Technical Report No. 9

# PRELIMINARY REPORT OF METHODOLOGY AND RESULTS FOR ANALYSIS OF PLANT PATTERN SUBPROJECT RESEARCH ON THE PAWNEE SITE

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GRASSLANDS BIOME

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## ABSTRACT

Distributional forms and dispersion characteristics of *Opuntia polyacantha* were examined in areas subjected to three grazing treatment rates (light, medium, and heavy). Determinations of non-randomness were made from comparisons of observed numbers of individuals per quadrat to the expected number per quadrat derived from a Poisson series. Frequency data were obtained from transects of 256 contiguous dm sq quadrats in 30 m x 30 m study plots within each grazing treatment. The analysis of variance technique applied to the frequency data gave an estimate of the clump sizes within each treatment. Mean area of clumps for the light, medium and heavy grazing treatments were: 4, 16, and 128; 4 and 128; and 8, 32, and 128 dm, respectively.

## CONCEPTS, INSTRUMENTATION, AND PERMANENT PLOT ESTABLISHMENT

### Functional Concepts of Ecosystem Pattern Studies

As an initial step toward development of adequate conceptual interactions with other research segments of the Grassland Biome Program, four scales of plant measurements and dispersion, based upon common vegetational characteristics, were developed. This information was distributed during the summer of 1969, but little response or feedback was observed. With the continued development of the Grassland Biome Program, it is expected that greater communication intermutation will be achieved to the benefit of the plant pattern subproject as well as other subprojects and the ecosystem analysis as a whole.

The four scales of measurement were developed upon subjective characterization of common shortgrass plains vegetation. The "micro-scale" level of measurement applied to the distribution of individual culms of herbaceous mat forming species such as blue grama and buffalo grass and perhaps annuals which grow in a dense or mat form. The "meso-scale" measurement would apply to the distribution of grass mat and bare ground interspaces. The "macro-scale" measures would evaluate dispersion characteristics of species which form distinct clumps within the matrix of grass and bare ground interspaces. Distribution of shrubs and prickly pear cactus would fit this level of measurement. "Mega-scale" measurements would be concerned with evaluation of vegetation types within the broad concept of grasslands. Criteria of measurement, characterization, and suggested relationships to ecosystem components of the four measurement levels are presented in Appendix A.

The evaluation of plant forms of distribution is subject to quantitative analysis. The positional arrangements of plants of a species and different species can be measured in terms solely related to analysis of the pattern characteristics. This kind of work has been published by many authors. Of much greater significance is the ecosystem functional aspect of plant distributional forms. In this context, pattern data can be utilized to evaluate the relationships of plant positions to biological processes within the system. Considerable discussion has occurred during the past year, especially with leaders of projects in the areas of primary productivity, plant structure, livestock utilization impact, and native bird population dynamics. Future work will entail cooperative field research with leaders in these other areas in an attempt to determine the functional relationships of plant patterns as related to other biome constituents.

Instrumentation Development (Field Microplotter)

The necessity for some kind of instrumentation to provide precise and detailed data of plant distribution characteristics became obvious with the recognition and definition of the micro-scale and meso-scale levels of plant pattern. From any given permanent point of origin and directionally defined base line, the location of a plant or object can be described and relocated by perpendicular coordinates. The field microplotter (Fig. 1) was designed to record positions based upon distance measures along two perpendicular axes. In addition, vertical displacement or microrelief can be measured at each point as a distance value above or below a horizontal plane extending from the point of origin. Data thus are given in terms of X, Y, and Z coordinates in units of 0.001 m. Although not field-tested at this time, resolution of measurement should be considerably less than one millimeter.

The basic frame of the microplotter consists of square aluminum tubing. Stand rods at the four corners have three kinds of height adjustments for leveling the frame. The stand rods are inserted through bronze bushings mounted in the frame corners. Horizontal movement is virtually nonexistent when the frame is properly positioned.

A metric rack is imbedded on the upper surface of the long axis (X axis) of the frame (Fig. 2). Distance parameters along the one-meter length of the X axis are obtained from the digital meter, which is driven by the system of gears meshed in the rack. Free movement along the X axis is achieved by a longitudinal Thompson ball-bearing system incorporated into blocks at the ends of the Y axis (Fig. 3). The bearings ride on parallel bars mounted on the X axis frame. Parameters of the 0.5 m length of the Y axis are obtained from similar mechanisms attached to Y axis arm, which is mounted on and moved perpendicularly to the X axis (Fig. 4 and 5). Measurements of microrelief are obtained by moving the pointer bar and recording parameters from a digital meter similar to the other axis.

Some modification and refinement of the field microplotter may be necessary for efficient research use. Operating procedures must be developed in considerabl detail for precise location of the instrument and subsequent data collection.

General specifications of the field microplotter are given below:

X axis travel = 1.065 m

Y axis travel = 0.516 m

Z axis travel = ca 0.72 m

Inside dimensions = 1.175 x 0.62 m

Frame height adjusted = 0.10 to 0.82 m

Weight = ca 15 kg

Establishment of Permanent Macro-plots

Initial field procedures involved the selection of uniform sites in three pastures subjected to treatments of light, moderate and heavy grazing by cattle. In addition to the general vegetational aspect, which differed from pasture to pasture because of the grazing treatment, the undulating nature of the terrain resulted in a variety of environmental habitats, each producing differences in species composition, productivity and pattern arrangements. A site was selected in each of the pastures which appeared to be uniformly representative. The three locations were on upland sites with apparent similar habitat characteristics of slope, soils, disturbance and plant-water relations. Subsequent vegetational data evaluation suggests, however, that the sites may not be as uniform as expected. It seems obvious that, in the future, pre-selection measurements of habitat charcteristics will be necessary in order to establish intensive study plots on sites uniformly representative among the pastures subjected to the three grazing treatments.

A permanent plot, 30 m x 30 m, was established at each site. A 3/8" x 24" rod was driven into the soil at the point of origin and at 30 m along perpendicular X and Y axes. The standard cover plate marker was driven into the soil in such a way that the plate covered the rod. Locations of these plots have been recorded within each pasture and filed with a Site Director.

When establishing the plots, the X axis was N-S oriented with a compass corrected for magnetic declination. A surveyor's transit was utilized to determine directions of the X and Y axes. Distance was measured with a steel tape, 30 m in length. To locate accurately the axes of the plot, two workers were required, one to position the rod along the tape and the other to sight through the transit for accurate angular determination. The margin of error in describing the two axes of the plot was no more than two millimeters at the 30 m distance from the point of origin.

## SAMPLING PROCEDURES FOR PRICKLY PEAR LOCATION DATA

### Grid Sampling of Total Macroplot

Investigation into spatial distribution characteristics of plains prickly pear (*Opuntia polyacantha*) at the Pawnee Site was initiated in June 1969. Prickly pear was selected as the first species to be investigated with reference to spatial distribution since observation of the area suggested differences in abundance and distribution as a result of the grazing intensity treatments. By a procedure of grid sampling, all prickly pear plants were located within each of the 30 m x 30 m plots.

Procedures for determination of prickly pear locations within each plot involved the assignment of consecutive digits (1-30) to each meter, counting from the point of origin to the 30th meter of the X and Y axes. To determine the location of any specific square meter, a 30 m chain first was positioned on the X axis beginning at the desired point along the Y axis. To obtain accurate alignment of meter coordinates within the 30 m x 30 x plot, two surveying transits were utilized for visual positioning along the chains. The X and Y axes originated from a southwest point of origin in the light and heavy grazed pastures, but from the northwest point of origin for the plot located in the moderate grazed pasture.

Each square meter within the 30 m x 30 m plots was subdivided, for frequency determination of prickly pear, into square decimeters by location of a meter square quadrat with 100 equal subdivisions. This quadrat was constructed with a frame of 1" sq dimension tubing. Through holes drilled into the tubing at 1 dm intervals, piano wires were stretched across the quadrat to form the square decimeter subdivisions. Tension of the wires was maintained by a spring load mechanism on each of the 18 wires. Position locations of prickly pear were described by X and Y decimeter coordinates within the square meter. Coordinate units (1-10) began at the point of origin of each square meter at the corner of the quadrat nearest the 30 m x 30 m plot point of origin. By this procedure, it was possible to locate each square decimeter (90,000) within a 30 m x 30 m plot. Accurate relocatability will be possible within each plot in the future, based on the three permanent rods which define the points of origin and X and Y coordinates.

Vegetational sampling procedures included the determination of prickly pear presence within square decimeters. Each decimeter square so occupied was identified by the X and Y coordinates of the square meter and the X and Y coordinates of the specific decimeter. For example, a reading of "M0507 D0208" described a decimeter square within a square meter, which was located in the fifth meter series of the Y axis where intersected by the seventh meter series of the X axis. Specification of the decimeter square within the square meter followed the same principle.

The foliage frequency data collection of prickly pear was recorded by rows of meters along the X axis of each plot. The meter square quadrat was repositioned from one meter location to the adjacent until the total 30 m of the row were completed. With the completion of alternative rows, the X axis chain and surveyor's transit were moved for recording data in the next two rows. Each repositioning of the quadrat was a two-man operation, requiring the use of the chain, for determination of distance, and the use of the surveyor's transit for proper angular alignment.

A tape recorder was utilized for rapid accumulation and storage of data. A keypunch operator transferred the data directly to punch cards for subsequent computer analysis.

### Transect Samples of Contiguous Quadrats

Transects of 256 contiguous quadrats were established to evaluate spatial distribution patterns of plains prickly pear. They were located within the 30 m x 30 m plots by a restricted randomization procedure. Transect directions were restricted, so that they were parallel to one or the other of the major plot axes but located randomly along the axis from which they originated.

Procedures for locating the transects included those utilized for the grid sampling of the 30 m x 30 m plots as described in the previous section. For location of transect quadrats, a 1 m x 1 dm plastic overlay, on which were inscribed contiguous decimeter squares with subdivisions dividing each square decimeter into 16 equal subsquares, was positioned over the desired row of decimeter squares within the meter square quadrat. For frequency values of prickly pear within each decimeter square, a third order identification was given by recording the total number of 1/16 $dm^2$ subunits within which the plant occurred. First and second order identification coordinates were given as described previously. As an example, a frequency value of 13 subunits within which *Opuntia* was present was recorded in the following form: M0705 D0108 F13.

### Yield and Density Estimates of Prickly Pear

A measurement of density and yield was made on each grazing treatment outside the periphery of each 30 m x 30 m sampling plot. Due to the inherent morphology of the species, differentiation between individuals is very difficult, especially from visual observations. Many *Opuntia* pads were separated by several inches, in some cases feet, appearing to be distinct plant units when in fact they were connected by heavy rhizomes at shallow depths. In the present study, distinction between individuals in each of the 70 quadrats 1/4 $m^2$ located at each study area was made by locating the root or rhizome system; pads not connected by roots or rhizomes were treated as individuals. By restricted random location procedures, quadrats were located sufficiently distant from one another that chances of one plant unit being counted more than once were reduced. Data were recorded in values of numbers of individual plants which occurred within each plot.

From each of the quadrats used to measure density, a yield reading was also obtained by clipping all *Opuntia* rooted within each quadrat. After clipping, samples were ovendried for three days at 105°C and weighed to the nearest .01 gm.

## PRICKLY PEAR PATTERN CHARACTERISTICS

This study is a preliminary evaluation of plant pattern analysis. Standard methods were used to determine the scales of heterogeneity of one species, *Opuntia polyacantha*. The information gained from this study will be utilized to determine methods and procedures necessary to produce a plant pattern study which can be integrated into an overall ecosystem analysis.

### Description of Study Area

The study area was the Pawnee Site, US-IBP Grassland Biome, located in Weld County, Colorado, approximately 40 km south of Cheyenne, Wyoming. Sampling was conducted in typical upland sites of the light, medium and heavy grazed pastures located in Sections 15 and 23 of Township 10N, Range 66W.

Within each site, a homogeneous plot 30 m on a side (.09 hectare) was selected for intensive study (Fig. 6). All plots with the exception of the medium grazed plot, were oriented with their X axis running from west to east. Comparisons made between sites were based on data taken from the .09 hectare plots.

Methods and Procedures

The spatial distribution of plains prickly pear (*Opuntia polyacantha*) was determined by the method proposed by Svedberg (1922). Within each site, density values were determined on 70 quadrats 1/4 $m^2$ in area. Quadrats containing 0, 1, 2, 3, etc., individuals were compared to expected values derived from a Poisson series and tested by a $X^2$ goodness of fit test for significance. Significant $X^2$ values indicated a clumped distribution.

Clump sizes within grazing treatments were found by applying the technique of Greig-Smith (1952) to frequency data taken from transects of contiguous quadrats. To facilitate a frequency value for each unit ($dm^2$) within a transect, units were subdivided into 16 equal subunits. Values derived from blocking adjacent units within a transect were subjected to an analysis of variance, the variance then being partitioned among the different block sizes. The peaks appearing when mean squares were plotted against the appropriate block sizes. The peaks appearing when mean squares were plotted against the appropriate block size indicate the mean area of a clump.

Conforming to past methods dealing with pattern analysis, samples within grazing treatments were formed by combining individual transects (Kershaw, 1958; Greig-Smith, 1961). An average frequency value was then obtained for each decimeter of the sample transects and the above analysis was performed, giving the clump sizes for the particular samples (Fig. 7, 8, 9, 11, 12, 13, 15, 16, 17). Finally, all lines within a grazing treatment were combined to give the total number and sizes of *O. polyacantha* clumps which were present in the three grazing treatments (Fig. 10, 14, and 18).

The number of transects within a study plot varied. In the light grazed plot, only three transects were read--all parallel to the X axis. In the medium and heavy grazed plots, more transects were examined (10 and 12), respectively. These transects paralleled both the X and Y axes. The number of samples compiled for each grazing treatment was three. The sample size varied among treatment. With only three transects examined in the light grazed plot, a sample consisted of only four transects each, while the three heavy grazed samples were of size three, three, and four transects. The summarization of data from Tables 13, 14 and 15 is listed in Tables 1 through 12.

The raw data taken from each transect are listed in Tables 13, 14 and 15 with the exception of transects 11 and 12 of the medium grazed plot, which are missing. The raw frequency values from these tables were used in constructing the analysis of variance tables necessary in predicting clump sizes of prickly pear.

Results and Discussion

The distribution of density values in each grazing treatment varied widely from calculated random expectations. Therefore, highly significant $X^2$ values were obtained, indicating that the distribution of *O. polyacantha* was highly aggregated, confirming visual observations.

For the sake of convenience, reference made to peaks (produced when mean square is plotted against block size) will indicate a clump size which corresponds to the block size of the particular peak. Within each grazing treatment, several different peaks were produced from the sample transects (three figures immediately preceding Fig. 10, 14, and 15). However, a combination of all transects within a grazing treatment reduced the number of peaks and generally lowered the height of any prevalent peak. A reduction in the number of peaks would be expected when all transects were combined to produce one graph, since it is possible for one graph to produce only four peaks. Generally, when a peak was present in at least two samples, it also appeared when samples were combined for a grazing treatment. Fig. 10, 14, and 15 (average of all transects within a grazing treatment) illustrate the most prevalent clump sizes of *O. polyacantha* found in the three grazing treatments. It is obvious from the data that variations in the scale of prickly pear pattern exist within treatments as well as among treatments. However, not all clump sizes were unique to a particular treatment. For example, block size 4 was present in both the light and medium grazed treatments, while block size 128 was common to all treatments. It is suspected that block size 128 is not a reliable estimate of clump size at that scale. Workers have found that block sizes preceding the largest block size usually have more significance and are more reliable estimates of actual clump size (Greig-Smith, 1961). Statistical techniques have been derived to alleviate the high variance produced in the larger block sizes and are used by many workers (Greig-Smith, 1961; Yarranton, 1969).

