A PHYTOSOCIOLOGICAL STUDY OF AN UPLIFTED MARINE BEACH RIDGE NEAR POINT BARROW, ALASKA

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

John James Koranda

1954

This is to certify that the

thesis entitled

A PHYTOSOCIOLOGICAL STUDY OF AN UPLIFTED MARINE BEACH RIDGE NEAR POINT BARROW, ALASKA

presented by

John James Koranda

has been accepted towards fulfillment of the requirements for

M. S. degree in Botany

Date 28 May 19[illegible]

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A PHYTOSOCIOLOGICAL STUDY OF AN UPLIFTED MARINE BEACH RIDGE NEAR POINT BARROW, ALASKA

By

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AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Botany and Plant Pathology

1954

Approved ____________________

This phytosociological study concerns the vegetation of an old uplifted marine beach ridge on the Arctic Coastal Plain, near Point Barrow, Alaska. It was undertaken to obtain some information about the distributional patterns of Arctic plants, to study the particular conditions presented by an old uplifted marine beach ridge and, finally, as a study in phytosociological methods and techniques.

The vegetational complex on the beach ridge was sampled quantitatively by list-quadrats placed randomly in a belt-transect. These quantitative data were evaluated by three statistical methods:

(1) Comparisons of the observed frequency distribution with the Poisson series.

(2) Density histograms -- which diagrammed the actual number of individuals occurring in each quadrat.

(3) Measures of aggregation -- statistical indices which evaluate the amount of relative aggregation in the distribution of a species.

Few species were found to have distributions that approximated the Poisson distribution. Frequencies occurred, in most cases, beyond the end of the theoretical distribution.

The density histograms revealed relationships existing between the contour of the beach ridge, soil pH, and the distribution of many species. The localized distributions of species, as shown on the histograms, were compared with the relative order indicated by the measures of aggregation. Close agreement between the histograms and

and the measures of aggregation existed when an appropriate quadrat size and number were used.

The effect of the number of quadrats and the size of the quadrat upon density, frequency, and the measures of aggregation were analyzed. Twenty-one quadrats were found to be as effective a sample as 100 if the object of the sampling was merely to determine the dominant species. If phytosociological relationships were to be investigated, a larger sample was recommended. The relative order of the species, in regard to the degree of aggregation, was affected by the number of quadrats used, especially when micro-distributional factors were present. It appeared from this study of tundra vegetation, where habitat differences occur in relatively short distances, that a 1.25 percent sample of the total area was not detailed enough to describe accurately the distributional aspects of the vegetation.

It was shown that density was proportional to quadrat size, when density was defined as the number of individuals per quadrat. Frequency, however, did not react to quadrat size in the same manner. The degree of aggregation apparently influenced the change of frequency that occurred when the quadrat size was reduced. Such species as Eriophorum scheuchzeri and Saxifraga cernua were cited as examples of this condition.

The measures of aggregation were also affected by quadrat size and tended to misrepresent the degree of aggregation when smaller quadrats were used. This was especially evident when the species were distributed very contagiously or locally.

A comparison was made of two transects, which represented distinct areas on the beach ridge. On the basis of species alone, the higher area could be defined as a more xeric area. The density differences of certain species occurring on these transects were also considered.

A photographic method was used to measure the percentage cover for two species, _Salix rotundifolia_ and _Petasites frigidus_. _Salix rotundifolia_ exhibited low cover values on extremely moist sites and areas where frost action was relatively more severe. The frequency of _S. rotundifolia_ in the photographic sample was very close to the quadrat-frequency of this species. The relationship of percentage cover to density was determined for _Petasites frigidus_. This species occurred on a hummock area where varying conditions of micro-relief were expressed in the size of the individual and, thus, the percentage of the quadrat covered. The varying conditions of micro-relief were effective in creating discrepancies in the density-percentage cover relationship.

An analysis of the structure of the beach ridge and the component soils revealed several correlations with vegetative characteristics. Soil-frost phenomena were shown to create a habitat which at times excluded a species but which, more often, merely caused a reduction in density. The particular conditions of active zone depth and snow cover were also discussed. The beach ridge was found to have a deeper active layer than either the marsh or polygonal habitats. The early withdrawal of snow cover was also indicated by the series of readings made in several sites and actual observation.

