013	.00014
30ASMU	-.00004	.00001	-.00002
31PSTE	-.00016	.00050	.00019
32STLI	-.00000	-.00004	-.00001
33ASFE	-.00000	-.00000	.00000
34PSES	.00000	-.00000	.00000
35THGR	.00000	-.00006	.00001
36SCUN	.00019	-.00033	-.00001
37ASVI	-.00000	.00000	.00000
38SPPI	-.00001	-.00011	-.00010
39GACO	-.00000	-.00001	-.00000
40CHVI	-.00002	.00002	.00001
41SIHY	-.00000	.00000	-.00000

Table 19. Continued.

b. (Continued)

Variable	Component Coefficients		
	1	2	3
42EUMA	-.00000	.00000	-.00001
43GRSO	-.00001	.00005	.00004
44ARPU	-.00000	-.00000	.00000
45MEOF	.00001	-.00001	.00001
46PEPU	.00000	-.00001	.00001
47SEPL	.00000	.00001	.00001
48SEUN	.00000	-.00001	.00001
49PAJA	-.00000	-.00001	-.00000
50HOPU	0.00000	0.00000	0.00000
51HEHI	.00000	.00000	.00000
52SPCR	-.00000	.00000	.00000
53ERRA	.00000	.00002	.00000
54MACO	-.00000	.00000	-.00000
55PSCU	-.00000	.00000	-.00000
56ASPU	-.00000	.00000	.00000
57EVPI	.00000	.00000	.00000
58VEBI	-.00000	.00000	.00000
59MEOP	.00000	-.00000	.00000
60ASMO	0.00000	0.00000	0.00000
61AMSA	.00000	.00000	.00000
62STLT	0.00000	0.00000	0.00000
63AMEA	.00000	.00000	.00000
64STCI	.00000	-.00000	-.00000
65YUGL	-.00001	-.00003	-.00004
66TRRA	-.00000	.00000	-.00000
67LYJU	-.00000	.00000	.00000
68ONOC	-.00000	.00000	-.00000
69CASP	-.00000	.00001	-.00001
70CAIN	-.00000	.00000	-.00000
71VEST	.00000	.00000	.00000
72MEAL	.00000	-.00001	-.00000
73LEER	.00001	.00003	.00003
74BOHI	.00004	.00003	.00002
75SISP	.00000	.00000	.00001
76HEAN	-.00000	-.00001	-.00001
77OEFR	.00000	-.00000	-.00000
78CIOC	.00000	.00000	.00000
79OXST	.00000	.00000	.00000
80LECA	.00000	.00000	.00000
81KYGL	-.00000	.00000	.00000
82RHGL	-.00000	.00000	.00000

Table 19. Continued.

b. (Continued)

Variable	Component Coefficients		
	1	2	3
83SFPL	.00000	.00000	.00000
84POAL	.00000	.00000	.00000
85SPSI	-.00000	.00000	.00000
86OELA	.00000	-.00000	.00000
87HEMA	.00001	.00000	.00005
88OPMA	-.00000	.00000	.00000
89MESP	.00001	.00000	-.00001
90ARTE	-.00000	-.00000	.00001
91LEOV	-.00000	-.00000	.00001
92TRPR	-.00000	.00000	-.00000
Variance	5226.39892	2649.25605	1638.58932
Percentage of Total Variance	43.44	22.01	13.62

Table 19. Continued.

c. Mean responses for each replicate on first three principal axes.

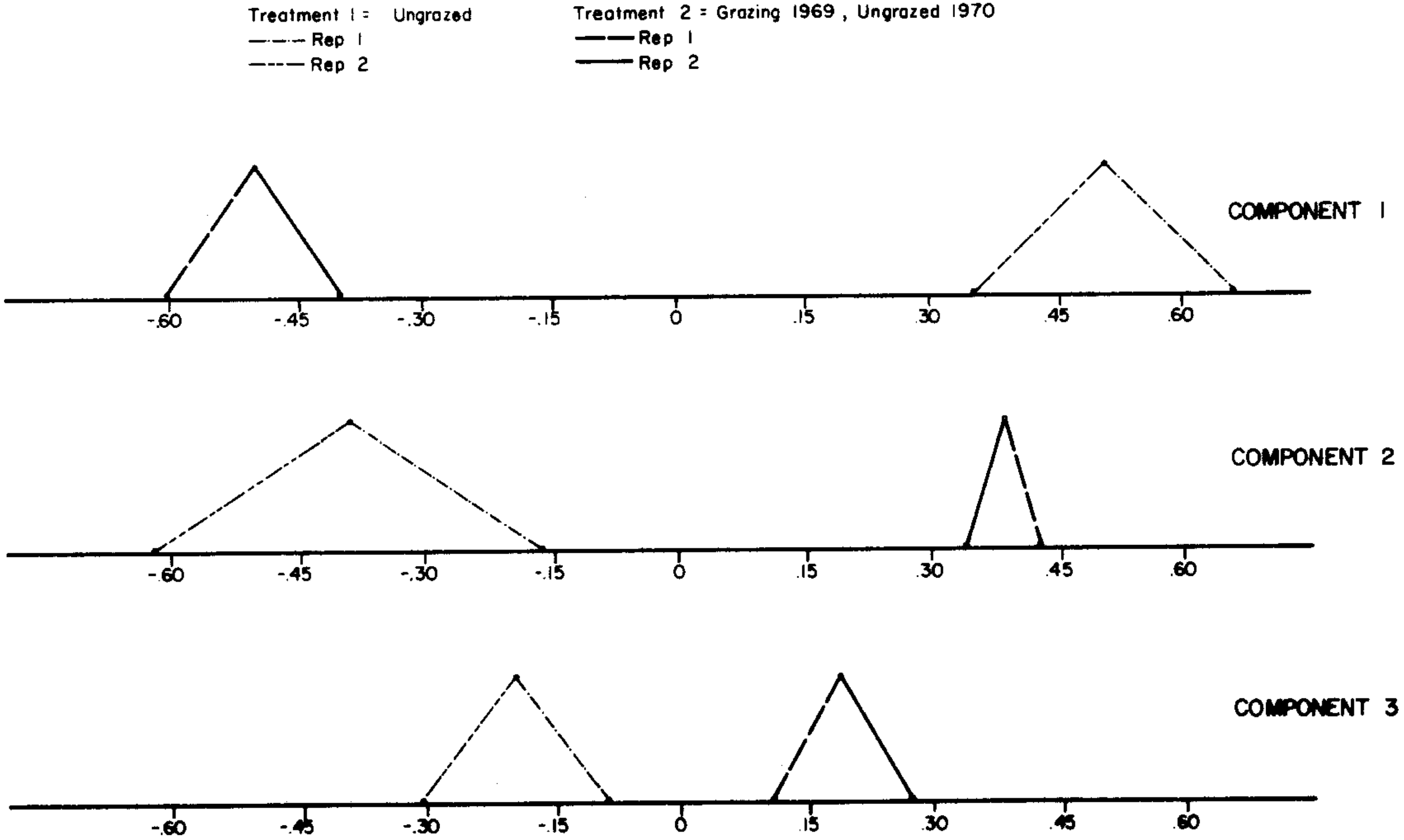

Table 20. 1970 Cottonwood Site--Principal Component Analysis 1--seven aboveground categories.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1CSG	81.770888	84.430271
2WSG	98.515306	54.451054
3WSSH	.380868	2.870299
4CSF	2.514398	4.895417
5WSF	.384576	3.666020
6CSSU	1.343136	8.403105
7OTH	.288383	6.187968

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1CSG	.00969	-.01123	.00047
2WSG	-.00484	-.02248	.00303
3WSSH	.00003	.00014	.00020
4CSF	.00017	-.00031	.00020
5WSF	.00002	-.00025	.00097
6CSSU	-.00008	-.00062	-.12004
7OTH	.00006	.00005	-.00032
Variance	8515.53443	1582.13985	69.28179
Percentage of Total Variance	83.10	15.43	0.68

Table 20. Continued.

c. Mean responses for each replicate on first three principal axes.

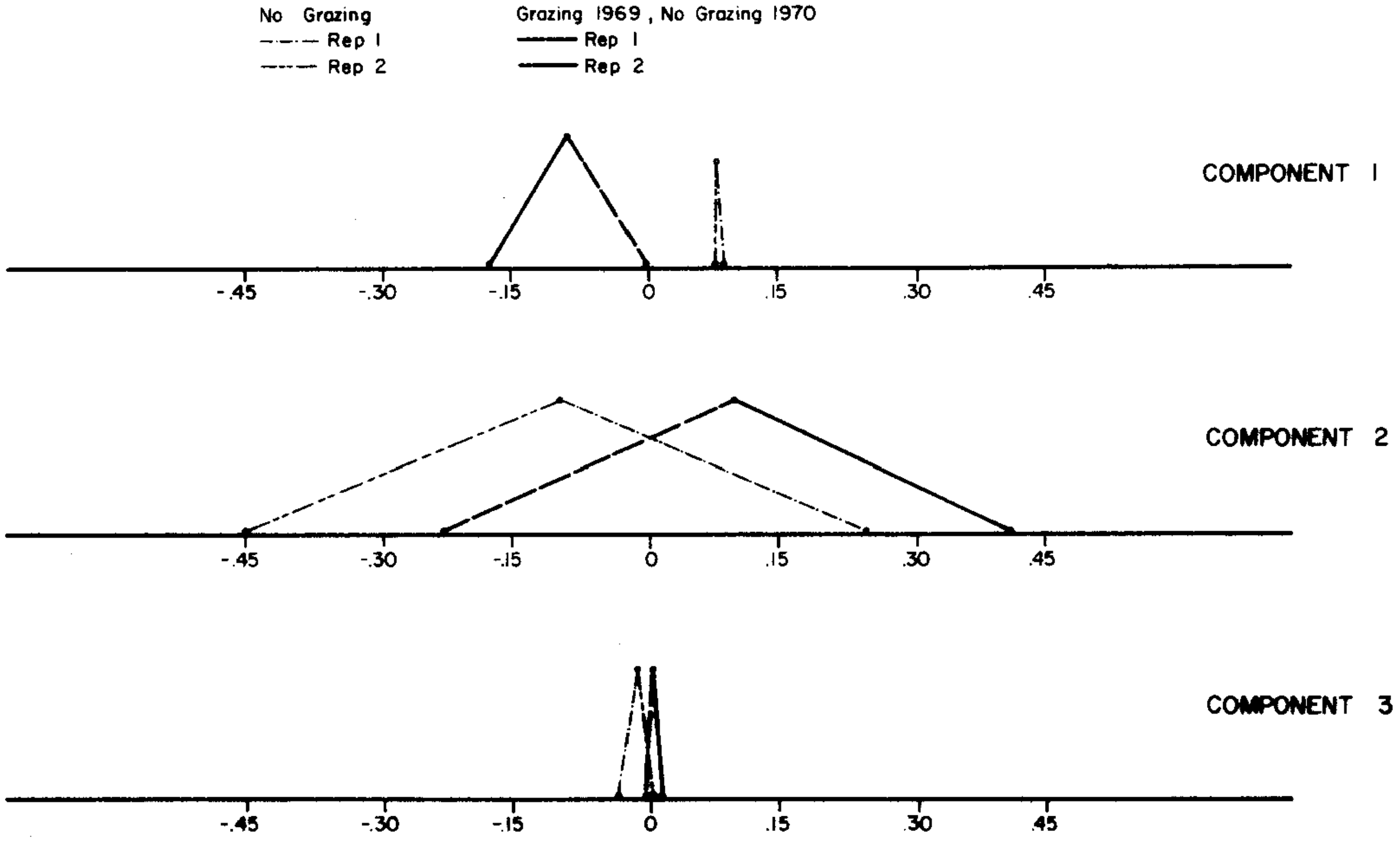

Table 21. 1970 Cottonwood Site--Principal Component Analysis 2 --28 aboveground species.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1AGSM	68.461736	75.530546
2BOGR	21.313215	18.707385
3BRJA	7.462722	11.009025
4BUDA	77.202327	52.583361
5CAEL	4.915582	5.107217
6LOOR	.043314	.419885
7MISC	.009112	.205181
8TRBR	.067574	.602973
9TRPR	.325937	1.844595
10SPCO	1.709191	3.919905
11VIAM	.348284	1.568618
12GUSA	.011578	.260696
13ACLA	.222446	3.316885
14ERAS	.021834	.288885
15POSE	.133156	2.364899
16OPFR	1.084536	7.754849
17OPPO	.259172	3.324060
18FEOC	.003708	.083494
19ARFR	.381026	2.871255
20FMUL	.279290	6.185421
21GRSQ	.060020	1.119652
22PSTE	.027890	.627979
23STVI	.786075	6.061646
24LIPU	.018205	.290580
25ARLU	.019270	.308862
26PSCU	.025306	.569800
27BRJA	.025030	.438275
28SPCR	.022110	.497854

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Table 21. Continued.

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1AGSM	.01013	-.01403	.00062
2BOGR	.00013	.00130	.05343
3BRJA	.00081	-.00089	.00059
4BUDA	-.00589	-.02425	.00235
5CAEL	.00011	-.00081	.00231
6LOOR	.00000	.00001	-.00008
7MISC	.00000	.00000	-.00001
8TRBR	.00000	-.00000	.00010
9TRPR	.00003	-.00008	-.00004
10SPCO	.00018	-.00024	.00116
11VIAM	-.00004	.00012	.00010
12GUSA	-.00000	-.00001	.00002
13ACLA	.00003	-.00020	-.00016
14ERAS	.00000	.00001	-.00001
15POSE	-.00001	.00014	-.00036
16OPFR	-.00011	-.00078	.00130
17OPPO	.00002	.00012	.00064
18FEOC	-.00000	.00000	.00001
19ARFR	.00004	.00009	-.00079
20FMUL	.00007	-.00002	-.00050
21GRSQ	-.00001	-.00015	.00010
22PSTE	.00000	-.00003	-.00008
23STVI	.00016	-.00052	.00039
24LIPU	.00000	-.00001	.00001
25ARLU	.00000	-.00000	-.00005
26PSCU	.00000	.00000	-.00004
27BRJA	.00000	.00002	-.00005
28SPCR	-.00000	-.00000	-.00002
Variance	7248.54520	1266.99748	348.25038
Percentage of Total Variance	79.11	13.83	3.80

Table 21. Continued.

c. Mean responses for each replicate on first three principal axes.

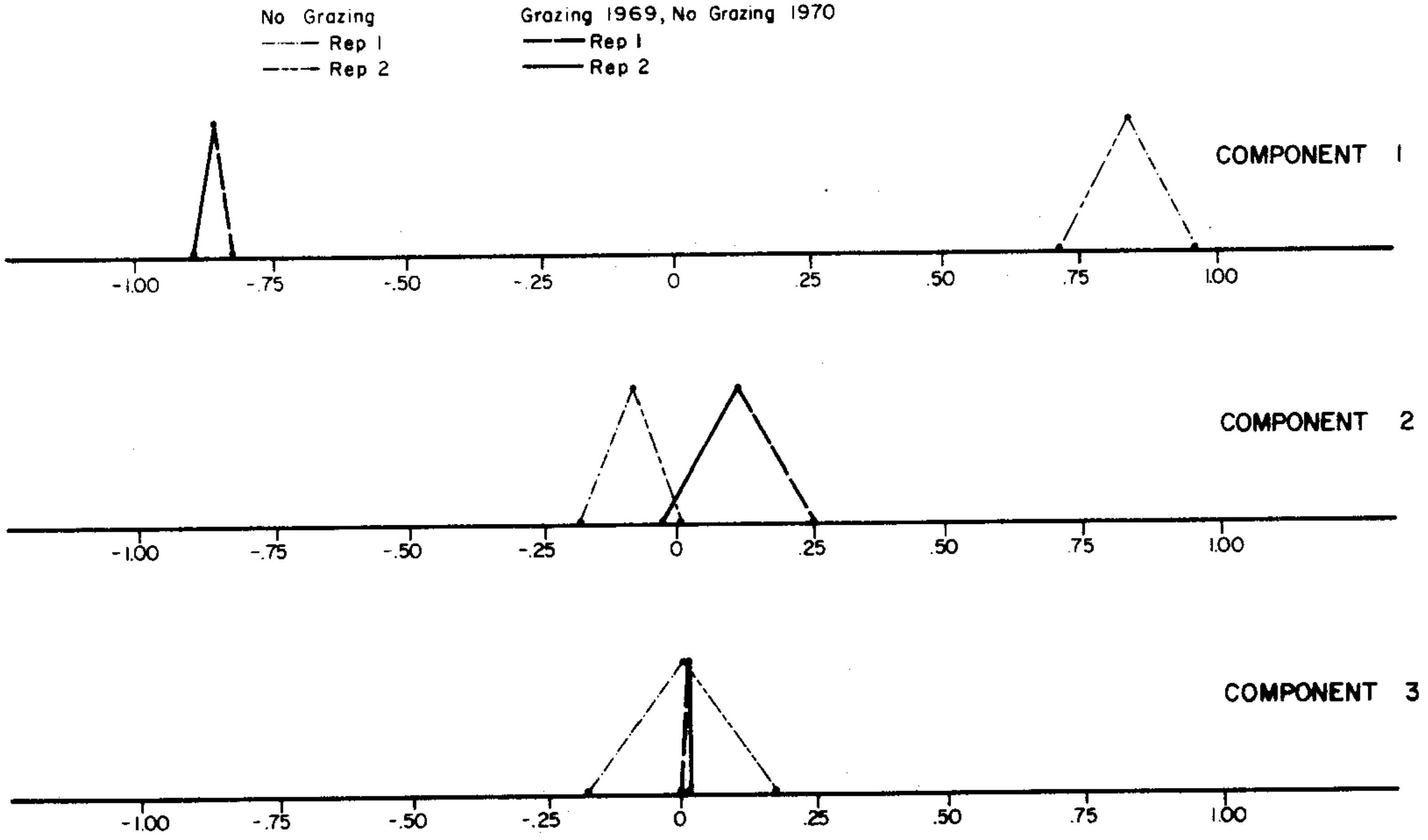


Table 22. 1970 Bridger Site--Principal Component Analysis 1--three aboveground functional groups.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1CSG	63.464939	32.791452
2CSF	40.847247	26.004234
3OTH	9.341984	13.512937

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1CSG	.04785	.02290	.00743
2CSF	.02753	-.03933	.00781
3OTH	-.00734	.00177	.07769
Variance	1289.43852	482.12947	162.53104
Percentage of Total Variance	66.67	24.93	8.40

Table 22. Continued.

c. Mean responses for each replicate on first three principal axes.