## Summary

The data from this study are of a preliminary nature as far as complete analysis of plant pattern is concerned. The techniques employed facilitated the objectives of this study, i.e., to determine if differences in clump size existed within and among grazing treatments. Figures illustrate that clump size did vary within and among grazing treatments. However, these differences cannot be solely related to grazing treatment. Therefore, these unexplainable difference elucidate the need for microenvironmental and biological data necessary to explain the existence of a particular clump size.

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# PRICKLY PEAR DISPERSION FORMS

## Introduction

Many analyses for determination of distribution characteristics of vegetation are described in the literature (Greig-Smith, 1964; Kershaw, 1964). In the previous section of this report, pattern of plains prickly pear was evaluated with density data derived from samples of 1/4 $m^2$ quadrats, while clump sizes were obtained from transects of 256 contiguous decimeter square quadrats.

The grid procedures described earlier provided population data of prickly pear locations, by square decimeter, within the three 30 m x 30 m macroplots, each of which contained 90,000 sq dm units. Evaluation of these data for determination of prickly pear spatial distribution parameters, as influenced by grazing treatments and site variability, was obtained by a program developed for analysis by digital computer. Future work will involve comparison of these population data to the samples derived from within the macroplots.

## Results and Discussion

The computer program written for the data collected by location of *Opuntia* plants described by X and Y coordinates allows the computation of several parameter associated with the spatial distribution of *Opuntia polyacantha*. Many of these parameters cannot be computed from data collected by other methods. Table 16 is a list of the parameters. Those marked with an asterisk have not been summarized and were not listed due to the space required. Fig. 19, 20, and 21 are graphic representations of each 30 m x 30 m study plot with exact locations of each frequency reading.

Fig. 19, 20, and 21 are graphic representations of the 30 m x 30 m sampling plots depicting the exact location (to a decimeter) of all *Opuntia* plants. IBM cards with frequency readings activated a cathode ray which exposed high speed 35mm film on the computer attachment. Therefore, all exposures appeared as black squares on the film, the smallest exposure representing a $dm^2$. With the smallest sampling unit being a $dm^2$, it is obvious that area of percentage cover, as indicated by the resolution shown on the figures, overestimates the real situation, since frequency data often included hits (clump: any two contiguous hits) wherein prickly pear cover was only a small portion of a square decimeter. The black portion of each figure therefore will naturally overestimate the actual cover of *Opuntia*. Even with the overestimation, the values in Table 16 can be utilized to compare the differences in *Opuntia* on the three grazing treatments.

Table 16 is a listing of parameters computed from the frequency data used to construct the photographs in Fig. 19, 20, and 21. Parameters without values have not been summarized. Trends on values listed in Table 16 under the three grazing treatments are supported by the printouts in Fig. 19, 20, and 21.

Average clump size was greatest in the heavy grazed pasture where large areas of contiguous hits were recorded. Unlike the light and medium grazed pastures, where average clump size was lower, large areas bare of *Opuntia* were recorded between clumps. It is obvious upon comparison of the three grazing treatments that more *Opuntia* clumps were recorded in the light grazed pasture than either of the other two. Many of these were in the two and three decimeter range, thereby lowering the average clump size. More individual contiguous hits were recorded in the light grazed plot than in the other two plots combined. This information may indicate that either seed germination or seedling survival is influenced by some biological or physical factor affected by grazing.

Yield data also substantiated that more *Opuntia* was present on the light grazed plot than the other plots. An estimate of yield for each treatment was obtained by clipping *Opuntia* from 70 quadrats 1/4 $m^2$. Quadrats were positioned outside the 30 m plots near the periphery to minimize disturbance within the plots. Samples were oven-dried for three days at 105°C and weighed to .01 gm. Yield values in gm/m$^2$ for the light, medium, and heavy grazed plots were 5.52, 1.80, and 2.08, respectively.

In the medium grazed plot where large interclump bare spaces were observed, the average distance between clump centers was largest (Fig. 20). Where the opposite conditions existed as in the light grazed plot, the mean distance was less.

The mean major and minor axes length of clumps was given for each series of recorded contiguous hits. This length was a line running through the center of mass of the clump, assuming that each decimeter had equal mass. The computer printout was in the form of a three-dimensional histogram giving the number of clumps in each class. Mean major axis length was plotted against angle of orientation of the long axis.

Clump orientation was expressed as the angle of orientation of the major axis. Clumps with their long axes oriented toward the north were given azimuth readings of zero, while readings of 90° indicated an east-west orientation. A frequency distribution of this parameter likewise was given.

An expression of clump configuration is obtained from degree of elongation percentage. A clump with an elongation percentage of 100 would be near an ellipse, while clumps near zero are circular in form. By the present sampling technique, a clump of two contiguous hits can only be elliptical in shape (degree of elongation percentage 100). Contiguous hits in the form of a square give only zero readings.

Summary

By grid sampling prickly pear locations within each 30 m x 30 m plot, data were derived, defined as populations occurring as a result of grazing treatments. Initial computer output was a graphic presentation of each macroplot with specific locations of all recorded *Opuntia* plant units. Observation of the figures show drastic differences in spatial distribution and abundance of prickly pear.

Computer programs were developed to evaluate clump sizes, numbers, and other parameters of each population. Greatest numbers of *Opuntia* clumps were present in the light grazed area but largest clumps occurred in the heavy use area. Irregular values from the moderate use pasture indicate that habitat characteristics of the three sites may not be uniform.

Data analysis of other measures is in process.

# APPENDIX A

## PLANT PATTERN MEASUREMENT LEVELS

### MICRO-SCALE MEASURES

Level of Accuracy: ±0.5 mm

Dimensions of Repeatability Units: probably no greater than 0.5 cm

Character of Measurement: At this level we are measuring the positional arrangement of individual plant stems, primarily blue grama, which may occur almost as a sole dominant in small mat unit, and mixtures of blue grama and buffalo grass which appear to have similar characteristics of dimensions. Other species occurring within the areas of high culm density will of course also be recorded.

Size of Areas Containing Uniform Repeatability Units: Grass mat units are usually no greater in area than one or two square feet, except perhaps in the prickly pear-grass associations in which the areas may be as large as four or five square feet.

Possible Uses of Data: (Relations to high density culm distribution)

1. Correlation of soil microorganism studies in terms of distribution in relation to plant distribution and species diversity.
2. Insect distribution
3. Variation in microenvironment
4. Influence on transpiration, photosynthesis, $CO_2$ synthesis and $O_2$ production.
5. Influence on plant structure variations.
6. Influence on small mammal distribution.
7. Influence on bird distribution.
8. Influence on grazing distribution.
9. Influence on livestock utilization preference and trend.
10. Influence on plant productivity, reproduction, and competition.
11. Plant response to microsoil variations.

MESO-SCALE MEASURES

Level of Accuracy: ±3.0 mm

Dimensions of Repeatability Units: 5 to 40 cm

Character of Measurements: Middle scale measurements of plant distribution involves the determination of repeatability units of grass mats and bare ground interspaces among the vegetational units. Microrelief is an extremely important character at this level of measurement. Horizontal measures will be utilized to evaluate dimensions of grass mat units and bare ground units as well as dimensions of repeatability units of the vegetation covered soil-bare ground complex.

Size of Areas Containing Uniform Repeatability Units: Vegetation covered units usually range from a few inches to one or two feet in diameter. The bare ground areas usually appear in a linear configuration but with a width ranging from approximately an inch to approximately six inches. Contiguous repeatability units of vegetation-bare ground may range up to dimensions of ten meters or more.

Possible Uses of Data: (Relations to grass mat-bare ground distribution)

1. Correlation of sod microorganism studies in terms of their distribution.
2. Insect distribution
3. Variation in microenvironment
4. Variation in transpiration, photosynthesis, $CO_2$ synthesis, on $O_2$ production as related to proximity and amounts of bare ground adjacent to grass mat areas.
5. Influence on plant structure variations
6. Influence on small mammal distribution
7. Influence on bird distribution
8. Influence on plant productivity, reproduction, and competition
9. Plant responses to soil variations

## MACRO-SCALE MEASURES

Level of Accuracy: ±2.0 cm

Dimensions of Repeatability Units: 0.5 to 4 m

Character of Measurements: These large scale measures concern the distribution of non-grass forms such as prickly pear and several shrubs within the general matrix of the grass-forb vegetation. The cactus clumps include grasses and other herbaceous species and during the growing season these areas can be distinguished by differences in color and structure of the grasses included within the areas. Prickly pear plants may be present in the areas designated as grass-forb vegetation. Shrub distribution and influence on associated vegetation is generally thought of in terms of mature plants.

Size of Areas Containing Uniform Repeatability Units: Cactus clumps range in area from one square foot to perhaps 150 square feet in area. Margins of these clumps are separated from one another by distances ranging from about one to five meters. Contiguous repeatability units may range in dimensions to several hundred meters. Mature shrubs are distributed similarly to the cactus clumps.

Possible Uses of Data: (Relations to cactus clump and mature shrub distribution)

Similar to the items mentioned in the description of micro- and meso-scale measures.

MEGA-SCALE MEASURES

Level of Accuracy: ±1.0 m

Dimensions of Repeatability Units: few to several hundred meters

Character of Measurements: The concept at this level of measurement would be similar to that of a micro-scale evaluation of vegetation types in which each type would be distinguished on the basis of such minor variations as vegetational composition and productivity or changes in physical factors such as soils, slope, and exposure. This phase of investigation is not now included as a part of the pattern project.

Size of Areas Containing Uniform Repeatability Units: This is not now known but would involve study of land units of several thousand acres.

Possible Uses of Data: (Relations of geographically dispersed vegetative types)

Similar to items mentioned in the micro-scale measures but extended to large areas of several hundred to several thousand acres.

Table 1. Analysis of variance for frequency data taken from line 3 of the light grazed treatment.

| Block Size (Ns) | $S(x)^2$ | $\frac{(Sx)^2}{Ns}$ | Sums of Squares | Degrees of Freedom | Mean Square (variance) |
|---|---|---|---|---|---|
| 1 | 707.00 | 707.00 | 251.50 | 128 | 1.96 |
| 2 | 911.00 | 455.50 | 172.20 | 64 | 2.70 |
| 4 | 1133.00 | 283.30 | 129.40 | 32 | 4.40* |
| 8 | 1231.00 | 153.90 | 49.60 | 16 | 3.10 |
| 16 | 1669.00 | 104.30 | 20.20 | 8 | 2.52 |
| 32 | 2691.00 | 84.10 | 16.00 | 4 | 4.00* |
| 64 | 4359.00 | 68.10 | 4.80 | 2 | 2.40 |
| 128 | 8105.00 | 63.30 | .30 | 1 | .30 |
| 256 | 16129.00 | 63.00 | --- | --- | --- |

*Mean squares producing a significant peak.

Table 2. Analysis of variance for frequency data taken from line 2 of the light grazed treatment.

| Block Size (Ns) | $S(x)^2$ | $\frac{(Sx)^2}{Ns}$ | Sums of Squares | Degrees of Freedom | Mean Square (variance) |
|---|---|---|---|---|---|
| 1 | 250.00 | 250.00 | 84.00 | 128 | .66 |
| 2 | 332.00 | 166.00 | 61.00 | 64 | .92* |
| 4 | 420.00 | 105.00 | 25.00 | 32 | .78 |
| 8 | 640.00 | 80.00 | 33.30 | 16 | 2.06 |
| 16 | 724.00 | 46.70 | 21.50 | 8 | 2.68* |
| 32 | 808.00 | 25.20 | 4.30 | 4 | 1.87 |
| 64 | 1338.00 | 20.90 | 3.90 | 2 | 1.94* |
| 128 | 2176.00 | 17.00 | 1.00 | 1 | 1.00 |
| 256 | 4096.00 | 16.00 | --- | --- | --- |

*Mean squares producing a significant peak.

Table 3. Analysis of variance for frequency data taken from line 1 of the light grazed treatment.

| Block Size (Ns) | $S(x)^2$ | $\frac{(Sx)^2}{Ns}$ | Sums of Squares | Degrees of Freedom | Mean Square (variance) |
|---|---|---|---|---|---|
| 1 | 409.00 | 409.00 | 156.50 | 128 | 1.22 |
| 2 | 505.00 | 252.50 | 76.70 | 64 | 1.20 |
| 4 | 703.00 | 175.80 | 55.70 | 32 | 1.74* |
| 8 | 961.00 | 120.10 | 27.10 | 16 | 1.69 |
| 16 | 1487.00 | 93.00 | 27.90 | 8 | 3.49 |
| 32 | 2085.00 | 65.10 | 20.60 | 4 | 5.15* |
| 64 | 2829.00 | 44.50 | 5.30 | 2 | 2.65 |
| 128 | 5017.00 | 39.20 | 11.00 | 1 | 11.00* |
| 256 | 7225.00 | 28.20 | --- | --- | --- |

*Mean squares producing a significant peak.

Table 4. Analysis of variance for frequency data taken from the average of all lines (3) within the light grazed treatment.

| Block Size (Ns) | $S(x)^2$ | $\frac{(Sx)^2}{Ns}$ | Sums of squares | Degrees of freedom | Mean Square (variance) |
|---|---|---|---|---|---|
| 1 | 160.47 | 160.47 | 49.87 | 128 | .39 |
| 2 | 221.20 | 110.60 | 36.11 | 64 | .56 |
| 4 | 297.94 | 74.49 | 20.13 | 32 | .63* |
| 8 | 434.85 | 54.36 | 6.51 | 16 | .41 |
| 16 | 765.61 | 47.85 | 7.74 | 8 | .97* |
| 32 | 1283.59 | 40.11 | 2.77 | 4 | .69 |
| 64 | 2389.10 | 37.34 | 3.60 | 2 | 1.80 |
| 128 | 4319.10 | 33.74 | 2.32 | 1 | 2.32* |
| 256 | 8044.30 | 31.42 | --- | --- | --- |

*Mean squares producing a significant peak.

Table 5. Analysis of variance for frequency data taken from the average of all lines (12) within the medium grazed treatment.

| Block Size (Ns) | s(x)2 | $\frac{(Sx)^2}{Ns}$ | Sums of Squares | Degrees of Freedom | Mean Square (variance) |
|---|---|---|---|---|---|
| 1 | 28.42 | 28.42 | 6.18 | 128 | .05 |
| 2 | 44.94 | 22.24 | 4.88 | 64 | .08 |
| 4 | 69.44 | 17.36 | 5.08 | 32 | .16* |
| 8 | 98.23 | 12.28 | 2.04 | 16 | .13 |
| 16 | 163.88 | 10.24 | .71 | 8 | .09 |
| 32 | 304.94 | 9.53 | .30 | 4 | .07 |
| 64 | 589.88 | 9.23 | .04 | 2 | .02 |
| 128 | 1177.00 | 9.19 | 2.12 | 1 | 2.16* |
| 256 | 1798.61 | 7.03 | --- | --- | --- |

*Mean squares producing a significant peak.