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A DISSERTATION

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ACKNOWLEDGMENTS

The author wishes to express his sincere thanks to Mr. Daniel Q. Thompson, who provided the opportunity for this study and constantly encouraged the writer during the progress of the field work.

Grateful acknowledgment is also due to Dr. William B. Drew, major professor, for assistance and guidance in the preparation of manuscript and the innumerable other details that inevitably appear in the processing of scientific data.

Dr. Ira L. Wiggins, Scientific Director of the Arctic Research Laboratory, graciously allowed the writer to use his herbarium and aided him is becoming familiar with the local flora.

Drs. Charles L. Gilly and George W. Parmalee are to be sincerely thanked for their expert assistance in the preparation of the manuscript.

He is also extremely grateful to Dr. John W. Thomson, University of Wisconsin, for the lichen identifications which served as reference specimens for this study.

The moss specimens were graciously identified by Drs. William Steere and Howard Crum. The alga specimen was checked by Dr. Gerald W. Prescott.

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INTRODUCTION

Ecological studies of Arctic plants have been mainly of a descriptive nature and few investigators have attempted to ascertain the phytosociological aspects of Arctic plant communities. The time required for a detailed phytosociological study often prohibits investigations of this type. The extremely short vegetative period and lack of facilities in the Arctic, in general, have deterred investigators from conducting prolonged studies in these areas. The Arctic Research Laboratory at Point Barrow, Alaska, under the Office of Naval Research, for several years has provided a base of operations for many informative and detailed studies which will add considerably to the knowledge of Arctic biology.

This study, phytosociological in approach, was undertaken to obtain some information about the distributional patterns of Arctic species, to study the particular conditions presented by an old uplifted marine beach ridge and, finally, as a study in phytosociological methods and techniques. Although only limited soil data were obtained, some of the relationships between plant species and the soil can be observed, where the soil is a relatively unstable medium because of soil-frost activity.

Review of Literature

Wiggins (1951) in his study of the distribution of vascular plants on polygonal ground near Point Barrow, Alaska, mentioned the interesting and unpredictable variations in the vegetational cover from site to site and the accompanying problems in the ecology of such micro-habitats.

This study is concerned with the same beach ridge upon which one of Wiggins' sites was located. He found that there was more variation in the habitats and, also, more vegetational variation on the beach ridge site than in any other of his study areas. The sparser lichen cover on this ridge was also noted.

Acock (1940) conducted a study on raised shingle beaches and associated habitats in an inner fjord region in Spitzbergen. Many of the same species involved in his study were present in the vicinity of Point Barrow. He noted that soil-frost phenomena (fissure polygons), by causing soil heterogeneity, gave rise to a hyperdispersion of species that was similar to the banded communities occurring on the shingle beaches where differential snow cover seemed to be the determining ecological factor.

Russell and Wellington (1940) made detailed physiological and ecological studies on Arctic vegetation on Jan Mayen Island, north of Iceland. They analyzed climatic and edaphic factors in view of variations in the type of vegetation and found that shelter, time of snow retreat, water supply and available mineral nutrients were the most important factors. Nitrogen deficiency was found to be common in that area and in Arctic regions in general.

An exhaustive study by Gelting (1934), on the vascular plants of East Greenland, described the differences in vegetation occurring between the outer coast and the inner fjord region. The phytogeography of numerous Arctic species was discussed and ecological and distributional data were furnished. This paper affords an excellent comparison with

North American Arctic studies in regard to circumpolar distributions of species.

Böcher (1951) described the distributions of plants in the circumpolar area in relation to ecological and historical factors and discussed many of the species that were mentioned in the aforementioned articles.

Lindsey (1952) used photographic techniques in studying the ancient beaches above Great Bear and Great Slave Lakes, in the Canadian Arctic. Lichens and flowering plants were evaluated according to percentage cover obtained from photographic data.

Several authors have studied soil-frost phenomena (cryopedologic features) in relation to vegetation in Alaska with very interesting results. Hopkins and Sigafoos (1950) and Sigafoos (1951, 1952) studied the relationship of soil-frost activities and vegetation occurring on the Seward Peninsula and defined the processes referred to by the general term frost action.

Benninghoff (1952) discussed soil-frost and vegetation interactions in Alaska and outlined a vegetation-soil-frost cycle.

Many other authors have conducted soil-frost and vegetation studies in Alaska and some of these citations will be included in the list of references.