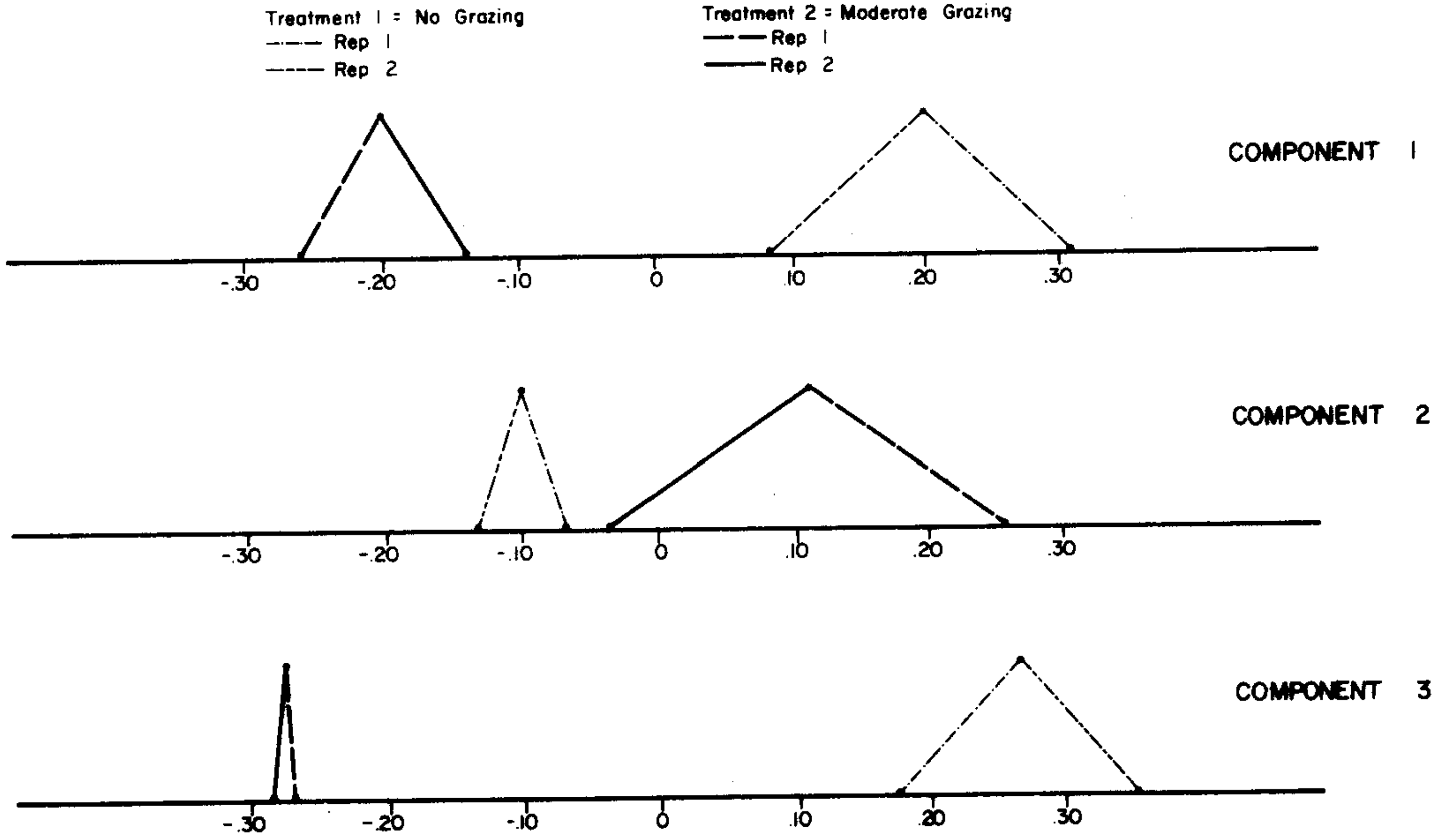


Table 23. 1970 Bridger Site--Principal Component Analysis 2--18 aboveground species--Standing dead included.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1FEID	30.802915	17.002125
2MIGR	10.991093	10.520628
3LUAR	12.763401	15.621381
4ERSP	.921862	3.085951
5ARCO	2.833441	3.266633
6AGSU	13.915830	18.406347
7ACMI	2.456478	2.535782
8MIFB	18.410648	13.051404
9STDEAD	9.343563	13.514921
10KOCR	.901700	1.889130
11DAIN	6.043360	6.873412
12AGGL	.770040	2.027390
13CEAR	1.271660	2.964748
14GABO	.990891	4.060147
15AGGR	.422470	2.360060
16A6MI	.013036	.204884
17STRI	.510405	2.187139
18CASE	.309636	1.493731

Table 23. Continued.

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1FEID	-.02489	-.02810	.04162
2MIGR	-.00982	-.00693	-.00212
3LUAR	-.01693	-.02070	-.04518
4ERSP	-.00190	.00046	-.00050
5ARCO	-.00173	-.00266	-.00149
6AGSU	-.03262	.03902	.00410
7ACMI	-.00227	-.00091	.00001
8MIFB	-.01370	.00572	-.01858
9STDEAD	.01289	.01529	.01063
10KOCR	-.00131	-.00020	-.00011
11DAIN	-.00318	-.01026	.00059
12AGGL	-.00031	-.00069	.00012
13CEAR	-.00125	-.00081	-.00223
14GABO	-.00301	.00077	.00376
15AGGR	-.00124	.00094	.00098
16A6MI	-.00000	-.00003	.00003
17STRI	.00010	-.00062	.00010
18CASE	.00052	.00021	.00116
Variance	407.10021	315.28218	233.82369
Percentage of Total Variance	27.98	21.67	16.07

Table 23. Continued.

c. Mean responses for each replicate on first three principal axes.

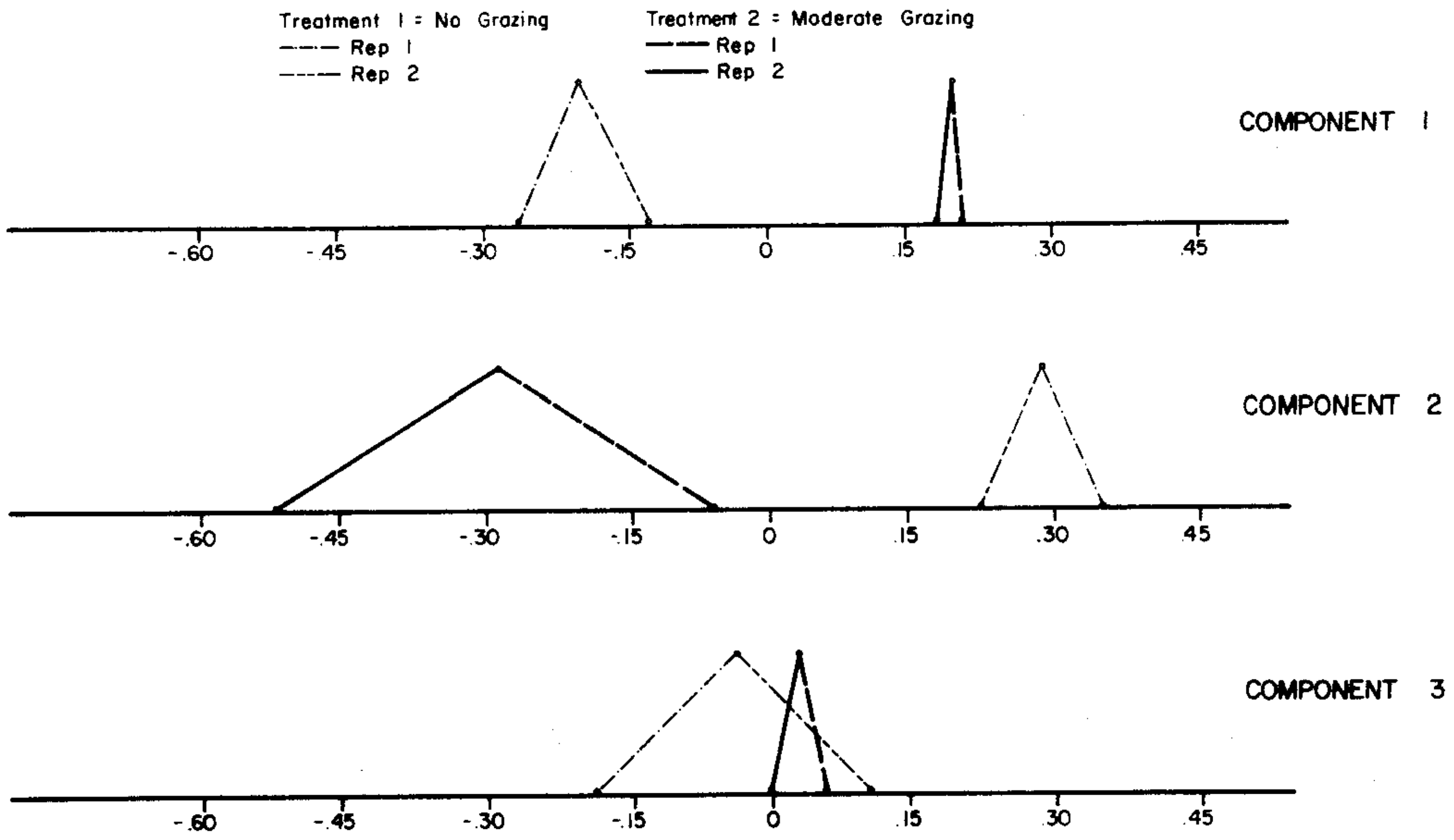


Table 24. 1970 Bridger Site--Principal Component Analysis 3--17 aboveground species--Standing dead excluded.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1FEID	30.802915	17.002125
2MIGR	10.991093	10.520628
3LUAR	12.763401	15.621381
4ERSP	.921862	3.085951
5ARCO	2.833441	3.266633
6AGSU	13.915830	18.406347
7ACMI	2.456478	2.535782
8MIFB	18.410648	13.051404
9KOCR	.901700	1.889130
10DAIN	6.043360	6.873412
11AGGL	.770040	2.027390
12CEAR	1.271660	2.964748
13GABO	.990891	4.060147
14AGGR	.422470	2.360060
15A6MI	.013036	.204884
16STRI	.510405	2.187139
17CASP	.309636	1.493731

Table 24. Continued.

b. Component coefficients.

Variable	Component coefficients		
	1	2	3
1FEID	-.02343	.03810	.03549
2MIGR	-.00828	.00690	-.00097
3LUAR	-.01475	.02386	-.05100
4ERSP	-.00199	-.00011	-.00063
5ARCO	-.00146	.00308	-.00196
6AGSU	-.03830	-.03331	.00568
7ACMI	-.00221	.00140	-.00024
8MIFB	-.01476	-.00341	-.02002
9KOCR	-.00131	.00045	-.00021
10DAIN	-.00166	.01046	.00024
11AGGL	-.00027	.00086	-.00005
12CEAR	-.00104	.00074	-.00220
13GABO	-.00307	-.00032	.00406
14AGGR	-.00136	-.00075	.00109
15A6MI	.00001	.00002	.00004
16STRI	.00015	.00067	-.00001
17CASP	.00042	-.00010	.00109
Variance	392.48034	301.86991	231.31022
Percentage of Total Variance	30.85	23.72	18.18

Table 24. Continued.

c. Mean responses for each replicate on first three principal axes.

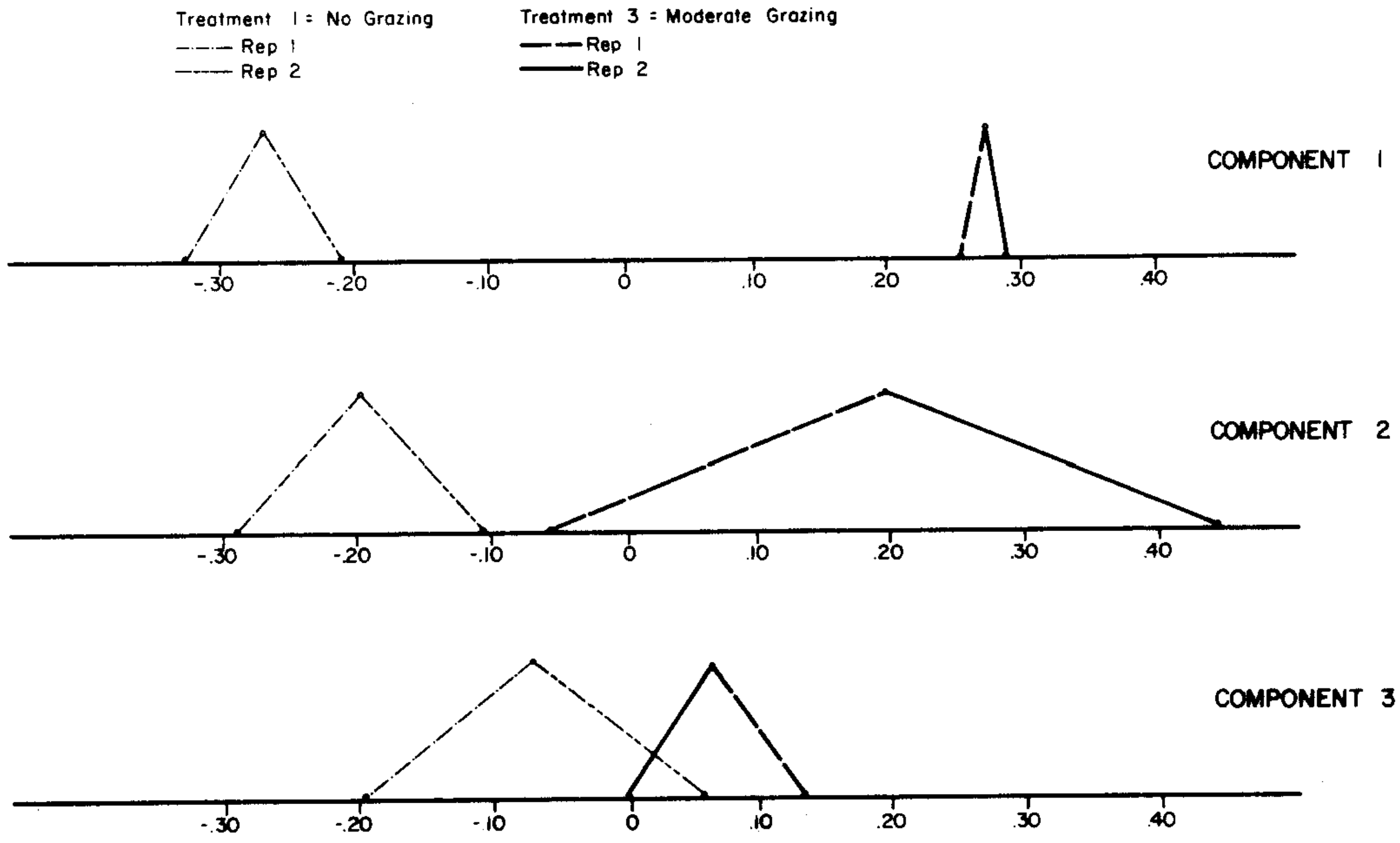


Table 25. 1970 Dickinson Site--Principal Component Analysis 1--seven aboveground categories.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1CSG	116.924337	63.935336
2WSG	41.907551	52.960906
3WSSH	.609898	3.543125
4CSF	7.947449	14.987748
5WSF	32.258265	48.631259
6CSSU	.022245	.311429
7OTH	186.221837	155.806397

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1CSG	-.00048	.01380	.00811
2WSG	.00027	.00538	-.01579
3WSSH	.00002	-.00001	-.00016
4CSF	-.00003	-.00015	.00017
5WSF	-.00032	.00377	-.00741
6CSSU	-.00000	-.00000	.00001
7OTH	-.00636	-.00100	-.00092
Variance	24490.69218	4263.35165	2695.44467
Percentage of Total Variance	72.52	12.62	7.99

Table 25. Continued.

c. Mean responses for each replicate on first three principal axes.