Table 6. Analysis of variance for frequency data taken from the average of lines 1, 2, 9 and 12 of the medium grazed treatment.

| Block Size (Ns) | $S(x)^2$ | $\frac{(Sx)^2}{Ns}$ | Sums of Squares | Degrees of Freedom | Mean Square (variance) |
|---|---|---|---|---|---|
| 1 | 52.37 | 52.37 | 12.87 | 128 | .10 |
| 2 | 79.00 | 39.50 | 10.41 | 64 | .16 |
| 4 | 116.37 | 29.09 | 10.20 | 32 | .32* |
| 8 | 151.12 | 18.89 | 4.54 | 16 | .28 |
| 16 | 229.62 | 14.35 | 2.44 | 8 | .30 |
| 32 | 381.25 | 11.91 | 2.35 | 4 | .59 |
| 64 | 611.87 | 9.56 | 2.83 | 2 | 1.42 |
| 128 | 861.25 | 6.73 | 1.81 | 1 | 1.81* |
| 256 | 1260.25 | 4.92 | --- | --- | --- |

*Mean Squares producing a significant peak.

Table 7. Analysis of variance for frequency data taken from the average of lines 3, 4, 5 and 6 of the medium grazed treatment.

| Block Size (Ns) | $s(x)^2$ | $\frac{(Sx)^2}{Ns}$ | Sums of Squares | Degrees of Freedom | Mean Square (variance) |
|---|---|---|---|---|---|
| 1 | 100.87 | 100.87 | 31.25 | 128 | .24 |
| 2 | 139.25 | 69.62 | 27.34 | 64 | .43* |
| 4 | 169.13 | 42.28 | 14.81 | 32 | .46 |
| 8 | 219.75 | 27.47 | 6.72 | 16 | .42 |
| 16 | 332.00 | 20.75 | 1.75 | 8 | .22 |
| 32 | 608.25 | 19.00 | .94 | 4 | .23 |
| 64 | 1155.62 | 18.06 | 2.67 | 2 | 1.34 |
| 128 | 1970.12 | 15.39 | 1.56 | 1 | 1.56* |
| 256 | 3541.44 | 13.83 | --- | --- | --- |

*Mean squares producing a significant peak.

Table 8. Analysis of variance for frequency data taken from the average of lines 7, 8, 10 and 11 of the medium grazed treatment.

| Block Size (Ns) | S(x)2 | $\frac{(Sx)^2}{Ns}$ | Sums of Squares | Degrees of Freedom | Mean Square (variance) |
|---|---|---|---|---|---|
| 1 | 39.56 | 39.56 | 11.78 | 128 | .90* |
| 2 | 55.56 | 27.78 | 10.14 | 64 | .79 |
| 4 | 70.56 | 17.64 | 5.98 | 32 | .19 |
| 8 | 93.31 | 11.66 | 2.66 | 16 | .17 |
| 16 | 144.06 | 9.00 | 1.07 | 8 | .13 |
| 32 | 253.69 | 7.93 | 1.19 | 4 | .30* |
| 64 | 431.44 | 6.74 | .25 | 2 | .13 |
| 128 | 830.31 | 6.49 | 2.30 | 1 | 2.30* |
| 256 | 1072.56 | 4.19 | --- | --- | --- |

*Mean squares producing a significant peak.

Table 9. Analysis of variance for frequency data taken from the average of lines 1, 2, 3 and 4 of the heavy grazed treatment.

| Block Size (Ns) | $S(x)^2$ | $\frac{(Sx)^2}{Ns}$ | Sums of Squares | Degrees of Freedom | Mean Square (variance) |
|---|---|---|---|---|---|
| 1 | 119.81 | 119.81 | 37.90 | 128 | .30 |
| 2 | 163.81 | 81.91 | 21.24 | 64 | .33* |
| 4 | 242.69 | 60.67 | 8.80 | 32 | .28 |
| 8 | 414.94 | 51.87 | 10.48 | 16 | .66* |
| 16 | 662.06 | 41.39 | 2.53 | 8 | .32 |
| 32 | 1243.56 | 38.86 | 3.80 | 4 | .95* |
| 64 | 2243.81 | 35.06 | 1.45 | 2 | .73 |
| 128 | 4301.56 | 33.61 | 2.50 | 1 | 2.50* |
| 256 | 7965.56 | 31.11 | --- | --- | --- |

*Mean squares producing a significant peak.

Table 10. Analysis of variance for frequency data taken from the average of lines 5, 7 and 9 of the heavy grazed treatment.

| Block Size (Ns) | $S(x)^2$ | $\frac{(Sx)^2}{Ns}$ | Sums of Squares | Degrees of Freedom | Mean Square (variance) |
|---|---|---|---|---|---|
| 1 | 168.46 | 168.46 | 45.04 | 128 | .35 |
| 2 | 247.27 | 123.44 | 31.36 | 64 | .49 |
| 4 | 368.30 | 92.08 | 15.87 | 32 | .50 |
| 8 | 609.79 | 76.21 | 20.16 | 16 | 1.26* |
| 16 | 896.88 | 56.05 | 11.00 | 8 | 1.38 |
| 32 | 1441.45 | 45.05 | 5.88 | 4 | 1.47 |
| 64 | 2506.57 | 39.17 | 2.00 | 2 | 1.00 |
| 128 | 4759.30 | 37.18 | 5.74 | 1 | 5.74* |
| 256 | 8047.88 | 31.44 | --- | --- | --- |

*Mean squares producing a significant peak.

Table 11. Analysis of variance for frequency data taken from the average of lines 6, 8 and 10 of the heavy grazed treatment.

| Block Size (Ns) | $S(x)^2$ | $\frac{(Sx)^2}{Ns}$ | Sums of Squares | Degrees of Freedom | Mean Square (variance) |
|---|---|---|---|---|---|
| 1 | 192.35 | 192.35 | 38.11 | 128 | .30 |
| 2 | 290.48 | 154.24 | 39.31 | 64 | .61 |
| 4 | 459.73 | 114.93 | 34.24 | 32 | 1.07* |
| 8 | 645.52 | 80.69 | 19.31 | 16 | 1.20 |
| 16 | 982.07 | 61.38 | 11.29 | 8 | 1.41 |
| 32 | 1602.95 | 50.09 | 11.63 | 4 | 2.91* |
| 64 | 2461.67 | 38.46 | 2.09 | 2 | 1.04 |
| 128 | 4655.80 | 36.37 | 1.88 | 1 | 1.88* |
| 256 | 8828.48 | 34.49 | --- | --- | --- |

*Mean squares producing a significant peak.

Table 12. Analysis of variance for frequency data taken from the average of all lines (10) within the heavy grazed treatment.

| Block Size (Ns) | $S(x)^2$ | $\frac{(Sx)^2}{Ns}$ | Sums of Squares | Degrees of Freedom | Mean Square (variance |
|---|---|---|---|---|---|
| 1 | 85.86 | 85.86 | 14.71 | 128 | .11 |
| 2 | 142.30 | 71.15 | 11.97 | 64 | .19 |
| 4 | 236.72 | 59.18 | 7.64 | 32 | .24 |
| 8 | 412.34 | 51.54 | 7.09 | 16 | .44* |
| 16 | 711.22 | 44.45 | 2.18 | 8 | .27 |
| 32 | 1352.68 | 42.27 | 6.21 | 4 | 1.55* |
| 64 | 2307.88 | 36.06 | 1.26 | 2 | .63 |
| 128 | 4454.44 | 34.80 | 3.02 | 1 | 3.02* |
| 256 | 8136.04 | 31.78 | --- | --- | --- |

*Mean squares producing a significant peak.

Table 13. Foliage frequency of *Opuntia polyacantha* taken from 3 transects of contiguous quadrats in light grazed treatment.

| Line 1 | | Line 2 | | Line 3 | |
|---|---|---|---|---|---|
| Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** |
| 14 | 4 | 33 | 2 | 14 | 1 |
| 19 | 5 | 34 | 2 | 15 | 3 |
| 20 | 8 | 43 | 6 | 16 | 2 |
| 21 | 3 | 84 | 4 | 31 | 6 |
| 31 | 1 | 93 | 2 | 32 | 2 |
| 63 | 1 | 96 | 3 | 53 | 3 |
| 78 | 5 | 98 | 1 | 54 | 8 |
| 79 | 1 | 99 | 5 | 70 | 2 |
| 81 | 4 | 100 | 5 | 71 | 8 |
| 84 | 7 | 101 | 5 | 75 | 3 |
| 89 | 1 | 103 | 3 | 76 | 4 |
| 90 | 8 | 104 | 2 | 78 | 1 |
| 91 | 6 | 133 | 7 | 79 | 6 |
| 94 | 4 | 137 | 1 | 87 | 3 |
| 95 | 2 | 148 | 3 | 88 | 6 |
| 97 | 3 | 170 | 2 | 104 | 1 |
| 111 | 4 | 189 | 3 | 105 | 6 |
| 128 | 2 | 191 | 1 | 108 | 3 |
| 165 | 4 | 206 | 1 | 134 | 3 |
| 167 | 1 | 209 | 1 | 135 | 2 |
| 184 | 4 | 247 | 3 | 141 | 2 |
| 185 | 1 | 248 | 2 | 142 | 1 |
| 224 | 3 | | | 143 | 1 |
| 250 | 3 | | | 144 | 8 |

(con't)

Table 13. (Continued)

| Line 3 (con't) | |
|---|---|
| Decimeter* | Number of occurrences** |
| 147 | 12 |
| 175 | 3 |
| 176 | 5 |
| 199 | 2 |
| 221 | 4 |
| 222 | 2 |
| 224 | 2 |
| 226 | 1 |
| 253 | 8 |
| 255 | 2 |

* Numbers identify the decimeter in which *Opuntia* was observed.
** Number of subunits within a decimeter occupied by *Opuntia polyacantha*.

Table 14. Foliage frequency of *Opuntia polyacantha* taken from 12 transects of 256 contiguous quadrats in medium grazed treatment.

| Line 1 | | Line 2 | | Line 3 | |
|---|---|---|---|---|---|
| Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** |
| 137 | 5 | 75 | 6 | 33 | 5 |
| 141 | 1 | 80 | 2 | 140 | 4 |
| 142 | 2 | 116 | 7 | 153 | 3 |
| 143 | 2 | 119 | 3 | 181 | 8 |
| 150 | 7 | 179 | 3 | 197 | 1 |
| 165 | 1 | 200 | 2 | 198 | 4 |
| 166 | 10 | 201 | 3 | 214 | 3 |
| 167 | 2 | 240 | 2 | 237 | 2 |
| 182 | 7 | 241 | 8 | 239 | 5 |
| 189 | 6 | | | | |
| 190 | 2 | | | | |
| 192 | 2 | | | | |
| 193 | 2 | | | | |
| 194 | 5 | | | | |
| 251 | 5 | | | | |
| 252 | 3 | | | | |
| 253 | 2 | | | | |

* Numbers identify the decimeter in which *Opuntia* was observed.
** Number of subunits within a decimeter occupied by *Opuntia polyacantha*.

Table 14. (Continued)

| Line 4 | | Line 5 | | Line 6 | |
|---|---|---|---|---|---|
| Decimeter* | Number of occurrences** | Decimeter * | Number of occurrences** | Decimeter* | Number of occurrences** |
| 18 | 7 | 1 | 1 | 130 | 2 |
| 26 | 1 | 17 | 4 | 131 | 1 |
| 27 | 1 | 18 | 4 | 139 | 1 |
| 33 | 2 | 46 | 2 | 140 | 6 |
| 34 | 3 | 47 | 7 | 141 | 4 |
| 89 | 1 | 54 | 2 | 149 | 4 |
| 105 | 3 | 55 | 8 | 160 | 5 |
| 106 | 1 | 56 | 2 | 161 | 8 |
| 153 | 2 | 59 | 8 | 162 | 6 |
| 154 | 6 | 60 | 6 | 169 | 1 |
| 155 | 5 | 72 | 1 | 170 | 4 |
| 157 | 4 | 73 | 6 | 171 | 7 |
| 159 | 3 | 74 | 2 | 180 | 4 |
| 244 | 1 | 89 | 3 | 184 | 6 |
| 246 | 2 | 99 | 3 | 187 | 4 |
| 251 | 5 | 199 | 2 | 197 | 2 |
| 252 | 2 | 204 | 9 | 198 | 4 |
| | | 206 | 3 | 201 | 1 |
| | | | | 202 | 7 |
| | | | | 252 | 3 |
| | | | | 253 | 5 |

Table 14. (Continued)

| Line 7 | | Line 8 | | Line 9 | |
|---|---|---|---|---|---|
| Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** |
| 92 | 2 | 122 | 5 | 1 | 3 |
| 122 | 3 | 166 | 5 | 70 | 2 |
| 123 | 1 | 167 | 9 | 73 | 1 |
| 166 | 1 | 168 | 3 | 74 | 5 |
| 167 | 4 | 237 | 4 | 180 | 3 |
| 168 | 1 | 238 | 2 | 181 | 7 |
| 173 | 3 | 240 | 2 | 197 | 5 |
| 177 | 1 | 243 | 4 | 213 | 1 |
| 241 | 5 | 244 | 5 | 226 | 2 |
| 254 | 2 | 245 | 5 | 239 | 2 |
| | | 254 | 5 | 240 | 1 |
| | | | | 241 | 1 |
| | | | | 245 | 1 |
| | | | | 254 | 2 |

Table 14. (Continued)

| Line 10 | | Line 11 | | Line 12 | |
|---|---|---|---|---|---|
| Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** |
| 1 | 3 | | | | |
| 197 | 2 | | | | |
| 206 | 2 | | | | |
| 213 | 6 | | | | |
| 214 | 6 | | | | |
| 215 | 3 | | | | |
| 239 | 6 | | | | |
| 240 | 3 | | | | |
| 243 | 1 | | | | |
| 244 | 1 | | | | |
| 245 | 2 | | | | |
| 246 | 2 | | | | |
| 252 | 4 | | | | |
| 253 | 8 | | | | |
| 254 | 2 | | | | |

Table 15. Foliage frequency of *Opuntia polyacantha* taken from 10 transects of 256 contiguous quadrats in heavy grazed treatment.

| Line 1 | | Line 2 | | Line 3 | |
|---|---|---|---|---|---|
| Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** |
| 10 | 2 | 14 | 2 | 20 | 2 |
| 11 | 3 | 15 | 2 | 49 | 2 |
| 16 | 6 | 18 | 2 | 51 | 3 |
| 17 | 3 | 19 | 2 | 71 | 2 |
| 28 | 9 | 36 | 4 | 94 | 6 |
| 51 | 3 | 38 | 4 | 95 | 4 |
| 55 | 6 | 63 | 4 | 102 | 5 |
| 75 | 2 | 66 | 2 | 103 | 5 |
| 76 | 1 | 67 | 1 | 104 | 7 |
| 78 | 2 | 81 | 2 | 105 | 1 |
| 79 | 7 | 82 | 3 | 112 | 9 |
| 80 | 3 | 90 | 3 | 113 | 3 |
| 132 | 4 | 99 | 8 | 193 | 3 |
| 133 | 5 | 100 | 2 | 198 | 2 |
| 143 | 5 | 101 | 1 | 199 | 6 |
| 156 | 5 | 102 | 1 | 201 | 1 |
| 157 | 1 | 107 | 1 | 214 | 1 |
| 158 | 7 | 110 | 2 | 224 | 4 |
| 159 | 2 | 111 | 1 | 254 | 9 |
| 160 | 9 | 113 | 9 | 255 | 6 |
| 170 | 1 | 114 | 3 | 256 | 3 |
| 176 | 2 | 115 | 5 | | |
| 177 (con't) | 2 | 117 (con't) | 3 | | |

Table 15. (Continued)

| Line 1 (con't) | | Line 2 (con't) | | Line 4 | |
|---|---|---|---|---|---|
| Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** |
| 184 | 1 | 119 | 3 | | |
| 203 | 2 | 120 | 10 | 1 | 2 |
| 204 | 2 | 122 | 5 | 2 | 4 |
| | | 139 | 7 | 3 | 2 |
| | | 140 | 3 | 4 | 4 |
| | | 141 | 3 | 35 | 6 |
| | | 145 | 4 | 37 | 2 |
| | | 146 | 4 | 38 | 3 |
| | | 150 | 4 | 39 | 2 |
| | | 153 | 4 | 42 | 4 |
| | | 154 | 1 | 61 | 4 |
| | | 165 | 6 | 62 | 1 |
| | | 168 | 2 | 81 | 4 |
| | | | | 82 | 3 |
| | | | | 85 | 6 |
| | | | | 87 | 1 |
| | | | | 250 | 7 |

* Numbers identify the decimeter in which *Opuntia* was observed.
** Number of subunits within a decimeter occupied by *Opuntia polyacantha*.

