THE EFFECT OF DISTURBANCES ON SPECIES DIVERSITY VALUES IN TALL GRASS PRAIRIE SITES

By

EDWIN LANE NETHERLAND, JR.

Bachelor of Science
Huntington College
Huntington, Indiana
1965

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1966

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Thesis Approved:

J. J. Crockett
Thesis Adviser

Glenn W. Todd

Kenneth E. Wiggins

Jerry Wilhm

John E. Thomas

N Durham
Dean of the Graduate College

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CHAPTER I

INTRODUCTION

A biotic community is composed of a few species with large numbers of individuals and many species with few individuals (Odum, Cantlon, and Kornicker, 1960). This pattern of distribution among species is thought to represent a meaningful relationship that has particular significance. Changes in the pattern are often associated with factors that lower community stability and reduce the number of species to one or two which are abundant.

Species diversity may be expressed quantitatively with a diversity index. Specific indices which have been used to measure diversity are discussed by Williams, 1944; Odum et al., 1960; McIntosh, 1967; and Wilhm, 1967, 1969, 1970. Wilhm (1967) stated that for most mathematical expressions maximum diversity exists if each individual belongs to a different species and minimum diversity exists if all individuals belong to the same species. The distribution of individuals into species lies between these extremes in most communities and diversity is intermediate.

The dominant species in tall grass prairie vegetation are perennial grasses. Forbs and other grasses are less abundant. The measurement of changes in the vegetational composition of tall grass prairie has typically been done by calculating and comparing frequency, relative composition, basal area, and density of species present. While assessment of changes in community composition can be made with this information, a method which would summarize vegetational changes succinctly would be beneficial to grassland investigators.

A study of a tall grass prairie was initiated and completed during the summer of 1971. This study was an attempt to determine if a diversity index would detect changes in community composition resulting from various disturbance factors which had been applied to prairie plots during previous years.

CHAPTER II

DESCRIPTION OF FIELD SITE

Climate and Vegetation

The site is located ¼SE, Sect. 17, T 19N, R1E, Payne County, Oklahoma. Previous experimentation at the site included a phenological study (Mueller, 1964), a microclimatic study (Skroch, 1965), and a secondary successional study (Hutchinson, 1969). Skroch established 18 experimental plots each measuring 18.29 m^2. Treatments applied to plots were plowing and discing; mowing, raking, and removing; and protection. Hutchinson (1969) added early and late spring burning treatments. Treatments were assigned to plots using the completely random design of Steele and Torrey (1960). The arrangement of plots is shown in Figure 1 for Plots 1 through 18. Plot 19 was established in May, 1971, in an adjacent area which had been sprayed with the herbicide Tordon in May of 1966.

Variation exists as to the year treatments were last applied. Protected plots have existed since 1952, while once-plowed plots have existed since 1964. While Hutchinson stated that burning was done in 1965 and 1966, Crockett said burning was also done in 1967.[1] Mowing, raking, and removing the vegetation and plowing each year was done in 1964, 1965, and 1966.

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[1]Personal communication, Jerry J. Crockett; Oklahoma State University; Stillwater, Oklahoma, 1972.

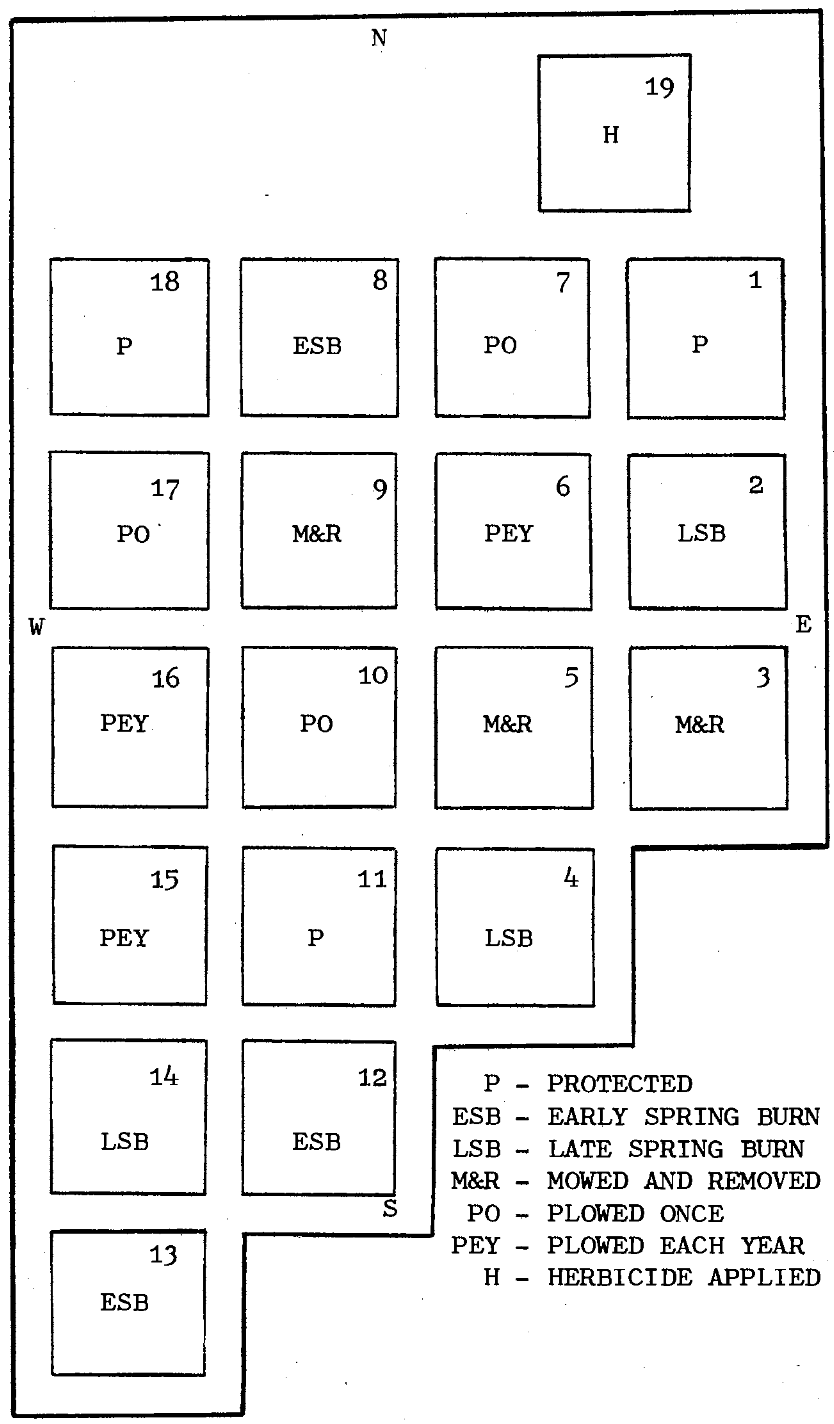

Figure 1. Plot Design

The topography of the area is a gently rolling plain. The site has a distinct east to west slope and a gentle south to north slope. Skroch stated that the site sloped two to four deg toward the west. Gray and Galloway (1959) have described soils of the site. Their Generalized Soil Map of Oklahoma shows that the site is located in the Central Reddish Prairies. The Dominant Great Soils Groups of this area are the Southern Brunizems and Regosols. The Southern Brunizems are zonal, well to moderately well drained, and generally occur on undulating to moderately sloping topography. They have a loamy surface soil 20.32 to 30.48 cm thick and reddish loamy to clayey subsoils. The study site is part of the Renfrow-Zaneis-Vernon Association.

Perennial grasses were dominant within the study site; however, Duck and Fletcher (1945) indicated the site to be part of the Quercus stellata[2], Quercus marilandica vegetation type. Blair and Hubbell (1938) showed the area to lie between the Osage Savanna and Mixed Grass Plains Biotic Districts. Bruner (1931) showed the study site to be part of the redbed plains, and he stated that soils were fine and well suited to the growth of grasses which dominate the region. Analysis of dominant grasses showed Andropogon scoparius, Andropogon gerardi, and Sorghastrum nutans to be dominant. Kelting (1954) and Buck and Kelting (1962) found these grasses to be dominant or of secondary importance in central Oklahoma tall grass prairie. Andropogon scoparius is the dominant species at the site. The site probably has not reached a climax condition and would be classified as the perennial bunch grass stage of Booth (1941).

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[2]Nomenclature follows that of Waterfall, 1966 unless otherwise indicated.

Mean annual temperature for the Stillwater area is 16.01 C, while annual precipitation averages at 81.74 cm. Table I shows average monthly temperature and precipitation values for a 30-year period (Curry, 1970). The average length of the growing season is 207 days beginning April 4 and lasting until October 28.

Soil Characteristics and Physiography

Influences of Slope and Soil Depth on Vegetational Composition

The experimental plots are located on the west facing slope. The plots vary in soil texture and topography. Observation of plots indicated that plots located at the top (east side) of the slope contained more sand than those at the middle and bottom. Several workers have shown that slope, edaphic, and topographical variations can influence vegetational composition and distribution within study sites. Hadley (1970) stated that a North Dakota prairie consisted of a mosaic of plant community types. He attributed this pattern to elevation, soil drainage characteristics, and soil salinity. Smeins and Olsen (1970) reported that within a 0.4 ha plot vegetation correlated most closely with topographic position and associated depth to the water table. A slope of 3 to 6 deg influenced water retaining capacity, depth of the A horizon, and depth to the water table. Zedler and Zedler (1969) stated that vegetational patterns in abandoned fields were closely related to topographical differences of less than one meter. Anderson and Fly (1955), Crockett, 1964), and Zavesky (1967) indicated that the degree of slope influenced vegetational composition in localized areas.

TABLE I

MEAN MONTHLY TEMPERATURE AND PRECIPITATION VALUES
OF THE PERIOD 1931 TO 1960*

Month	Temperature (°C)	Precipitation (cm)
January	3.28	2.95
February	5.67	3.43
March	9.79	4.72
April	15.90	7.26
May	20.29	11.73
June	25.52	10.77
July	28.08	8.97
August	27.97	8.15
September	23.46	8.59
October	17.51	7.06
November	9.51	4.70
December	4.89	3.40

*Data taken from U. S. Department of Commerce, 1971 Climatological Data for Stillwater Station.

Differences in degree of slope are often associated with moisture differences. Heitschmidt, Hulett, and Tomanek (1970) stated that prairie communities were primarily the result of a moisture gradient established by the combined effects of topography and soils. Geis and Doggess (1970) made similar conclusions concerning tree and shrub vegetation. Dix (1958) said variables such as exposure, slope, and topography correlate with soil moisture and are important because they influence soil moisture values. Bliss and Cox (1964) stated that factors such as depth of the A horizon, internal drainage, and available soil moisture were selective on prairie grasses and resulted in a mosaic pattern of plant communities. Bland and Kilburn (1966), Nicholson and Hulett (1969), and Odum (1960) indicated that soil textural differences correlated with differences in vegetational composition. Odum and Nicholson noted, however, that textural variation is related to soil moisture relationships such as water holding capacity.

Bliss and Cox (1964) and Smeins and Olsen (1970) observed that depth of the A horizon is related to available soil moisture. Ray (1959) noted that variation in species of grasses and forbs existed among three tall grass prairie plots. He suggested that A horizon depth and textural differences were related to this varition. Hulett, Van Amburg, and Tomank (1969a) stated that soil depth heterogeneity within a shallow limy range site resulted in differences in range composition and production.

Quantitative Analysis of A Horizon Depth

There were several statistically significant differences of A horizon depth occurring among plots having the same vegetational treatment.

Six random soil samples were taken within each plot to a depth of 0.76 m. The samples were collected with a geotome, and sampling was done during May and early June, 1971. The lower limit of the A horizon was defined as the point at which the soil lost its granular crumbly structure and became blocky, non-granular, and clayey. Table II shows statistical differences among plots treated alike but which occupied varying positions along the east to west and south to north slopes. Table III indicates the frequency of the most abundant species in the three protected plots. Plot 1 was located at the top (east side) of the slope; Plot 11 was located approximately in the middle; and Plot 18 was located at the bottom. The distinct differences that occur among these three plots would suggest that differences in soil depth and slope influenced the vegetational composition. The frequency results are based on 300 Point Centered Quarter samples taken within each plot. The method of taking samples is explained fully in Chapter III.

Because differences in slope and topography can produce changes in vegetational composition, a block of plots similar in both slope and topography was selected for vegetative sampling. The analysis of variance, shown in Table IV, indicates that the plots do not differ significantly with respect to depth of the A horizon. It is believed that results from these plots will more accurately reflect differences in diversity due to treatments than would the plots which vary in A horizon depth and location along a slope.

TABLE II

MEAN, STANDARD ERROR, AND ANALYSIS OF VARIANCE OF A HORIZON DEPTH IN PLOTS HAVING THE SAME VEGETATIONAL TREATMENT

Plot	A Horizon Depth (cm) $\bar{\bar{X}}$	SE	AOV Source	df	MS	F
1	21.3	1.9	Between	2	107.3	5.12*
11	29.4	1.6	Within	15	20.9	
18	26.9	2.0	Total	17		
8	36.8	2.5	Between	2	237.2	5.64*
12	33.9	2.9	Within	15	42.0	
13	24.8	2.6	Total	17		
2	24.1	1.4	Between	2	84.9	5.08*
4	30.5	1.8	Within	15	16.7	
14	30.8	1.7	Total	17		
3	25.0	1.0	Between	2	24.5	1.39
5	26.7	1.5	Within	15	17.7	
9	29.0	2.4	Total	17		
7	34.3	2.6	Between	2	226.9	6.18*
10	25.8	2.4	Within	15	36.7	
17	22.3	2.4	Total	17		
6	22.3	1.7	Between	2	86.6	3.33
15	28.1	2.5	Within	15	26.0	
16	20.9	2.0	Total	17		

*Indicates significance at the .05 level. Tabulated F is 3.68.

TABLE III

FREQUENCY (%) OF MOST ABUNDANT SPECIES IN SAMPLES TAKEN FROM PROTECTED PLOTS

Plant Species	Plot 1	Plot 11	Plot 18
Ambrosia psilostachya	3.3	23.3	15.0
Andropogon gerardi	3.7	2.0	41.0
Andropogon scoparius	42.0	57.7	23.0
Andropogon ternarius	25.3	2.0	0.3
Aster ericoides	11.7	24.3	13.7
Bromus japonicus	0.0	22.0	42.7
Sorghastrum nutans	63.3	53.7	6.7
Sporobolus asper	3.3	5.67	28.0

TABLE IV

MEAN, STANDARD ERROR, AND ANALYSIS OF VARIANCE OF A HORIZON DEPTH IN PLOTS HAVING THE SAME VEGETATIONAL TREATMENT

Plot	A Horizon Depth (cm)		AOV			
	$\bar{X}$	SE	Source	df	MS	F
4	30.5	1.8	Between	5	26.5	0.97*
9	29.0	2.4				
10	25.8	2.4	Within	30	27.3	
11	29.4	1.6				
15	28.1	2.5	Total	35		
19	32.0	2.0				

*Not significant at the .01 and .05 levels. Tabulated F at the .01 level is 3.70. Tabulated F at the .05 level is 2.53.

CHAPTER III

METHODS AND MATERIALS

Point Centered Quarter

The Point Centered Quarter Method was originally developed by Cottam and Curtis (1956) for use in the sampling of tree and sapling compositions of woodlands in the northern Prairie-Forest Border Region. Dix (1961) noted that the method offered a rapid, quantitative means of sampling grassland vegetation which was thought to be highly efficient in detecting slight differences between closely related stands. Dix defined an individual as a stem plus its appendages.

A distinct problem in assessing species composition is the decision as to what actually constitutes an individual. Since most perennial grasses and many forbs reproduce vegetatively, the decision must be arbitrary. Walker (1970) used Point Centered Quarter and quadrat counting methods in the grasslands of Rhodesia. He concluded that results obtained by these methods were completely dependent on the definition of an individual. In addition to the species definition problem, various workers have indicated that the Point Centered Quarter Method overestimates or favors randomly distributed species such as single stalked forbs (Crockett, 1963; Risser and Zedler, 1968) and underestimates density (Good and Good, 1971).

Dix indicated that the Point Centered Quarter Method was not sensitive to seasonal aspect. His results showed no significant differences in the absolute densities of Bouteloua gracilis and Agropyron smithii in June and August in a western North Dakota grassland. These results suggest that dominant grasses would have the greatest influence on a diversity index over the entire growing season.

Mueller (1964) stated that the study site (described in Chapter II) was characterized by a prevernal, vernal, aestival, autumnal, and hiemal aspect. With the exception of the hiemal aspect each of the aspects is characterized by a specific group of species maturing and flowering. However, dominance is displayed by perennial grasses during all aspects.

If diversity were measured over the entire growing season, the ephemeral species of the prevernal and vernal aspects and the composite species of the autumnal aspect would produce differences in the diversity values obtained. The contribution of these species to the diversity index would be small in comparison to the dominant grasses and fluctuations in the index would most likely vary only slightly over the growing season.

Determining Numbers of Individuals Per Species

Samples were taken from plots by the Point Centered Quarter Method during the period June 14 to July 19, 1971. This was during the aestival aspect denoted by Mueller as occurring from May 5 to July 21. The sampling instrument consisted of a pointed rod with four projecting bars slightly above the pointed end. Bars were at right angles to the axis of the rod, and bars produced four equal quarters. When the sampling instrument was dropped to the ground, the nearest stem in each quarter was counted as one individual of a particular species. For example, two individuals of Andropogon scoparius, one of Sorghastrum nutans, and one of <u>Ambrosia psilostachya</u> would be counted in Figure 2. The method is plotless, i.e., species do not have to occur within a prescribed area.

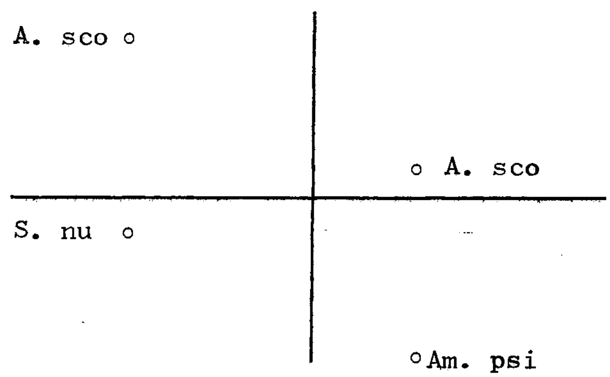

Figure 2. Example of a Point Centered Quarter Sample Taken in a Tall Grass Prairie

Samples were taken in a systematic random fashion. Figure 3 shows the position and distance between transect lines established in each plot. Sampling sites were specified every 24.9 cm along each transect line with a number previously recorded from a random numbers table. For example, number 54 indicated five steps backward, along the transect line, and four steps to the right. At the point of sampling the instrument was twirled slightly, dropped from a height approximately waist high, and samples were taken at the point of impact. In those cases where the random number indicated that the sample would be taken outside the boundary of the plot, the sample was taken at the boundary. There were 75 samples taken along each transect line producing a total of 300 samples per plot.