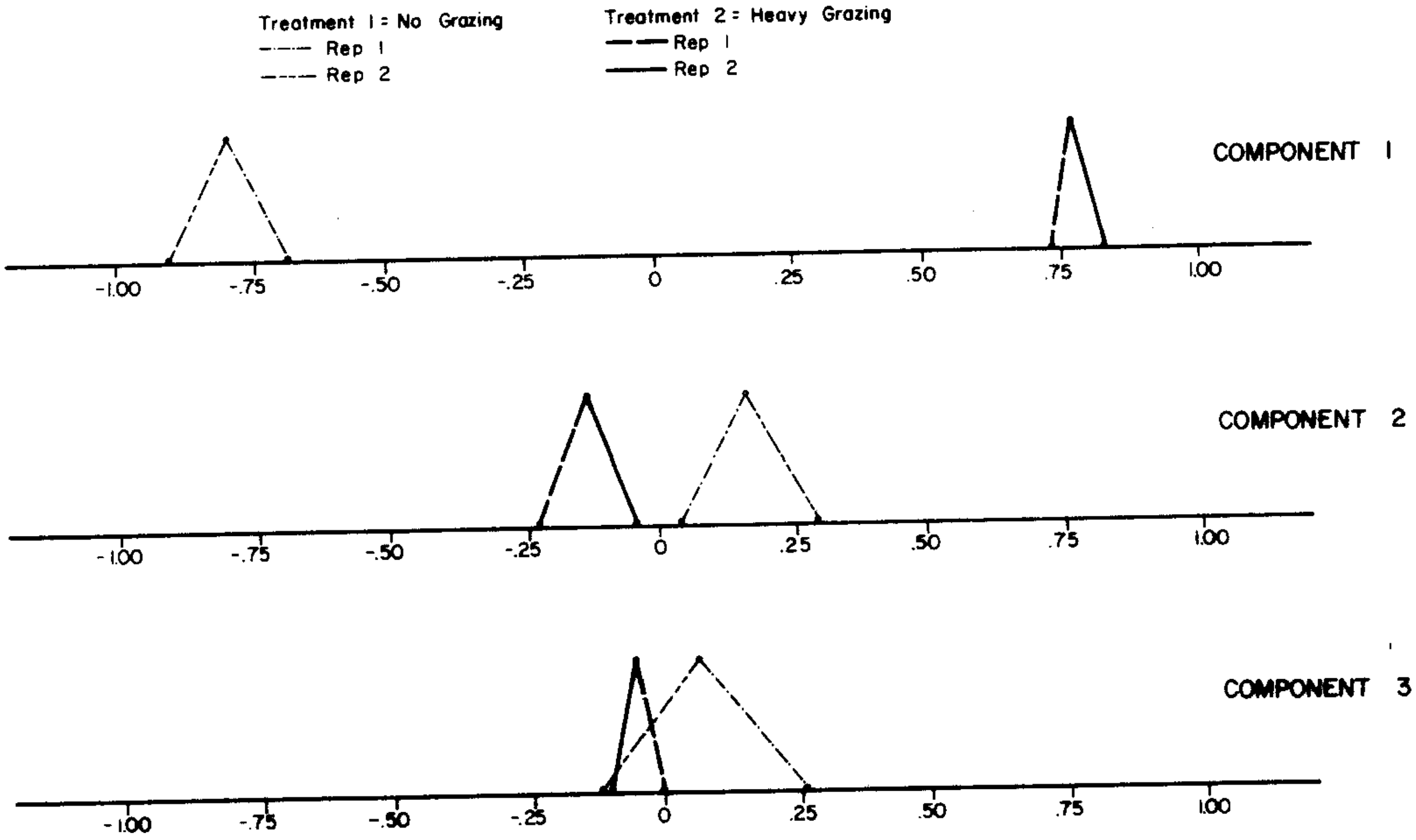


Table 26. 1970 Dickinson Site--Principal Component Analysis 2--63 aboveground species--Standing dead included.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1STDEAD	168.256939	168.015290
2STCO	68.033265	57.714049
3ARLO	.049388	.541309
4AGSM	18.446327	32.597283
5TROU	2.675918	5.748550
6CAEL	9.935714	10.961689
7FORB E	.103061	.709588
8BOGR	36.436735	45.113591
9ARLU	19.543673	45.498311
10CAMO	12.085918	22.999513
11SEDE	17.868571	28.902587
12KOCR	7.111429	13.447775
13FORB L	.034082	.301282
14ALTE	.069592	.390699
15COLI	.292653	1.997797
16LAFO	1.969796	11.765290
17EAFO 6	.103061	.494597
18EAFO	1.151837	9.451188
19OENU	.041020	.305073
20VINU	.130612	.739498
21CALO	5.430000	30.416392
22ASER	3.591429	16.208897
23POSE	.187755	1.336004
24CAFI	.260000	3.376547
25CAPE	.007347	.102857
26AGTR	.836735	5.715330
27CIUN	.057347	.663777
28SPCO	1.038163	2.676427
29GACO	.127551	.659734
30LAPU	.012449	.174286
31LASE	.184490	.977920
32ASSI	.471837	6.605714
33LOAM	.050000	.205858
34LIPU	1.833673	5.640366
35AFO6	.239592	2.473371
36EAFO4	.019592	.274286
37FEID	.045306	.447815
38PASR	.197959	1.361753
39CHLE	.027143	.197891
40LYJU	.474694	2.703356
41ECAN	.080000	.904961
42MAVI	.022245	.311429
43ROAR	.438367	3.196256
44EAFO 4	1.000204	2.303540
45LAFO 6	2.595306	5.665148
46ARFR	.610000	3.543595
47CIPU	.031837	.445714
48SOMO	.143878	1.240325

Table 26. Continued.

a. (Continued)

Variable	Mean	Standard Deviation
490XLA	.471224	4.119598
50CHVI	.179388	1.744037
51RACO	.083061	1.162857
52ARCA	.417755	5.609728
53EAFO 1	.003265	.045714
54EAAN 4	.020204	.200000
55POCO	.002653	.026892
56ERCA	.000204	.002857
57TAOF	.000612	.008571
58LOFO 6	.097959	1.371429
59PHHO	.009388	.131429
60APSP	.235918	2.479252
61SOMI	.033469	.468571
62PEPU	.031224	.437143
63CHAL	.009184	.128571

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1STDEAD	.00573	.00237	.00146
2STCO	.00066	-.01483	-.00880
3ARLO	.00000	.00002	-.00001
4AGSM	.00033	-.00208	.00090
5TRDU	.00007	-.00010	-.00017
6CAEL	-.00000	.00012	.00068
7FORB E	-.00000	.00003	-.00002
8BOGR	-.00038	-.00403	.01839
9ARLU	.00044	-.00611	.00960
10CAMO	-.00034	.00200	.00100
11SEDE	-.00051	.00193	-.00041
12KOCR	-.00018	.00080	.00021
13FORB L	-.00000	.00001	-.00001
14ALTE	.00000	.00002	.00000
15COLI	.00001	.00001	-.00009
16LAFO	-.00005	.00022	-.00024
17EAFO 6	-.00000	.00002	-.00002
18EAFO	-.00003	.00007	-.00010
19OENU	.00000	-.00000	-.00001
20VINU	.00001	.00002	.00000
21CALO	.00019	-.00065	.00087
22ASER	.00001	.00025	-.00046
23POSE	-.00001	-.00000	-.00002
24CAFI	-.00000	-.00001	-.00001

Table 26. Continued.

b. (Continued)

Variable	Component Coefficients		
	1	2	3
25CAPE	-.00000	.00000	-.00000
26AGTR	.00001	-.00021	.00004
27CIUN	.00000	.00001	-.00000
28SPCO	-.00001	-.00002	.00007
29GACO	.00000	.00000	-.00003
30LAPU	.00000	.00000	-.00000
31LASE	.00000	-.00004	-.00003
32ASST	.00000	.00008	-.00009
33LOAM	.00000	-.00001	-.00000
34LIPU	-.00002	.00002	-.00004
35EAF06	-.00001	.00005	-.00001
36EAF04	-.00000	.00000	-.00000
37FEID	-.00000	-.00000	.00000
38PASR	-.00000	-.00003	-.00004
39CHLE	.00000	-.00001	-.00001
40LYJU	-.00000	-.00005	.00005
41ECAN	.00000	.00001	-.00000
42MAVI	.00000	-.00000	-.00001
43ROAR	.00001	-.00009	-.00002
44EAFO 4	-.00003	.00006	.00015
45LAFO 6	-.00007	.00008	.00013
46ARFR	-.00002	-.00002	.00025
47CIPU	.00000	.00000	.00002
48SOMO	-.00000	.00000	.00000
49OXLA	-.00001	.00005	-.00009
50CHVI	-.00000	-.00002	-.00004
51RACO	.00000	-.00000	-.00002
52ARCA	-.00001	.00006	.00007
53EAFO 1	-.00000	.00000	.00000
54EAAN 4	-.00000	.00000	.00001
55POCO	.00000	-.00000	-.00000
56ERCA	.00000	-.00000	-.00000
57TAOF	.00000	-.00000	-.00000
58LOFO 6	-.00000	-.00001	-.00003
59PHHO	0.00000	0.00000	0.00000
60APSP	-.00001	.00001	-.00003
61SOMI	.00000	.00000	.00000
62PEPU	-.00000	.00000	.00001
63CHAL	.00000	-.00000	-.00001
Variance	29291.87194	3418.77841	1946.41956
Percentage of Total Variance	73.01	8.53	4.85

Table 26. Continued.

c. Mean responses for each replicate on first three principal axes.

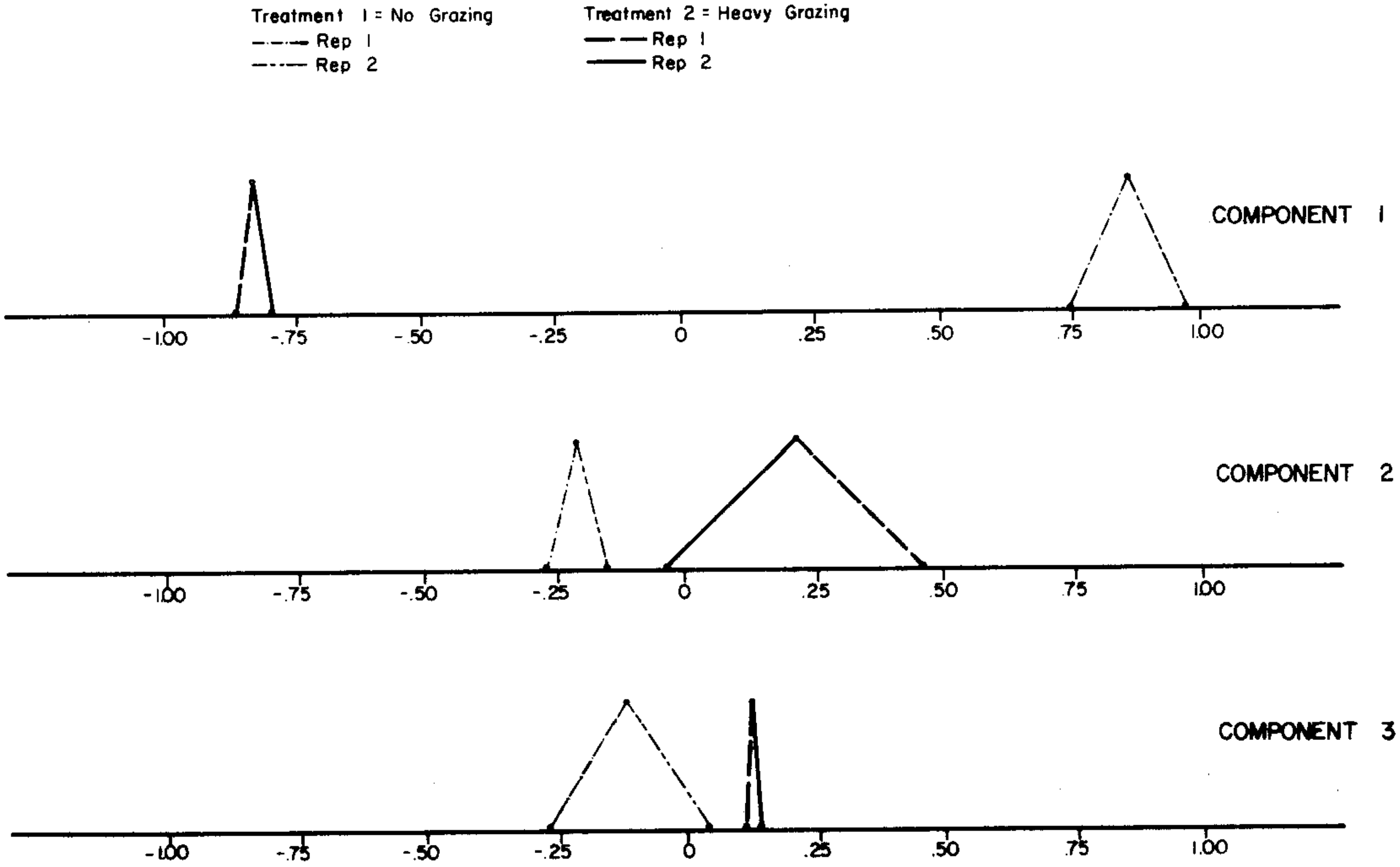


Table 27. 1970 Dickinson Site--Principal Component Analysis 3--62 aboveground species--Standing dead excluded.

a. Mean biomass values.

Variable	Mean	Standard Deviation
1STCO	68.033265	57.714049
2ARLO	.049388	.541309
3AGSM	18.446327	32.597283
4TROU	2.675918	5.748550
5CAEL	9.935714	10.961689
6FORB E	.103061	.709588
7BOGR	36.436735	45.113591
8ARLU	19.543673	45.498311
9CAMO	12.085918	22.999513
10SEDE	17.868571	28.902587
11KOCR	7.111429	13.447775
12FORB L	.034082	.301282
13ALTE	.069592	.390699
14COLI	.292653	1.997797
15LAFO	1.969796	11.765290
16EAFO 6	.103061	.494597
17EAFO	1.151837	9.451188
18OENU	.041020	.305073
19VINU	.130612	.739498
20CALO	5.430000	30.416392
21ASER	3.591429	16.208897
22POSE	.187755	1.336004
23CAFI	.260000	3.376547
24CAPE	.007347	.102857
25AGTR	.836735	5.715330
26CIUN	.057347	.663777
27SPCO	1.038163	2.676427
28GACO	.137551	.659734
29LAPU	.012449	.174286
30LASE	.184490	.977920
31ASST	.471837	6.605714
32LOAM	.050000	.205858
33LIPU	1.833673	5.640366
34EAFO6	.239592	2.473371
35EAFO4	.019592	.274286
36FEID	.045306	.447815
37PASR	.197959	1.361753
38CHLE	.027143	.197891
39LYJU	.474694	2.703356
40ECAN	.080000	.904961
41MAVI	.022245	.311429
42ROAR	.438367	3.196256
43EAFO 4	1.000204	2.303540
44LAFO 6	2.595306	5.665148
45ARFR	.610000	3.543595
46CIPU	.031837	.445714
47SOMO	.143878	1.240325

Table 27. Continued.

a. (Continued)

Variable	Mean	Standard Deviation
48OXLA	.471224	4.119598
49CHVI	.179388	1.744037
50RACO	.083061	1.162857
51ARCA	.417755	5.609728
52EAFO 1	.003265	.045714
53EAAN 4	.020204	.200000
54POCO	.002653	.026892
55ERCA	.000204	.002857
56TAOF	.000612	.008571
57LOFO 6	.097959	1.371429
58PHHO	.009388	.131429
59APSP	.235918	2.479252
60SOMI	.033469	.468571
61PEPU	.031224	.437143
62CHAL	.009184	.128571

b. Component coefficients.