Table 15. (Continued)

| Line 5 | | Line 6 | | Line 7 | |
|---|---|---|---|---|---|
| Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** |
| 10 | 1 | 32 | 4 | 8 | 6 |
| 20 | 3 | 33 | 3 | 47 | 2 |
| 22 | 5 | 49 | 2 | 48 | 2 |
| 23 | 1 | 50 | 6 | 49 | 1 |
| 49 | 2 | 55 | 4 | 52 | 2 |
| 54 | 2 | 56 | 4 | 75 | 2 |
| 55 | 3 | 57 | 6 | 76 | 5 |
| 56 | 6 | 76 | 5 | 80 | 1 |
| 57 | 6 | 85 | 4 | 122 | 2 |
| 81 | 6 | 87 | 4 | 126 | 2 |
| 84 | 5 | 106 | 3 | 127 | 7 |
| 85 | 8 | 107 | 4 | 134 | 4 |
| 86 | 9 | 108 | 4 | 139 | 2 |
| 87 | 6 | 109 | 8 | 140 | 4 |
| 106 | 3 | 110 | 4 | 141 | 7 |
| 107 | 2 | 111 | 3 | 148 | 3 |
| 108 | 8 | 112 | 7 | 155 | 1 |
| 109 | 4 | 113 | 1 | 156 | 1 |
| 111 | 5 | 132 | 2 | 215 | 1 |
| 112 | 5 | 133 | 4 | 238 | 2 |
| 113 | 9 | 134 | 2 | 240 | 5 |
| 114 | 3 | 135 | 4 | | |
| 128 | 3 | 136 | 4 | | |
| 129 (con't) | 2 | 137 (con't) | 8 | | |

Table 15. (Continued)

| Line 5 (con't) | | Line 6 (con't) | | Line 8 | |
|---|---|---|---|---|---|
| Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** |
| 130 | 2 | 210 | 8 | 8 | 1 |
| 133 | 3 | 213 | 2 | 9 | 4 |
| 134 | 4 | 216 | 1 | 10 | 7 |
| 136 | 12 | 217 | 1 | 49 | 5 |
| 137 | 4 | 227 | 6 | 52 | 5 |
| 212 | 6 | 228 | 3 | 51 | 2 |
| 215 | 1 | 229 | 1 | 62 | 8 |
| 225 | 3 | 230 | 1 | 100 | 9 |
| | | | | 127 | 4 |
| | | | | 128 | 1 |
| | | | | 133 | 9 |
| | | | | 134 | 6 |
| | | | | 139 | 6 |
| | | | | 140 | 1 |
| | | | | 157 | 4 |
| | | | | 160 | 7 |
| | | | | 238 | 3 |
| | | | | 237 | 4 |

Table 15. (Continued)

| Line 9 | | Line 10 | |
|---|---|---|---|
| Decimeter* | Number of occurrences** | Decimeter* | Number of occurrences** |
| 1 | 2 | 1 | 4 |
| 2 | 9 | 2 | 3 |
| 25 | 4 | 24 | 5 |
| 29 | 5 | 25 | 4 |
| 30 | 8 | 27 | 3 |
| 31 | 4 | 29 | 6 |
| 32 | 3 | 30 | 3 |
| 33 | 1 | 31 | 2 |
| 78 | 1 | 32 | 1 |
| 82 | 9 | 77 | 7 |
| 96 | 2 | 82 | 7 |
| 97 | 4 | 83 | 2 |
| 102 | 1 | 128 | 5 |
| 103 | 3 | 151 | 2 |
| 156 | 4 | 154 | 1 |
| 205 | 4 | 156 | 2 |
| 255 | 2 | 157 | 4 |
| | | 160 | 6 |

Table 16. A listing of parameters available by computer analysis of data taken by grid sampling of plains prickly pear.

| | Treatment | | |
|---|---|---|---|
| | Light Grazed | Medium Grazed | Heavy Grazed |
| Average size of clump ($m^2$) | .065 | .042 | .084 |
| Standard Deviation of clump size (m) | .105 | .0465 | .1237 |
| Average distance between clumps (m) | .761 | 1.313 | 1.162 |
| Number of clumps | 1978 | 665 | 848 |
| *Major axis length of clumps | | | |
| *Minor axis length of clumps | | | |
| *Area (square mile) of each clump | | | |
| *Major axis angle of orientation (degree) | | | |
| *Degree of elongation (percent) of clump | | | |
| *Frequency distribution of: | | | |
| Angle of orientation | | | |
| Area (square mile) | | | |
| Angle of orientation vs. mean major axis length | | | |

*Data have not been summarized.

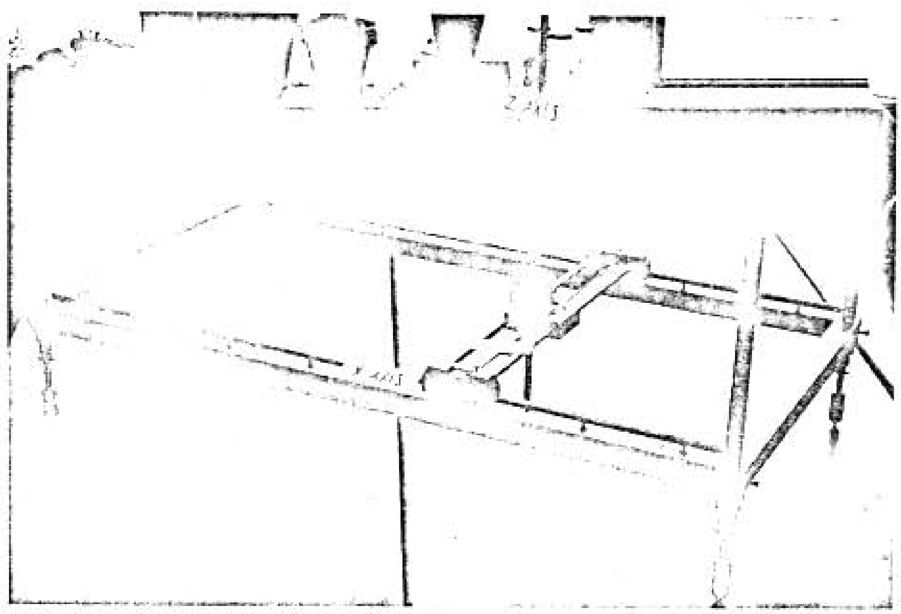

Fig. 1. General view of field microplotter with labels on the three axes which can prescribe location and microrelief changes in millimeter units within a plot 1 m x 0.5 m.

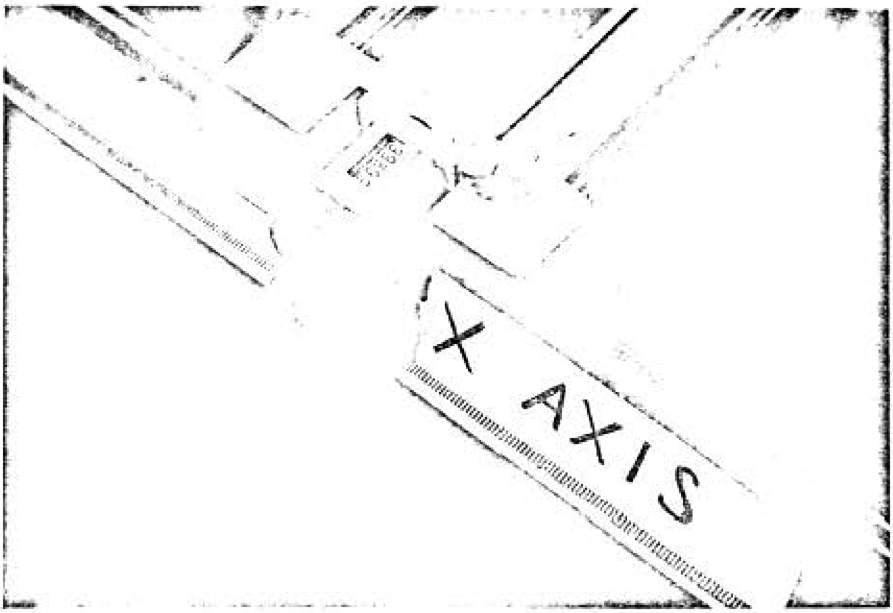


Fig. 2. Metric rack and gear system of the X axis digital meter which is mounted on a Thompson bearing support block attached to the Y axis arm.

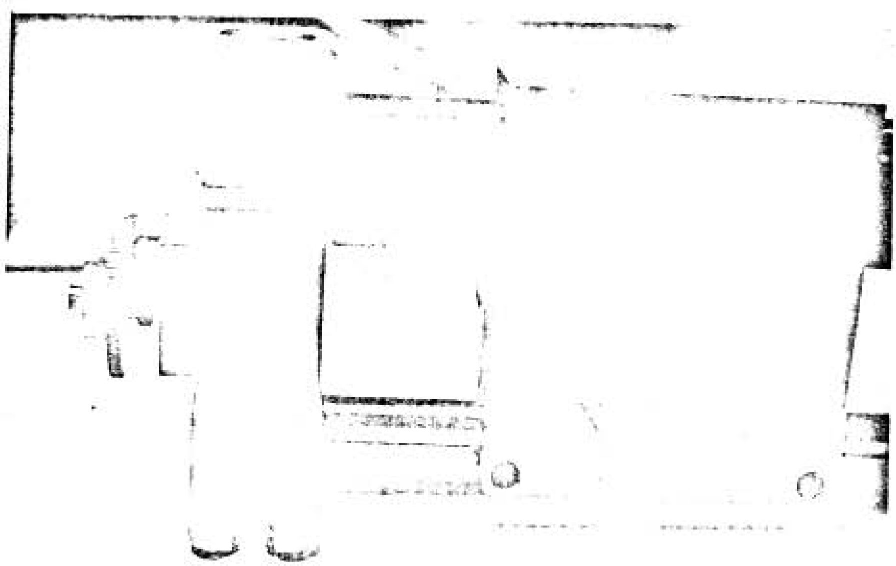

Fig. 3. Closeup view of longitudinal Thompson ball bearing system for movement along the X axis. The pointed bar is used to locate positions within the plot and to determine Z axis parameters.

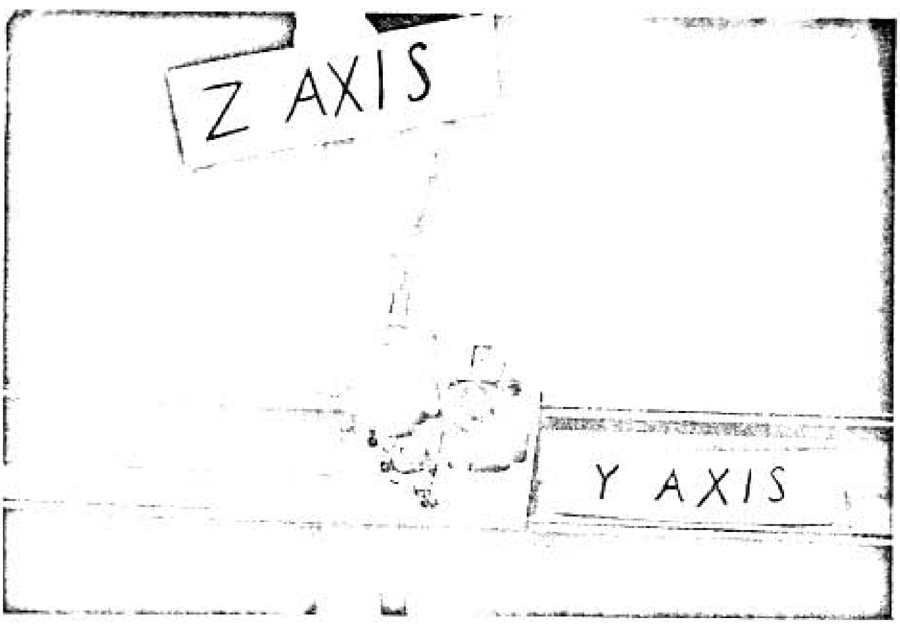


Fig. 4. The YZ head supports the mechanisms for determination of the Y axis and Z axis parameters. The YZ head is movable on the Y axis arm with Thompson bearings attached to the bearing support blocks.

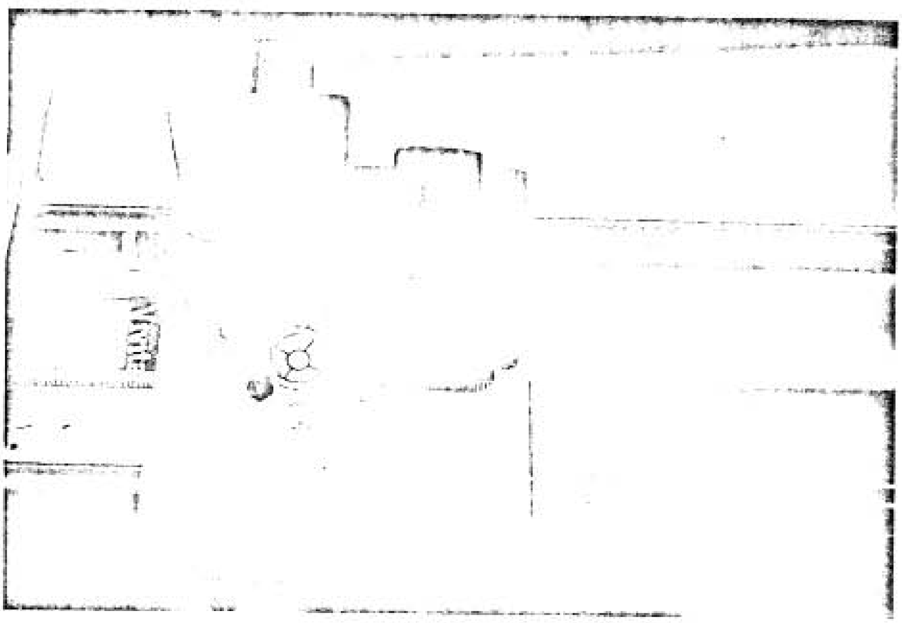

Fig. 5. Closeup of the YZ head showing metric rack and gear systems of the Y and Z axes. The bubble level is utilized to aid in leveling the frame of the microplotter. The digital display system provides a rapid and accurate means of determining quantitative values.