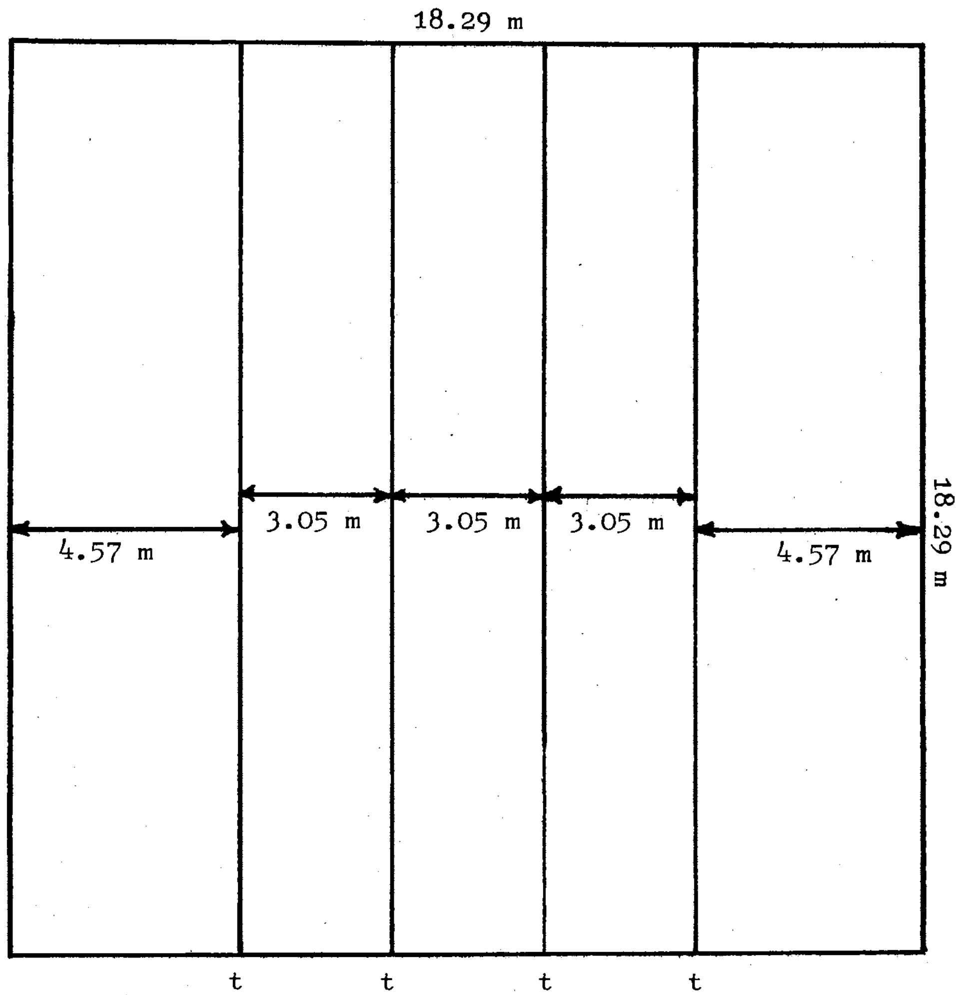

Figure 3. Location of and Distance Between Transect Lines (t) in Each Plot

An equalization of sampling occurred among the plots in order that sampling would start and finish approximately at the same time for all plots. After 100 Point Centered Quarter samples had been taken in a plot, sampling was discontinued and begun in another plot. Due to influences of weather and increased sampling proficiency, the number of samples taken darily per plot was irregular; i.e., 30 samples may have been taken in one plot, 100 samples in another plot, and 20 samples in a third plot. This irregularity in sampling is not believed to have any significant influence on measure of diversity values since species composition would most likely have remained rather constant during the sampling period.

Since preliminary sampling of vegetation in three diverse prairie sites indicated that identification of species was difficult when plants were shorter than 12.70 cm, those grasses were not included as part of the data. Forbs shorter than 7.72 cm were recorded only when a definite species identification could be made.

Clip Quadrat

Phytomass was collected during the period July 26 to September 10, 1971. Specific sampling dates for each plot are shown in Figure 18. Penfound (1964) indicated that peak productivity was reached in Oklahoma grasslands in late July and then declined thereafter. It was thought that the relative importance of the dominant perennial grasses among treated plots would be best shown at the period of peak productivity. However, due to the time required to process samples, sampling was extended past this period.

Sampling areas were chosen by the systematic random technique previously described. Samples were taken at each 73.2 cm division along each transect line. This resulted in 25 samples taken along each transect line with a total of 100 samples per plot. The sampling unit was a 0.1 m^2 quadrat. At the point of sampling the quadrat was dropped to the ground from approximately wasit high. All vegetation occurring within the boundaries of the quadrat was cut approximately 1.27 cm above the surface of the ground. After 25 samples had been collected in a plot, sampling was begun in another plot. No more than 50 quadrats were cut on any day. Species phytomass was determined by hand separation of species. An individual was defined as a stem plus its appendages. After separation was finished, phytomass of each species was placed in a separate sack and labeled as to plot and sample number. Sacks were stored in a cooler at 6 to 7 C in order to lessen losses in weight due to respiration and action by mold. Since separation of species was tedious and numbers of samples cut in the field accumulated faster than they could be separated into species, field samples were also stored in the cooler until separation could be started.

After separation of species had been accomplished for all samples, the samples were oven dried at 70 C for 48 hr and then weighed to the nearest 0.01 g.

Diversity values, based on numbers of individuals, were calculated using the diversity index $\overline{d} = -\sum_{i=1}^{s} (n_i/n)\log_2 (n_i/n)$ (Shannon and Weaver, 1963) where n_i is the number of individuals of the i^{th} species, n is cumulative individuals, and s is the number of species. For phytomass diversity values were calculated using the index $\overline{d} = -\sum_{i=1}^{s} (w_i/w)\log^2 (w_i/w)$ (Wilhm, 1968) where w_i is the phytomass contributed by the i^{th}

species, w is cumulative phytomass, and s is the number of species. For both methods of calculation the samples were pooled. Pooling of samples was suggested by Pielou (1966b) for areas which contained sessile organisms having a patchy spatial arrangement.

CHAPTER IV

REVIEW OF LITERATURE

Measurement of Species Diversity

Components which influence diversity values are numbers of species and the equitability of distribution of numbers of individuals or biomass among species. The Shannon-Wiener function, $H = -\sum_{i=1}^{s} p_i \log_2 p_i$, measures diversity where s is total species and p_i is the observed proportion of individuals that belong to the i^{th} species. Kochsiek and Wilhm (1969) note that the p_i are equal to N_i/N. The N_i/N are population values which can be estimated from the sample values n_i/n to yield the equation $\bar{d} = -\sum_{i=1}^{s} (n_i/n)\log_2(n_i/n)$. Lloyd and Ghelardi (1964) stated that diversity will increase with increasing numbers of species. However, the function is also influenced by the evenness with which the individuals are distributed among species. A maximum possible value, for a given s, occurs if all species are equally abundant. The maximum value is never realized because species are not equally distributed even among species of comparable size using the same resources.

Monk (1966b) reported that a Puerto Rican rainforest and a temperate forest from Florida had similar diversity values even though the rainforest had many more species. Fifty per cent of the species in the rainforest had a sampling probability of less than 0.01. These species decreased the equitability component of the index. Monk concluded that $\bar{H}$ as a measure of diversity will tend to plateau after a community is composed of more than 12-15 species. Sager and Hasler (1969) stated that the main effect being measured in Shannon's index seems to arise from the component of relative abundance. Their results indicated that phytoplankton species in excess of the 10-15 most abundant ones had little effect on the diversity index.

Pielou (1966b) used an index derived from information theory to assess the diversity value of a tract of herbaceous vegetation. She explained that when diversity, H_k, is plotted against sample number, k, the curve levels off. This leveling occurs because addition of new quadrats to progressively pooled samples has two opposing effects. Diversity is reduced since common species are added more rapidly than rare or localized species previously recorded. Diversity is increased because unrecorded species will be brought into the sample.

Wilhm and Dorris (1968) stated that diversity indices derived from information theory express the relative importance of each species, are dimensionless, and are independent of sample size. Since these indices are dimensionless, either numbers or biomass can be used. Wilhm (1968) stated that the change from numbers to biomass redefines diversity in biomass terms and is more closely related to energy distribution among species.

Bechtel and Copeland (1970) found that significant differences existed between numbers and biomass indices when measuring fish species diversity. They indicated that both biomass and numbers of organisms should be utilized when studying the diversity of higher trophic levels.

Species diversity indices allow the comparison of communities or changes within a community. Patten (1962) stated that diversity could be used to describe changes in phytoplankton community composition and successional status. Wilhm (1969) noted that an unfavorable limiting factor such as pollution resulted in decrease in values of species diversity. Monk (1967) compared diversity values of successional stages in the eastern deciduous forest and concluded that climax communities on comparable sites are always higher in diversity than successional ones.

Studies assessing species diversity have dealt mainly with phytoplankton, aquatic invertebrates, and deciduous forests. Results of studies done in grasslands are conflicting. McNaughton (1967) attempted to assess the functional significance of species diversity in a California annual grassland. He concluded that diversity generated community stability, dominance generated community productivity, and increasing the number of species in a stand decreased efficiency. Singh and Misra (1969) after investigating the grasslands at Varanasi, India, indicated that McNaughton's generalizations may not hold true for all grasslands. They concluded that species diversity increased productive efficiency of the system, while dominance made the system stable though less efficient for production. In both of the above mentioned studies diversity was equated with the total species present.

Effects of Disturbance Factors on Vegetational Changes in the Tall Grass Prairie

Late Spring Burning

Late spring burning of true prairie vegetation results in increased herbage yields and a reduction of broadleaved species. The effects of burning usually last no more than 4 to 6 years. Anderson et al. (1970) stated that, although burning does reduce soil moisture, moisture levels are often sufficiently high that the reduction does not reduce yields.

The increase in herbage yields has been shown to be related to litter removal (Duvall, 1962; Ehrenreich, 1959; Hulbert, 1969; and Grelen and Epps, 1967). Removal of litter results in higher soil temperatures and increased light intensity. Old (1969) stated that higher soil temperatures influenced vegetation directly by increasing photosynthetic activity of grasses and indirectly by increasing microbial activity. Increased microbial activity results in increased foliar content of nitrogen and phosphorous early in the season. Increased solar radiation increases photosynthetic efficiency of prairie grasses and results in higher flowering rates in August.

Anderson et al. (1970) stated that late spring burning resulted in an increase of desirable species such as Andropogon gerardi and a decrease of broadleaved species and undesirable grasses. Old (1969) noted that spring burning eliminated woody species within a midwest prairie. Post fire development of perennial prairie grasses and forbs was rapid due to extensive rhizome and tap root development. Other workers have indicated that burning controls or reduces broadleaved species (Graves and McMurphy, 1969; Hutchinson, 1969; Kucera and Koelling, 1964; and Owensby and Anderson, 1967). Dix (1960) reported that the greatest differences in species composition in burned and unburned stands were noted in a 4 year old burn. He suggested a lag in the adjustment of perennial species to the modified environment.

Late spring burning effects last only a few years because litter accumulation, after cessation of burning, eventually becomes as abundant as it was prior to burning. Old (1969) reported that litter accumulation reached a semi-equilibrium 3 years after a burn in an Illinois prairie. Ehrenreich and Aikman (1963) stated that it took only 4 to 6 years of protection following burning of an Iowa prairie, for litter to accumulate to the extent that it equaled or exceeded the annual yield of vegetation. Kucera and Koelling (1964) reported that annual burning of a central Missouri prairie for 5 years resulted in a uniform cover of prairie grasses. However, burning every fifth year produced no appreciable differences when compared to control plots.

Mowing With Removal of Mulch

Mowing of vegetation with removal of mulch has no significant effect on species composition of tall grass prairie vegetation. Changes in plant phytomass due to mowing are variable. Crockett (1966) sampled a relict prairie after it had been mowed for 3 successive years. He concluded that mowing resulted in increased basal cover of established species. Launchbaugh (1955) stated that mowing after vegetation had reached maturity had no harmful effect on species composition. Skroch (1965) reported that the quality of vegetational composition improved materially in one growing season after mowing and removal of mulch due to a decrease in forb species. Hulbert (1969) stated that when litter is abundant in grasslands, removal of it by fire or clipping results in increased grass growth. His results showed denuded plots to have higher soil temperatures and increased yields. Vogel and Bjugstad (1968) reported that clipping *Andropogon scoparius*, *Andropogon gerardi*, and *Sorghastrum nutans* at the seed ripened stage or later, for 3 successive years, increased both yield and spring initiated tillering of plants. Hutchinson (1969) mowed and removed vegetation within the study site delineated in Chapter II in 1964, 1965, and 1966. Although he noted that changes in relative density and relative frequency of individual vegetative species had occurred (e.g., *Andropogon scoparius*), he concluded that mowing resulted in an increase in absolute composition (stems/m^2) and phytomass.

Penfound (1964) stated that a denuded prairie had more species than a protected prairie. He attributed this increase to a removal of mulch which had previously limited ecesis. Denudation also resulted in an increase in total biomass and in individual species biomass. However, subsequent measurement of the mowed area for 3 successive years indicated a steady decrease in biomass which, by the third year, was considerably lower than a protected prairie. Ehrenreich (1959, 1963) reported that 2 consecutive years of clipping native vegetation at the end of the growing season resulted in a 16% reduction in yield. Nieland and Curtis (1956) stated that certain species will decrease in relation to increased grazing or clipping. These species were, in order of disappearance, *Andropogon gerardi*, *Panicum virgatum*, *Elymus canadensis*, *Sorghastrum nutans*, and *Andropogon scoparius*. They concluded that decreases related to clipping resulted primarily from loss of photosynthetic tissue.

Plowing

Plowing is a form of disturbance which, when discontinued, results in secondary succession. Booth (1941) stated that revegetation of abandoned fields in central Oklahoma and southeastern Kansas followed this pattern: 1) weed stage - lasts 2 to 3 years and is composed of *Helianthus annuus*, *Erigeron canadensis*, *Digitaria sanguinalis*, *Haplopappus ciliatus*, *Croton glandulosus*, and others; 2) annual grass stage - lasts 9 to 13 years and is dominated by *Aristida oligantha*;

3) perennial bunchgrass - lasts an undetermined length of time and is dominated by Andropogon scoparius; 4) climax prairie - follows the perennial bunchgrass stage and is dominated by Andropogon scoparius, Andropogon gerardi, Panicum virgatum, and Sorghastrum nutans. After 30 years the areas Booth studied were still in the bunchgrass stage and did not appear to be nearing the fully developed prairie. Tomanek, Albertson, and Riegel (1955) reported that a field abandoned for 33 years in central Kansas had not reached climax.

Plowing of native prairie vegetation results in increased phytomass and substantial changes in species composition. Rice and Penfound (1954) attributed increased yield to the greater availability of minerals (particularly nitrogen) resulting from the decomposition of organic matter plowed under. Penfound and Rice (1957a) reported that a native tall grass prairie plowed annually for 5 years showed significant changes in the relative foliage cover of dominant species. After 1 year of plowing, Andropogon gerardi, Andropogon scoparius, and Sorghastrum nutans decreased while Leptoloma cognatum and the weedy forb Ambrosia psilostachya increased. After 3 years of plowing the composite Helianthus annuus was dominant. Penfound and Rice concluded that annual plowing changed plant populations by progressively destroying the propagules of the original prairie plants. Penfound and Rice (1957b) reported that four years after replowing an abandoned field the only important species, on the basis of relative cover, were Aster ericoides and Leptoloma cognatum. Skroch (1965) sampled plots which had been plowed once within the study site delineated in Chapter II. His results showed a decrease in all dominant grasses. Weedy forbs comprised 48.1% of the vegetation while grasses comprised 51.9%. Ambrosia psilostachya comprised 14.4% of the total composition in the plowed plots. Other forbs of importance were _Aster ericoides_, _Helianthus annuus_, _Strophostyles leiosperma_, _Solanum eleagnifolium_, and _Psoralea tenuiflora_. Protected plots had a relative composition of 81.7% grasses and 18.3% forbs. Hutchinson (1969) continued Skroch's work and reported that 2 years after plowing, once-plowed plots were dominated by _Ambrosia psilostachya_. Three years after plowing the annual grass _Aristida oligantha_ was dominant. Phytomass was greater the second and third years after plowing in once-plowed plots than in protected plots. _Sorghastrum nutans_ increased from 5.5 to 17.4% of the total phytomass over a 3 year period. Hutchinson attributed this increase to the nondestruction of _Sorghastrum nutans_ propagules, and he predicted that _Sorghastrum nutans_ would become the major dominant in the once-plowed plots in the ensuing years. Hutchinson noted that plowing each year had unpredictable results. The yearly turning over of organic matter increased phytomass only slightly. Species whose propagules were not buried too deeply were favored. Others reporting increased herbage yield due to plowing, discing, and spring toothing, or ripping grasslands are Brown and Everson (1952) and Heady (1952).

Herbicide Application

Experimentation suggests that Tordon[1] controls broadleaved herbaceous and woody species while leaving no long lasting soil residue. Arnold and Santelmann (1966) reported that the application of Picloram

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[1]Tordon is the commercial name of a herbicide which contains Picloram (4-amino-3,5,6-trichloropicolinic acid) as the active ingredient.

to native range did not reduce forage production or desirable plant frequency at applications of 1,2, and 4 lb./acre (0.454, 0.907, and 1.814 kg/0.405 ha). Forb production was reduced with Achillea lanulosa, Aster ericoides, and Vernonia baldwini being effectively controlled. Goring, Youngson, and Hamaker (1965) noted that because of its persistence in soil and susceptibility to leaching Picloram had been extremely effective on deep rooted plants via soil applications Eisinger and Moore (1970) stated that Picloram's herbicidal effectiveness is attributed to mobility and resistance to breakdown within plants. They concluded that Picloram functions as a growth regulator of the auxin type with a herbicidal action similar to that of 2,4,-D. Persistence of Picloram in soils is related to organic matter concentration (Herr, Stroube, Ray, 1966; and Grover, 1968) and to concentration of Picloram applied (Herr et al., 1966; Grover, 1967; and Goring et al., 1965).

Keys and Friesen (1968) reported that recovery of the herbicide applied at rates of 8 oz/acre (0.227 kg/0.405 ha) or higher in the fall declined to approximately 10% after 24 months. For rates of 32 and 48 oz/acre (0.907 and 1.36 kg/0.405 ha) recovery declined to 6% after 35 months. Goring et al. (1965) applied Tordon at rates of 1.44 to 4.20 lb./acre (0.653 to 1.905 kg/0.405 ha) in California, South Dakota, Kansas, and Minnesota. Losses of Tordon ranged from 58-96% within 1 year after application and from 78-100% within 2 years after application. The greatest percentage loss of Tordon occurred at the lowest concentrations. Herr et al. (1966) reported little or no persistence of Picloram at the end of a 15 month study period at applications of 2,4, and 8 oz/acre (0.057, 0.113, and 0.227 kg/0.405 ha). However, at applications rates of 32 and 64 oz/acre (0.907 and 1.814 kg/0.405 ha) residues were present more than 430 days after application. Hoffman, Merkle, and Haas (1972) reported that Picloram was not detected in soil at depths of 0.000-0.129 m following application of Tordon 225 Mixture at the rate of 0.5 lb./acre (0.227 kg/0.405 ha) for 3 consecutive years. Hoffman (1971) reported that a test for Picloram residue in south Texas soils showed none persisting in 0.152 and 0.152 to 0.257 m soil depths 540 days from initial application. Application rates were 0.5 and 0.75 gal/acre (1.893 and 2.848 liters/0.405 ha) Tordon 225 Mixture. Scifres, Burnside, and McCarty (1969) reported that more Picloram was detected in the 0.610 and 0.914 m depth from plots treated 1, 2, and 3 years before sampling than in plots sampled the year of treatment. Their results indicate downward movement of Picloram into the soil.

CHAPTER V

RESULTS

Individual Treatments

Results from sampling each treatment will be discussed separately, and a final analysis will compare results for all treatments. The term abundance is used to refer to species which had both relative composition and frequency percentages equal to or greater than 3.0%. These species would tend to have a greater influence on diversity calculations than species with lower values. The plateau points shown on the various diversity curves are defined as the points after which the diversity values show little variation. The selection of these points was made arbitrarily.

Protected Plots

Frequency and relative composition percentages shown in Tables V, VI, and VII indicated that a few species were abundant and widely distributed while the majority of species were rare. This pattern was apparent for all other treatments. Frequency percentages obtained by 0.1 m^2 quadrats were higher than Point Centered Quarter percentages because of the larger sized sampling unit.