In addition to those articles which were pertinent to this study, several recent publications were used as source material for phytosociological formulae and computations. Curtis (1950) reviewed and clarified the usage of such terms as density, frequency, abundance, and many others.

He obtained experimental data from artificial populations to illustrate the interrelationships of phytosociological characters.

Evans (1952) analyzed the influence of the size of quadrat on the distributional patterns of plant populations in his studies on an old-field community in southeastern Michigan. The size of quadrat was shown to have an effect upon frequency and abundance and to have a marked effect upon the measures of dispersion.

One of the most extensive reviews of the quantitative aspects of plant distributions was made by Goodall (1952). A complete list of phytosociological references was included.

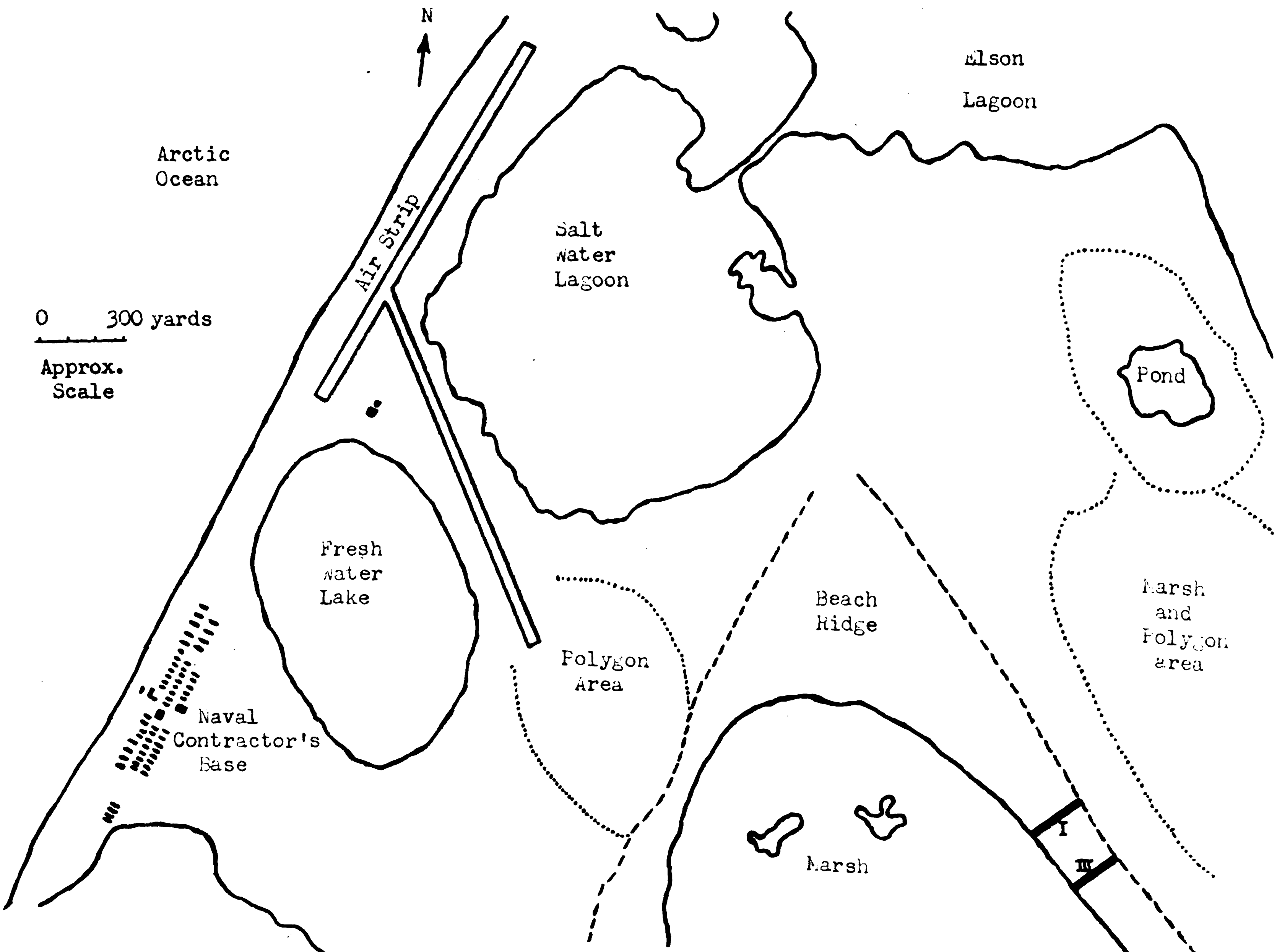
Description and History of Study Area

This study was conducted in the summer of 1953 at Point Barrow, Alaska, under contract with the Office of Naval Research and the Arctic Institute of North America. Reconnaissance, to attain familiarity with the local flora and to locate suitable study sites, was made during the previous summer, 1952.