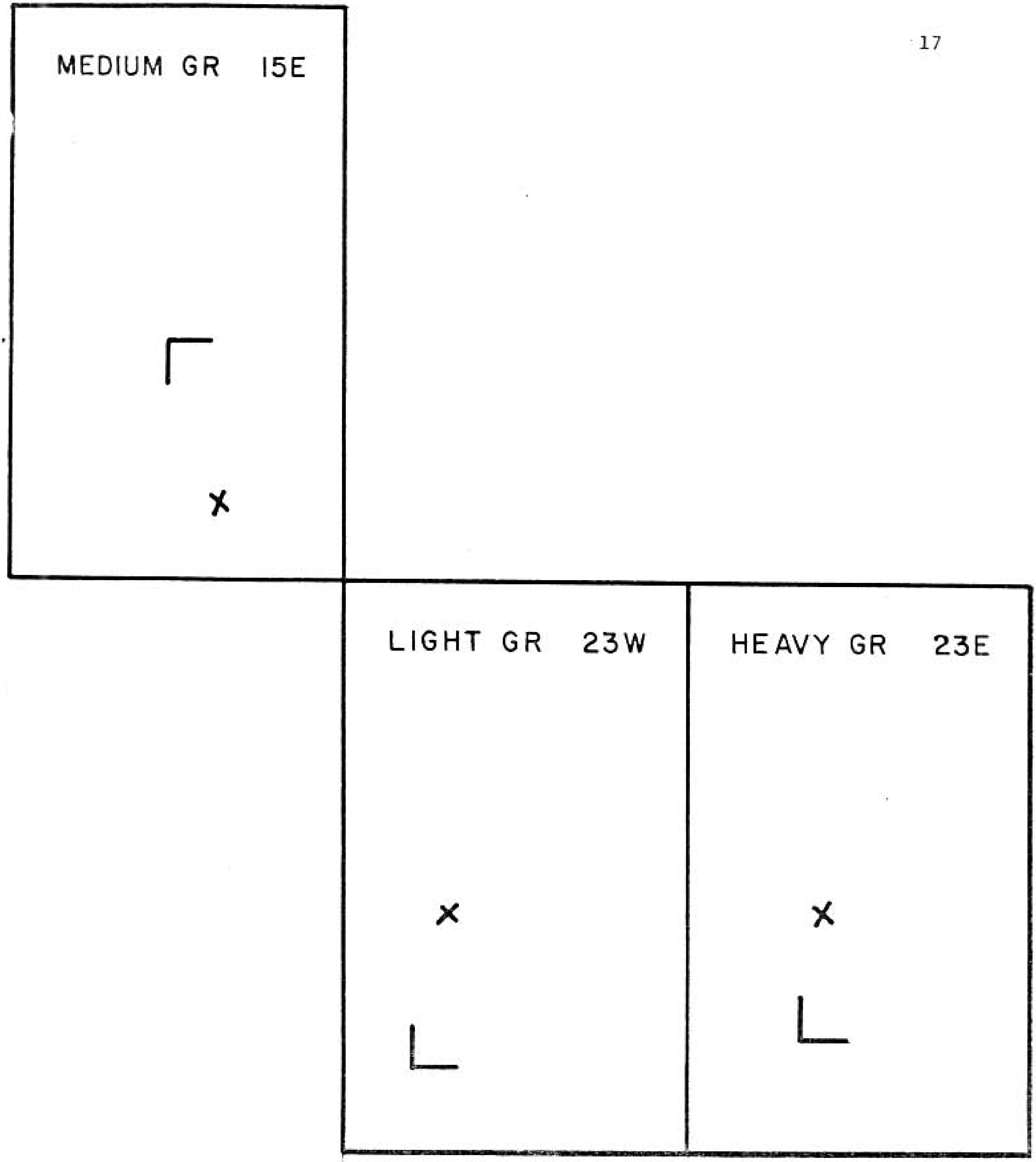


Fig. 6. Right angles within grazing treatments give approximate locations of 30 x 30 m plots. X's locate microwatersheds.

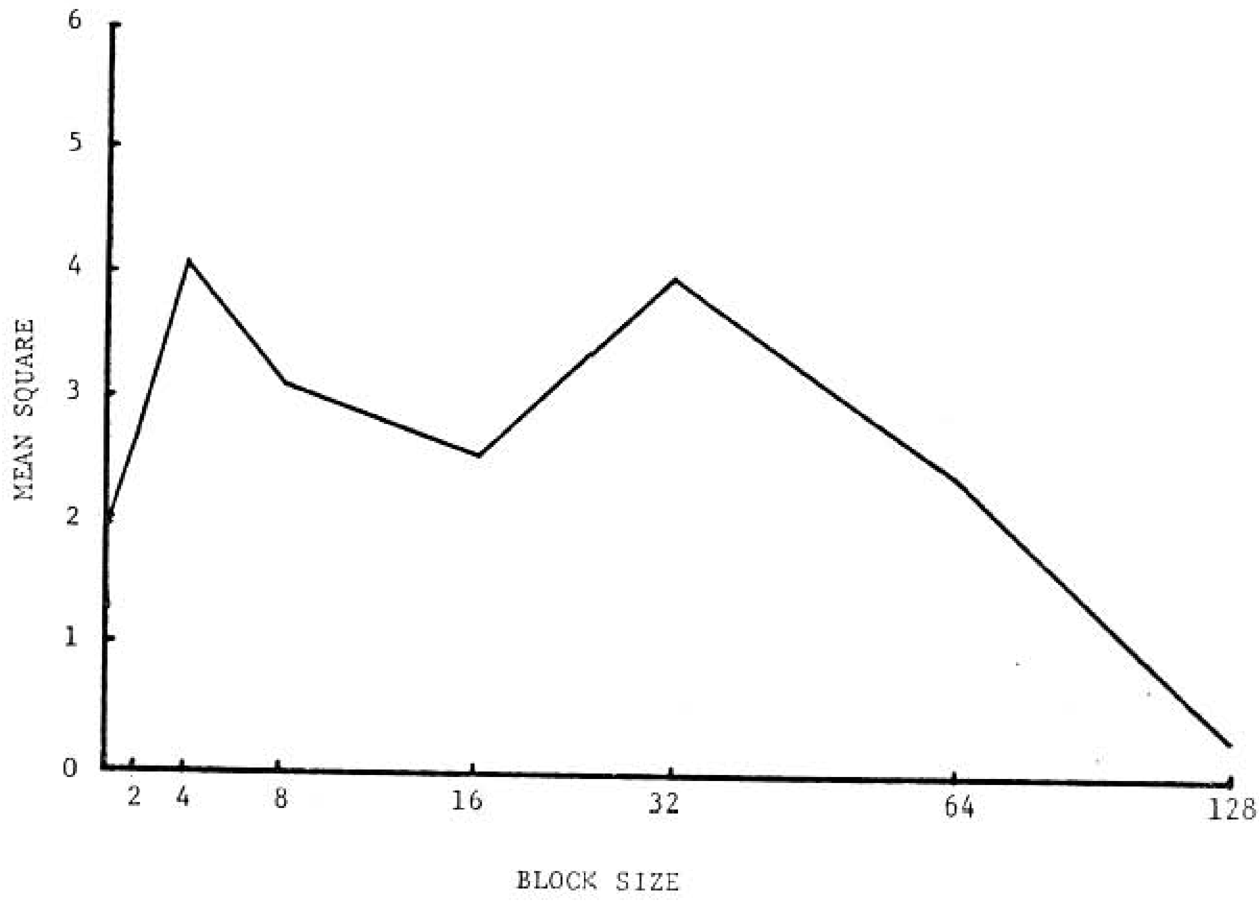


Fig. 7. Mean square against block size. Block sizes corresponding to peaks indicate the mean area of *Opuntia* clumps appearing in sample three.

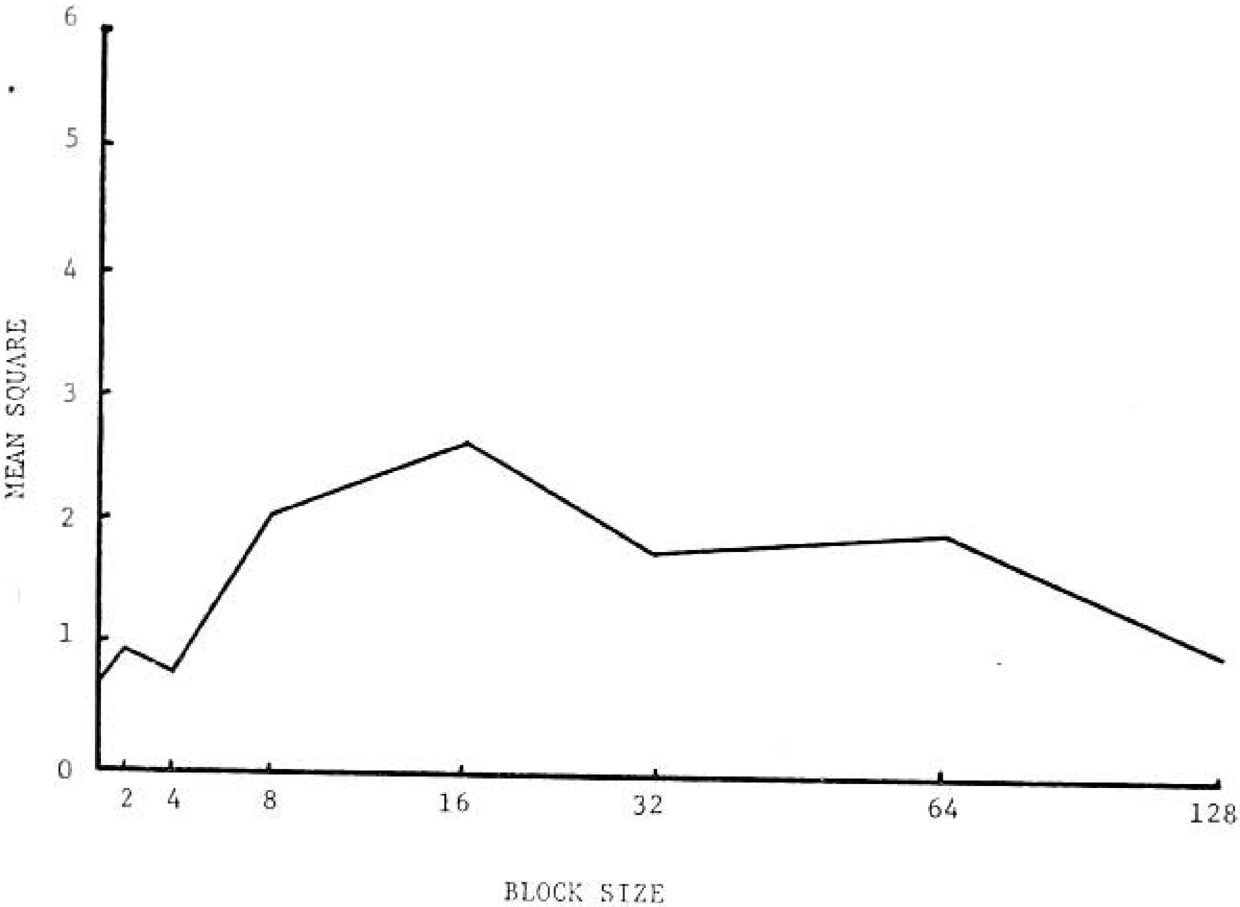


Fig. 8. Mean square against block size. Block sizes corresponding to peaks indicate the mean area of *Opuntia* clumps appearing in sample two.

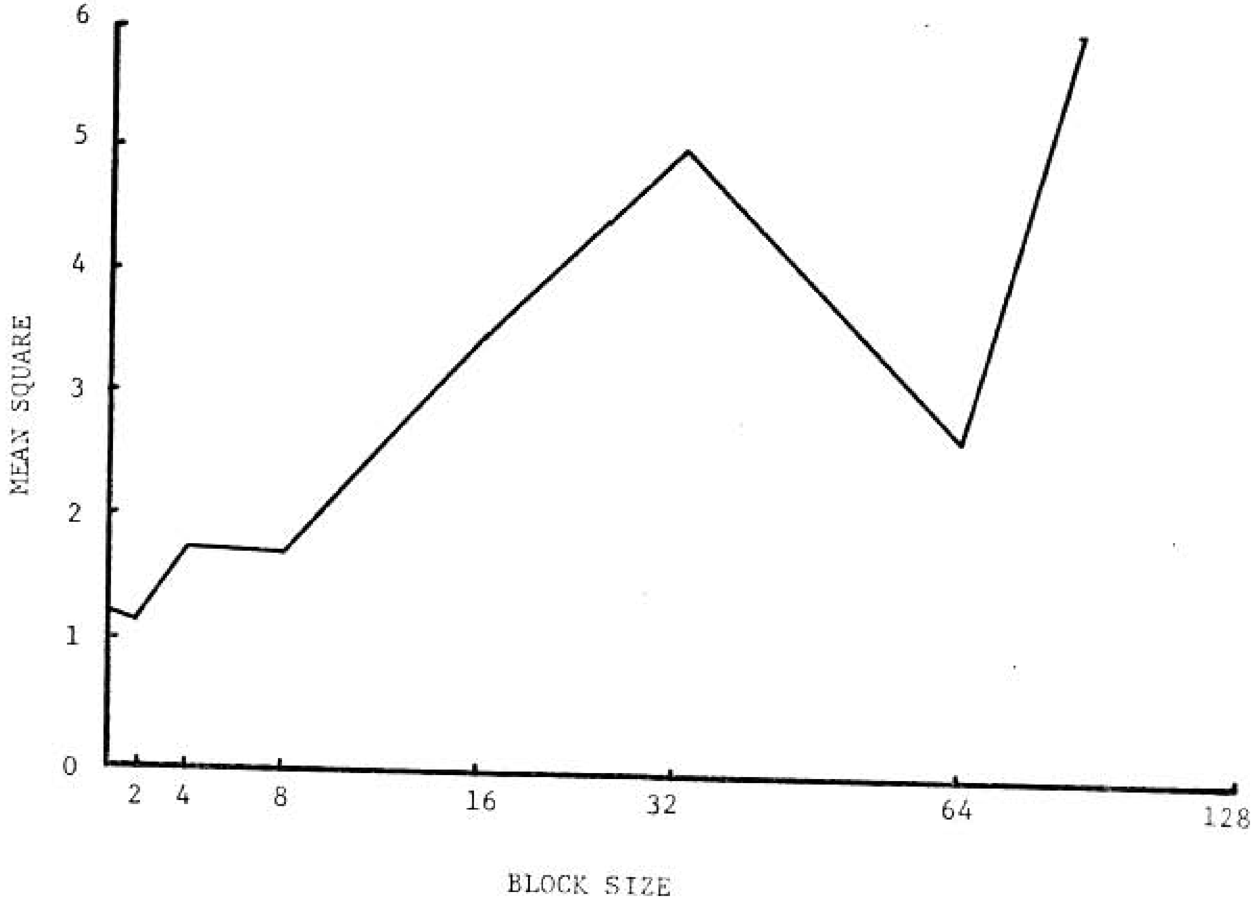


Fig. 9. Mean square against block size. Block sizes corresponding to peaks indicate the mean area of *Opuntia* clumps appearing in sample one.