Species of abundance in Plot 1 were *Andropogon scoparius*, *Andropogon ternarius*, *Aster ericoides*, *Panicum oligosanthes*, and *Sorghastrum nutans*. The most abundant species in Plot 11 were *Ambrosia psilostachya*,

TABLE V

PLOT 1 RESULTS BASED ON POINT CENTERED QUARTER SAMPLES (PCQ) AND QUADRAT SAMPLES (Q)

Species	PCQ*			Q**		
	Individuals	Frequency	Relative Composition	Weight	Frequency	Relative Composition
Achillea lanulosa	1	0.3	0.1	0.2	3	0.0**
Ambrosia psilostachya	13	3.3	1.1	17.5	19	1.2
Andropogon gerardi	23	3.7	1.9	43.9	10	2.9
Andropogon saccharoides	9	1.3	0.8	13.6	18	0.9
Andropogon scoparius	338	42.0	28.2	281.6	82	18.6
Andropogon ternarius	129	25.2	10.8	130.0	42	8.6
Antennaria campestris	1	0.3	0.1	-	-	-
Aristida oligantha	6	1.7	0.5	1.0	13	0.1
Aristida purpurascens	-	-	-	3.36	10	0.2
Artemesia ludoviciana	1	0.3	0.1	-	-	-
Asclepias viridis	-	-	-	0.2	1	0.0
Aster ericoides	40	11.7	3.3	67.8	52	4.5
Bouteloua curtipendula	7	1.3	0.6	2.2	2	0.1
Bromus japonicus	-	-	-	0.2	1	0.0
Carex sp.	34	8.7	2.8	15.9	21	1.1
Cassia fasciculata	3	1.0	0.3	0.4	3	0.0
Cirsium undulatum	1	0.3	0.1	-	-	-
Croton sp.	-	-	-	0.1	1	0.0
Desmanthus illinoensis	1	0.3	0.1	0.7	1	0.1
Diodia teres	10	2.0	0.8	0.9	11	0.1
Elymus canadensis	-	-	-	0.2	1	0.0
Eragrostis spectabilis	5	1.3	0.4	2.5	1	0.2
Erigeron strigosus	2	0.7	0.2	-	-	-
Euphorbia marginata	-	-	-	0.1	1	0.0
Hiereracium longipilum	3	1.0	0.3	0.4	1	0.0
Juncus interior	3	1.0	0.3	0.6	1	0.0
Leptoloma cognatum	7	1.7	0.6	5.3	13	0.4
Lespedeza capitata	1	0.3	0.1	-	-	-
Lespedeza virginica	11	3.7	0.9	21.9	19	1.5
Liatris punctata	5	1.3	0.4	9.0	5	0.6
Linum sulcatum	5	1.7	0.4	1.7	14	0.1
Oxalis Dillenii	1	0.3	0.1	0.1	1	0.0
Panicum oligosanthes	46	12.0	3.8	19.6	38	1.3
Panicum virgatum	7	1.7	0.6	3.8	1	0.3
Petalostemum purpurea***	1	0.3	0.1	-	-	-
Polygala verticillata	1	0.3	0.1	0.3	6	0.0
Psoralea tenuiflora	3	1.0	0.3	3.3	4	0.2
Rudbeckia hirta	2	0.7	0.2	-	-	-
Solanum torreyi	-	-	-	0.6	1	0.0
Solidago sp.	39	8.3	3.3	13.3	6	0.9

TABLE V. (Continued)

Species	PCQ* Individuals	Frequency	Relative Composition	Q** Weight	Frequency	Relative Composition
Solidago rigida	19	5.0	1.6	13.3	6	0.9
Sorghastrum nutans	398	63.3	33.2	795.3	92	52.5
Sporobulus asper	15	3.3	1.3	26.9	9	1.8
Talinum parviflorum	2	0.3	0.2	-	-	-
Tridens flavus	2	0.7	0.2	-	-	-
Unknown species	2	0.7	0.2	-	-	-

*Frequency was based on 300 Point Centered Quarter Samples. Relative Composition was based on 1200 individuals. Total number of species was 38.

**Frequency was based on 100 0.1 m^2 quadrats. Relative composition was based on the combined phytomass of all species which was 1514.1 g. Total number of species was 36.

***Waterfall (1966) refers to this genus as Dalea. Most taxonomic works refer to it as Petalostemum.

**Species were weighed to the nearest 0.01 g. For purposes of clarity and accuracy relative composition and frequency values were rounded to the nearest 0.1 g. Species having relative composition and frequency values of less than 0.05 were rounded to 0.0.

TABLE VI

PLOT 11 RESULTS BASED ON POINT CENTERED QUARTER SAMPLES (PCQ) AND QUADRAT SAMPLES (Q)

Species	PCQ* Individuals	PCQ* Frequency	PCQ* Relative Composition	Q** Weight	Q** Frequency	Q** Relative Composition
Achillea lanulosa	26	3.3	2.2	11.7	28	0.4
Acalphya sp.	2	0.7	0.2	-	-	-
Ambrosia psilostachya	93	23.3	7.8	252.1	89	9.2
Andropogon gerardi	12	2.0	1.0	153.7	7	5.6
Andropogon saccharoides	19	4.7	1.6	49.0	27	1.8
Andropogon scoparius	349	57.7	29.1	845.2	93	30.9
Andropogon ternarius	8	2.0	0.7	13.7	4	0.5
Apocynum cannabinum	-	-	-	1.5	1	0.1
Aristida oligantha	3	1.0	0.3	1.3	10	0.1
Aristida purpurascens	-	-	-	0.2	3	0.0
Artemesia ludoviciana	5	1.0	0.4	19.8	7	0.7
Asclepias sp.	-	-	-	3.2	1	0.1
Asclepias viridis	3	0.3	0.3	8.8	2	0.3
Aster ericoides	101	24.3	8.4	201.2	78	7.4
Bouteloua curtipendula	4	0.3	0.3	10.7	1	0.4
Bromus japonicus	113	22.0	9.4	47.3	89	1.7
Carex sp.	13	4.0	1.1	12.5	28	0.5
Cassia fasciculata	5	1.7	0.4	9.3	8	0.3
Croton capitatus	3	1.0	0.3	0.8	4	0.0
Desmodium sessilfolium	-	-	-	1.1	1	0.0
Elymus canadensis	1	0.3	0.1	2.6	4	0.1
Elymus virginicus	-	-	-	0.1	1	0.0
Eragrostis intermedia	2	0.7	0.2	-	-	-
Eragrostis spectabilis	-	-	-	6.4	4	0.2
Euphorbia marginata	-	-	-	0.7	1	0.0
Juncus interior	3	1.0	0.3	0.2	2	0.0
Leptoloma cognatum	19	5.3	1.6	25.8	34	0.9
Lespedeza capitata	1	0.3	0.1	-	-	-
Lespedeza virginica	7	1.7	0.6	7.8	2	0.3
Linum sulcatum	1	0.3	0.1	0.7	2	0.0
Oxalis Dillenii	1	0.3	0.1	0.1	2	0.0
Panicum oligosanthes	29	6.7	2.4	34.0	36	1.2
Psoralea tenuiflora	8	2.3	0.7	22.0	4	0.8
Sabatia campestris	2	0.3	0.2	-	-	-
Solanum carolinense	-	-	-	1.7	2	0.1
Solanum torreyi	4	1.3	0.3	10.0	5	0.4
Solidago sp.	11	3.0	0.9	50.7	8	1.9
Sorghastrum nutans	310	53.7	25.8	804.1	79	29.4
Sporobulus asper	16	5.7	1.3	31.6	13	1.2
Strophostyles leiosperma	8	3.0	0.7	13.5	26	0.5
Symphoricarpos orbiculatus	3	0.7	0.3	78.5	4	2.9

TABLE VI (Continued)

Species	PCQ* Indi-vid-uals	Fre-quency	Rela-tive Compo-sition	Q** Weight	Fre-quency	Rela-tive Compo-sition
Ulmus americana	2	0.7	0.2	-	-	-
Unknown species	8	3.0	0.8	-	-	-

*Frequency was based on 300 Point Centered Quarter samples. Relative Composition was based on 1200 individuals. Total number of species was 34.

**Frequency was based on 100 0.1 m^2 quadrats. Relative composition was based on the combined phytomass of all species which was 2733.5 g. Total number of species was 37.

TABLE VII

PLOT 18 RESULTS BASED ON POINT CENTERED QUARTER SAMPLES (PCQ) AND QUADRAT SAMPLES (Q)

Species	PCQ*			Q**		
	Indi-vid-uals	Fre-quency	Rela-tive Compo-sition	Weight	Fre-quency	Rela-tive Compo-sition
Achillea lanulosa	8	2.3	0.7	7.9	10	0.2
Acalphya sp.	2	0.7	0.2	0.2	5	0.0
Ambrosia psilostachya	55	15	4.6	280.0	65	8.31
Andropogon gerardi	360	41.0	30.0	1403.2	49	41.6
Andropogon saccharoides	8	1.7	0.7	41.3	19	1.2
Andropogon scoparius	141	23.0	11.8	360.78	58	10.7
Andropogon ternarius	2	0.3	0.2	-	-	-
Aristida oligantha	2	0.7	0.2	3.9	14	0.1
Aristida purpurascens	-	-	-	0.1	1	0.0
Aster ericoides	55	13.7	4.6	175.6	60	5.2
Baptisia sp.	1	0.3	0.1	-	-	-
Bouteloua curtipendula	7	1.0	0.6	13.6	3	0.4
Bouteloua gracilis	-	-	-	5.0	4	0.2
Bromus japonicus	259	42.7	21.6	168.1	91	5.0
Carex sp.	17	5.3	1.4	10.7	19	0.3
Cassia fasciculata	-	-	-	4.9	5	0.1
Cornus sp.	1	0.3	0.1	-	-	-
Croton capitatus	2	0.7	0.2	3.7	5	0.1
Elymus canadensis	3	1.0	0.3	4.8	6	0.1
Juncus interior	5	1.3	0.4	1.4	4	0.0
Leptoloma cognatum	12	3.3	1.0	34.2	22	1.0
Lespedeza virginica	2	0.3	0.2	0.5	1	0.0
Linum sulcatum	-	-	-	0.2	1	0.0
Oxalis Dillenii	1	0.3	0.1	0.2	3	0.0
Panicum oligosanthes	4	1.0	0.3	8.2	9	0.2
Physalis sp.	1	0.3	0.1	-	-	-
Plantago virginica	-	-	-	0.2	2	0.0
Psoralea tenuiflora	18	5.3	1.5	46.3	15	1.4
Solanum eleagnifolium	-	-	-	2.3	1	0.1
Solidago sp.	-	-	-	0.8	2	0.0
Sorghastrum nutans	48	6.7	4.0	318.6	25	9.5
Sporobulus asper	162	28.0	13.5	465.5	66	13.8
Strophostyles leiosperma	3	1.0	0.3	1.0	6	0.0
Teucrium canadense	9	2.7	0.8	6.4	3	0.2
Ulmus americana	1	0.3	0.1	-	-	-
Unknown species	2	0.7	0.2	-	-	-

*Frequency was based on 300 Point Centered Quarter Samples. Relative Composition was based on 1200 individuals. Total number of species was 28.

TABLE VII (Continued)

**Frequency was based on 100 0.1 m^2 quadrats. Relative composition was based on the combined phytomass of all species which was 3369.5 g. Total number of species was 30.

Andropogon scoparius, Aster ericoides, and Sorghastrum nutans. Bromus japonicus resulted in high frequency percentages for both sampling methods, but relative composition values were contradictory. Abundant species in Plot 18 were Ambrosia psilostachya, Andropogon gerardi, Andropogon scoparius, Aster ericoides, Sorghastrum nutans, and Sporobulus asper.

Diversity values were similar when based on numbers of individuals (Figure 4)[1]. However, differences between Plots 1 and 18 were apparent when values based on numbers of individuals were compared to values based on phytomass (Figures 4 and 5). The disparity between the values was due to the equitability of distribution among species; i.e., distribution was more equitable among species when values were based on numbers in Plots 1 and 18. Diversity values for Plot 11 based on both numbers of individuals and phytomass were approximately equal (Figures 4 and 5). Species which showed greater relative composition percentages, based on phytomass, were Sorghastrum nutans in Plot 1 and Andropogon gerardi in Plot 18. The lowered diversity value in Plot 1, based on phytomass (Figure 5), would be partially attributed to the dominance of Sorghastrum nutans while in Plot 18 the contribution by Andropogon gerardi to the phytomass diversity value was slightly higher than its contribution to the diversity value based on numbers. This occurs because an n_i which contributes 37% to the total sample will make maximum contribution to total diversity (Wilhm, 1968). Wilhm's results also show that an n_i contributing 50% to the total sample makes less of a

[1]Calculated diversity values, based on numbers of individuals, were plotted for every fifth value. Since only four individuals were added for every Point Centered Quarter sample taken, the diversity value changed very gradually as samples were pooled.

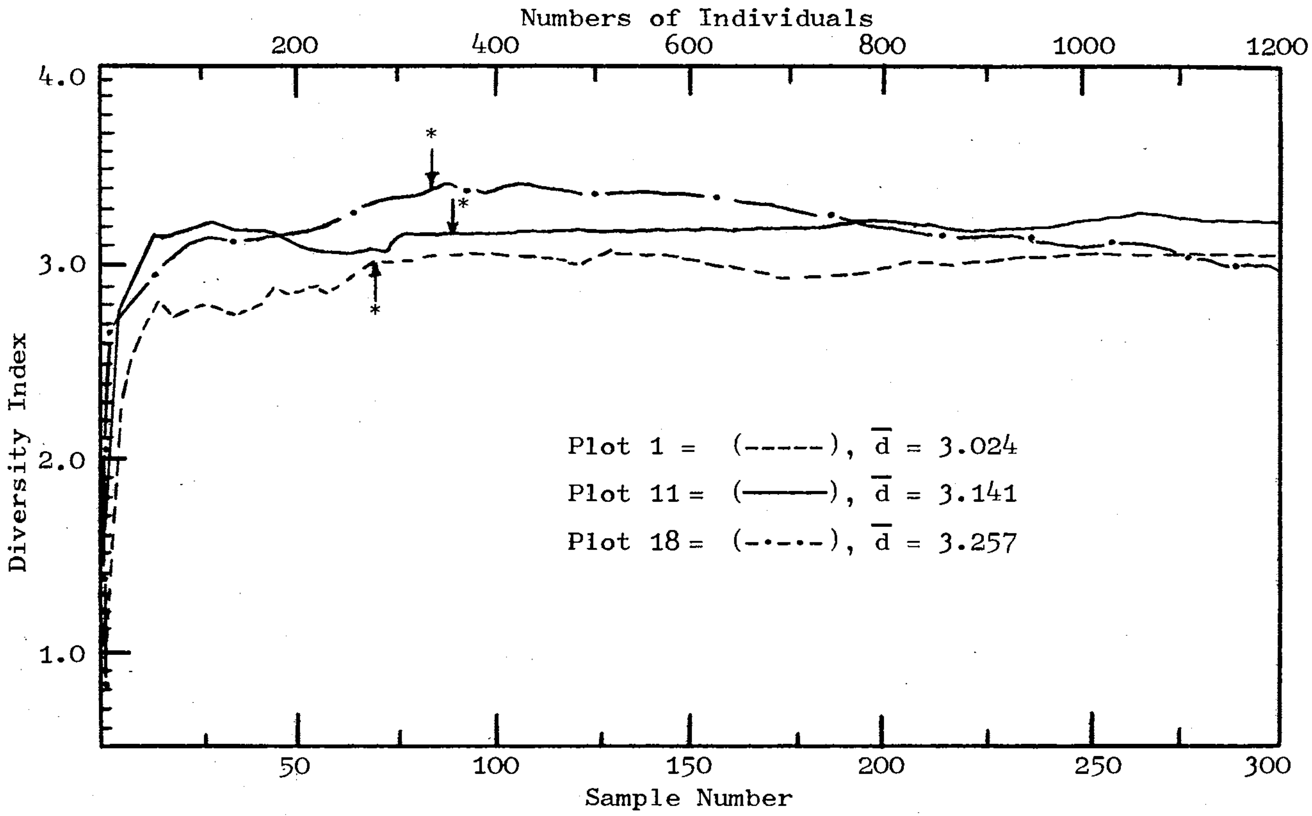

Figure 4. Graph of Diversity Index $\bar{d} = -\sum_{i=1}^{s} (n_i/n)\log_2(n_i/n)$ for Protected Plots Based on Pooled Point Centered Quarter Samples. (Diversity values calculated for every fifth sample were plotted. An asterisk indicates the point where diversity plateaus. The $\bar{d}$ values are averages based on all values past the plateau.)

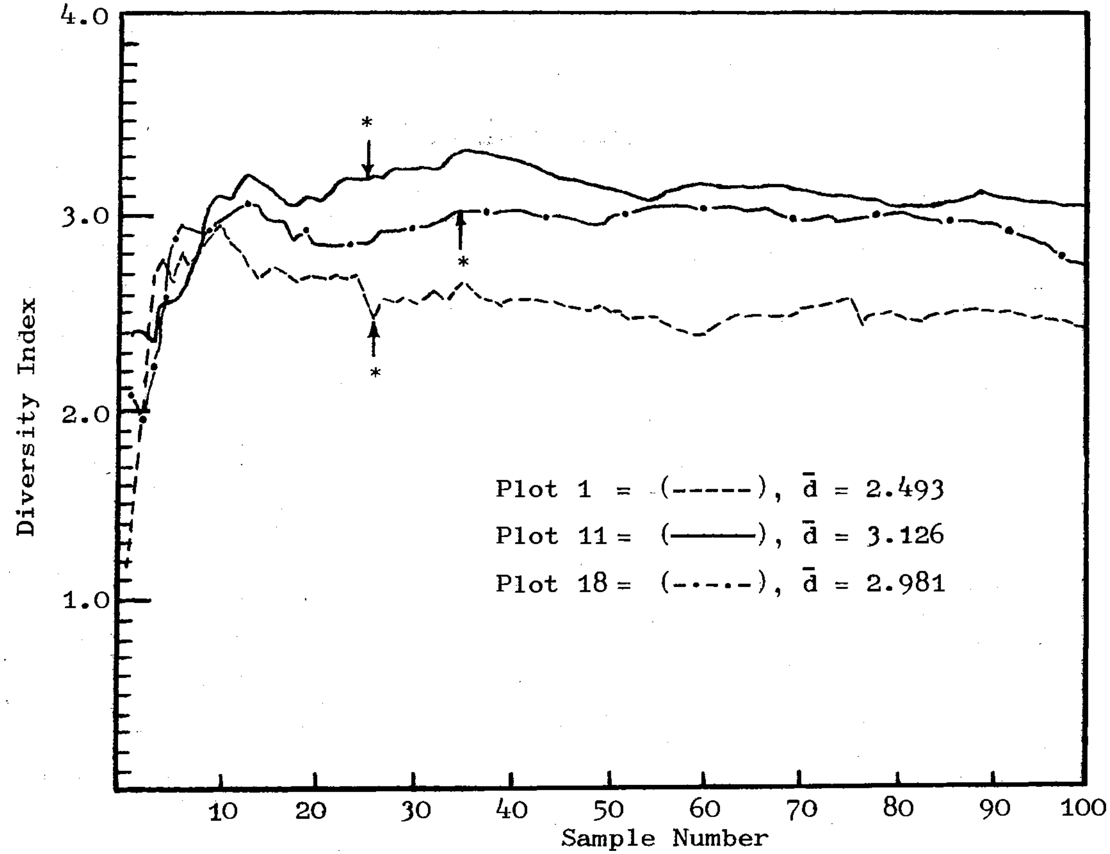

Figure 5. Graph of Diversity Index $\bar{d} = -\sum_{i=1}^{s} (w_i/w)\log_2(w_i/w)$ for Protected Plots Based on 100 0.1 m^2 Quadrats. (An asterisk indicates the point where diversity plateaus. The $\bar{d}$ values are averages based on all values past the plateau.)

contribution to total diversity than an n_i which contributes 30%. Therefore, the lower phytomass diversity value in Plot 1 was due to a decrease in the value contributed to total diversity by _Sorghastrum nutans_ plus a decrease in the equitability of distribution of phytomass among species (Table V). While the contribution to the phytomass diversity value by _Andropogon gerardi_ was slightly higher, the lower phytomass diversity value for Plot 18 was due to the decrease in the equitability of distribution of phytomass among species (Table VII).