Variable	Component Coefficients		
	1	2	3
1STCO	.01338	.00216	.00902
2ARLO	-.00001	.00002	-.00001
3AGSM	.00269	-.00095	.00441
4TROU	.00033	.00034	.00014
5CAEL	-.00012	-.00056	-.00006
6FORB E	-.00003	.00003	-.00002
7BOGR	.00050	-.02119	.00454
8ARLU	.00618	-.00433	-.02031
9CAMO	-.00277	-.00143	-.00059
10SEDE	-.00333	-.00140	.00111
11KOCR	-.00126	-.00066	.00025
12FORB L	-.00001	.00001	-.00001
13ALTE	-.00001	.00002	-.00002
14COLI	.00001	.00009	.00007
15LAFO	-.00037	-.00004	.00026
16EAFO 6	-.00002	.00003	-.00000
17EAFO	-.00017	-.00012	.00028
18OENU	.00001	.00001	.00001
19VINU	.00000	.00004	-.00005
20CALO	.00127	.00101	-.00508
21ASER	-.00009	.00081	-.00093
22POSE	-.00001	-.00000	.00003
23CAFI	.00002	.00005	-.00016

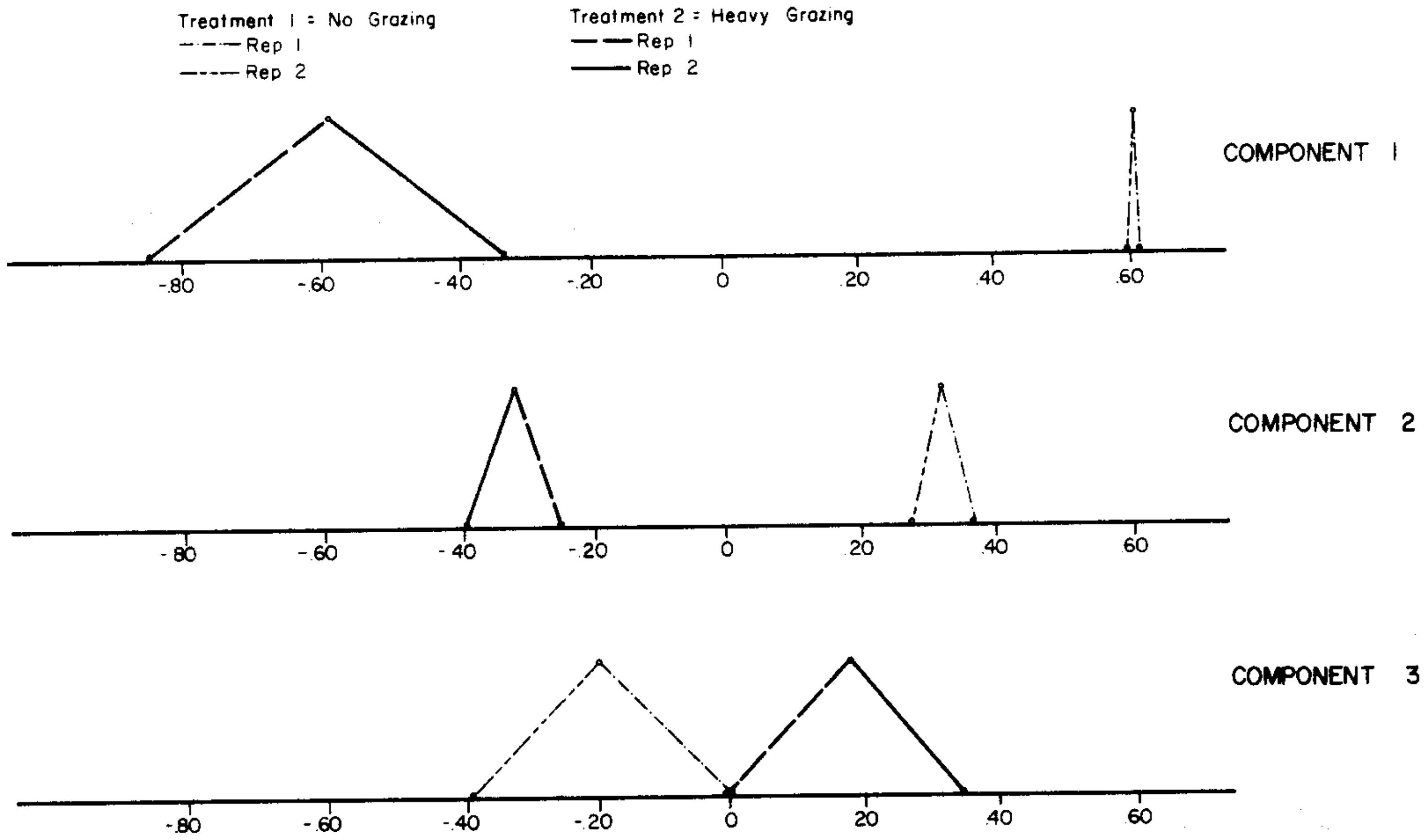
Table 27. Continued.

b. (Continued)

Variable	Component Coefficients		
	1	2	3
24CAPE	-.00000	-.00000	.00000
25AGTR	.00022	.00007	-.00050
26CIUN	.00000	.00002	-.00002
27SPCO	-.00002	-.00015	.00018
28GACO	.00001	.00003	.00003
29LAPU	-.00000	.00000	.00000
30LASE	.00004	.00004	-.00005
31ASST	-.00004	.00013	.00007
32LOAM	.00001	.00001	.00000
33LIPU	-.00010	-.00014	.00051
34EAF06	-.00006	.00001	-.00002
35EAF04	-.00001	-.00000	-.00000
36FEIO	-.00000	-.00001	.00001
37PASR	.00002	.00002	.00002
38CHLE	.00001	.00001	.00002
39LYJU	.00002	-.00011	.00017
40ECAN	.00000	.00002	.00001
41MAVI	.00000	.00001	.00001
42ROAR	.00010	.00007	-.00022
43EAFO 4	-.00015	-.00024	.00012
44LAFO 6	-.00031	-.00040	.00040
45ARFR	-.00005	-.00033	.00017
46CIPU	.00000	-.00001	-.00002
47SOMO	-.00001	-.00001	.00001
48OXLA	-.00006	.00004	.00008
49CHVI	.00000	.00001	.00003
50RACO	.00001	.00003	-.00001
51ARCA	-.00009	-.00007	-.00002
52EAFO 1	-.00000	-.00000	.00000
53EAAN 4	-.00000	-.00001	.00000
54POCO	.00000	.00000	.00000
55ERCA	.00000	.00000	.00000
56TAOF	.00000	.00000	.00000
57LOFO 6	.00000	.00001	.00003
58PHHO	0.00000	0.00000	0.00000
59APSP	-.00003	.00000	.00002
60SOMI	.00001	.00000	.00002
61PEPU	-.00001	-.00001	.00000
62CHAL	.00000	.00000	.00000
Variance	4045.86417	2082.80052	1775.58079
Percentage of Total Variance	34.03	17.52	14.93

Table 27. Continued.

c. Mean responses for each replicate on first three principal axes.



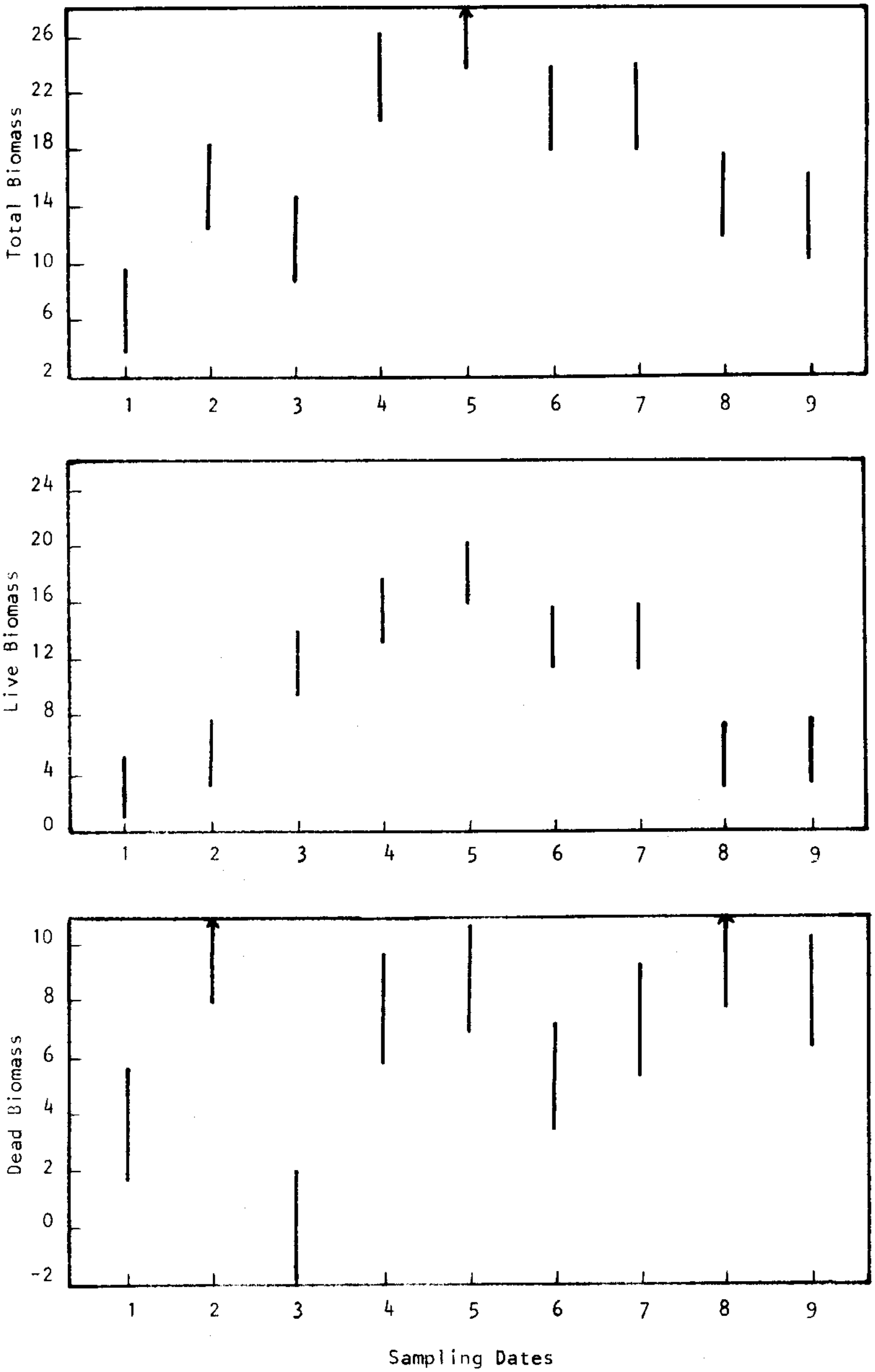


Fig. 1. Bison Site, individual comparisons of sampling dates.

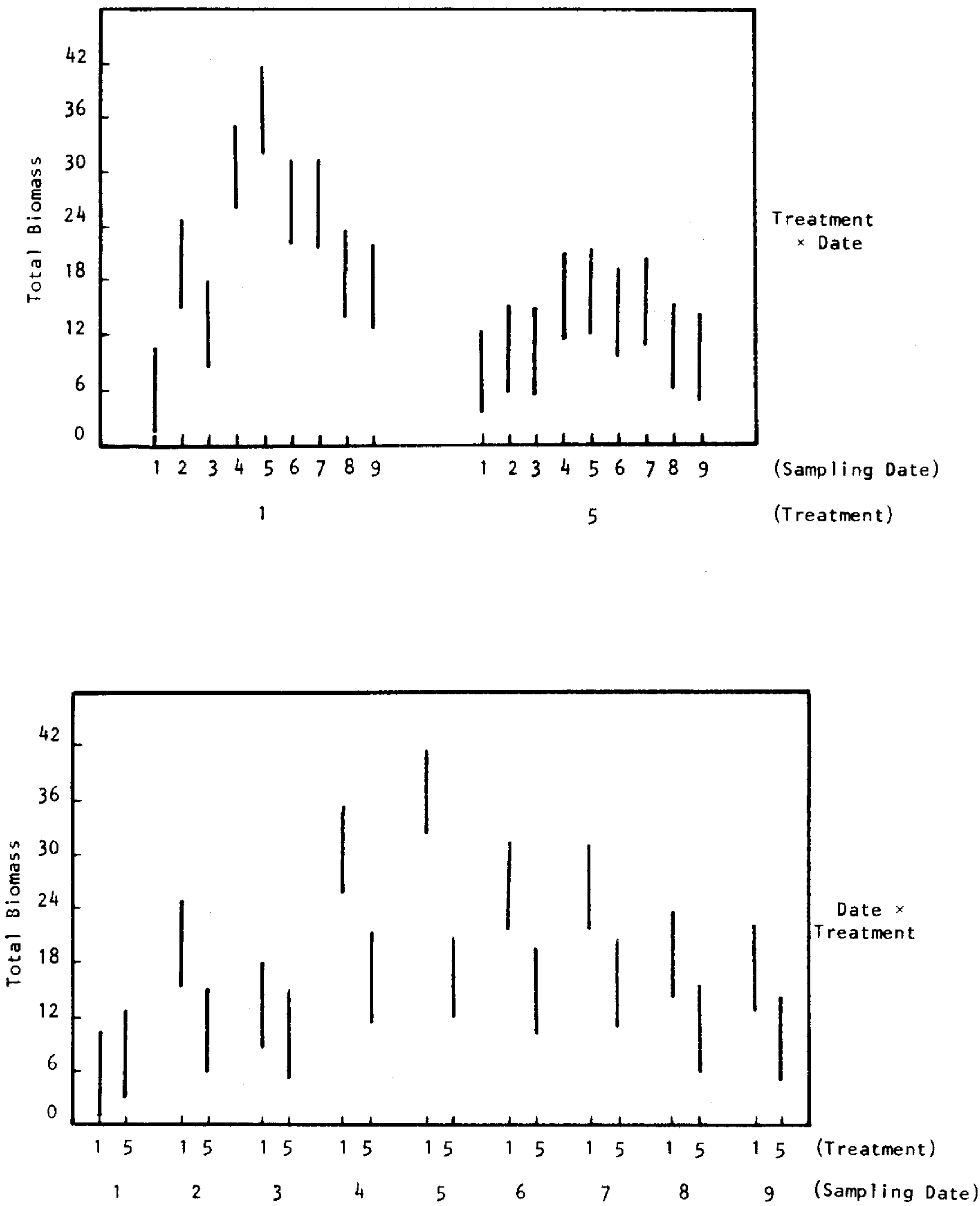


Fig. 2a. Bison Site, individual comparisons of the treatment × date interaction for total biomass.