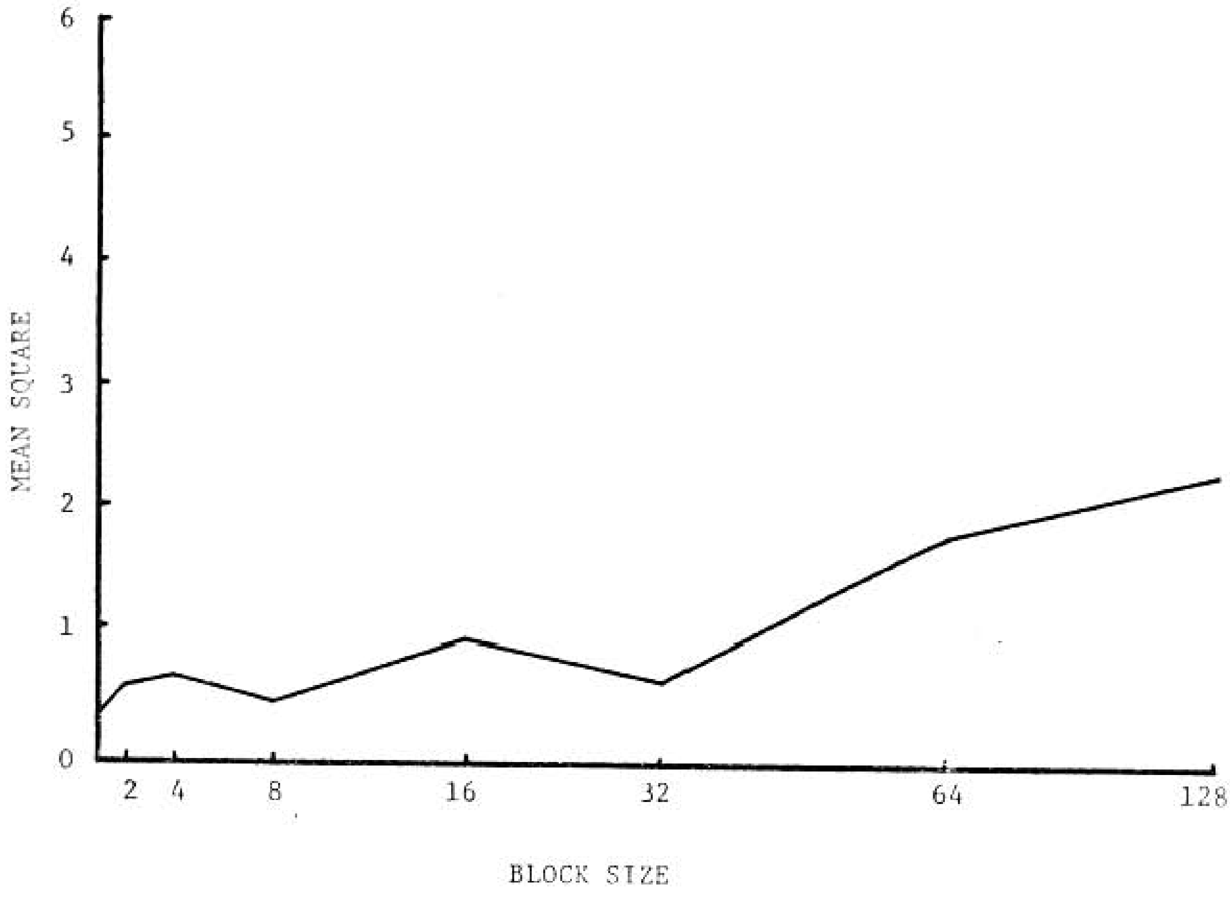


Fig. 10. Mean square against block size. Block sizes corresponding to peaks indicate the mean area of *Opuntia* clumps when all lines were combined.

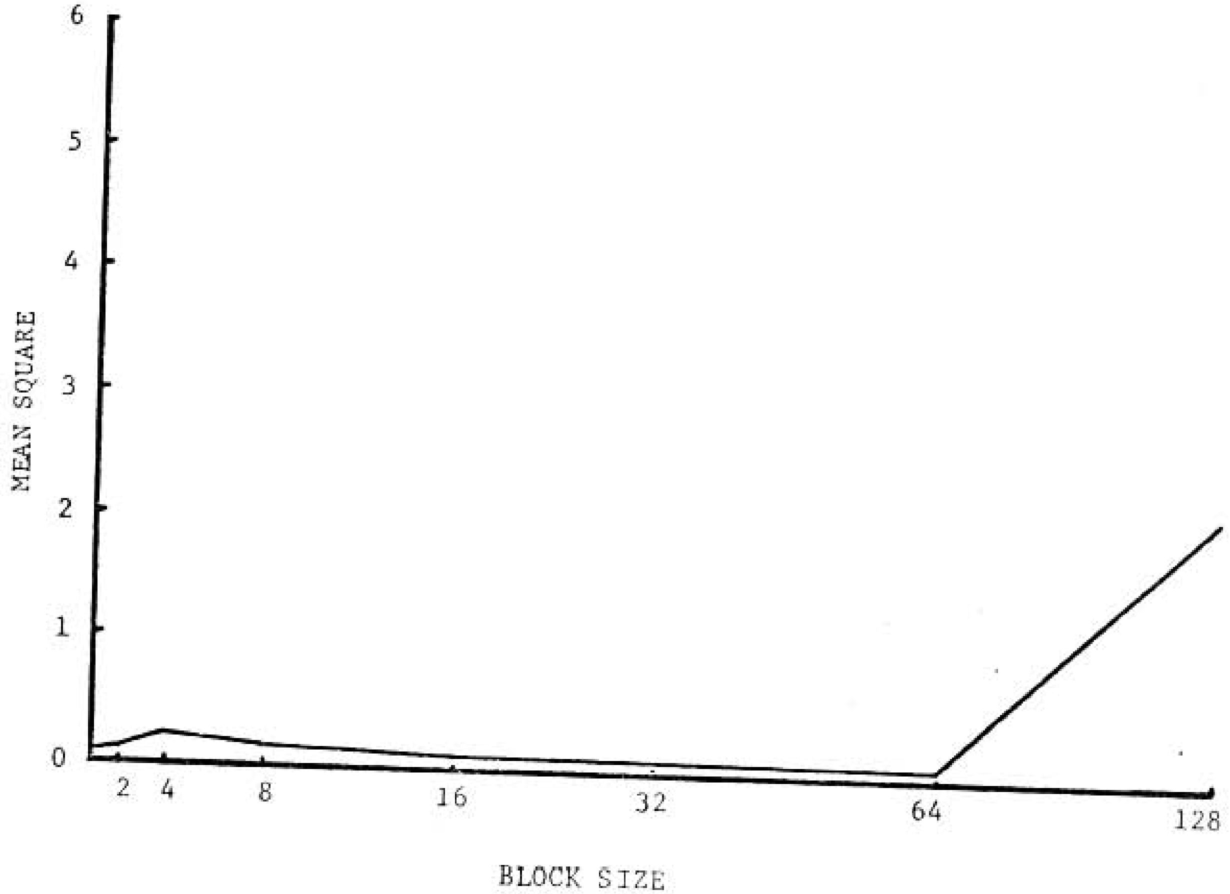


Fig. 11. Mean square against block size. Block sizes corresponding to peaks indicate the mean area of *Opuntia* clumps when all lines were combined.

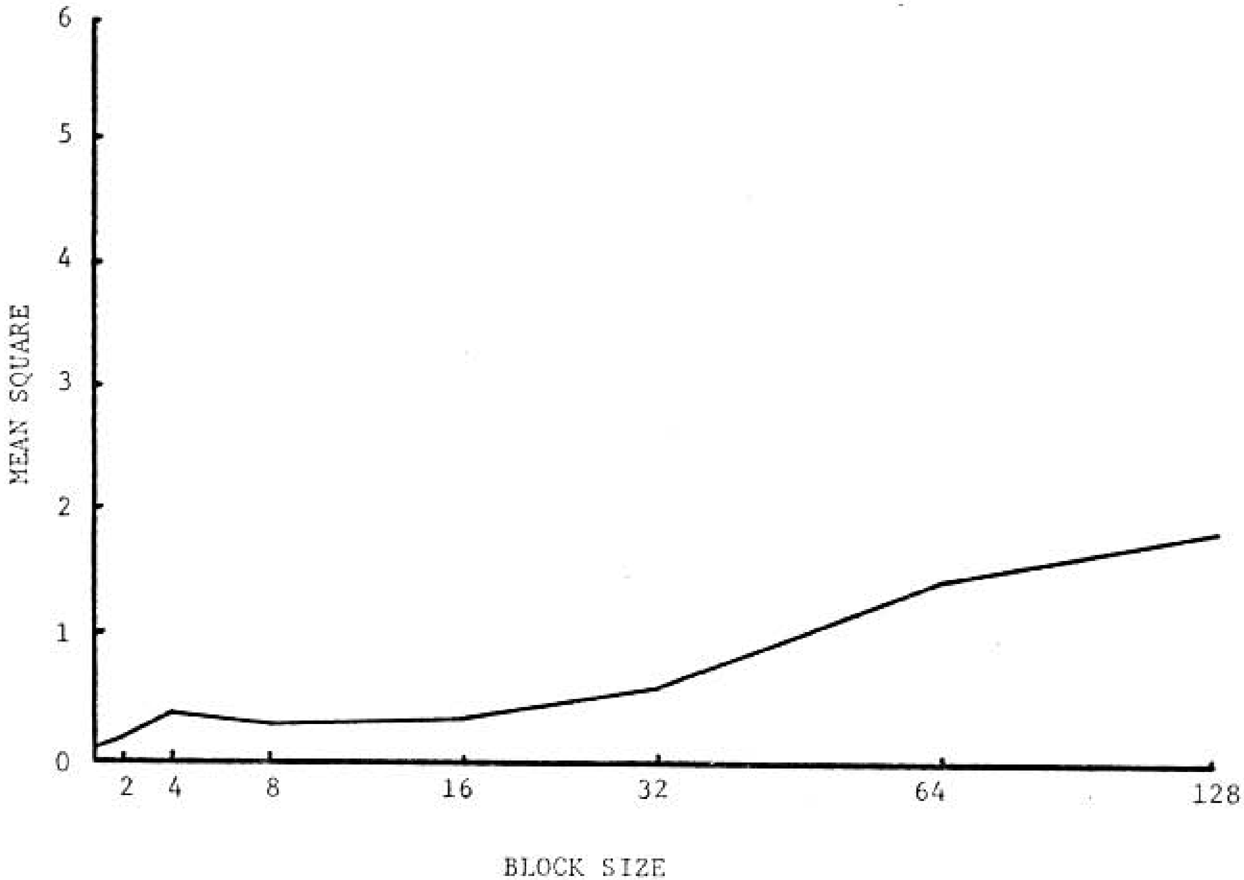


Fig. 12. Mean square against block size. Block sizes corresponding to peaks indicate the mean area of *Opuntia* clumps appearing in sample two.

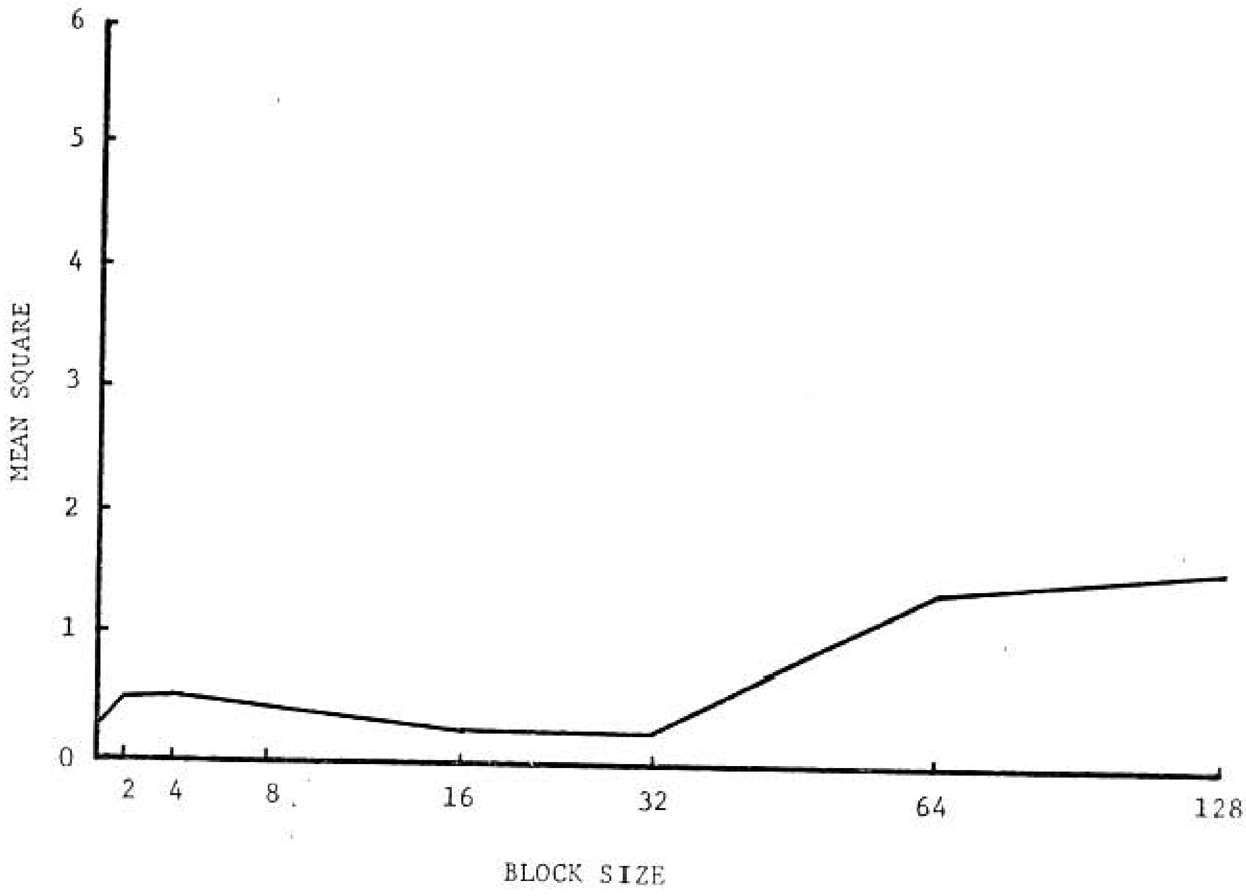


Fig. 13. Mean square against block size. Block sizes corresponding to peaks indicate the mean area of *Opuntia* clumps appearing in sample one.