Protected plots were variable as to total phytomass and dominant species. Plot 1 produced a total phytomass, for the 100 0.1 m^2 quadrats sampled, of 1514.1 g. This amount was considerably less than Plots 11 and 18 which produced 2733.5 and 3369.5 g, respectively. Variation in phytomass could be attributed to differences in soil moisture and to differential production of phytomass by abundant species. Featherly (1946) stated that _Andropogon ternarius_ (abundant in Plot 1) occurred on dry sandy soils as a filler grass which seldom appeared in perfect stands. Weaver (1960) stated that many years of soil sampling showed the available water content of soil to always be higher under stands of _Andropogon gerardi_ than under stands of _Andropogon scoparius_. Plot 18 was characterized by a frequency of 49% for _Andropogon gerardi_ (Table VII). This species occurred mainly in the northern half of the plot. _Andropogon scoparius_, _Sorghastrum nutans_, and _Sporobulus asper_ were more frequent in the southern half of the plot. Featherly stated that _Sporobulus asper_ occurred on dry soils, and Weaver (1954) noted that _Sporobulus asper_ was a xeric grass which would rapidly spread even in dry soils. The results of species distribution within Plot 18 would indicate higher soil moistures in the northern portion of the plot since

Andropogon gerardi was concentrated in that part. The concentration of *Andropogon gerardi* was reflected in the diversity curves for Plot 18. The diversity value, based on numbers of individuals, began to decrease rather steadily at approximately 150 samples (Figure 4). The value, based on phytomass, decreased after 80 samples (Figure 5). In both instances *Andropogon gerardi* was the only species which made a significant contribution.

Late Spring Burn Plot

Species most frequently encountered were *Ambrosia psilostachya*, *Andropogon scoparius*, *Andropogon ternarius*, *Aster ericoides*, and *Sorghastrum nutans* (Table VIII). The abundance of *Andropogon ternarius* would indicate that Plot 4 had a drier, sandier soil than the adjacent, Protected Plot 11.

The greater relative composition of *Andropogon scoparius* and a less equitable distribution of phytomass among species resulted in a lower phytomass diversity value (Figure 7) than that based on numbers of individuals (Figure 6).

Mowed and Removed Plot

Ambrosia psilostachya, *Andropogon scoparius*, *Aster ericoides*, and *Sorghastrum nutans* were most abundant in this plot (Table IX).

The diversity value based on numbers of individuals (Figure 8) showed a gradual increase with a plateau being reached at sample number 210. The dominance of *Andropogon scoparius* kept the diversity value low, and by sample 75 the value was only 2.256. In plots 1 and 4 the diversity plateau was reached by sample 75, and little variance occurred

TABLE VIII

PLOT 4 RESULTS BASED ON POINT CENTERED QUARTER SAMPLES (PCQ) AND QUADRAT SAMPLES (Q)

Species	PCQ*			Q**		
	Indi-vid-uals	Fre-quency	Rela-tive Compo-sition	Weight	Fre-quency	Rela-tive Compo-sition
Achillea lanulosa	15	5.0	1.3	5.0	21	0.2
Acalphya sp.	4	1.7	0.3	0.2	5	0.0
Ambrosia psilostachya	73	20.0	6.1	118.9	68	4.8
Andropogon gerardi	1	0.3	0.1	-	-	-
Andropogon saccharoides	8	2.3	0.7	1.8	3	0.1
Andropogon scoparius	521	71.0	43.4	1425.9	98	57.4
Andropogon ternarius	170	30.7	14.2	191.2	54	7.7
Antennaria campestris	1	0.3	0.1	0.1	1	0.0
Apocynum cannabinum	2	0.7	0.2	-	-	-
Aristida oligantha	4	1.3	0.3	1.1	13	0.0
Aristida purpurascens	-	-	-	0.8	5	0.0
Artemesia ludoviciana	-	-	-	0.2	1	0.2
Asclepias viridis	2	0.7	0.2	16.4	3	0.7
Aster ericoides	55	14.3	4.6	90.8	69	3.7
Bromus japonicus	10	1.7	0.8	3.8	23	0.2
Carex sp.	16	4.7	1.3	5.5	11	0.2
Cassia fasciculata	6	1.7	0.5	20.1	22	0.8
Cirsium undulatum	0	0	0	0.1	1	0.0
Crataegus sp.	-	-	-	0.1	2	0.0
Croton sp.	-	-	-	0.1	2	0.0
Diodia teres	-	-	-	0.1	1	0.0
Elymus canadensis	1	0.3	0.1	1.2	2	0.1
Eragrostis intermedia	1	0.3	0.1	0.3	3	0.0
Eragrostis spectabilis	6	1.7	0.5	2.8	14	0.1
Gnaphalium obtusfolium	-	-	-	0.2	1	0.0
Hieracium longipilum	2	0.7	0.2	6.8	2	0.3
Juncus interior	4	1.3	0.3	0.3	4	0.0
Leptoloma cognatum	31	9.0	2.6	16.2	38	0.7
Lespedeza capitata	1	0.3	0.1	-	-	-
Lespedeza virginica	11	2.3	0.9	51.1	14	2.1
Linum sulcatum	5	1.7	0.4	1.8	13	0.1
Opuntia sp.	1	0.3	0.1	-	-	-
Oxalis Dillenii	3	1.0	0.3	0.3	2	0.0
Panicum oligosanthes	31	9.0	2.6	18.3	50	0.7
Physalis sp.	1	0.3	0.1	0.5	1	0.0
Plantago aristida	1	0.3	0.1	-	-	-
Plantago virginica	1	0.3	0.1	0.0	1	0.0
Polygala verticillata	-	-	-	0.0	1	0.0
Psoralea tenuiflora	-	-	-	52.5	3	2.1
Rhus copallina	-	-	-	2.0	1	0.1

TABLE VIII (Continued)

Species	PCQ* Individuals	PCQ* Frequency	PCQ* Relative Composition	Q** Weight	Q** Frequency	Q** Relative Composition
Rudbeckia hirta	3	0.7	0.3	-	-	-
Solanum carolinense	3	1.0	0.3	0.1	1	0.0
Solanum eleagnifolium	-	-	-	1.4	1	0.1
Solanum torreyi	-	-	-	3.3	3	0.1
Solidago sp.	8	2.3	0.7	6.8	11	0.3
Solidago rigida	2	0.7	0.2	-	-	-
Sorghastrum nutans	183	33.0	15.3	402.8	90	16.2
Sporobulus asper	8	2.3	0.7	5.9	8	0.2
Strophostyles leiosperma	4	1.3	0.3	4.2	13	0.2
Symphoricarpos orbiculatus	-	-	-	18.1	2	0.7
Tridens flavus	1	0.3	0.1	2.8	1	0.1
Unknown species	1	0.2	0.1	-	-	-
Vernonia baldwinii	-	-	-	1.6	1	0.1

*Frequency was based on 300 Point Centered Quarter Samples. Relative Composition was based on 1200 individuals. Total number of species was 38.

**Frequency was based on 100 0.1 m^2 quadrats. Relative composition was based on the combined phytomass of all species which was 2483.2 g. Total number of species was 45.

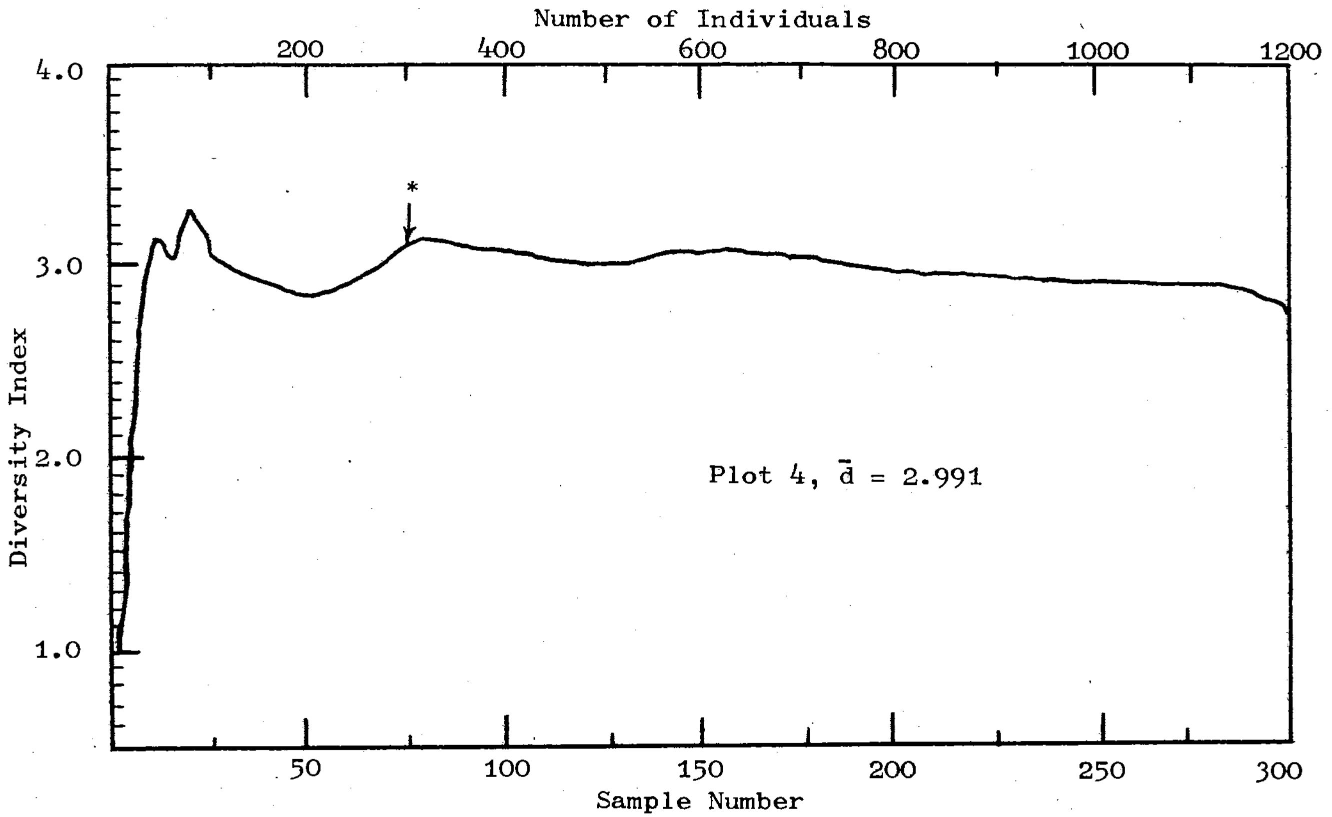

Figure 6. Graph of Diversity Index $\bar{d} = -\sum_{i=1}^{s}(n_i/n)\log_2(n_i/n)$ for Late Spring Burn Plot Based on Pooled Point Centered Quarter Samples. (Diversity values calculated for every fifth sample were plotted. An asterisk indicates the point where diversity plateaus. The $\bar{d}$ value is an average based on all values past the plateau.)

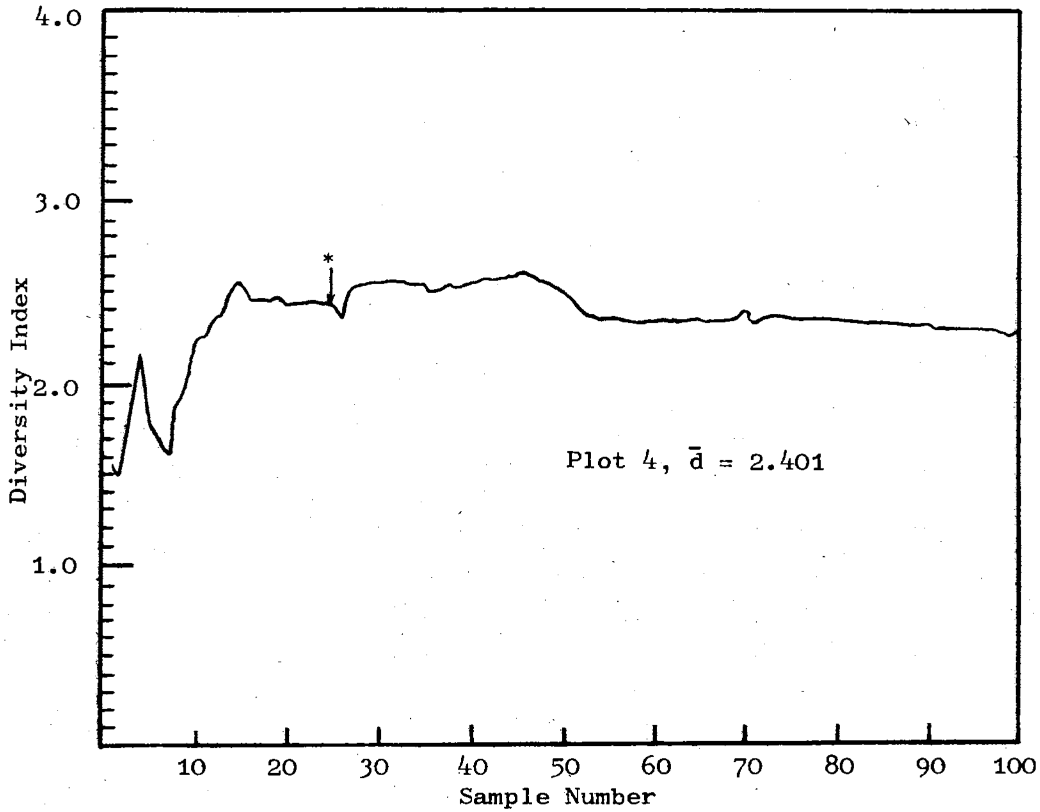

Figure 7. Graph of Diversity Index $\bar{d} = -\sum_{i=1}^{s} (w_i/w)\log_2(w_i/w)$ for Late Spring Burn Plot Based on 100 0.1 m^2 Quadrats. (An asterisk indicates the point where diversity plateaus. The $\bar{d}$ value is an average based on all values past the plateau.)

TABLE IX

PLOT 9 RESULTS BASED ON POINT CENTERED QUARTER SAMPLES (PCQ) AND QUADRAT SAMPLES (Q)

Species	PCQ*			Q**		
	Indi-vid-uals	Fre-quency	Rela-tive Compo-sition	Weight	Fre-quency	Rela-tive Compo-sition
Achillea lanulosa	17	5.3	1.4	6.2	27	0.3
Acalphya sp.	1	0.3	0.1	-	-	-
Ambrosia psilostachya	45	13.7	3.8	102.3	78	4.7
Andropogon gerardi	34	3.7	2.8	92.0	11	4.2
Andropogon saccharoides	7	1.0	0.6	25.7	11	1.2
Andropogon scoparius	588	80.0	49.0	859.1	94	39.6
Andropogon ternarius	36	6.7	3.0	39.0	23	1.8
Aristida oligantha	4	1.0	0.3	3.6	28	0.2
Aristida purpurascens	-	-	-	13.7	17	0.6
Artemesia ludoviciana	1	0.3	0.1	-	-	-
Asclepias viridis	1	0.3	0.1	-	-	-
Aster ericoides	90	22.3	7.5	195.0	88	9.0
Bouteloua curtipendula	7	2.3	0.6	-	-	-
Bromus japonicus	13	3.0	1.1	5.2	26	0.2
Carex sp.	16	5.0	1.3	1.4	10	0.1
Cassia fasciculata	5	1.7	0.4	6.5	16	0.3
Crataegus sp.	-	-	-	0.0	1	0.0
Croton capitatus	-	-	-	0.7	3	0.0
Desmodium sessilfolium	-	-	-	1.6	1	0.1
Diodia teres	-	-	-	0.2	1	0.0
Eragrostis intermedia	9	2.3	0.8	0.6	3	0.0
Eragrostis spectabilis	2	0.7	0.2	4.7	3	0.2
Juncus interior	6	1.7	0.5	0.1	3	0.0
Leptoloma cognatum	23	4.7	1.9	14.0	40	0.6
Lespedeza capitata	3	1.3	0.3	14.5	3	0.7
Lespedeza virginica	3	0.7	0.3	0.3	5	0.0
Liatris punctata	-	-	-	0.4	1	0.0
Linum sulcatum	6	2.0	0.5	1.7	11	0.1
Oxalis Dillenii	2	0.7	0.2	-	-	-
Panicum oligosanthes	24	6.7	2.0	17.5	41	0.8
Plantago aristida	2	0.7	0.2	0.1	1	0.0
Plantago virginica	1	0.3	0.1	0.1	2	0.0
Polygala incarnata	1	0.3	0.1	-	-	-
Psoralea tenuiflora	15	4.0	1.3	86.0	10	4.0
Rudbeckia hirta	1	0.3	0.1	0.1	1	0.0
Sabatia campestris	-	-	-	0.1	1	0.0
Solanum eleagnifolium	-	-	-	0.3	1	0.0
Solidago sp.	4	1.3	0.3	3.9	11	0.2
Solidago rigida	1	0.3	0.1	-	-	-
Sorghastrum nutans	207	32.3	17.3	631.5	77	29.1

TABLE IX (Continued)

Species	PCQ* Individuals	Frequency	Relative Composition	Q** Weight	Frequency	Relative Composition
Sporobulus asper	21	5.3	1.8	36.5	27	1.7
Strophostyles leiosperma	1	0.3	0.1	3.7	14	0.2
Tragia betonicifolia	-	-	-	0.0	1	0.0
Unknown species	2	1.7	0.2	-	-	-

*Frequency was based on 300 Point Centered Quarter Samples. Relative composition was based on 1200 individuals. Total number of species was 34.

**Frequency was based on 100 0.1 m^2 quadrats. Relative composition was based on the combined phytomass of all species which was 2168.0 g. Total numberof species was 36.

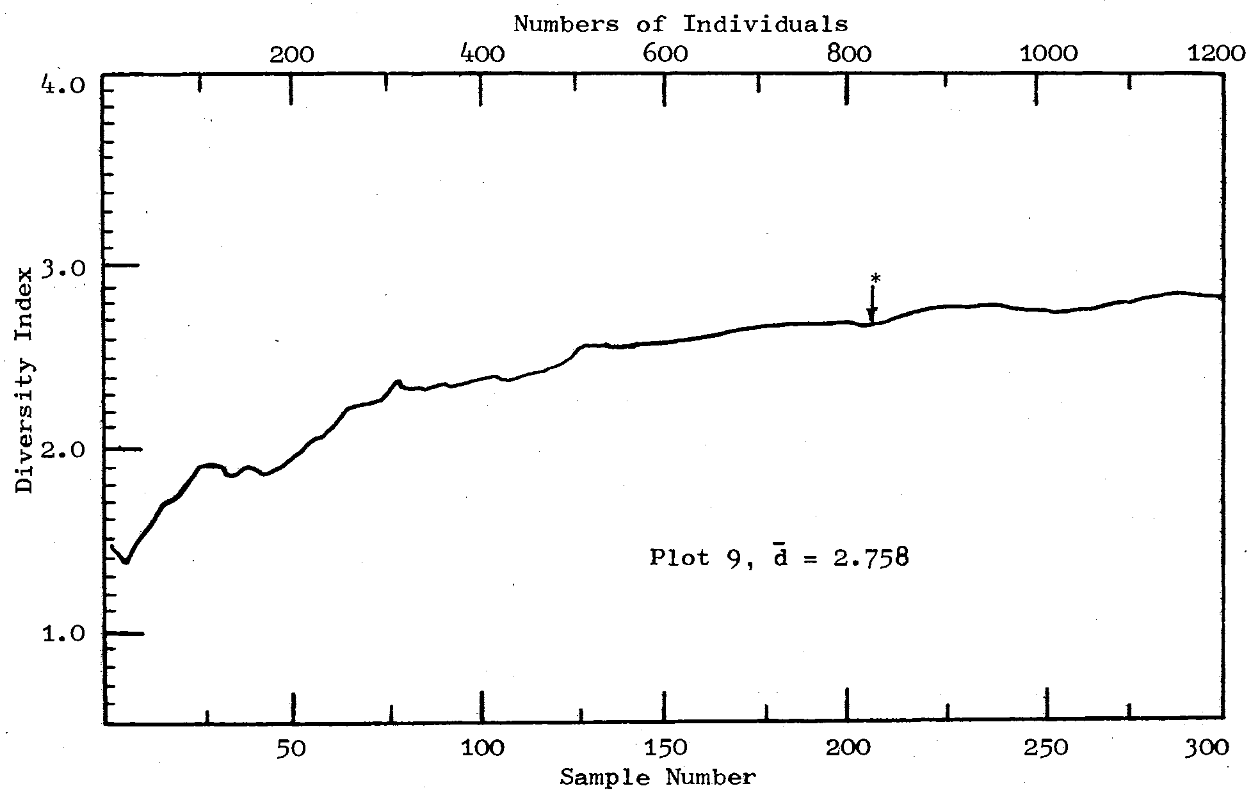

Figure 8. Graph of Diversity Index $\bar{d} = -\sum_{i=1}^{s}(n_i/n)\log_2(n_i/n)$ for Mowed and Removed Plot Based on Pooled Point Centered Quarter Samples. (Diversity values calculated for every fifth sample were plotted. An asterisk indicates the point where diversity plateaus. The $\bar{d}$ value is an average based on all values past the plateau.)

after that. The gradual increase in diversity from samples 75 to 210 in Plot 9 was because eight of twelve new species collected had a total of more than one individual. The average number of individuals per species was 3.67. In Plot 1 of fourteen new species collected between samples 75 to 210, only five had more than one individual. The average number of individuals per species was 1.79. In Plot 4, of nine new species collected between samples 75 to 210, only four had more than one individual, the average being 2.44. Although dominance of *Andropogon scoparius* lowered the diversity value in Plot 9, the greater equitability of species between samples 75 to 210 resulted in a gradual increase in the diversity value.