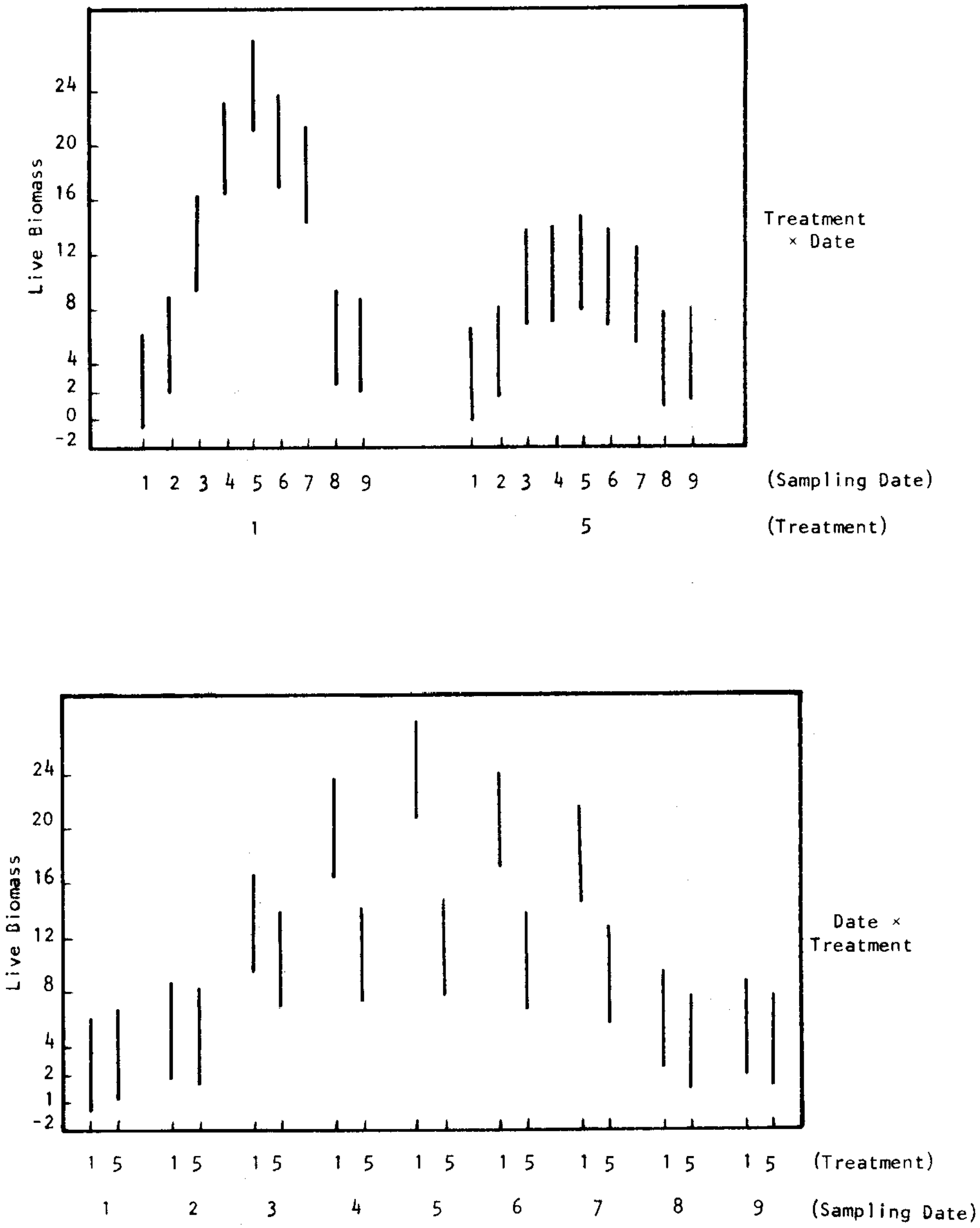


Fig. 2b. Bison Site, individual comparisons of the treatment × date interaction for live biomass.

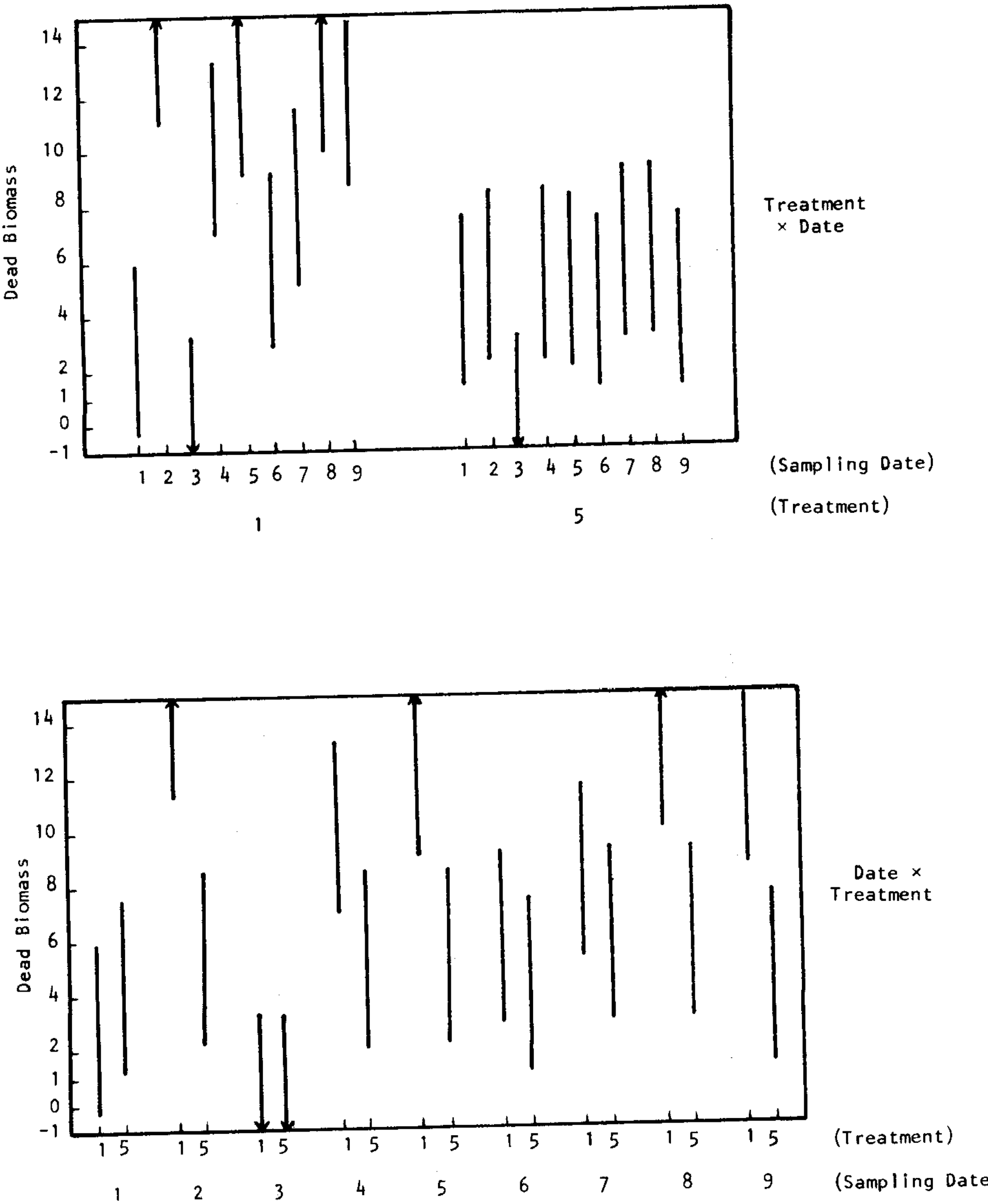


Fig. 2c. Bison Site, individual comparisons of the treatment × date interaction for dead biomass.

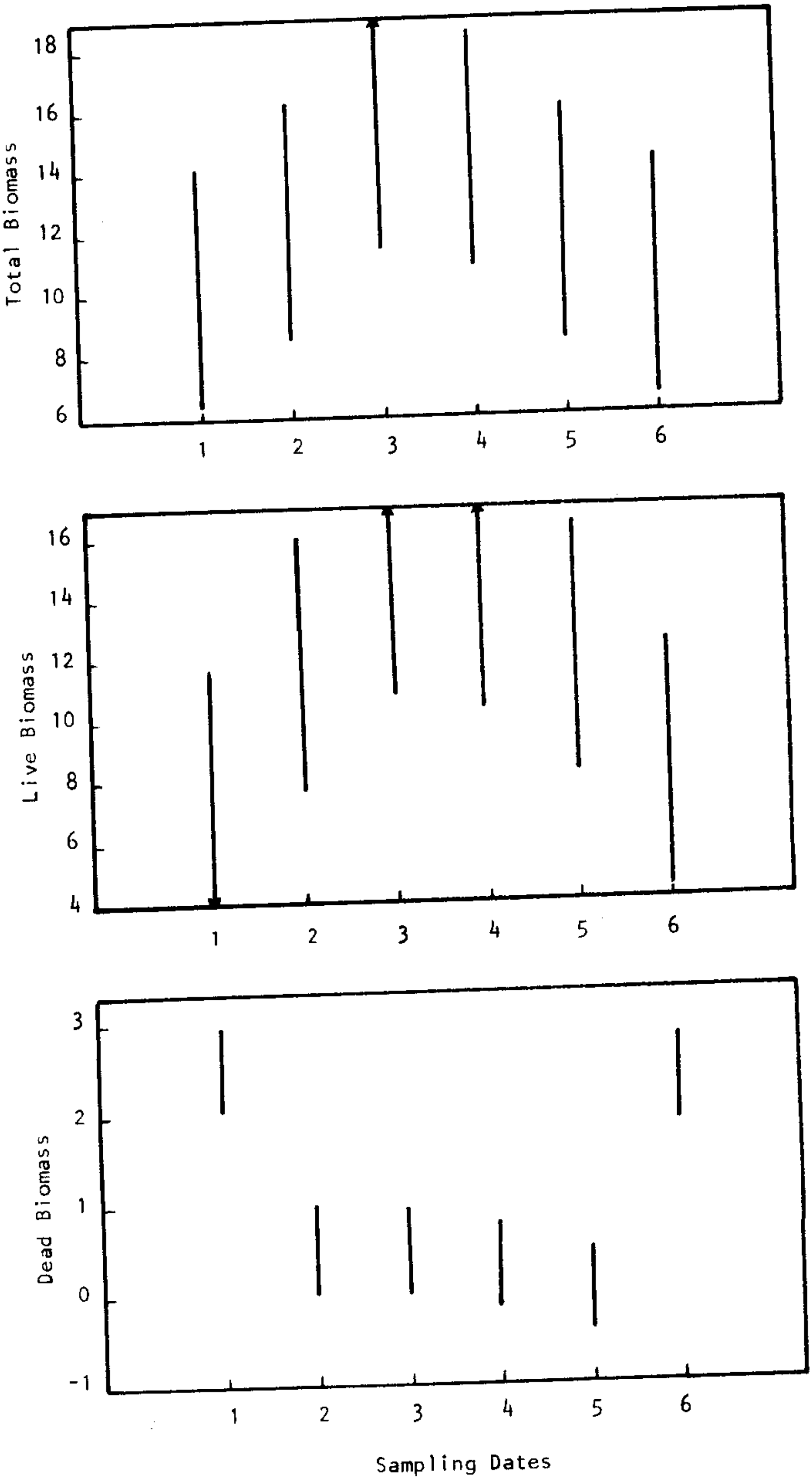


Fig. 3. Bridger Site, individual comparisons of sampling dates.

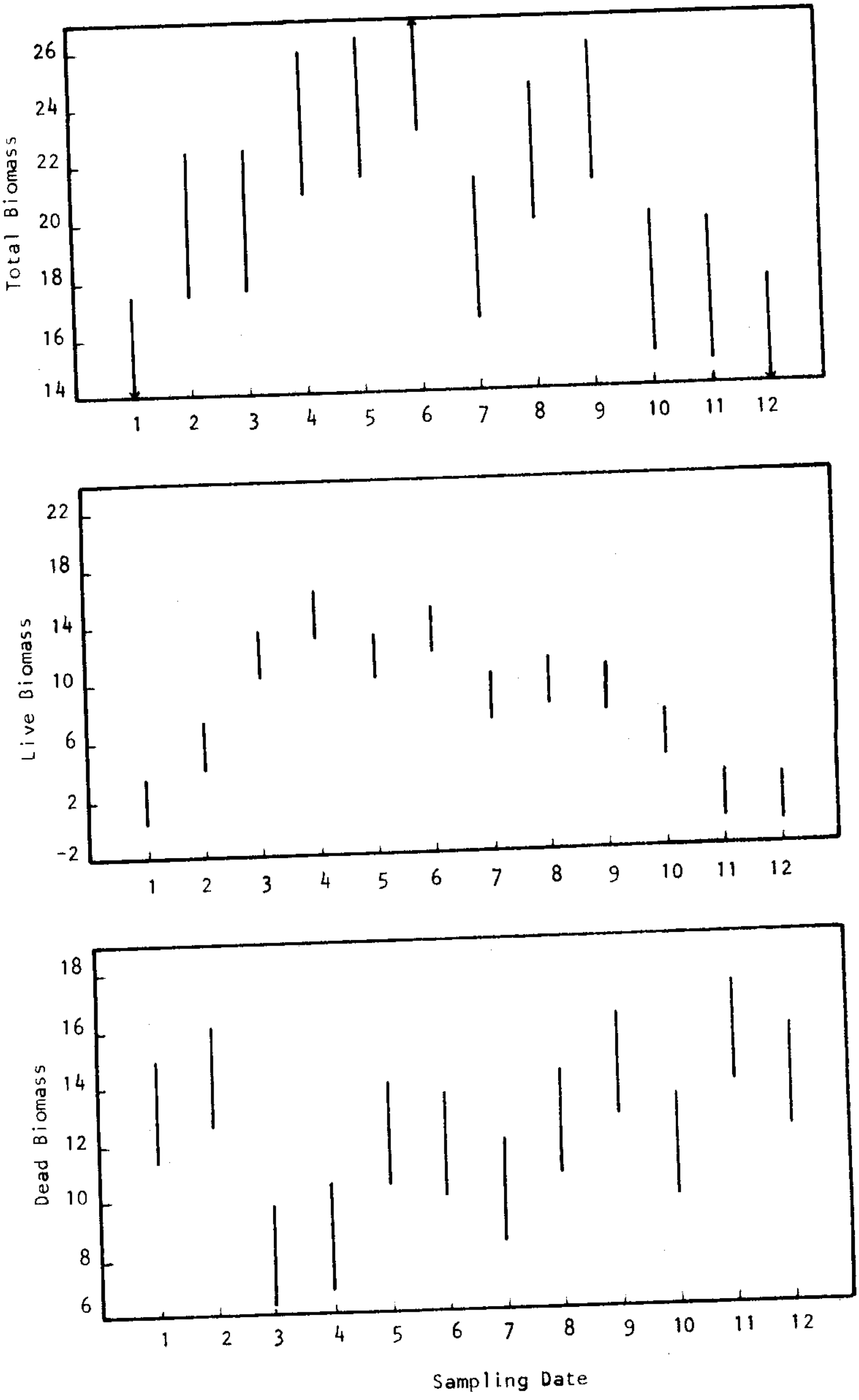


Fig. 4. Cottonwood Site, individual comparisons of sampling dates.