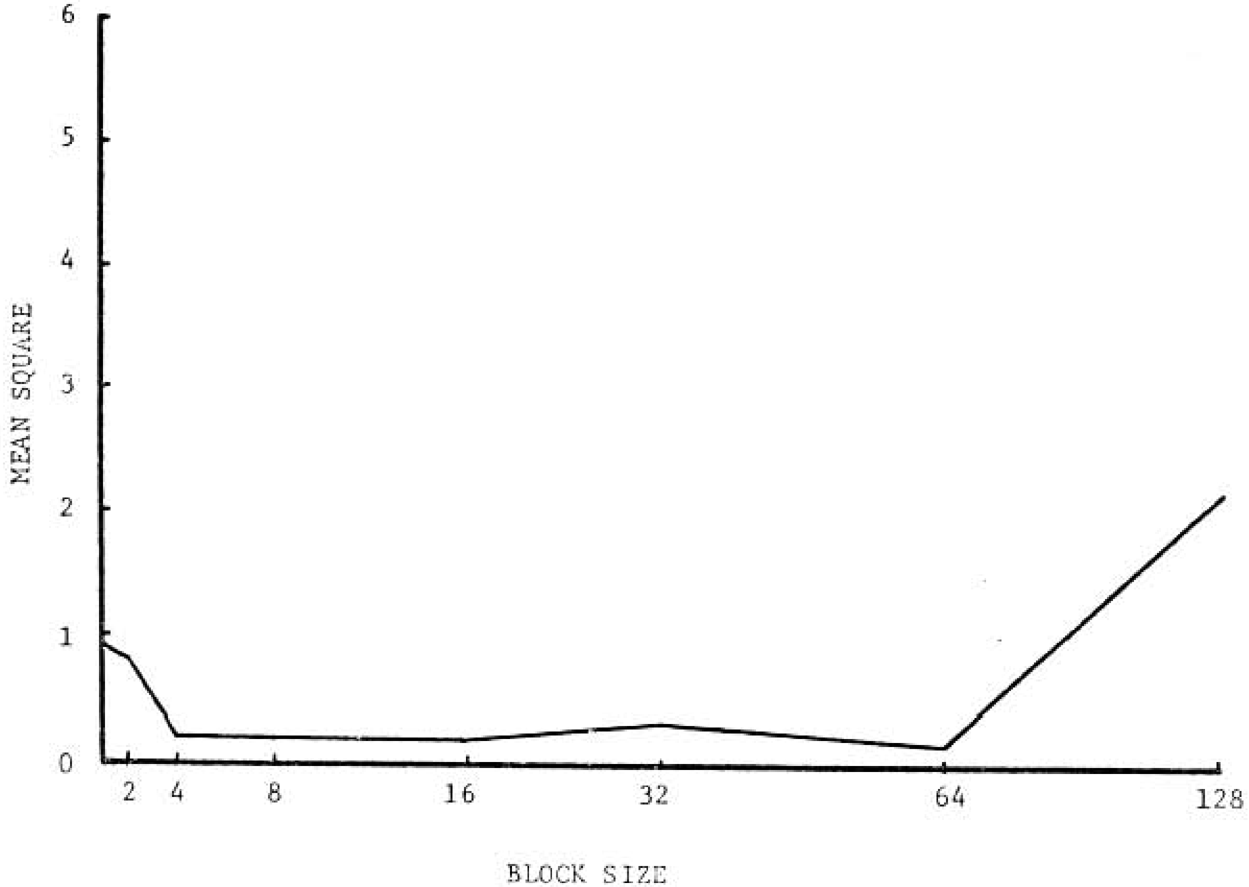


Fig. 14. Mean square against block size. Block sizes corresponding to peaks indicate the mean area of *Opuntia* clumps appearing in sample three.

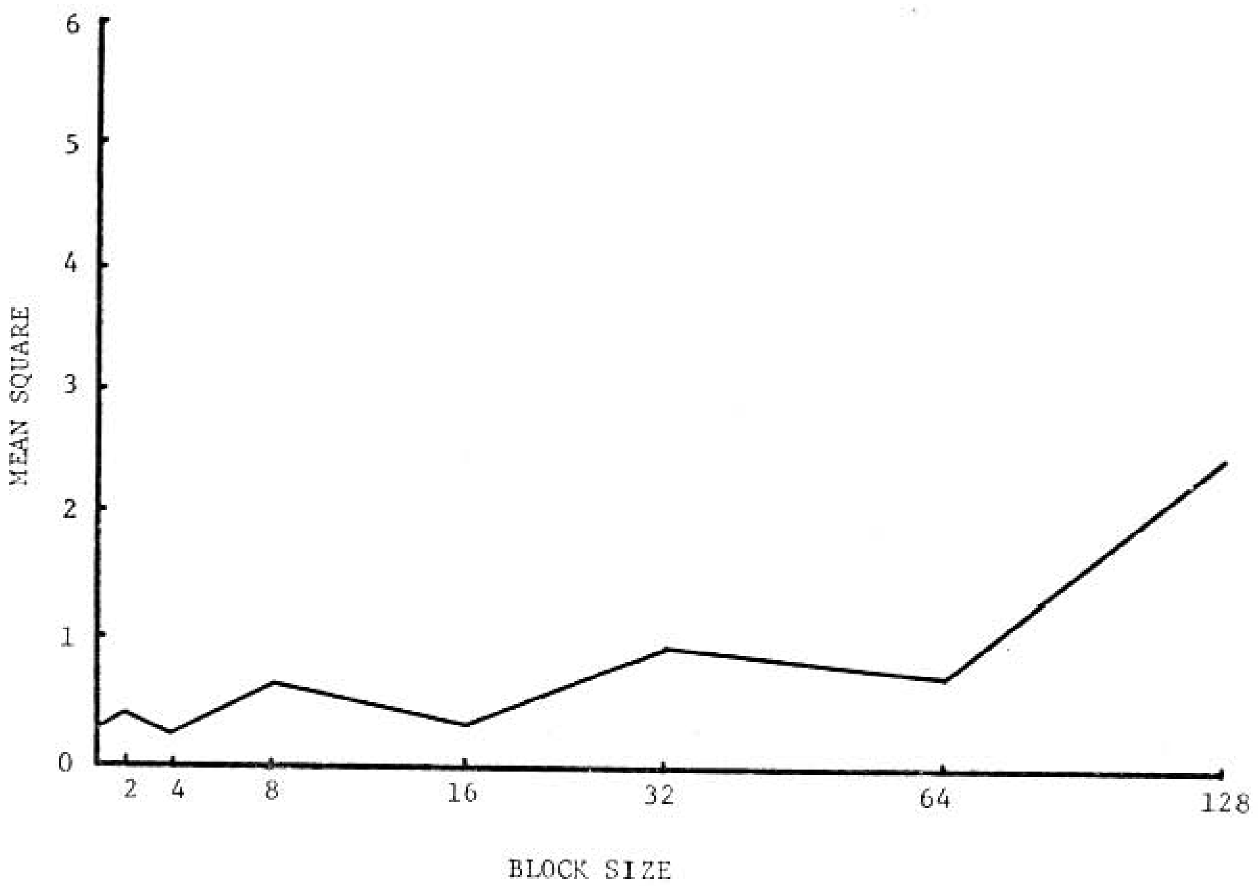


Fig. 15. Mean square against block size. Block sizes corresponding to peaks indicate the mean area of *Opuntia* clumps appearing in sample one.

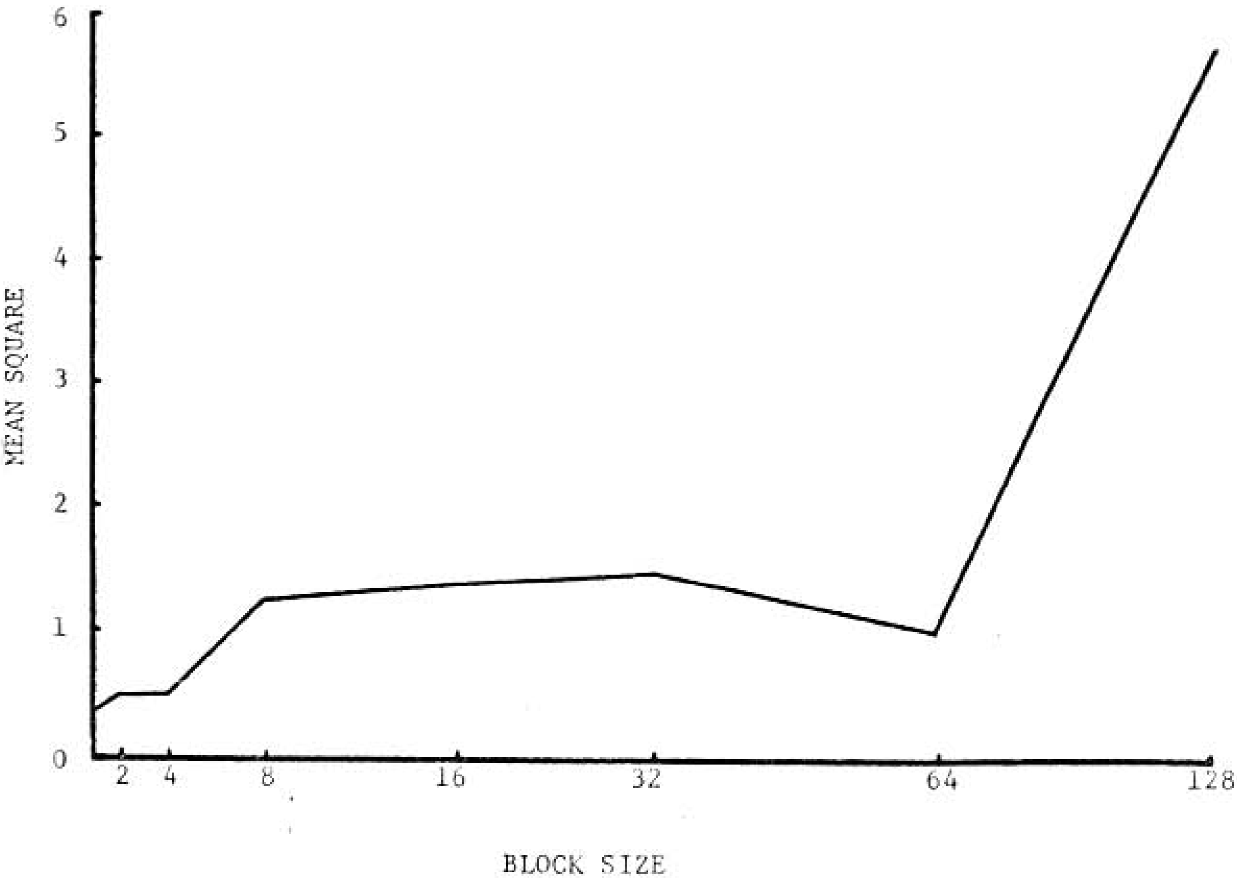


Fig. 16. Mean square against block size. Block sizes corresponding to peak indicate the mean area of *Opuntia* clumps appearing in sample two.

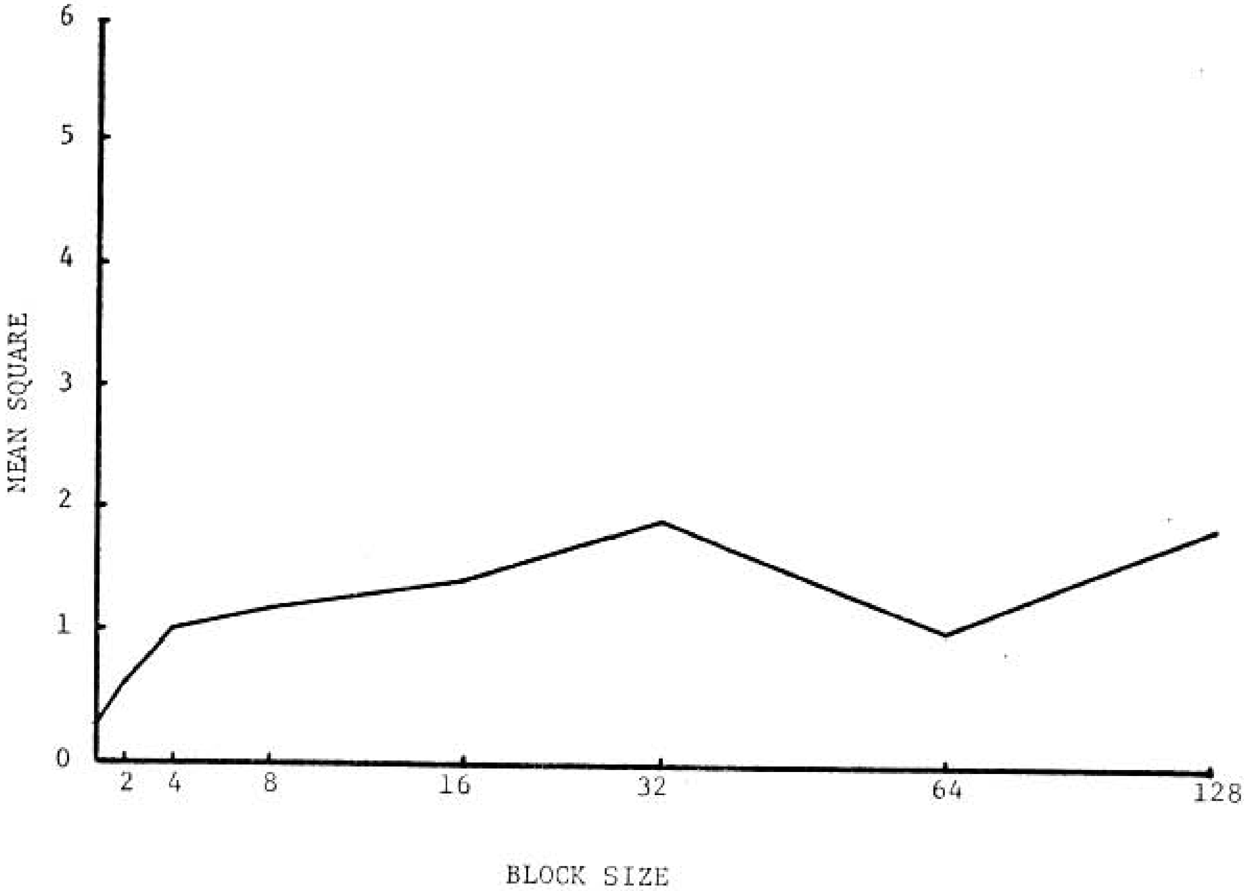


Fig. 17. Mean square against block size. Block sizes corresponding to peaks indicate the mean area of *Opuntia* clumps appearing in sample three.