Diversity based on numbers (Figure 8) was higher than the value based on phytomass (Figure 9). The lower phytomass value was due to a less equitable distribution of phytomass among species.

Plowed Plots

Abundant species in Plot 10 were *Ambrosia psilostachya*, *Andropogon scoparius*, *Aster ericoides*, and *Sorghastrum nutans* (Table X). Comparison of diversity values showed a pattern similar to other treatments; i.e., a higher value based on numbers of individuals (Figure 10) as compared to the value for phytomass (Figure 11). The greater dominance of *Sorghastrum nutans* plus a less equitable distribution of phytomass contributed to the lower phytomass value.

Species of abundance in Plot 15 were *Ambrosia psilostachya*, *Andropogon saccharoides*, *Andropogon scoparius*, *Artemesia ludoviciana*, *Aster ericoides*, *Leptoloma cognatum*, *Panicum virgatum*, and *Sorghastrum nutans* (Table XI). The diversity value based on numbers of individuals

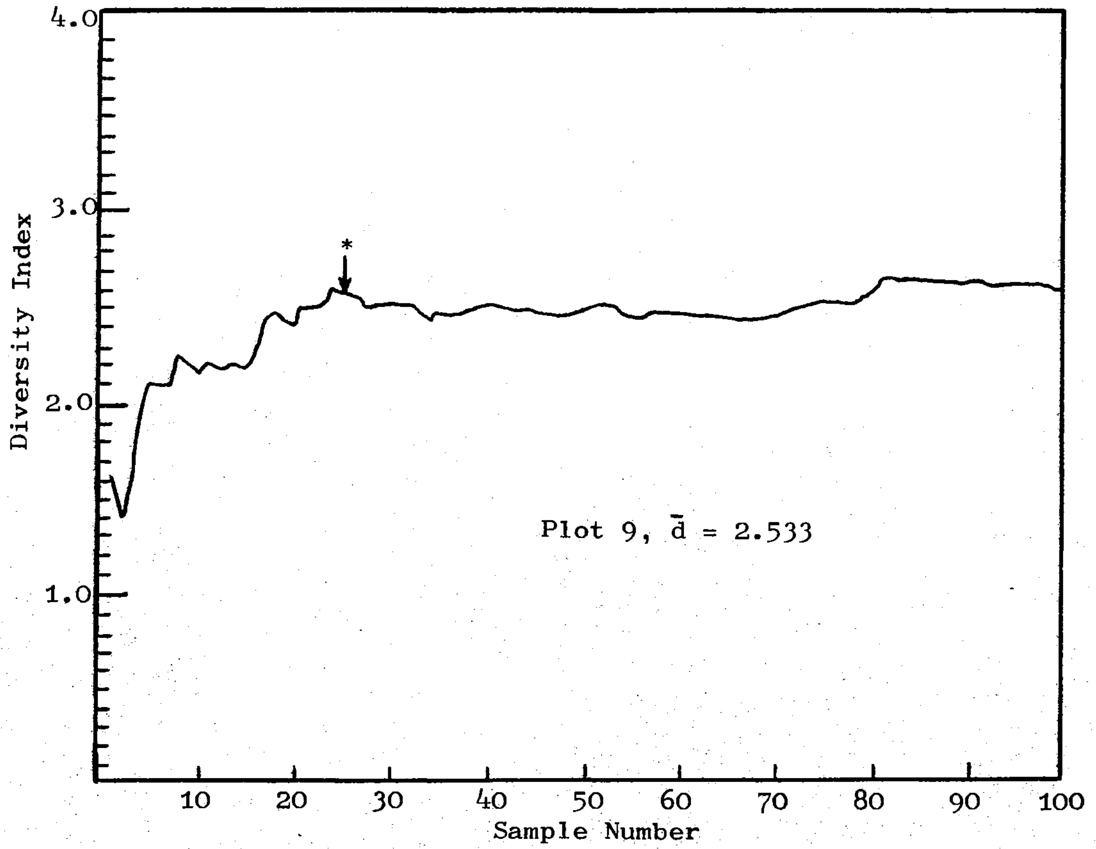

Figure 9. Graph of Diversity Index $\bar{d} = -\sum_{i=1}^{s}(w_i/w)\log_2(w_i/w)$ for Mowed and Removed Plot Based on 100 0.1 m^2 Quadrats. (An asterisk indicates the point where diversity plateaus. The $\bar{d}$ value is an average based on all values past the plateau.)

TABLE X

PLOT 10 RESULTS BASED ON POINT CENTERED QUARTER SAMPLES (PCQ) AND QUADRAT SAMPLES (Q)

Species	PCQ* Individuals	PCQ* Frequency	PCQ* Relative Composition	Q** Weight	Q** Frequency	Q** Relative Composition
Acacia angustissima	12	3.0	1.0	28.7	11	0.8
Achillea lanulosa	16	4.7	1.3	7.0	15	0.2
Acalphya sp.	-	-	-	0.0	1	0.0
Ambrosia psilostachya	43	11.3	3.6	153.6	43	4.2
Andropogon gerardi	4	1.0	0.3	0.7	1	0.0
Andropogon saccharoides	12	3.3	1.0	62.3	22	1.7
Andropogon scoparius	353	59.0	29.4	1072.9	90	29.5
Andropogon ternarius	6	1.7	0.5	12.7	2	0.4
Apocynum cannabinum	1	0.3	0.1	--	-	-
Aristida oligantha	7	1.7	0.6	0.7	7	0.0
Aster ericoides	96	20.7	8.0	289.8	69	8.0
Baptisia sp.	-	-	-	8.4	2	0.2
Bouteloua curtipendula	1	0.3	0.1	-	-	-
Bromus japonicus	72	15.0	6.0	47.4	58	1.3
Carex sp.	1	0.3	0.1	5.3	4	0.2
Cassia fasciculata	-	-	-	2.7	4	0.1
Crataegus sp.	1	0.3	0.1	-	-	-
Croton capitatus	-	-	-	0.5	1	0.0
Desmodium sessilfolium	-	-	-	3.8	1	0.1
Eragrostis spectabilis	3	1.3	0.3	5.2	6	0.1
Erigeron strigosus	1	0.3	0.1	-	-	-
Euphorbia marginata	1	0.3	0.1	-	-	-
Gnaphalium obtusfolium	--	-	-	0.1	1	0.0
Juncus interior	2	0.3	0.2	0.4	1	0.0
Leptoloma cognatum	15	4.0	1.3	41.1	47	1.1
Lespedeza virginica	14	4.0	1.2	169.7	18	4.7
Linum sulcatum	-	-	-	0.7	2	0.0
Oxalis Dillenii	2	0.7	0.2	-	-	-
Panicum oligosanthes	24	5.3	2.0	29.8	28	0.8
Petalostemum purpureus	2	0.3	0.2	-	-	-
Physalis sp.	1	0.3	0.1	0.6	1	0.0
Plantago virginica	3	0.7	0.3	0.0	1	0.0
Psoralea tenuiflora	4	1.3	1.3	20.1	4	0.6
Sabatia campestris	-	-	-	0.1	1	0.0
Solidago sp.	28	7.0	2.3	14.7	13	0.4
Solidago rigida	3	1.0	0.3	-	-	-
Sorghastrum nutans	438	74.7	36.5	1615.6	92	44.4
Sporobulus asper	8	1.3	0.7	30.4	8	0.8
Strophostyles leiosperma	13	3.3	1.1	10.7	25	0.3

TABLE X (Continued)

Species	PCQ* Indi-vid-uals	PCQ* Fre-quency	PCQ* Rela-tive Compo-sition	Q** Weight	Q** Fre-quency	Q** Rela-tive Compo-sition
Unknown species	2	0.7	0.2	-	-	-
Vernonia baldwinii	1	0.3	0.1	2.8	2	0.1

*Frequency was based on 300 Point Centered Quarter Samples. Relative Composition was based on 1200 individuals. Total number of species was 32.

**Frequency was based on 100 0.1 m^2 quadrats. Relative composition was based on the combined phytomass of all species which was 3638.2 g. Total number of species was 32.

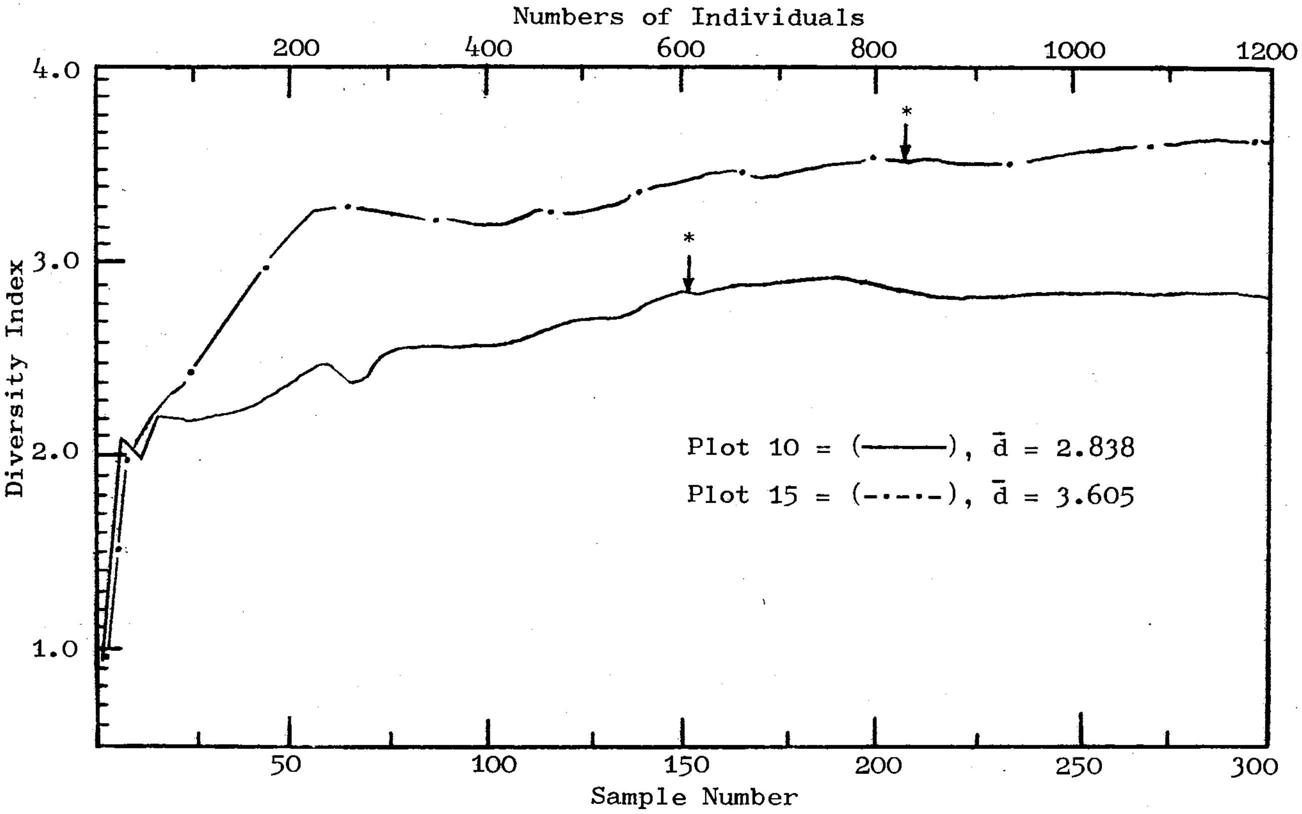

Figure 10. Graph of Diversity Index $\bar{d} = -\sum_{i=1}^{s}(n_i/n)\log_2(n_i/n)$ for Plowed Plots Based on Pooled Point Centered Quarter Samples. (Diversity values calculated for every fifth sample were plotted. An asterisk indicates the point where diversity plateaus. The $\bar{d}$ values are based on all values past the plateau.)

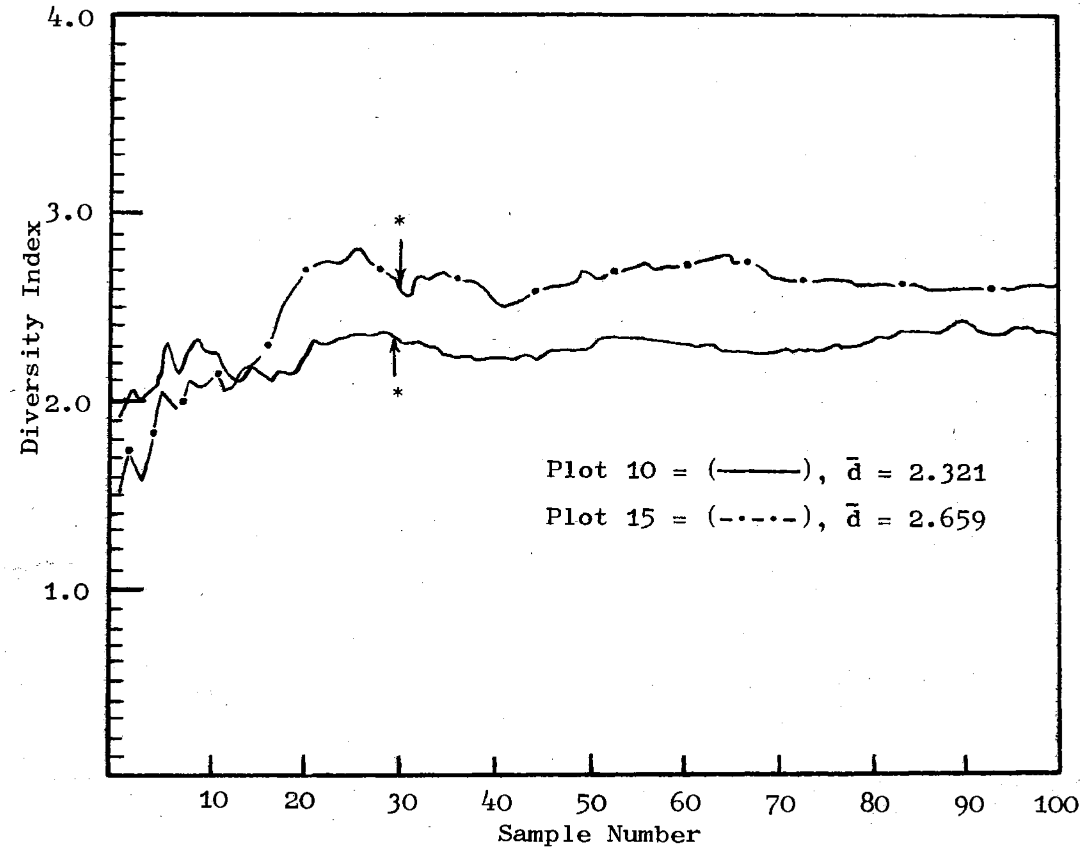

Figure 11. Graph of Diversity Index $\bar{d} = -\sum_{i=1}^{s} (w_i/w)\log_2(w_i/w)$ for Plowed Plots Based on 100 0.1 m^2 Quadrats. (An asterisk indicates the point where diversity plateaus. The $\bar{d}$ value is an average based on all values past the plateau.)

TABLE XI

PLOT 15 RESULTS BASED ON POINT CENTERED QUARTER SAMPLES (PCQ) AND QUADRAT SAMPLES (Q)

	PCQ*			Q**		
Species	Individuals	Frequency	Relative Composition	Weight	Frequency	Relative Composition
Achillea lanulosa	31	6.3	2.6	28.0	34	0.7
Acalphya sp.	-	-	-	1.3	15	0.0
Ambrosia psilostachya	50	12.7	4.2	102.7	53	2.6
Andropogon saccharoides	48	10.3	4.0	84.7	46	2.1
Andropogon scoparius	233	31.7	19.4	992.9	74	25.1
Andropogon ternarius	7	1.0	0.6	-	-	-
Aristida oligantha	20	5.3	1.7	5.7	26	0.1
Artemesia ludoviciana	58	15.0	4.8	137.9	42	3.5
Asclepias viridis	4	1.3	0.3	-	-	-
Aster ericoides	93	23.3	7.8	158.2	71	4.0
Bromus japonicus	140	27.3	11.7	56.1	93	1.4
Carex sp.	10	2.7	0.8	2.5	7	0.1
Cassia fasciculata	1	0.3	0.1	9.6	13	0.2
Croton capitatus	-	-	-	0.5	4	0.1
Elymus canadensis	3	1.0	0.3	4.4	5	0.1
Eragrostis intermedia	11	3.3	0.9	4.3	15	0.1
Eragrostis spectabilis	2	0.7	0.2	17.7	10	0.5
Juncus interior	1	0.3	0.1	0.1	1	0.0
Leptoloma cognatum	43	8.0	3.6	109.6	51	2.8
Lespedeza virginica	10	2.0	0.8	67.9	8	1.7
Linum sulcatum	1	0.3	0.1	-	-	-
Neptunea lutea	2	0.3	0.2	-	-	-
Opuntia sp.	2	0.3	0.2	-	-	-
Oxalis Dillenii	1	0.3	0.1	-	-	-
Panicum oligosanthes	26	6.3	2.2	17.7	19	0.5
Panicum virgatum	71	10.7	5.9	323.7	25	8.2
Physalis sp.	1	0.3	0.1	0.7	2	0.0
Plantago virginica	1	0.3	0.1	0.0	1	0.0
Polygala verticillata	-	-	-	0.1	1	0.0
Psoralea tenuiflora	9	2.7	0.8	39.5	8	1.0
Solanum carolinense	-	-	-	2.3	4	0.1
Solanum eleagnifolium	7	2.0	0.6	7.8	9	0.2
Solanum torreyi	-	-	-	0.4	1	0.0
Solidago sp.	41	7.7	3.4	17.2	17	0.4
Solidago rigida	1	0.3	0.1	-	-	-
Sorghastrum nutans	256	35.3	21.3	1733.4	54	43.7
Sporobulus asper	6	1.7	0.5	32.5	11	0.8
Strophostyles leiosperma	1	0.3	0.1	0.7	2	0.0
Tridens flavus	4	1.0	0.3	3.7	2	0.1
Unknown species	2	0.7	0.3	-	-	-

TABLE XI (Continued)

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*Frequency was based on 300 Point Centered Quarter Samples. Relative Composition was based on 1200 individuals. Total number of species was 34.

**Frequency was based on 100 0.1 m^2 quadrats. Relative composition was based on the combined phytomass of all species which was 3963.8 g. Total number of species was 32.

(Figure 10) was the highest value obtained for all plots. The species Ambrosia psilostachya, Artemesia ludoviciana, Aster ericoides, and Bromus japonicus were single stemmed species. As noted in Chapter III the Point Centered Quarter Method of sampling favors single stemmed species having a random distribution. These species helped produce the high diversity value for numbers of individuals because of their contribution to the equitability component of the diversity index. Relative composition percentages for phytomass (Table XI) showed these species to have lower values, particularly Aster ericoides and Bromus japonicus. The lower diversity value based on phytomass was again due to the decrease in equitability of distribution among species.