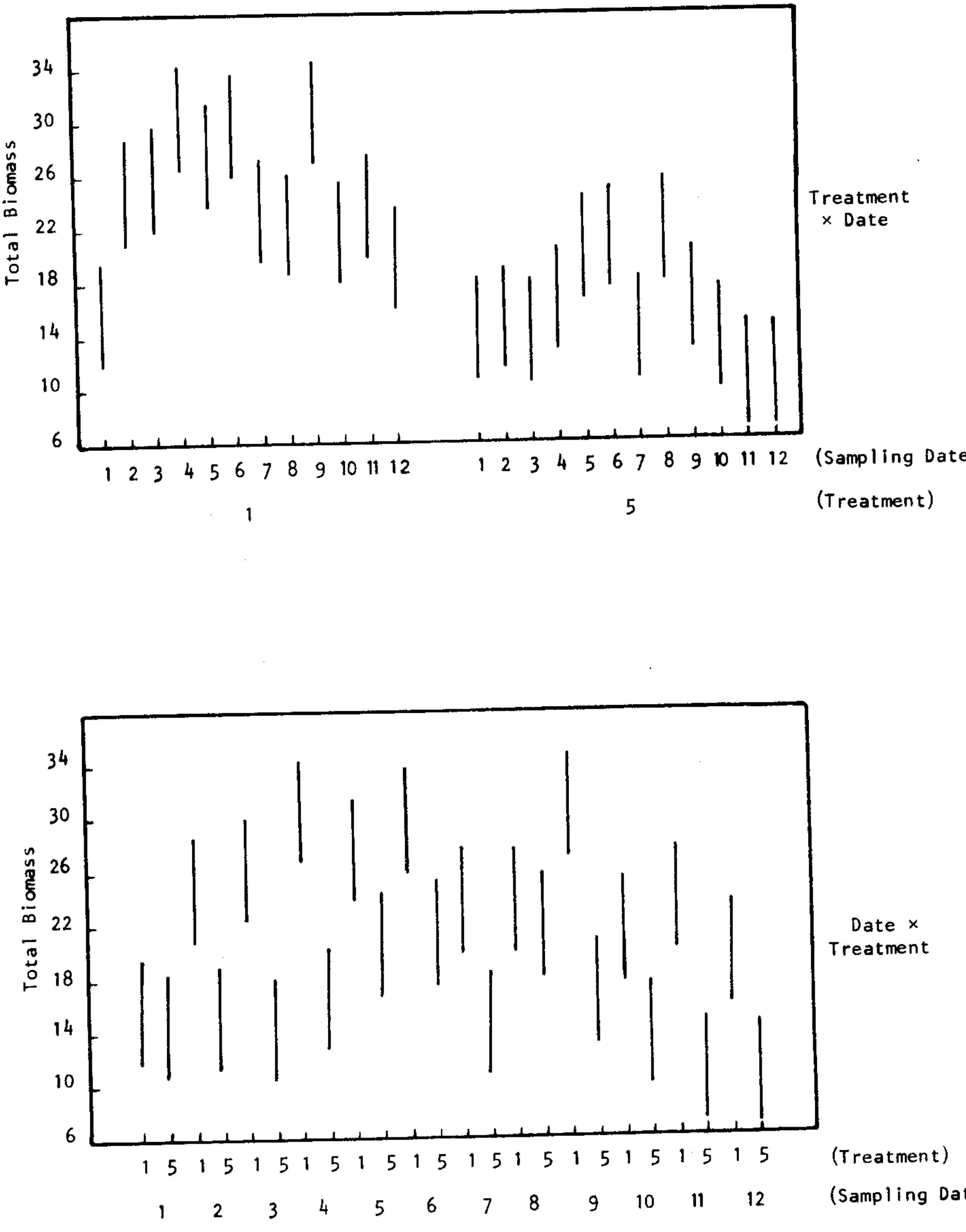
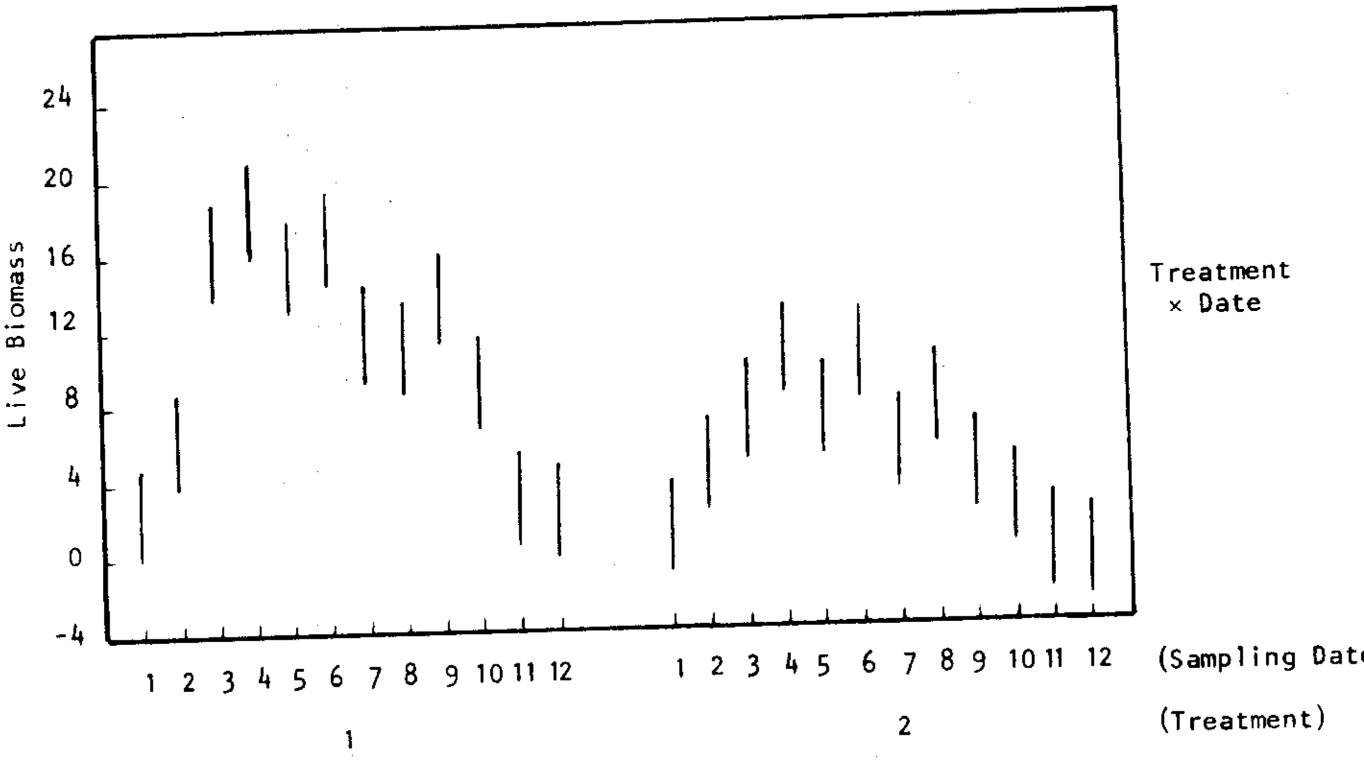


Fig. 5a. Cottonwood Site, individual comparisons of the treatment × date interaction for total biomass.



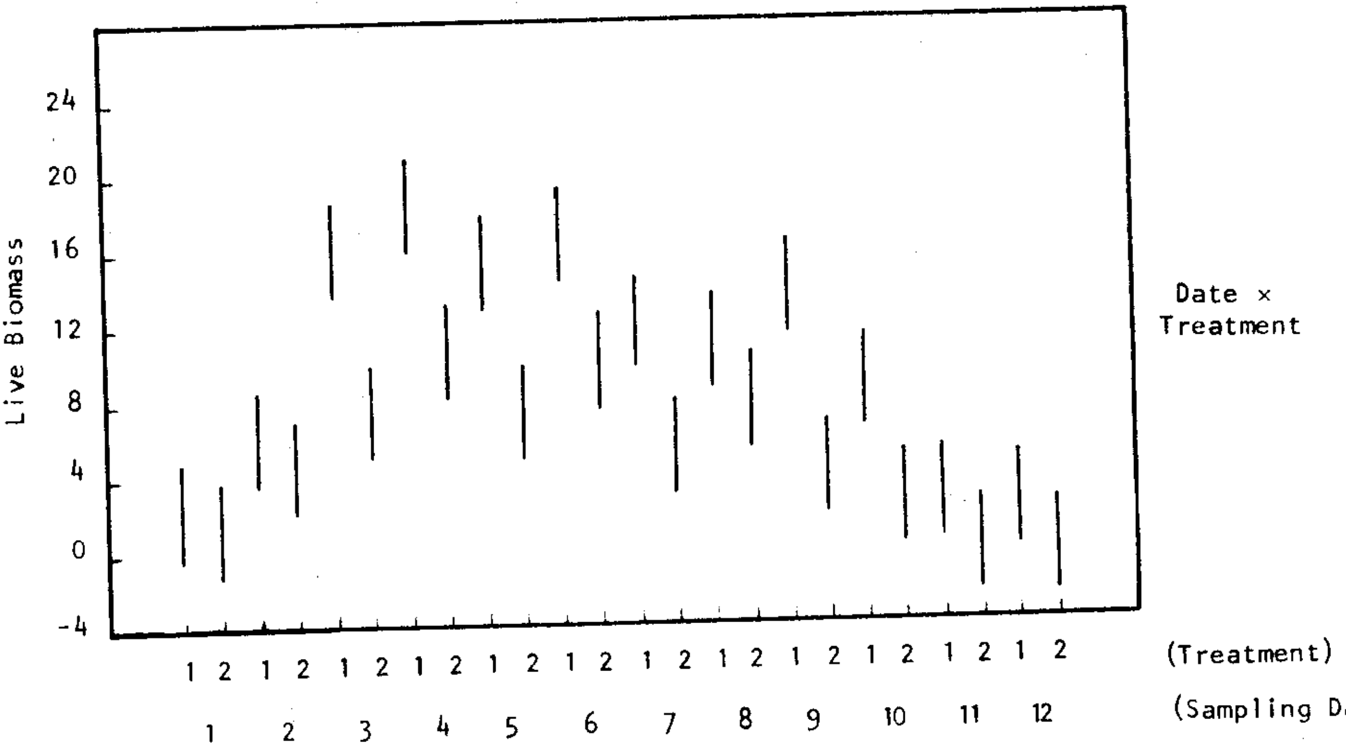
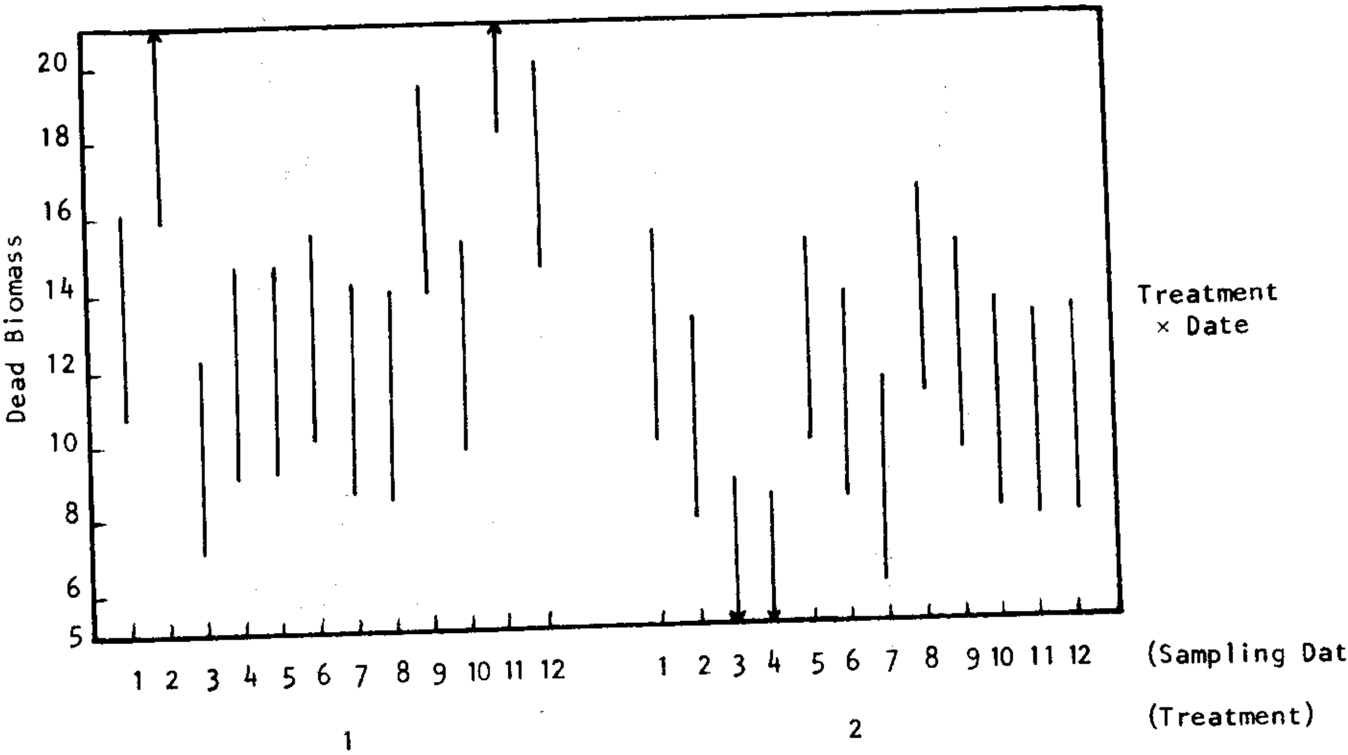


Fig. 5b. Cottonwood Site, individual comparisons of the treatment × date interaction for live biomass.



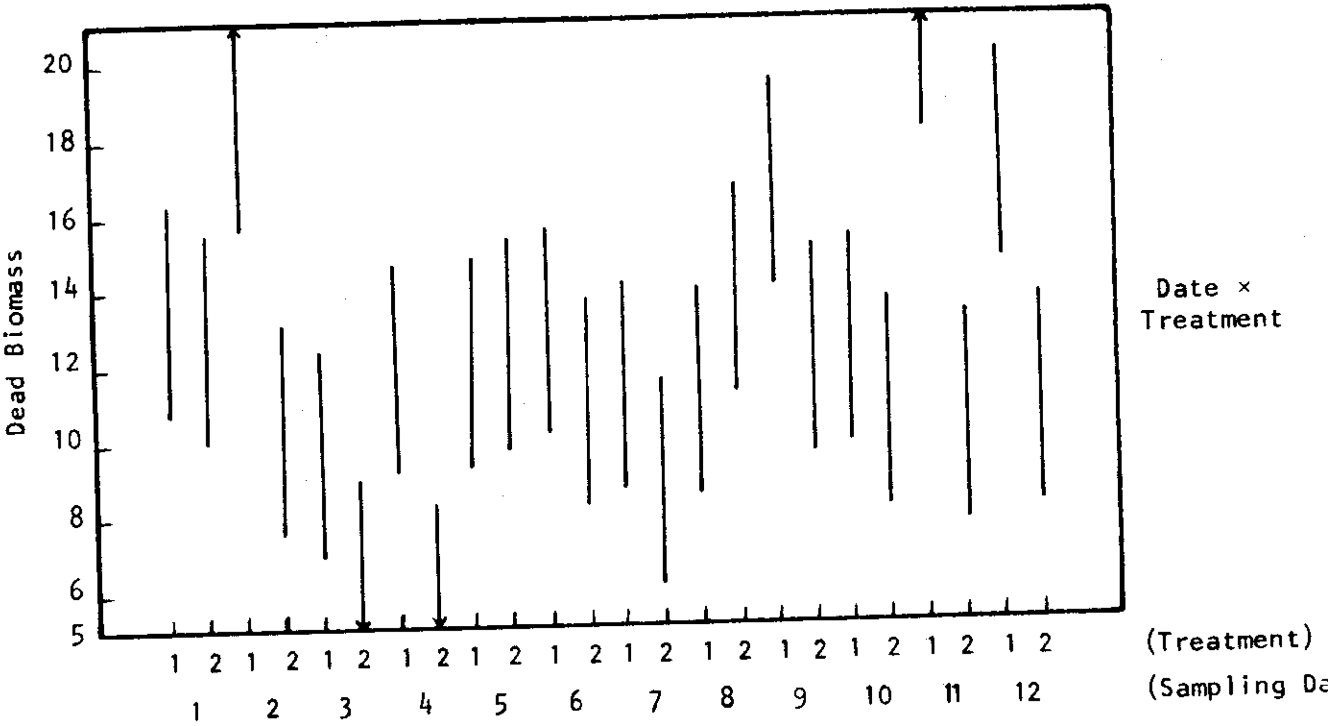


Fig. 5c. Cottonwood Site, individual comparisons of the treatment × date interaction for dead biomass.

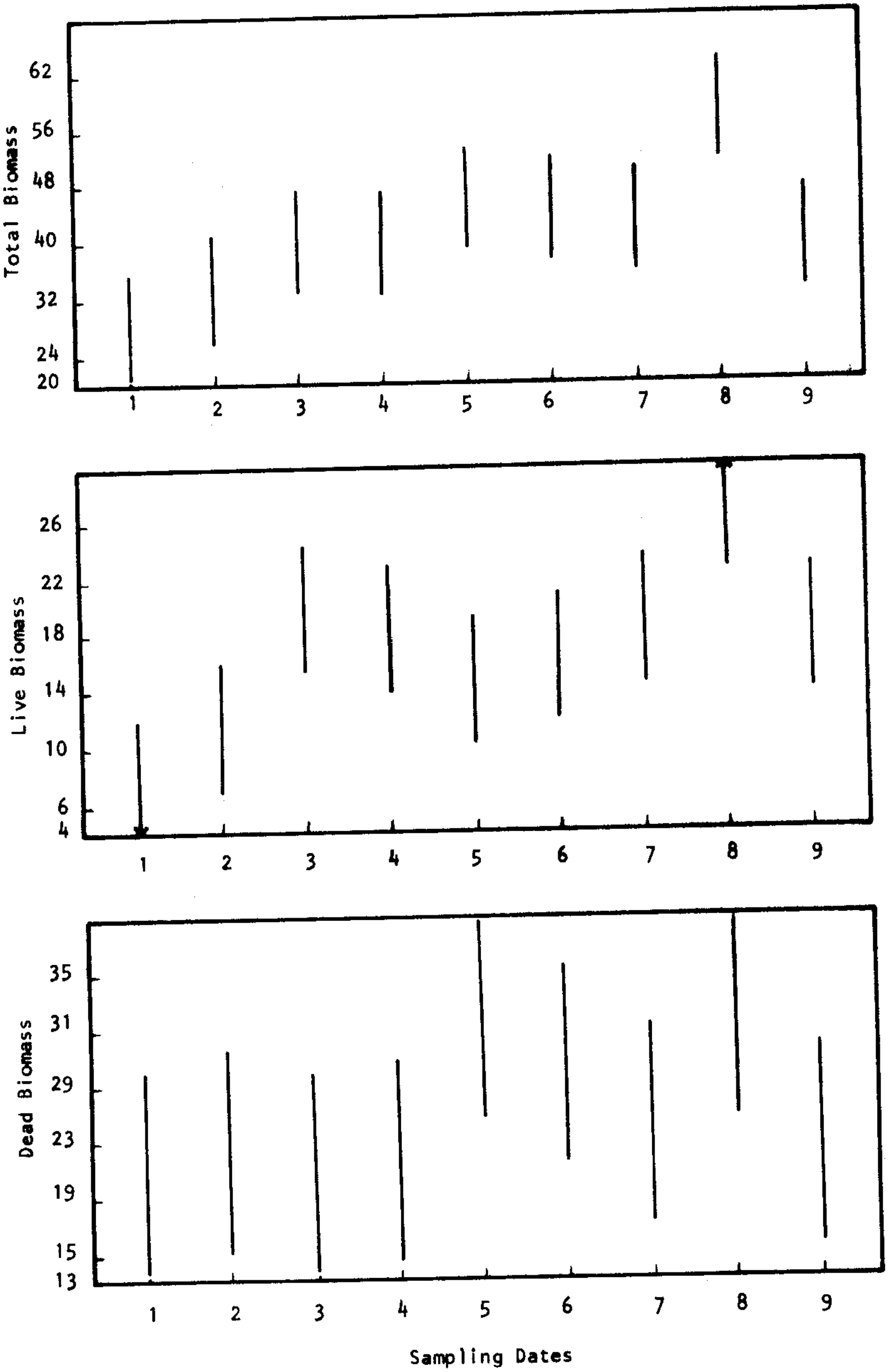


Fig. 6. Dickinson Site, individual comparisons of sampling dates.