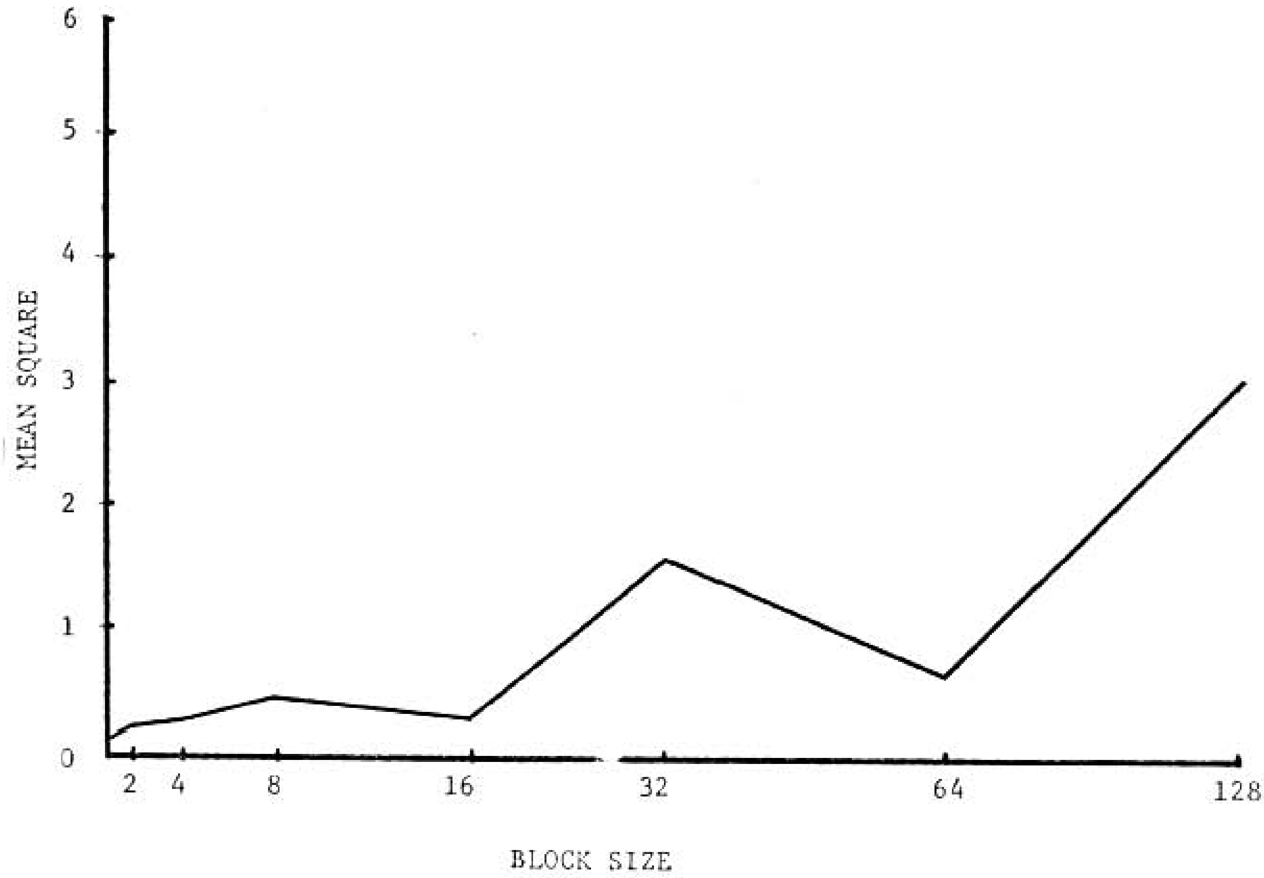


Fig. 18. Mean square against block size. Block sizes corresponding to peaks indicate the mean area of *Opuntia* clumps when all lines were combined.

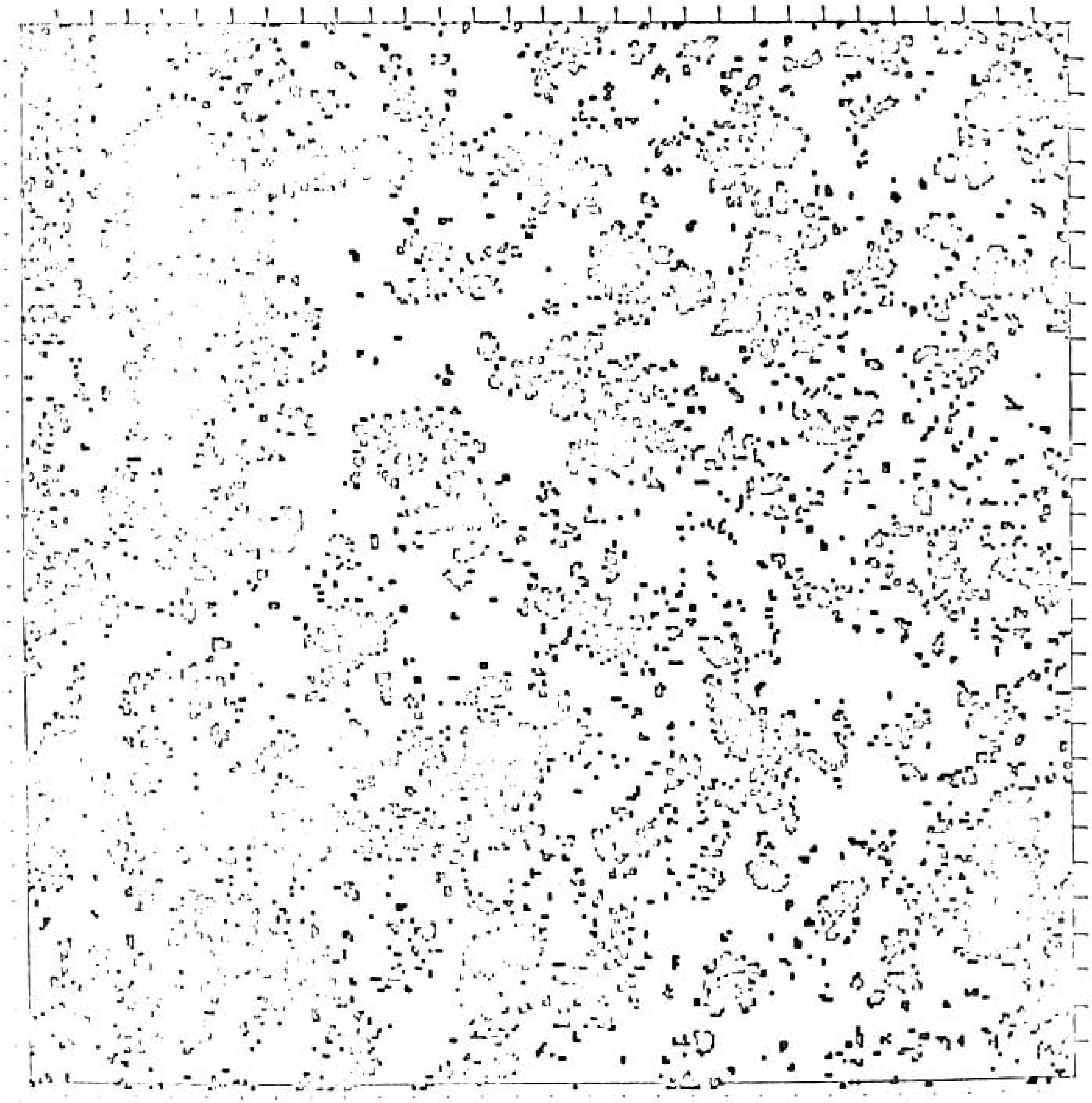

Fig. 19. Graphic illustration showing locations of frequency readings within the light grazed 30 m x 30 m sampling plot.

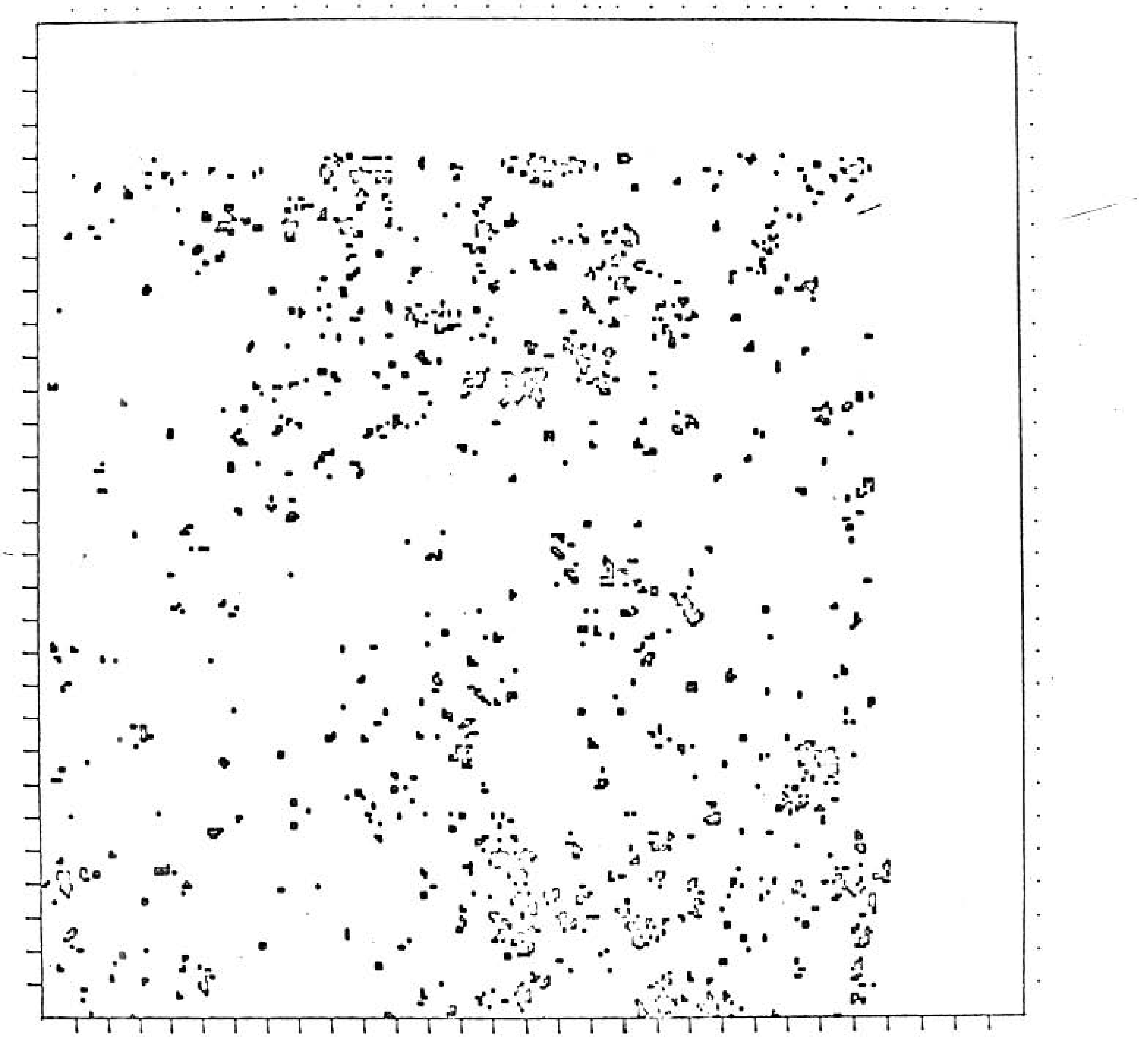

Fig. 20. Graphic illustration showing locations of frequency readings within the medium grazed 30 m x 30 m sampling plot.

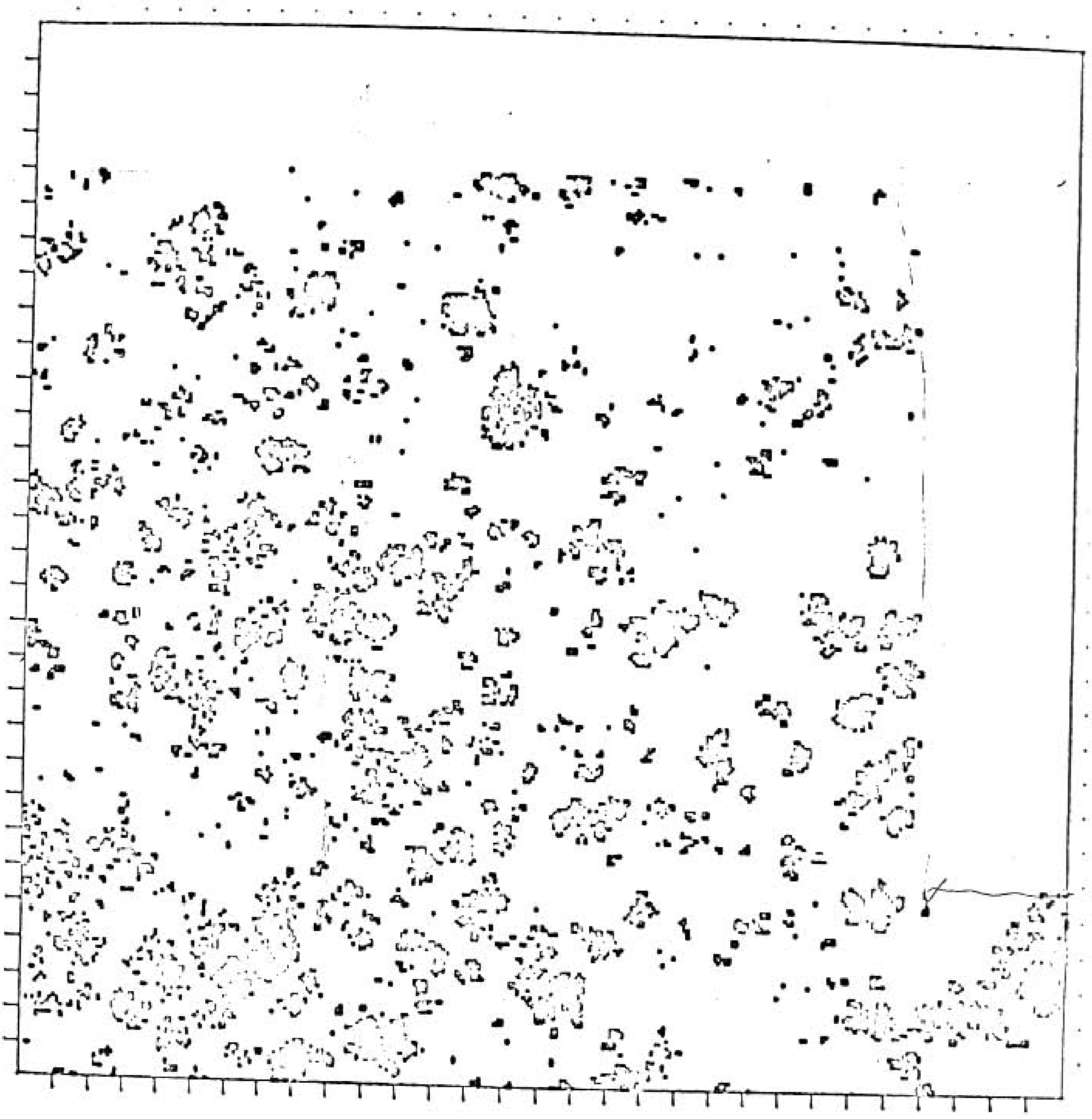

Fig. 21. Graphic illustration showing locations of frequency readings within the heavy grazed 30 m x 30 m sampling plot.