Herbicide Treatment Plot

Abundant in Plot 19 were the species Ambrosia psilostachya, Andropogon gerardi, Andropogon scoparius, Artemesia ludoviciana, Sorghastrum nutans, and Sporobulus asper (Table XII). Within plot observations indicated that the western and northern sections had the greatest concentration of Andropogon gerardi, which indicates high soil moisture in these areas.

Diversity showed a pattern similar to other plots; i.e., a higher value based on numbers of individuals (Figure 12) as compared to the value based on phytomass (Figure 13). Again the lower value based on phytomass was due to the decrease in the equitability of distribution of phytomass among species.

Analysis of All Treatments

Diversity within various plots was a function of the equitability

TABLE XII

PLOT 19 RESULTS BASED ON POINT CENTERED QUARTER SAMPLES (PCQ) AND QUADRAT SAMPLES (Q)

Species	PCQ* Indi- vid- uals	PCQ* Fre- quency	PCQ* Rela- tive Compo- sition	Q** Weight	Q** Fre- quency	Q** Rela- tive Compo- sition
Achillea lanulosa	8	2.3	0.7	2.6	4	0.1
Acalphya sp.	-	-	-	2.0	1	0.1
Ambrosia psilostachya	39	11.7	3.3	79.4	51	2.7
Andropogon gerardi	252	33.7	21.0	878.8	54	30.2
Andropogon saccharoides	9	2.0	0.8	32.2	14	1.1
Andropogon scoparius	280	42.0	23.3	570.6	69	19.6
Andropogon ternarius	20	4.0	1.7	24.4	8	0.8
Aristida oligantha	7	1.3	0.6	0.5	11	0.0
Aristida purpurascens	1	0.3	0.1	0.1	1	0.0
Artemesia ludoviciana	47	9.3	3.9	146.8	27	5.1
Aster ericoides	5	1.7	0.4	21.4	12	0.7
Bouteloua curtipendula	17	2.0	1.4	1.7	1	0.1
Bromus japonicus	30	7.7	2.5	11.9	28	0.4
Carex sp.	2	0.7	0.2	0.5	2	0.0
Cassia fasciculata	3	1.0	0.3	1.1	4	0.0
Cirsium undulatum	-	-	-	0.6	1	0.0
Croton capitatus	5	1.3	0.4	1.9	7	0.1
Diodia teres	-	-	-	0.3	3	0.0
Elymus virginicus	4	1.0	0.3	1.6	5	0.1
Eragrostis intermedia	-	-	-	0.1	1	0.0
Eragrostis spectabilis	3	0.7	0.3	0.2	1	0.0
Euphorbia marginata	-	-	-	0.1	1	0.0
Gutierrezia dracunculoides	1	0.3	0.1	-	-	-
Hieracium longipilum	2	0.7	0.2	0.8	3	0.0
Juncus interior	10	2.3	0.8	0.5	2	0.0
Kuhnia sp.	-	-	-	2.3	1	0.1
Leptoloma cognatum	37	8.0	3.1	22.0	36	0.8
Lespedeza capitata	-	-	-	6.1	1	0.2
Lespedeza virginica	3	1.0	0.3	-	-	-
Linum sulcatum	-	-	-	0.1	1	0.0
Oxalis Dillenii	1	0.3	0.1	-	-	-
Panicum oligosanthes	24	6.3	2.0	21.6	30	0.7
Panicum virgatum	6	1.3	0.5	25.3	3	0.9
Plantago aristida	3	0.7	0.3	-	-	-
Plantago virginica	2	0.7	0.2	0.0	1	0.0
Polygala verticillata	6	2.0	0.5	0.0	1	0.0
Solidago sp.	-	-	-	13.8	7	0.5
Solidago rigida	2	0.7	0.2	-	-	-
Sorghastrum nutans	322	46.0	26.8	874.6	79	30.1
Sporobulus asper	36	9.3	3.0	142.5	23	4.9

TABLE XII (Continued)

Species	PCQ* Indi-viduals	Frequency	Relative Composition	Q** Weight	Frequency	Relative Composition
Teucrium canadense	3	0.7	0.3	1.81	1	0.1
Tridens flavus	4	1.0	0.3	7.8	4	0.3
Elymus canadensis	3	1.0	0.3	2.6	3	0.1
Ulmus americana	-	-	-	0.0	1	0.0
Unknown species	2	0.7	0.2	-	-	-
Vernonia baldwinii	-	-	-	6.9	1	0.2

*Frequency was based on 300 Point Centered Quarter Samples. Relative Composition was based on 1200 individuals. Total number of species was 34.

**Frequency was based on 100 0.1 m^2 quadrats. Relative composition was based on the combined phytomass of all species which was 2907.6 g. Total number of species was 40.

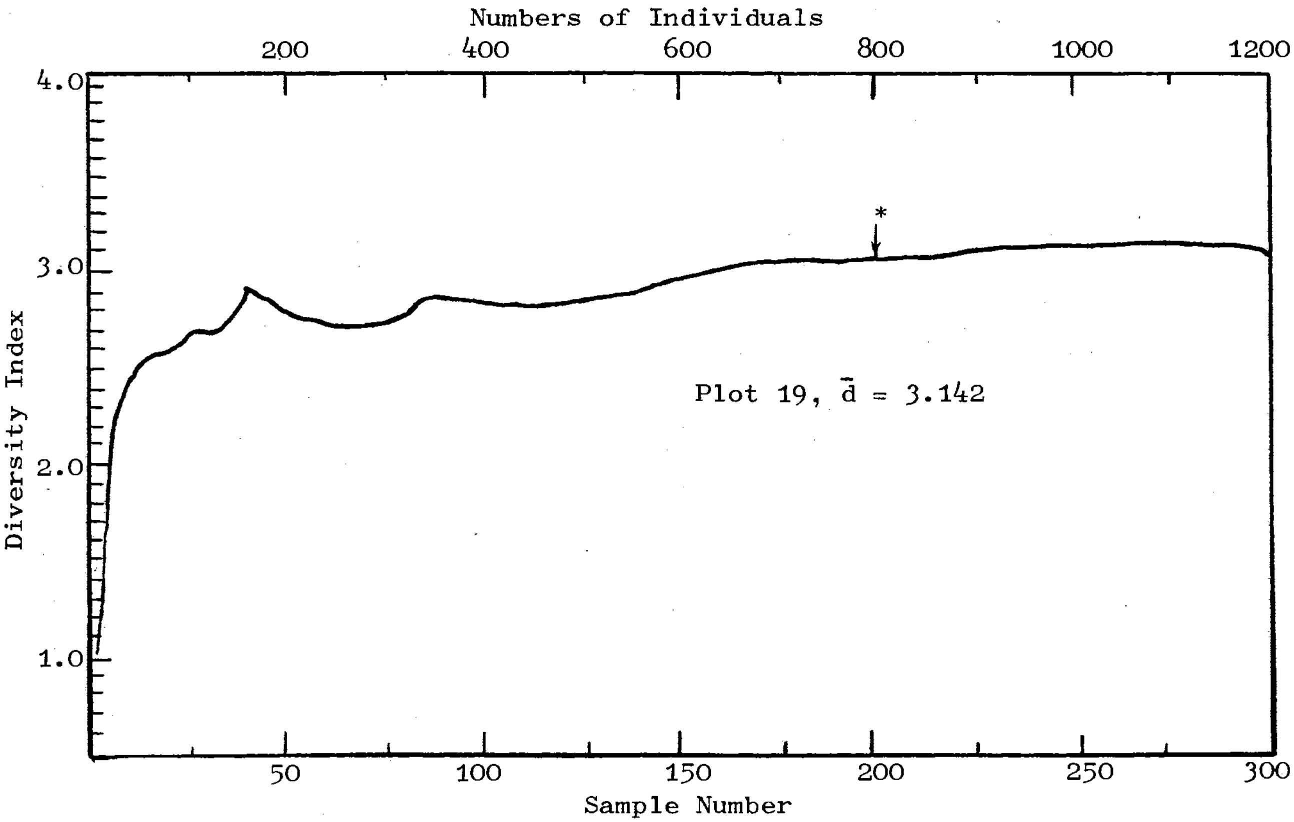

Figure 12. Graph of Diversity Index $\bar{d} = -\sum_{i=1}^{s}(n_i/n)\log_2(n_i/n)$ for Herbicide Plot Based on Pooled Point Centered Quarter Samples. (Diversity values calculated for every fifth sample were plotted. An asterisk indicates the point where diversity plateaus. The $\bar{d}$ value was based on all values past the plateau.)

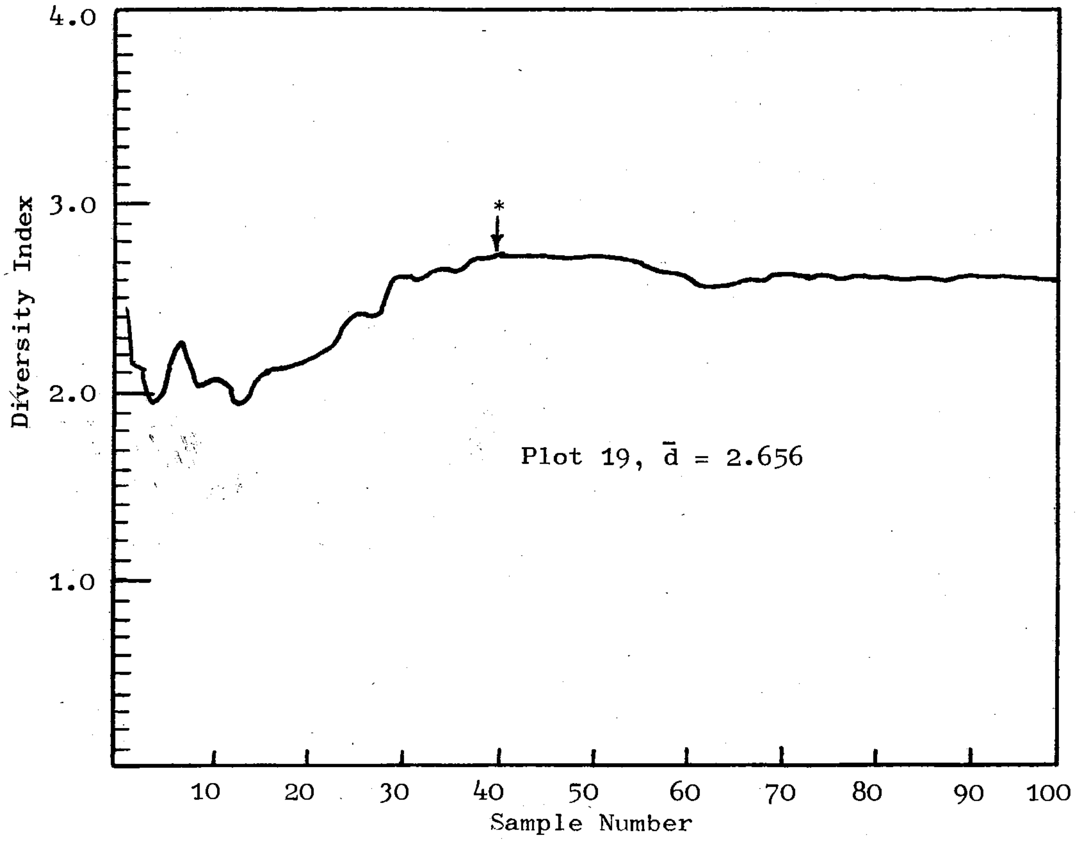

Figure 13. Graph of Diversity Index $\bar{d} = -\sum_{i=1}^{s} (w_i/w)\log_2(w_i/w)$ for Herbicide Plot Based on 100 0.1 m^2 Quadrats. (An asterisk indicates the point where diversity plateaus. The $\bar{d}$ value is an average based on all values past the plateau.)

of distribution among the species and was not dependent on numbers of individuals, numbers of species, or total phytomass. Figure 14 indicates there was no consistent relationship between total phytomass and diversity. Plots 1, 4, 9, and 10 had similar diversity values but differed in total phytomass. Figure 15 shows no consistent relationship existed between diversity and numbers of species. For example, Plots 9, 11, 15, and 19 had similar numbers of species but different $\bar{d}$ values based on number of individuals. Plot 4 had the greatest number of species but one of the lowest diversity values based on phytomass. Table XIII shows the amount of phytomass accumulated at the diversity plateau for each plot. This value was variable among plots since they produced varying amounts of phytomass; however, in most plots the diversity plateau was reached by 25 samples, the average being 29.4

Numbers of individuals recorded at the diversity plateau are shown in Table XIII. The number is variable with the range extending from 280 to 840 individuals. As noted previously, the variability in numbers of Point Centered Quarter samples needed to reach the diversity plateau could be accounted for by the distribution of species within the plot. When distribution of species, which can significantly influence the diversity index, tends to be random the number of samples required to reach the diversity plateau is smaller than when distribution of abundant species is nonrandom. Figure 16 shows a hypothetical community consisting of 10 species and 100 individuals. Although species composition and diversity are the same, the randomness or nonrandomness of species distribution determines the shape of the diversity curve and the point at which diversity plateaus.

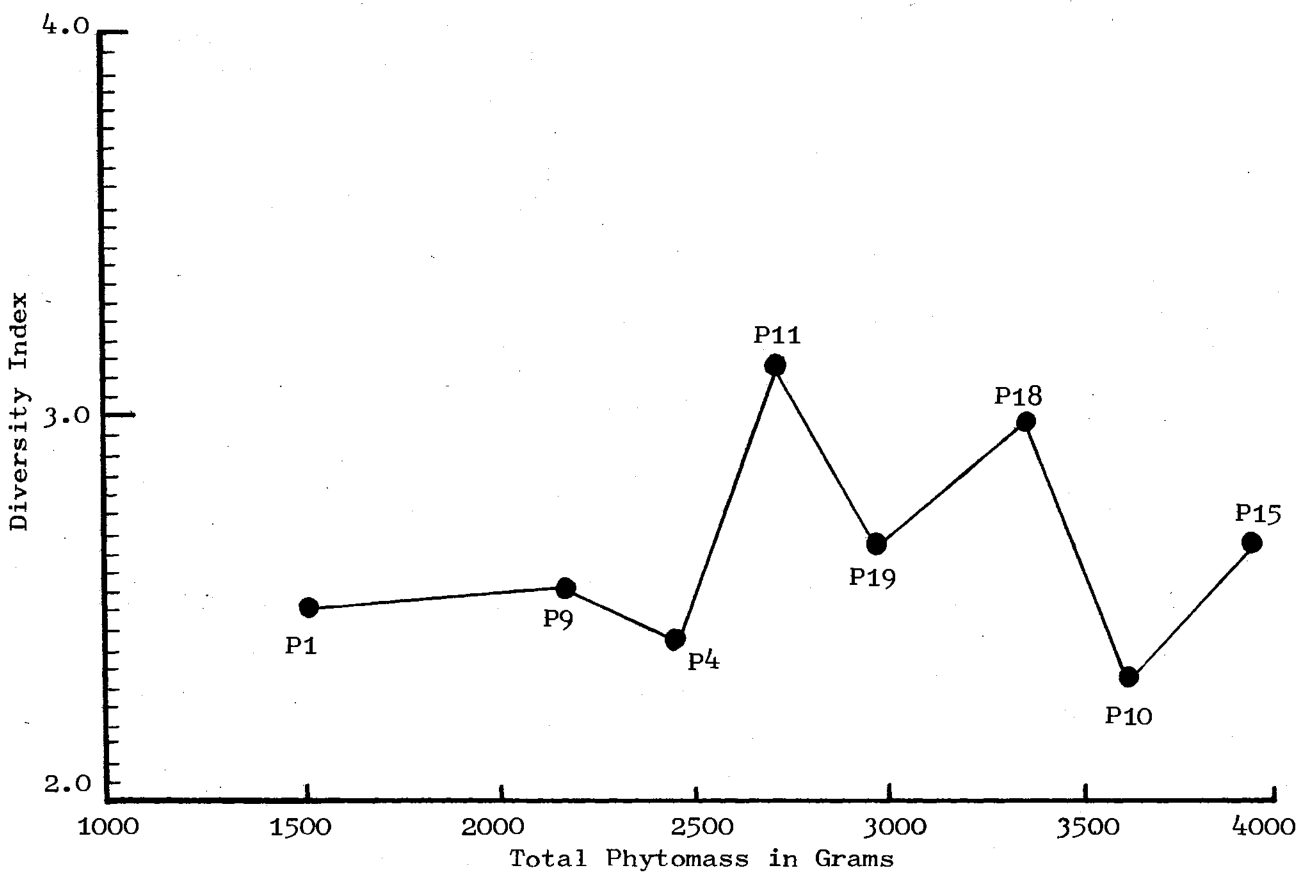

Figure 14. The Relationship Between the Diversity Index $\bar{d} = -\sum_{i=1}^{s} (w_i/w)\log_2(w_i/w)$ and Total Phytomass. (Specific plots are designated by the letter P.)

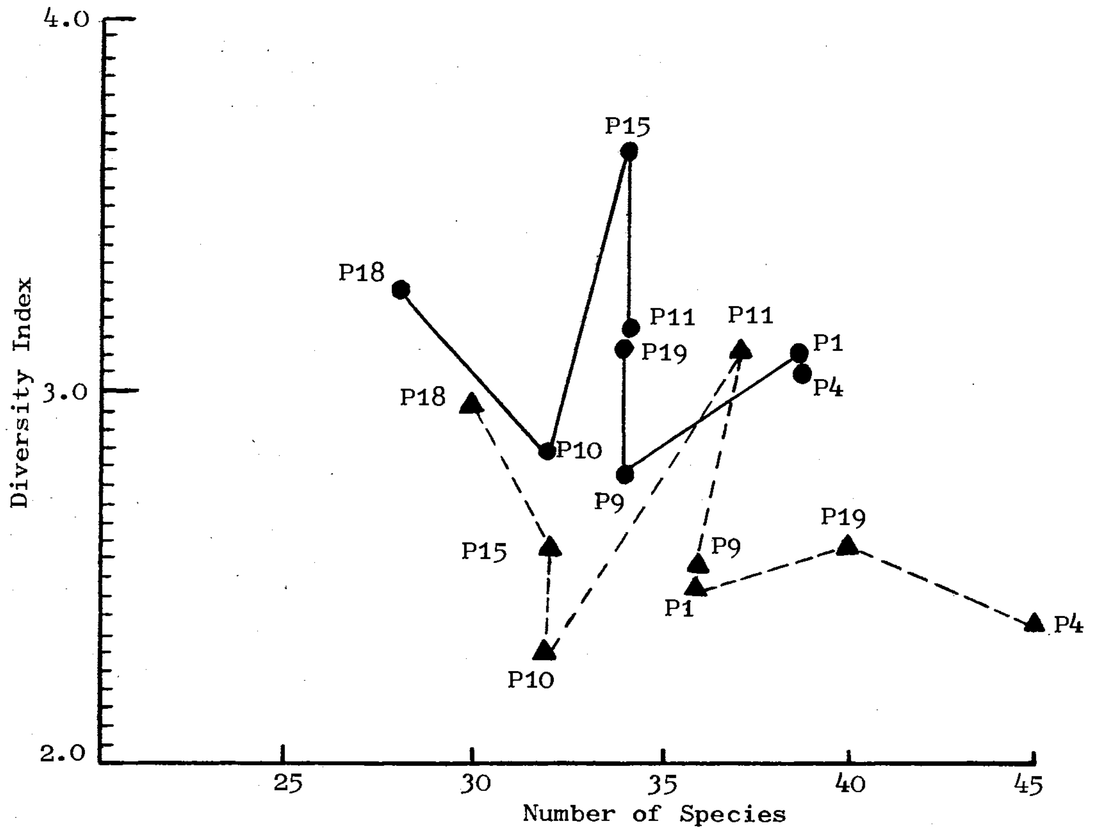

Figure 15. The Relationship Between Number of Species and the Diversity Index. (Solid line = diversity based on numbers of individuals; dashed line = diversity based on Phytomass. Specific plots are designated by the letter P.)