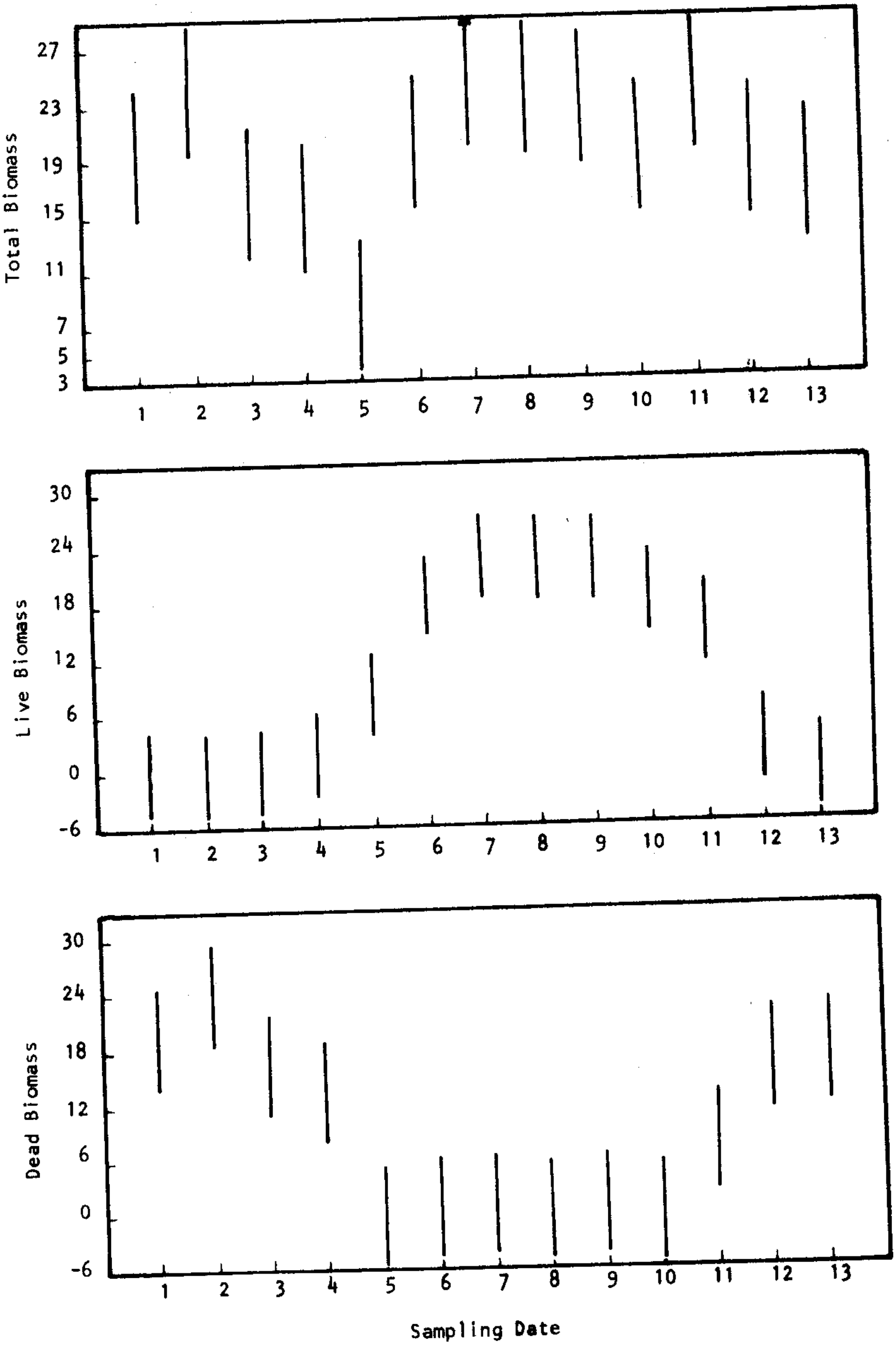
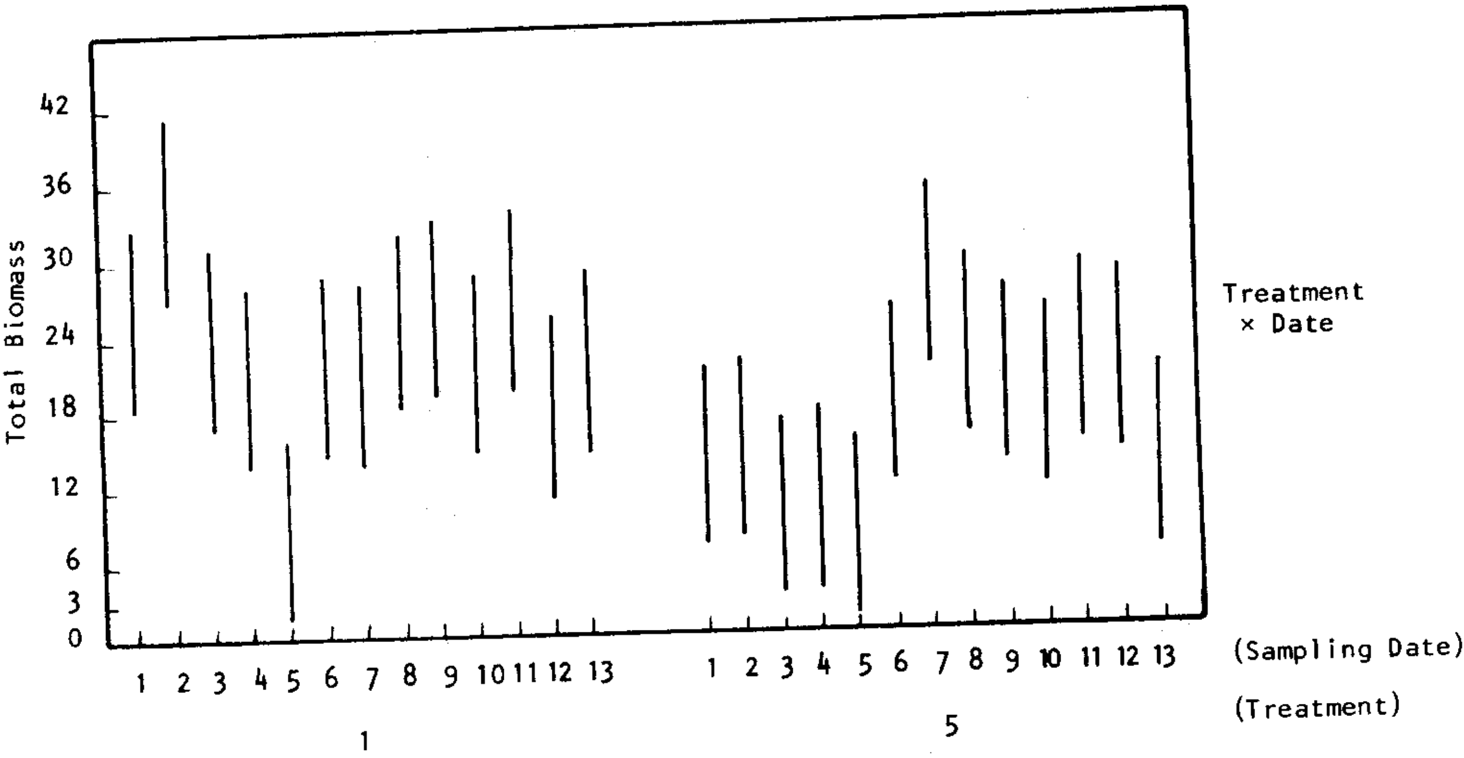


Fig. 7. Hays Site, individual comparisons of sampling dates.



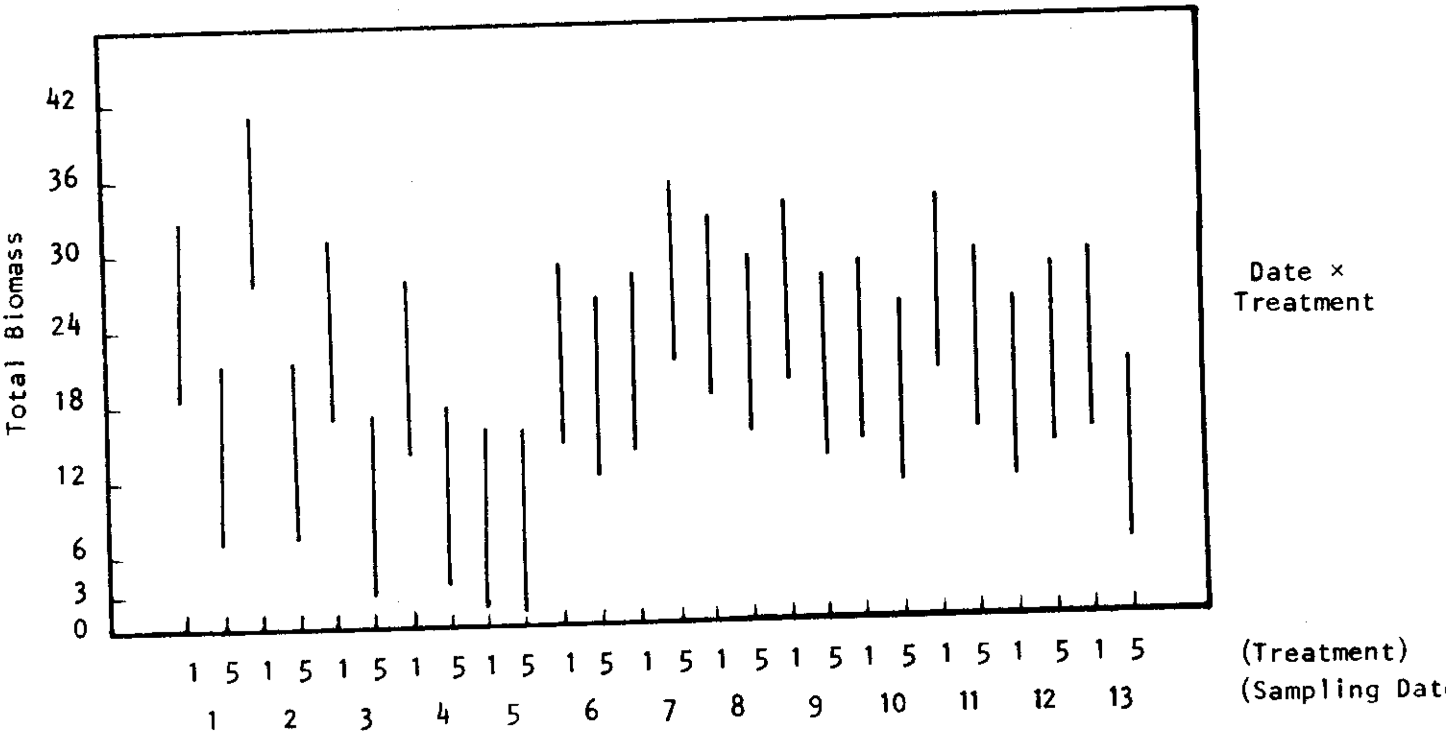


Fig. 8a. Hays Site, individual comparisons of the treatment × date interaction for total biomass.

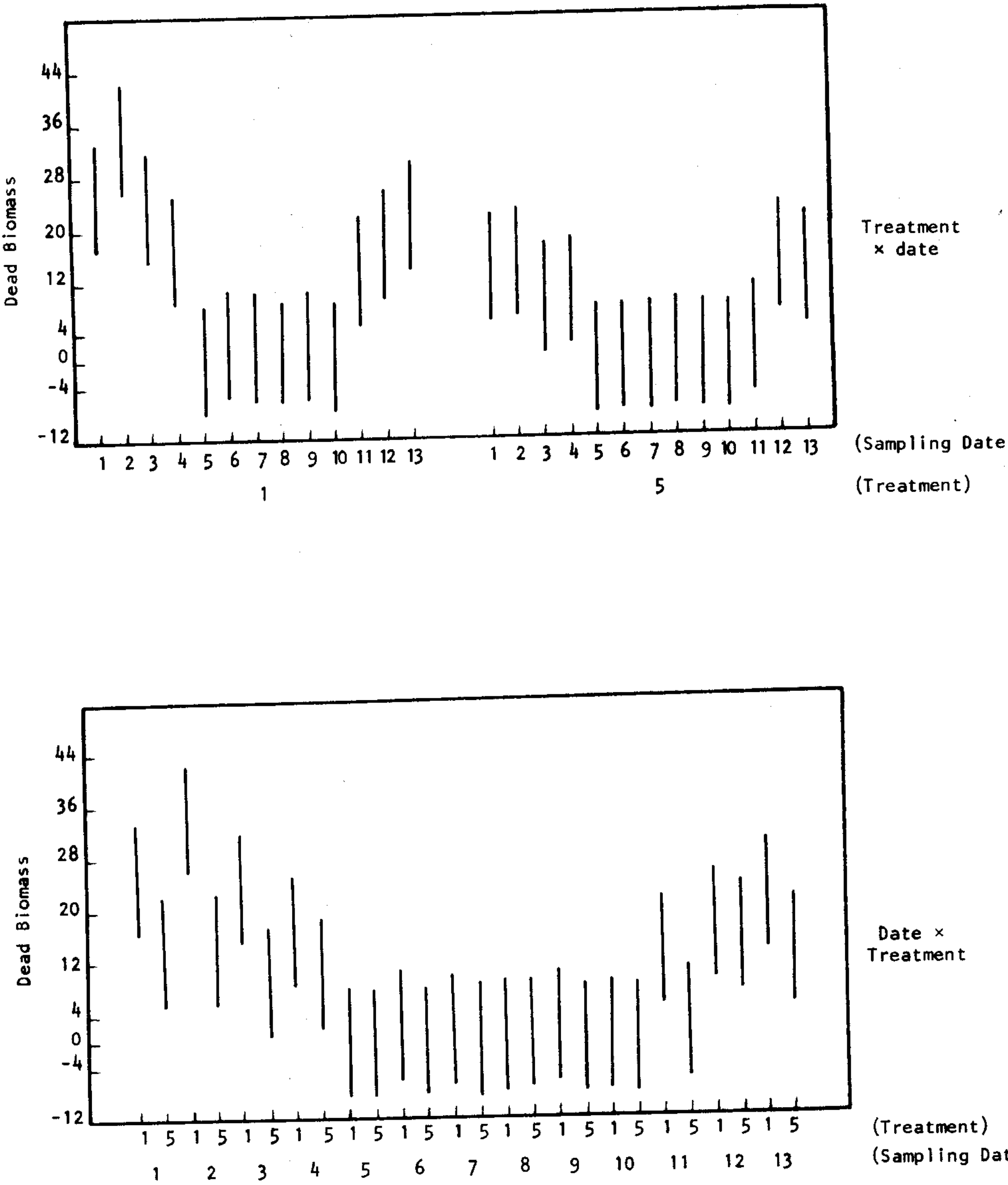


Fig. 8b. Hays Site, individual comparisons of the treatment × date interaction for dead biomass.