TABLE XIII

NUMBER OF SPECIES, SPECIES DIVERSITY, AND THE POINT AT WHICH DIVERSITY PLATEAUED WITHIN EACH PLOT BASED ON 1200 INDIVIDUALS (N) AND CUMULATIVE PHYTOMASS (P). TOTAL PHYTOMASS PER PLOT (GRAMS) IS ALSO SHOWN

Plot		N	P
	Number of Species	38	36
1	Diversity	3.024	2.493
	Diversity Plateau	280	218.4
	Total Phytomass	-	1514.1
	Number of Species	34	37
11	Diversity	3.141	3.126
	Diversity Plateau	360	583.4
	Total Phytomass	-	2733.5
	Number of Species	28	30
18	Diversity	3.257	2.981
	Diversity Plateau	340	978.6
	Total Phytomass	-	3369.5
	Number of Species	38	45
4	Diversity	2.991	2.401
	Diversity Plateau	280	503.9
	Total Phytomass	-	2483.2
	Number of Species	34	36
9	Diversity	2.758	1.533
	Diversity Plateau	840	441.0
	Total Phytomass	-	2168.0
	Number of Species	32	32
10	Diversity	2.838	2.321
	Diversity Plateau	620	1165.5
	Total Phytomass	-	3638.8
	Number of Species	34	32
15	Diversity	3.605	2.659
	Diversity Plateau	840	973.8
	Total Phytomass	-	3963.8
	Number of Species	34	40
19	Diversity	3.142	2.656
	Diversity Plateau	840	1043.6
	Total Phytomass	-	2907.6

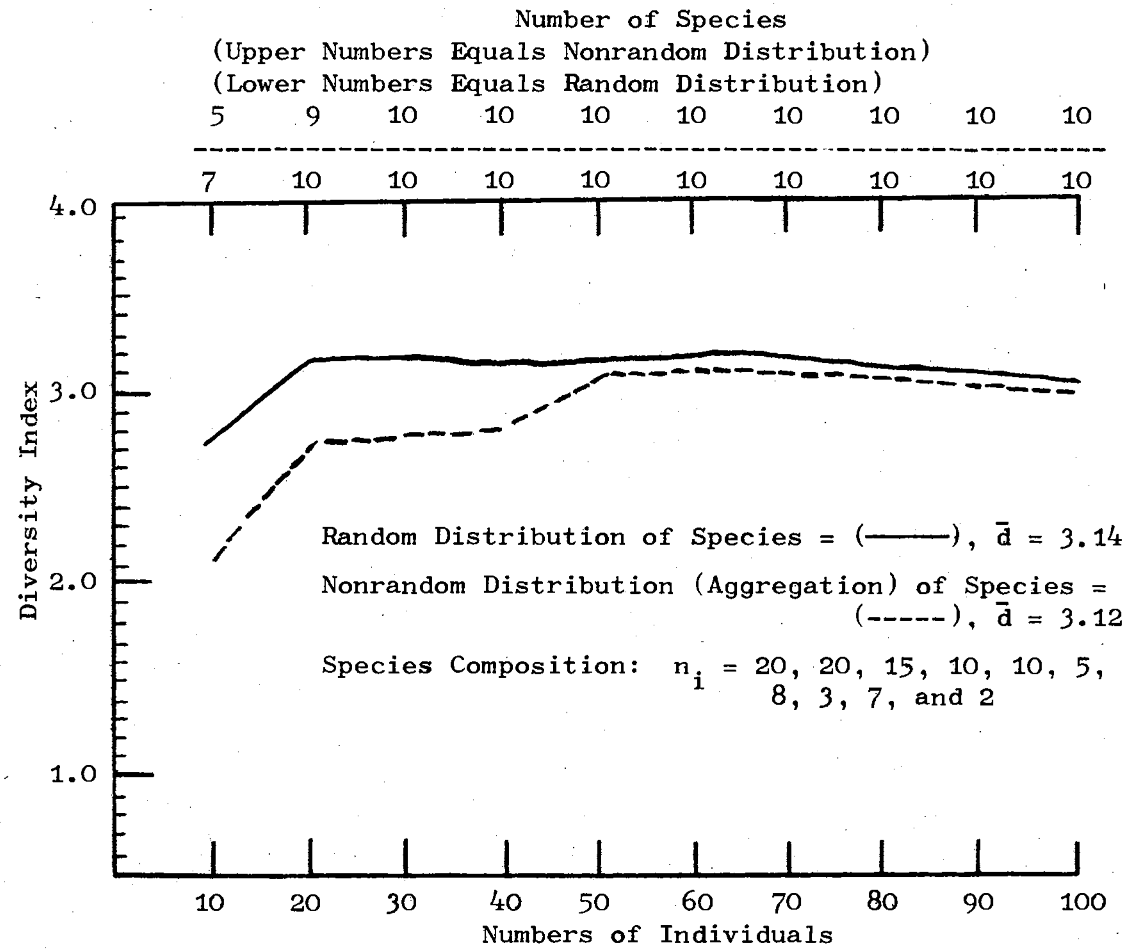

Figure 16. Diversity Curves for a Hypothetical Population of 100 Individuals and 10 Species

As noted previously the diversity value based on phytomass reached a plateau by 25 samples in the majority of plots. When the diversity for the entire plot based on 100 0.1 m^2 quadrats was compared to the value calculated for the first 25 samples in each plot, the latter value did not vary more than plus or minus 6% from the former. An exception was Plot 19 where diversity, by sample number 25, was only 84% of that calculated for the entire plot.

Table XIV is based on the assumption that 25 0.1 m^2 quadrats were sufficient to give reliable estimates of diversity within each plot. Table XIV shows that diversity varied within each plot and that the variance is related to the percent phytomass contributed by the two dominant species. Figure 17 shows the relationship between diversity and total dominance, where dominance is the per cent total of the dominant species added together.

The variation in dominance and, therefore, diversity within plots, is caused by two variables acting jointly or independently. The first variable is within-plot variability of factors such as slope, soil moisture, available minerals, and soil temperatures. Interaction of these factors influences the distribution of phytomass among species, even in small localized areas, and can, therefore, influence the calculated diversity value.

Whether increased dominance was a function of within-plot variability or of greater productivity is difficult to assess. Some differences, however, were apparent. In Plot 15 the greater phytomass encountered during the third sampling period (see Figure 18 and Table XIV) was due to the species Panicum virgatum. This species had a frequency value of 25, but of the 323.7 g contributed by Panicum virgatum, 229.6 g was

TABLE XIV

TOTAL PHYTOMASS, PERCENTAGE OF PHYTOMASS CONTRIBUTED BY DOMINANT SPECIES, AND DIVERSITY BASED ON EACH SET OF 25 0.1 m^2 QUADRATS TAKEN WITHIN PLOTS AT VARIOUS DATES

Plot	Samples	Phytomass	Diversity*	Per Cent of Phytomass**			
				A. sc	S. nu	A. ge	S. as
	1 - 25	218.4	2.637	17.4	47.3	--	--
1	26 - 50	368.8	2.321	25.3	45.3	--	--
	51 - 75	369.1	2.448	21.9	45.9	--	--
	76 - 100	555.7	1.991	12.5	64.0	--	--
	1 - 25	583.4	3.151	20.1	29.1	--	--
11	26 - 50	667.7	2.933	30.2	32.2	--	--
	51 - 75	722.4	2.831	35.3	25.9	--	--
	76 - 100	764.5	2.673	35.5	30.5	--	--
	1 - 25	695.0	2.840	13.3	25.6	20.4	17.8
18	26 - 50	758.1	2.974	16.6	10.0	30.2	16.9
	51 - 75	964.3	2.932	12.5	5.9	32.6	20.4
	76 - 100	952.1	1.618	2.3	0.8	75.5	1.8
	1 - 25	503.9	2.424	52.5	18.0	--	--
4	26 - 50	705.2	2.525	50.4	19.3	--	--
	51 - 75	66.7	1.791	64.9	14.9	--	--
	76 - 100	607.6	1.979	61.5	13.3	--	--
	1 - 25	441.0	2.549	39.5	23.9	--	--
9	26 - 50	559.8	2.265	42.4	30.5	--	--
	51 - 75	560.9	2.318	46.2	23.2	--	--
	76 - 100	610.0	2.647	30.9	36.8	--	--
	1 - 25	952.4	2.327	41.1	29.6	--	--
10	26 - 50	971.5	2.180	32.0	46.1	--	--
	51 - 75	842.1	2.146	29.4	46.6	--	--
	76 - 100	885.9	2.399	13.9	55.6	--	--
	1 - 25	794.1	2.723	21.0	45.4	--	--
15	26 - 50	982.6	2.392	28.1	43.4	--	--
	51 - 75	1296.0	2.330	19.2	46.0	--	--
	76 - 100	891.5	2.367	33.8	39.3	--	--
	1 - 25	650.9	2.277	18.5	21.4	41.6	--
19	26 - 50	595.1	2.860	22.5	34.6	12.1	--
	51 - 75	827.6	2.416	19.1	33.8	30.5	--
	76 - 100	827.4	2.457	18.1	30.1	34.2	--

TABLE XIV (Continued)

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*The diversity value given is the average of the last five calculated values for each set of 25 samples.

**Dominant species are *Andropogon scoparius* (A. sc), *Sorghastrum nutans* (S. nu), *Andropogon gerardi* (A. ge), and *Sporobulus asper* (S. as).

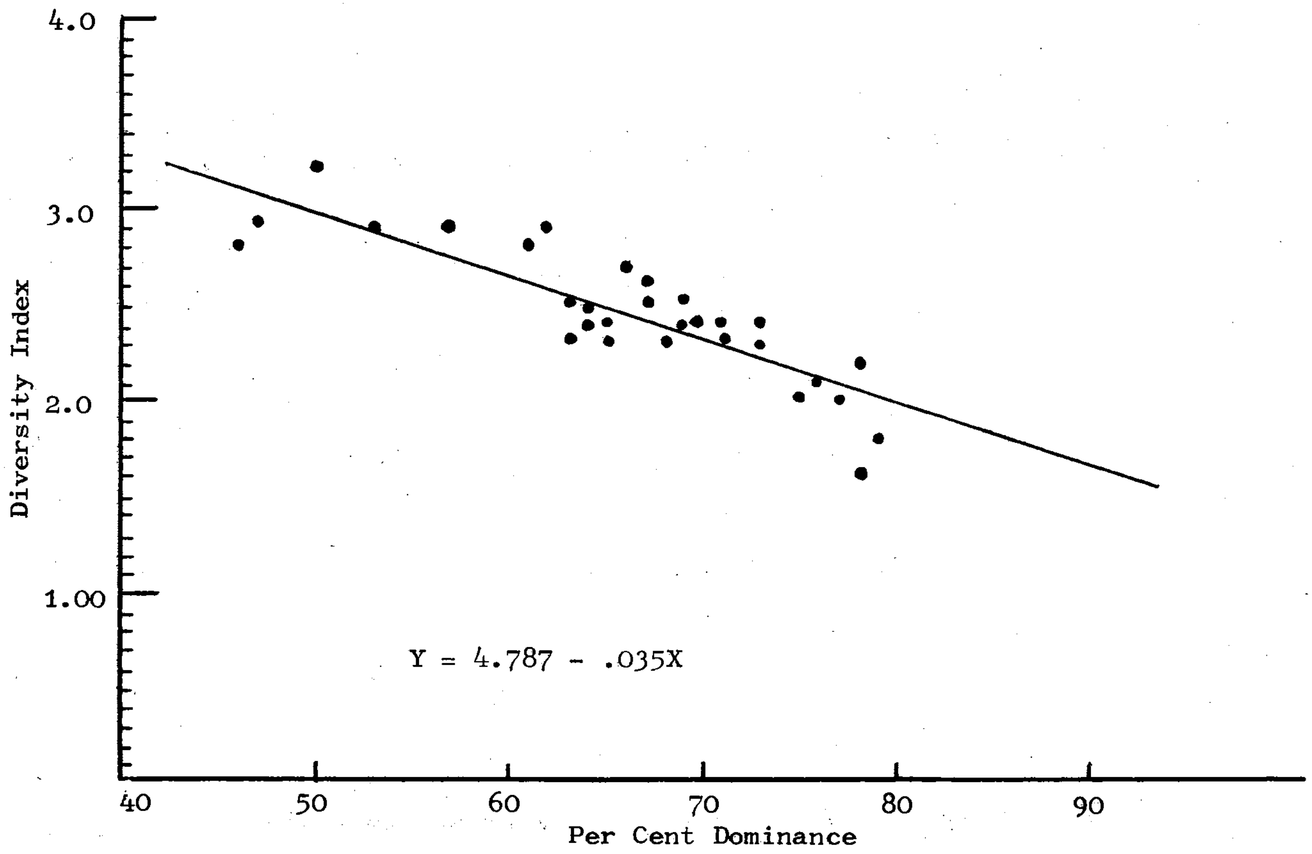

Figure 17. The Relationship Between Per Cent Dominance of the Two Dominant Species and Calculated Diversity for all Within Plot Values Given in Table XIV

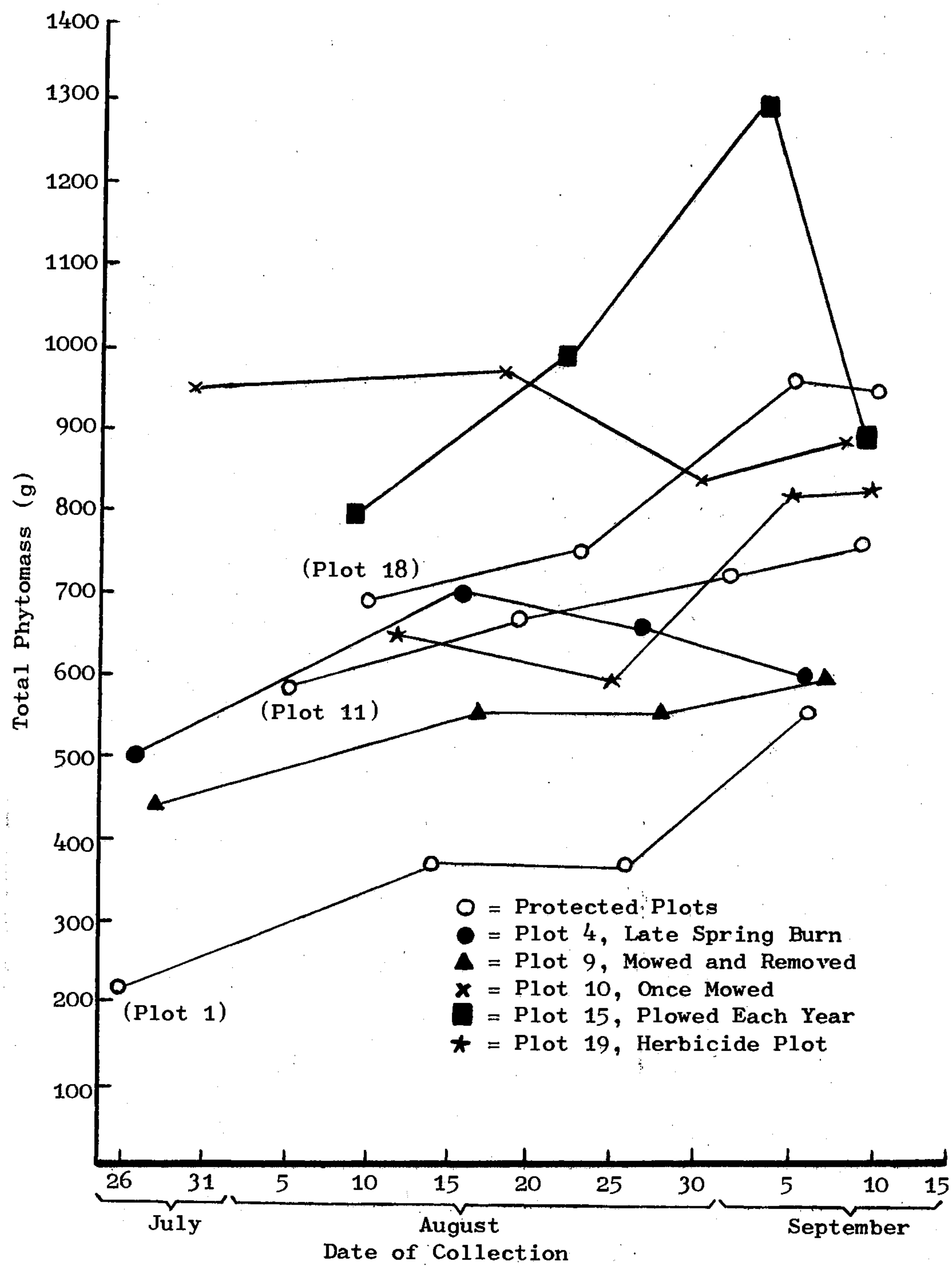

Figure 18. Total Phytomass Collected Within Plots at Various Sampling Dates

encountered during the third sampling period. This species, along with Andropogon scoparius and Sorghastrum nutans, was dominant during the third sampling period and helped produce a low diversity value. Plot 18 had a greater percentage of Andropogon gerardi in the northern portion of the plot. Also, during the last two sampling periods the plants were at anthesis. The combination of aggregation of plants and flowering and fruiting produced a significantly greater amount of phytomass for the last two sampling periods (Figure 18). The low diversity value for the last sampling period (Table XIV) is a reflection of the greater amount of Andropogon gerardi collected. The gradual increase in phytomass over time in Plot 11 may have been due to a greater productivity of Andropogon scoparius and Sorghastrum nutans. Mueller (1964) investigated the same area shown in Figure 1 in 1963, and he stated that flowering, production of seed, and dissemination of seed for Andropogon scoparius was August 17, September 6, and October 3, respectively, for a protected area. Although anthesis varies annually, the steady increase in phytomass of Plot 11 (Figure 18) may have been due partially to an increased productivity of Andropogon scoparius. While the contribution by Andropogon scoparius to the total diversity value increased for each sampling period in Plot 11, the steady decline in diversity would indicate that as this species became more dominant there was a less equitable distribution of phytomass among species.

An attempt was made to determine whether the within-plot diversity values calculated for the various treatments (Table XIV) were significantly different. An analysis of variance performed on these values is not statistically valid because the experimental error could not be measured appropriately due to the exclusion of replicate plots for all treatments except protection. The decision to limit sampling to specified plots plus the fact that treatments had already been performed on the plots eliminated the possibility of using a randomized block design.

The analysis of variance was performed on the within-plot diversity values calculated for Plots 4, 9, 10, 11, 15, and 19. Table XV shows the analysis of variance. The error mean square was calculated from the within-plot diversity values shown in Table XIV. Results indicate that significant differences do exist between treatments at both the .05 and .01 levels of significance. The Newman-Kuels Test (Snedecor and Cochran, 1967) was used to test for real differences among treatment means. Table XVI shows that Plot 11 (Protected) was significantly different from Plot 4 (Late Spring Burn) and Plot 10 (Once-Plowed). Mean values for Plots 4, 10, 9, 15, and 19 were not significantly different. The Studentized Range Test, $Q = (\bar{X}max - \bar{X}min)/S\bar{x}$, was also used, and the same significant differences were shown. Both of these tests showed that to detect significance, the magnitude of difference between the Protected plot (Plot 11) and any other plot had to be 0.507 or greater.

Table XIII shows the diversity values based on phytomass which were obtained from 100 0.1 m^2 quadrats. Since replicates were not taken, the actual magnitude of difference between values which would indicate significance is unknown. When the value of the Protected plot is compared to all other treatment values, the differences obtained are 0.725, 0.573, 0.805, 0.467, and 0.470 for Plots 4, 9, 10, 15, and 19, respectively. These differences, when compared to the above mentioned value of 0.507, would suggest that some real differences may exist. However, since no analysis of variance could be made for the diversity values

TABLE XV

ANALYSIS OF VARIANCE FOR WITHIN PLOT DIVERSITY VALUES OF PLOTS 4, 9, 10, 11, 15, AND 19

Source	df	MS	F*
Between	5	0.248	4.867
Within	18	0.051	
Total	23		

*Tabulated F at the .05 level is 2.77 and at the .01 level, 4.25. Significant differences are shown at both levels.