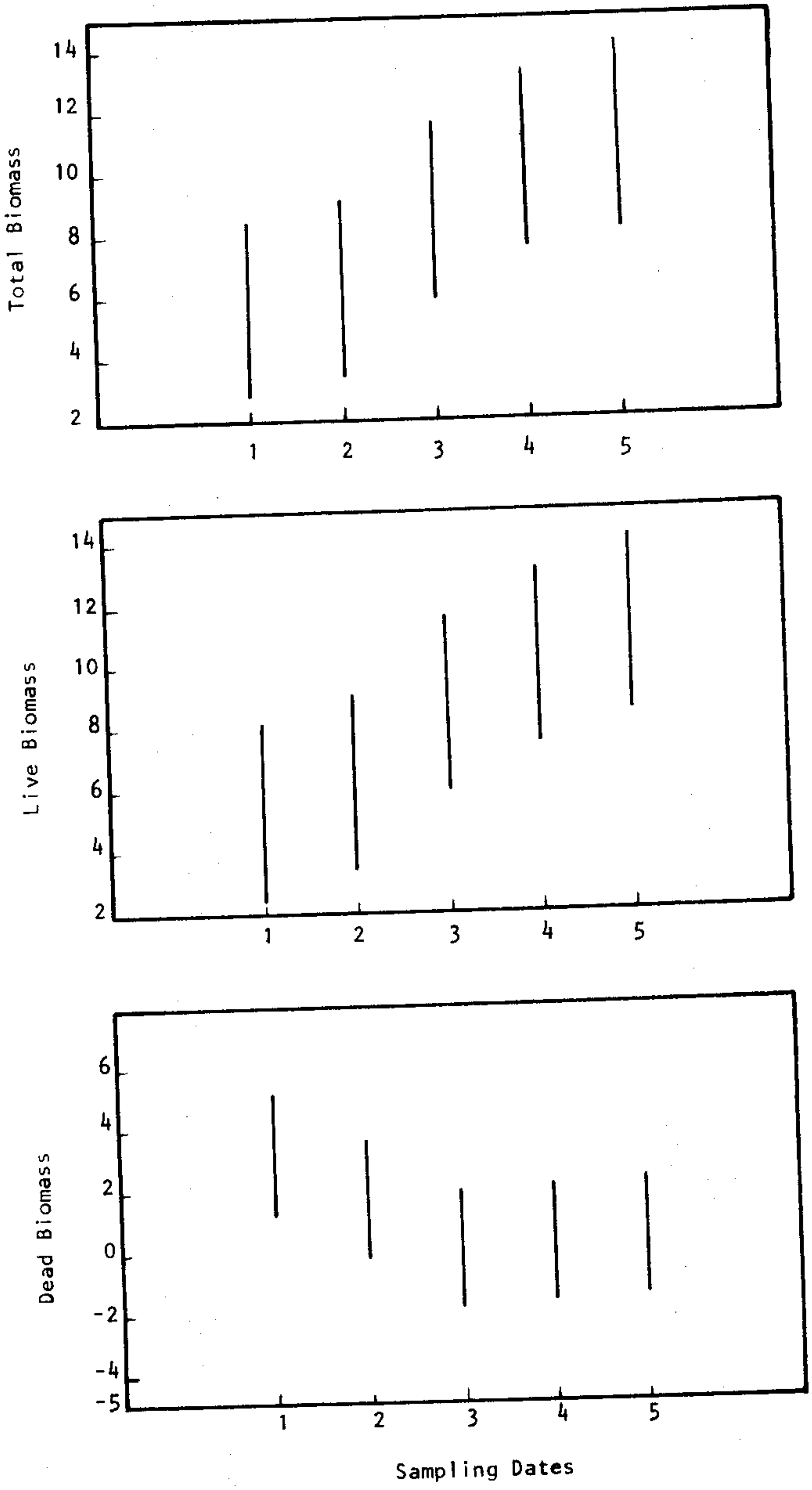


Fig. 9. Jornada Site, individual comparisons of sampling dates.

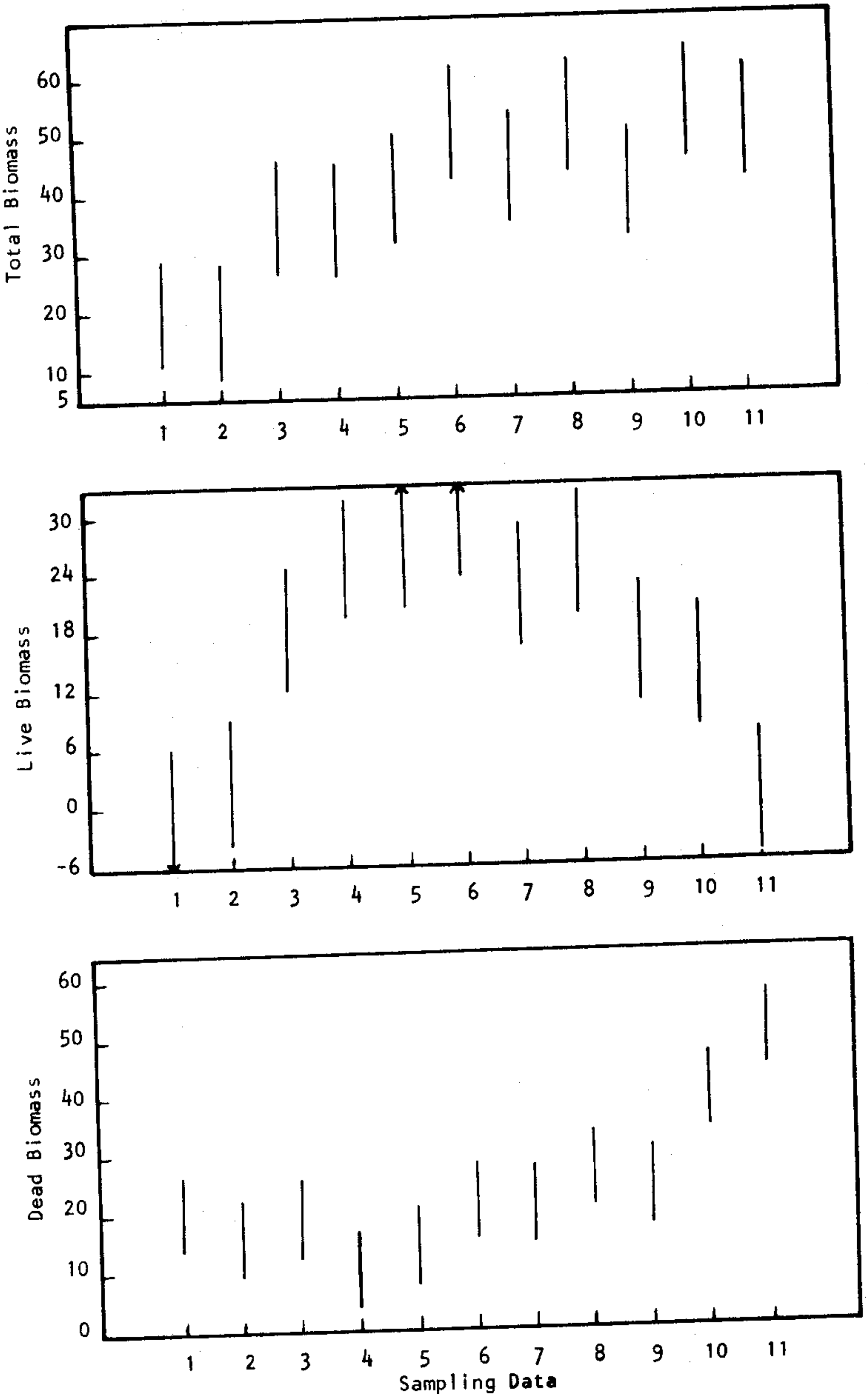


Fig. 10. Osage Site, individual comparisons of sampling dates

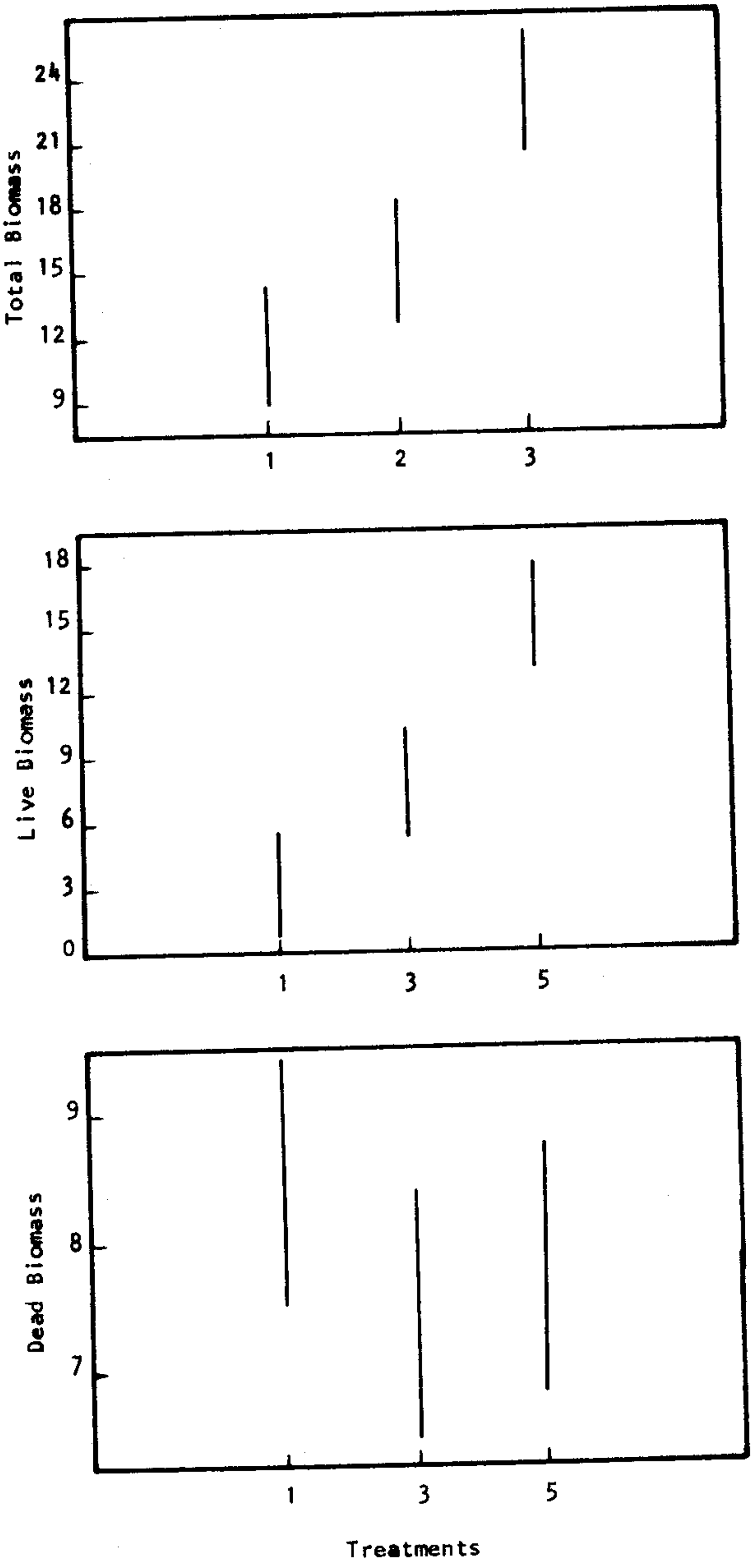


Fig. 11. Pantex Site, individual comparisons of treatments.

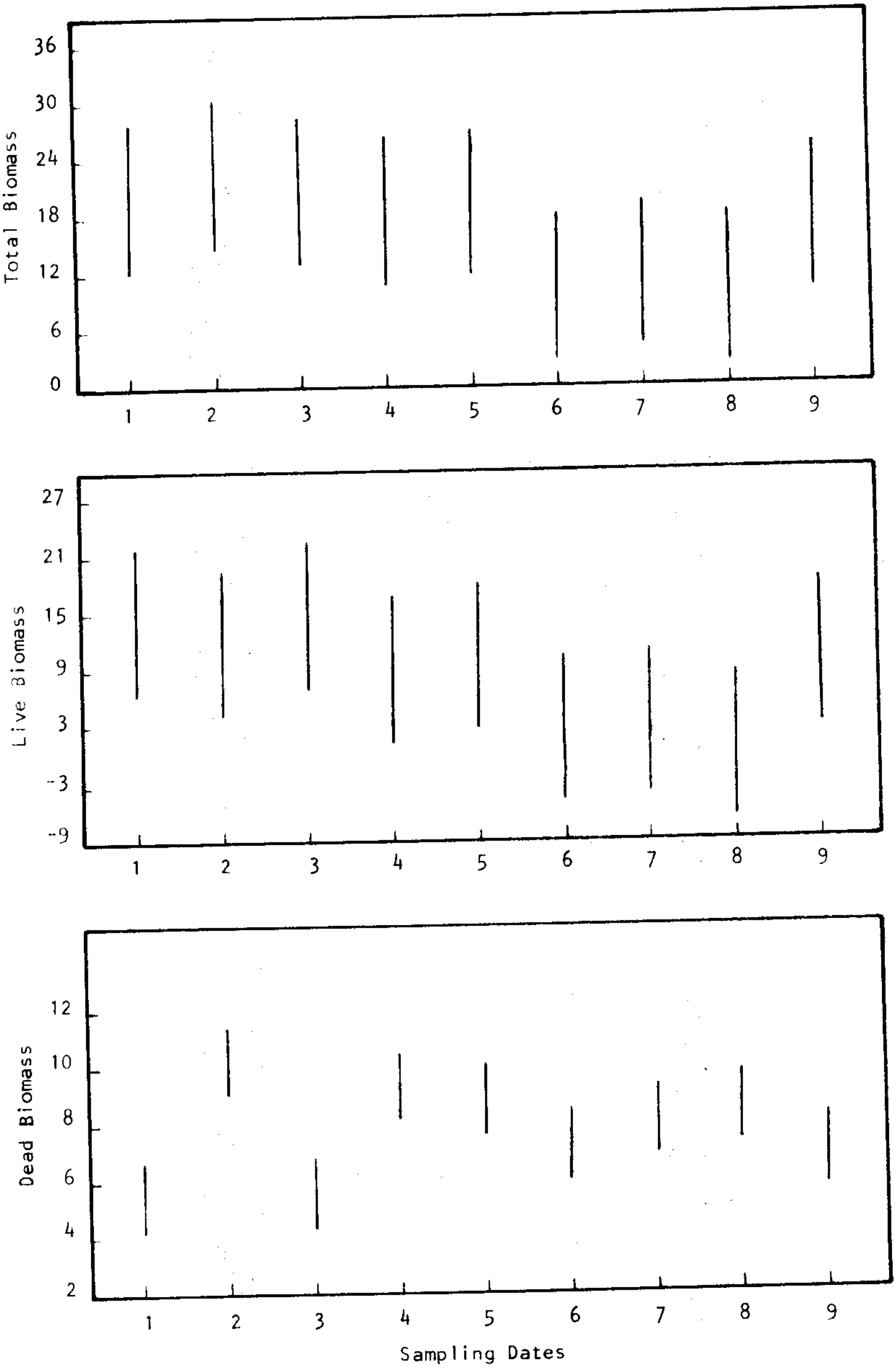


Fig. 12. Pantex Site, individual comparisons at sampling dates.

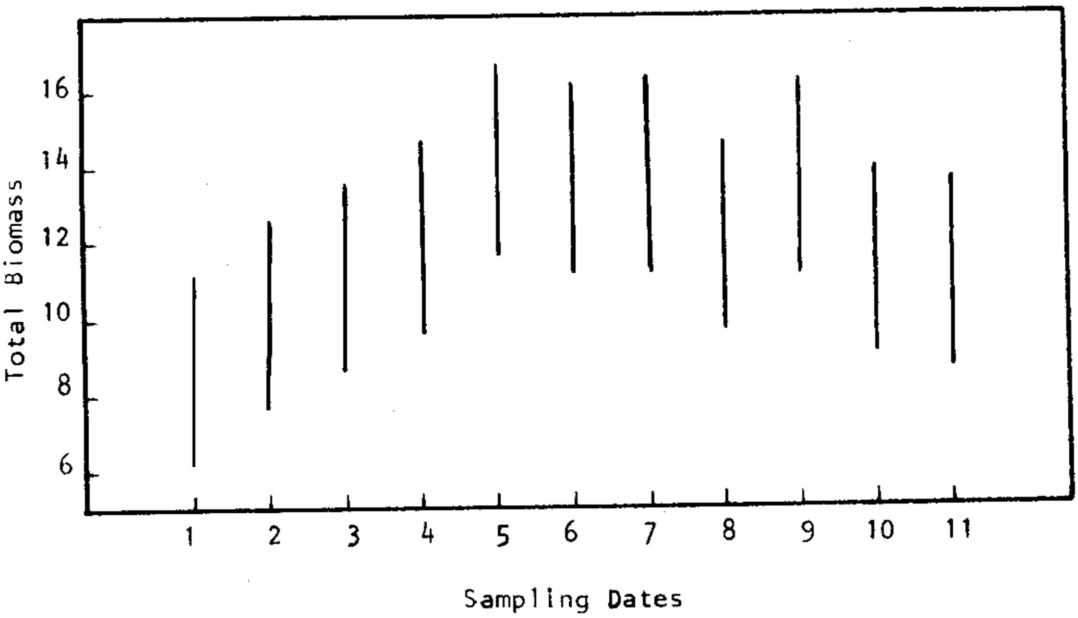


Fig. 13. Pawnee Site, individual comparisons of sampling dates.

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