TABLE XVI

RESULTS OF NEUMAN-KEULS TEST FOR SIGNIFICANT DIFFERENCES BETWEEN MEANS

Plot	$\bar{X}$ *	Treatments	$Q_{(.05)}Sx$ **	$\bar{X}$ Differences
Protected (11)	2.897			
Herbicide (19)	2.503	5	.4836	$\bar{X}_{19} - \bar{X}_{4} = .3240$
Plowed Each Year (15)	2.453			
Mowed and Removed (9)	2.445			
Once-Plowed (10)	2.263	5	.4836	$\bar{X}_{11} - \bar{X}_{10} = .6340$ ***
Late Spring Burn (4)	2.179	6	.5074	$\bar{X}_{11} - \bar{X}_{4} = .7180$ ***

*Means are based on the within-plot diversity values shown in Table XIV.

**Q value is based on values shown in Table A 15 of Snedecor and Cochran (1967). $S\bar{x} = \sqrt{.051/4} = .113$

***Indicates significant difference.

based on 100 0.1 m^2 quadrats, actual significant differences could not be ascertained.

Pattern of Diversity

The diversity curve gives an indication of the spatial distribution of abundant species since the point at which diversity plateaus and the shape of the curve are dependent on this distribution.

Another pattern which exists is the rapid initial rise in the phytomass diversity values, followed by a decline and an eventual stabilization. Diversity curves for Plots 1, 11, 18, 4, and 10 showed this pattern (Figures 5, 7, and 11). Pielou (1966b) showed the diversity curve resulting from the pooling of herbaceous vegetation followed the above mentioned pattern. This pattern exists because species are initially added at a rapid rate. The contribution to the total diversity value by these species usually causes an increase in the diversity value. For the first few samples rare species may make as great, or greater, a contribution to total diversity than dominant species. A point is reached where rate of addition of new species decreases. The per cent contribution to phytomass by the dominant species stabilizes at 30 to 50% since phytomass of these species is continuously being added as samples are pooled. Wilhm (1968) noted that a species which contributes 37% to the total samples makes the maximum contribution to total diversity. The per cent contribution to total phytomass by the rare species tends to decrease as samples are pooled and, therefore, their contribution to total diversity tends to decrease. When this point is reached the diversity value tends to decline. The diversity value eventually stabilizes since the per cent contribution to total phytomass by the dominant and abundant species tends to become constant as samples are pooled. Addition of new species past the 25^{th} sample does not usually cause any appreciable change in the diversity value; however, it does help to stabilize the value.

CHAPTER VI

DISCUSSION

Relationship of Diversity to Local Environmental Differences in Protected Areas

Protected plots varied in degree of slope, depth of the soil A horizon, and probably in available soil moisture. These differences produced variations in species composition of the three protected plots. Based on numbers of individuals per species, diversity showed an increased value proceeding from the east side of the slope to the west even though soil depth and angle of the slope was variable. This pattern was not evident when diversity was based on phytomass per species. Differences in the values obtained by the two sampling methods were due to the degree of dominance exerted by the dominant perennial grasses.

Assessment of a prairie, whether it be qualitative or quantitative, must take into account the dominance of the perennial grasses. Weaver (1968) stated that *Andropogon scoparius* and *Andropogon gerardi* were the most important dominants of the prairie, constituting about 70% or more of the vegetation. He noted that they were so abundant and vigorous that their influence upon the habitat and their effects upon other species determined to a great extent the conditions under which all the remaining species associated with them must develop.

Perennial grasses were dominant in the protected plots; however, dominance was exhibited by different species. Also, when diversity was based on phytomass per species, values were variable. These results indicate that plots treated alike may show different diversity values depending on local environmental differences in slope, soil moisture, soil depth, and variation in plant distribution within the plot.

Influence of Various Disturbance Factors on Diversity Values in the Tall Grass Prairie

Although treatments were applied several years prior to sampling, diversity values and species composition indicated that alteration in numbers of individuals per species and species phytomass were still evident by the summer of 1971. While seasonal differences in moisture and temperature could influence this variation, it was believed that treatment effects had the greatest influence.

It is evident that the two methods of sampling resulted in different information concerning diversity in the plots. The index based on numbers of individuals per species is sensitive to those species which are abundant but which do not represent any significant contribution to the phytomass of the plot (e.g., Bromus japonicus and Aristida oligantha). The index based on phytomass per species indicates the equitability of phytomass distribution among abundant species. This is particularly true of the dominant perennial grasses, e.g., Andropogon scoparius, Andropogon gerardi, and Sorghastrum nutans. Comparable areas with equal numbers of species may show quite different diversity values if one species contains much more phytomass than any other species.

When treatments were ranked on the basis of diversity values obtained, the sequence of values based on numbers of individuals was:

Plot 15, Plowed Each Year = 3.605

Plot 19, Herbicide = 3.142

Plot 11, Protected = 3.141

Plot 4, Late Spring Burn = 2.991

Plot 10, Once-Plowed = 2.838

Plot 9, Mowed and Removed = 2.758.

When diversity was based on phytomass per species, the ranking of treatments was:

Plot 11, Protected = 3.126

Plot 15, Plowed Each Year = 2.659

Plot 19, Herbicide = 2.656

Plot 9, Mowed and Removed = 2.553

Plot 4, Late Spring Burn = 2.401

Plot 10, Once-Plowed = 2.321.

Protected Versus Plowed Each Year Treatment

Plot 15 (Plowed Each Year) had the highest diversity based on numbers of individuals and the second highest value when based on species phytomass. Although *Sorghastrum nutans* was the dominant species, the abundance of several forbs and subdominant grasses resulted in the higher diversity value. Abundance of these species would suggest that secondary succession had not proceeded to the point where severe competition by dominant species and accumulation of mulch would have eliminated or reduced less abundant species. Frequency values in Plot 15 indicate that several species were widely distributed. If these values are compared to frequency values for Plot 11 (Protected), it can be seen that several species were common to and distributed throughout both plots. However, the extent of the distribution varies. In Plot 11 Andropogon scoparius and Sorghastrum nutans had a more uniform distribution than they had in Plot 15. Also, several species which were abundant and widely distributed in Plot 15 were not as abundant or widely distributed in Plot 11, e.g., Acalypha sp., Andropogon saccharoides, Aristida oligantha, Artemesia ludoviciana, Eragrostis intermedia, Eragrostis spectabilis, and Leptoloma cognatum. The weedy forb Ambrosia psilostachya had a greater frequency in the protected plot. Hutchinson (1969) stated that fire lanes plowed between all plots supported a large population of Ambrosia psilostachya and probably created a seed source, which effected its spread into adjacent plots.

Late Spring Burn Treatment

Several workers have stated that late spring burning results in an increase of desirable species and a reduction of broadleaved species. Others have shown that late spring burning results in increased herbage yields due to litter removal. After cessation of burning, litter accumulation becomes as abundant as it was prior to burning within a 3 to 6 year period.

Phytomass collected for Plot 4 (Late Spring Burn) and Plot 11 (Protected) were similar, i.e., 2483.2 and 2733.5 g, respectively. Any positive effects on increased herbage yield due to late spring burning had become inoperative. Relative composition values for Andropogon scoparius in Plot 4 indicate that it was the most dominant species, particularly on a phytomass basis. Frequency values show that it was uniformly distributed throughout the plot. These results indicate that burning favored the increase of Andropogon scoparius. The dominance of

Andropogon scoparius was expressed in the diversity value based on phytomass (2.401) to a greater extent than the index based on numbers of individuals (2.991) because its contribution to total diversity was reduced.

Mowed and Removed Treatment

Mowing of vegetation, with removal of mulch, has been said to have no significant effect on species composition of tall grass prairie vegetation (Launchbaugh, 1955; and Crockett, 1966). However, Skroch (1965) reported that forb species decreased one growing season after mowing. Hutchinson (1969) reported that relative frequency of *Andropogon scoparius* decreased 20% while phytomass production increased after 3 years of mowing and removing vegetation while it was still dormant. Other workers have also reported increased phytomass production due to mowing (Hulbert, 1969; Penfound, 1964). Penfound stated, however, that measurement of a mowed prairie for 3 successive years after mowing showed a steady decrease in biomass which was lower than a protected area by the end of the third year.

Less phytomass was collected in the mowed and removed plot than the protected plot. This would indicate that any effects of mowing on increased yield had been eliminated by the time of sampling. The diversity value, based on numbers of individuals, showed the mowed plot to be the least diverse of all plots. This low value was due to the dominance of *Andropogon scoparius*. When diversity was based on phytomass, the mowed plot ranked fourth out of the six treated plots with a value of 2.533. These results indicate that mowing affected species composition on both a numbers and phytomass basis. Adjustment of species to a climax situation had not occurred by the time of sampling.

Once-Plowed Treatment

A greater amount of phytomass was produced in Plot 10 (Once-Plowed, 3638.8 g) than in Plot 11 (Protected, 2733.5 g). Plot 15 (Plowed Each Year) had the greatest amount of phytomass (3963.8 g). As suggested by Rice and Penfound (1954), this increase in phytomass may have been due to the greater availability of minerals resulting from the decomposition of organic matter plowed under. Plowing once was initially done in 1964, and six growing seasons passed before sampling occurred.

Diversity values indicated that plowing once produced vegetational changes distinctly different from those obtained for the Protected and Plowed Each Year treatments. Diversity values obtained for these treatments were among the highest diversity values recorded while those for the Once-Plowed Plot were the lowest. These low values for the Once-Plowed Plot resulted from dominance of *Sorghastrum nutans* and *Andropogon scoparius* and a less equitable distribution of phytomass among species. Hutchinson (1969) predicted that *Sorghastrum nutans* would become the dominant species in the Once-Plowed Plot due to the lack of destruction of its propagules by the plowing process. Examination of species frequencies for the two plowed plots shows that *Andropogon scoparius* and *Sorghastrum nutans* had a more uniform distribution in the Once-Plowed Plot than they had in the Plowed Each Year Plot. Relative composition values, however, were quite similar. These results would suggest that as secondary succession proceeds, the dominants become more uniformly distributed and through competition would eliminate or reduce less abundant forbs and grasses.

Herbicide Treatment

Although the rate of application of Tordon to Plot 19 was unknown, the approximate time of application was May, 1966. Whatever the rate of application, it is obvious from the persistence studies on Picloram that activity of Picloram would have been negligible at the time of sampling for this study. Frequency and relative composition values for Plot 19 indicate that the forb *Aster ericoides* was not abundant in this plot. All other plots had an abundance and wide distribution of this species. As suggested by Arnold and Santelmann (1966), Picloram may have reduced and controlled *Aster ericoides*. This reduction was still evident at the time of sampling in 1971.

Based on phytomass, only *Andropogon gerardi*, *Andropogon scoparius*, and *Sorghastrum nutans* made a significant contribution to diversity. For example, the diversity value calculated for the 100^{th} sample in Plot 19 (phytomass for all species was pooled up to and including the 100^{th} sample) was 2.636. There were 40 species found in Plot 19, but the diversity contribution of the three dominant species was 1.504 or approximately 57% of the total diversity value. Dominant grasses were not physically removed or destroyed during treatment, and it is unlikely that this plot is nearing a climax state since the dominants present are those denoted by Booth (1941), Buck and Kelting (1962), and Kelting (1954) as being dominant in the tall grass climax prairie. Had the species *Aster ericoides* been present, diversity values would have been slightly higher for both sampling methods since it would have contributed to the diversity value.

Summary of All Treatments

Values obtained from diversity indices indicated that differences existed in the vegetational composition of plots which were subjected to various types of disturbances. Although values based on numbers of individuals were different than those based on species phytomass, some trends were apparent for the treatments.

The Protected Plot basically had high diversity values based on numbers of individuals per species and phytomass per species. Dominants in this plot had nearly equal relative composition values and a uniform distribution. These results would indicate that as succession proceeds toward the climax state, there tends to be an equitable distribution of the dominant species. In addition, other species were abundant enough (e.g., *Aster ericoides*) that they contributed significantly to the diversity value. These observations are similar to the ones made by Monk (1967) of forest vegetation. He stated that climax communities on comparable sites were always higher in diversity than successional ones. He further stated that diversity in communities belonging to the same sere would exhibit an initial increase related to species addition. This would be followed by an equitability of species composition characteristic of mature successional communities. The conversion from the mature successional to the climax form is accompanied by a second species introduction and a trend toward equitability.

It is believed that the Herbicide Plot was also approaching a climax state since the dominants present were characteristic of the climax prairie, distributed uniformly in the plot, and had similar relative composition values. The diversity value (3.142) was almost identical to the value for the Protected Plot (3.141). The value based on species phytomass (2.656) differed from the Protected Plot (3.126). Had the species *Aster ericoides* been abundant, it is likely that the value would have been higher and ranked second behind the Protected Plot value.

Diversity values for the Late Spring Burn Plot were among the lower values reported. Hutchinson (1969) reported that the initial effect of late spring burning was to cause a decrease in the relative density, relative frequency, and absolute composition of *Andropogon scoparius*.

Burning also caused a reduction in forb composition. It is thought that the post fire development of *Andropogon scoparius* was rapid due to the presence of its underground parts. Since litter was removed by the burning process, increased herbage yields and tillering would have been promoted due to the higher soil temperatures and greater nutrient availability. These factors would have given a competitive advantage to *Andropogon scoparius* over those forbs and grasses which did not develop as rapidly. The dominance of *Andropogon scoparius* was reflected in the low diversity values.

Diversity values for the Mowed and Removed Plot were among the lowest values reported. These results are contrary to the opinion that mowing, with removal of mulch, has no significant effect on species composition of the tall grass prairie. *Andropogon scoparius* had a frequency of 80% for Point Centered Quarter Samples. No other plot had as great a percentage. This would suggest that *Andropogon scoparius* exhibited a uniform distribution within the plot. Relative composition values indicate that it was the dominant species in the plot.

Hutchinson reported that mowing and removing the vegetation for 3 years, while vegetation was dormant, resulted in an increase in total density and more vigorous growth of Andropogon scoparius. Several other workers have shown that clipping, like late spring burning, eliminates mulch and results in increased grass growth. The time and frequency of clipping are, however, related to this response. Vogel and Bjustad (1968) reported that clipping Andropogon scoparius at the seed ripened stage or later, for three successive years, increased both yield and spring initiated tillering of plants. It is believed that mowing, with removal of mulch, increased the yield and tillering of Andropogon scoparius. This gave Andropogon scoparius a competitive advantage over other species present and resulted in its dominance which was still in evidence by the summer of 1971.

The low diversity values for the Once-Plowed Plot contrasted sharply with the high values for the Plowed Each Year Plot. As noted by Hutchinson, plowing once evidently did not destroy the propagules of Sorghastrum nutans since this species increased rather rapidly after plowing ceased. He also noted that conditions of abundant nutrients and moisture allowed its rhizomes to spread rapidly. The dominance of Sorghastrum nutans in Plot 10 was evident for the time of sampling in 1971 and along with the less equitable distribution of phytomass among species, was the main factor influencing the low diversity values obtained in Plot 10. A typical successional series was not followed in this plot because plowing once favored the rapid establishment of Sorghastrum nutans. Plowing Each Year evidently did destroy the propagules of species to a greater extent than did plowing once. Hutchinson reported that there were still remnants of the original dominant vegetation remaining after three years of plowing; however, *Aristida oligantha*, an annual grass, was the dominant species of the vegetation. Although plowing ceased in 1966 in the Plowed Each Year Plot, certain forbs and subdominant grasses were present in enough abundance at the time of sampling (1971) that they significantly affected the diversity value. It is believed that these species were present due to a lack of severe competition.

The disturbance factors previously discussed produced noticeable changes in the vegetational composition. These changes may persist for several years. Mowing and burning had similar influences on vegetational changes in that they favored the development of one species, *Andropogon scoparius*. This resulted in low diversity values for these treatments. Plowing once favored the rapid increase of *Sorghastrum nutans*. The dominance of this species also resulted in a low diversity value. Plowing Each Year, Protection, and Herbicide treatments all resulted in high values of diversity. However, the high values in the Protected and Herbicide Plots were based on the equitability of distribution among species which are typically found in a prairie nearing climax. The high values for the Plowed Each Year Plot were due to the abundance of several species which had not been reduced or eliminated by competition by the dominant species.

Results reported in this study indicate that diversity indices can be used as an analytical tool to measure both spatial and temporal changes in grassland vegetation.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Disturbance factors such as burning, mowing and removing vegetation, and plowing produce changes in the vegetational composition of the tall grass prairie. These changes have typically been measured in terms of frequency, density, basal area, relative composition, and basal cover of the variously occurring species. A study was done in a tall grass prairie near Stillwater, Oklahoma during the summer of 1971. This study tested the relative usefulness of a diversity index in measuring changes in vegetational composition brought about by various disturbance factors.

Protected plots showed distinct differences in species composition and amount of phytomass produced. These differences were a result of local environmental changes in soil depth, soil moisture, and degree of slope. Diversity values, based on species phytomass, indicated differences existed in species composition among protected plots. Diversity values based on numbers of individuals did not reflect these differences to any significant extent. Sampling of vegetation was limited to an area of similar soil depth, slope, and topography in an attempt to eliminate local environmental influences which would possibly influence species composition to a greater extent than would the treatments that had been applied.

Diversity values based on numbers of individuals per species consistently showed higher values than those based on phytomass per species. The method of sampling numbers of individuals included those species which did not contribute significant amounts of phytomass.

Diversity values obtained were shown to be related to the equitability of distribution of numbers of individuals and phytomass among the species present. Diversity values were not related to numbers of species present or total phytomass.

The point at which the diversity curve plateaued was shown to be related to the spatial distribution of species within a plot. However, this was more evident for the curves based on numbers of individuals than it was for those based on species phytomass. Several of the diversity curves based on species phytomass showed a pattern of an initial rapid increase in the diversity value, followed by a decline, and eventually a stabilization. This pattern was attributed to a rapid rate of addition of species during the early stages of sampling.

The effects of disturbance on vegetation cause the following variation in diversity values:

(1) Mowing and Late Spring Burning - Both of these treatments favored the dominance of *Andropogon scoparius*. This resulted in low values of diversity for these treatments relative to the values for the protected area.

(2) Once-Plowed and Plowed Each Year - Plowing once favored the development and dominance of *Sorghastrum nutans*. This resulted in low values of diversity relative to the protected area. Plowing Each Year resulted in the invasion of several forb species and subdominant grasses which

were still abundant at the time of sampling. Abundance of these species in addition to the abundance of the dominant perennial grasses resulted in the highest diversity value obtained based on numbers of individuals per species and the second highest value based on species phytomass.

(3) Protection and Application of Herbicide - Although the species Aster ericoides was absent, it was concluded that the Herbicide Plot was nearing a climax state. This area and the protected area had high diversity values relative to other treatments. These values were a result of a greater equitability of distribution of individuals and phytomass among species present. It is believed that as succession proceeds toward the climax state there tends to be a trend towards equitability of distribution of individuals and phytomass among those species which are characteristic of the tall grass prairie.

(4) Protection and Plowed Each Year - Although diversity values for the protected and plowed each year areas were high, the values for the Plowed Each Year treatment were due to the abundance of several species which had not been eliminated or reduced by competition.

Results reported in this study indicate that diversity indices can be used as analytical tools to assess spatial and temporal variation in the vegetational composition of grasslands. If spatial variation is to be measured, a list of abundant species can indicate changes that occur in vegetational composition due to variations in slope, soil moisture, soil depth, and topography.

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VITA

Edwin Lane Netherland, Jr.

Candidate for the Degree of

Doctor of Education

Thesis: THE EFFECT OF DISTURBANCES ON SPECIES DIVERSITY VALUES IN TALL GRASS PRAIRIE SITES

Major Field: Higher Education

Biographical:

Personal Data: Born in Louisville, Kentucky, January 23, 1942, the son of Mr. and Mrs. Edwin L. Netherland, Sr.

Education: Graduated from South Side High School, Ft. Wayne, Indiana in June, 1960; received a Bachelor of Science degree with a major in Biological Science from Huntington College in June, 1965; received a Master of Science degree in Natural Science from Oklahoma State University in August, 1966; completed requirements for the Doctor of Education degree at Oklahoma State University in July, 1972.

Professional Experience: Instructor in the Biological Sciences at Northern Oklahoma College, 1966-1969. Graduate Teaching Assistant, Department of Botany and Plant Pathology, Oklahoma State University, 1969-1972.

Organizations: Professional: Phi Delta Kappa; Honorary: Phi Kappa Phi.