The study area was located in the vicinity of Point Barrow, Alaska, which lies at the northernmost extremity of the Arctic Coastal Plain (Latitude - N. 71° 18' 56", Longitude - W. 156° 36' 16"). The coast of the plain at this point is prolonged into a triangular area, bounded on the west by the Chukchi Sea and on the east by the Beaufort Sea. The geomorphic history of the coastal plain was one of emergence and uplift, with progradation of the coastline occurring in the post-glacial period (Rex 1953). Intermittent uplift has produced a pattern of shorelines and barrier beaches. The beaches were, and still are, being formed by the combined activities of waves, currents, and ice action. As the coastal area was uplifted, the beaches were drained and raised, and various sediments such as loess were deposited upon the original sand and gravel. Permafrost (permanently frozen ground) is present throughout the coastal plain and is interestingly modified in these uplifted beach ridges.

In the vicinity of the Naval Contractor's Base, near the Eskimo village of Barrow, several old beach ridges were quite evident. They occurred inland on the tundra and could be recognized by their slightly higher elevation and better drained surfaces. The northernmost of these ridges was 500 to 2,000 yards from the present Arctic Ocean beach. It was over two miles long, roughly "U" shaped, with the open part of the "U" facing south-southeast (approx. 152° E. of magnetic N.). This northernmost ridge was chosen as the site of the study area. Text Figure I is a diagram of the beach ridge and vicinity.

The western portion of the ridge extended southwest, paralleling the coastline, and was transected by the drainage of a salt lagoon called Middle Salt Lagoon. On the eastern portion of the ridge, there was a high area that attracted attention because of its interesting and uncommon assemblage of species in the immediate vicinity of the coast. This area was, very likely, the most xeric site on the eastern portion of the beach ridge. The ridge sloped gradually downward from the seaward side to the landward side which formed the inside of the "U" shaped structure of the entire ridge. The width of the ridge at the study area was slightly over one hundred meters. The inside perimeter of the ridge, within the basin enclosed by the ridge, had been modified by the action of waves as evidenced by several small terraces of gravel and a definite wave-cut margin, especially on the eastern portion of the ridge. There were also several persistent ponds, remnants of an old drained lake or lagoon, in the center of the basin enclosed by the beach ridge.



Text Figure I. Diagram of the Point Barrow Area adapted from an Aerial Photograph

METHODOLOGY

Sampling of Vegetation

To sample the qualitative and quantitative vegetational changes that occurred on the beach ridge, a belt transect one meter wide and 100 meters in length was outlined with stakes and string line. The beach ridge, at the transect zone, was oriented 44° West of magnetic North. The transect heading was 55° East of magnetic North so that the transect was nearly at right angles to the long axis of the beach ridge. The transect began at the lower or inland side of the ridge and extended to the top or seaward side which was 2.7 meters higher than the lower end. The transect was surveyed by the plane table method so that the actual profile of the slope was known.

The area of the transect was sampled by the list-quadrat method. After preliminary trials, a quadrat size of 0.05 square-meter was decided upon since larger sizes gave frequencies that were too high. The quadrats were distributed through the one hundred square-meter area of the transect by a method designed tc avoid bias and achieve a random placement of samples. Each square-meter of the transect was sampled with a 20 x 25 cm. quadrat. The placement of the quadrat in each square-meter was determined by drawing from ten lots, each of which represented a particular position in the square-meter. The lots were rescrambled after each drawing. Each of these positions, actually 0.1 square-meter in area, was taken to have an inside and an outside position which was alternated with each quadrat. Thus, the sampling procedure was a combination of a random and a regular system of quadrat placement. The placement of the 100 quadrats was determined before the counting began.

To facilitate the placing of the quadrat within the square-meter being sampled, a wooden frame with an inside area of one square-meter was constructed. The inside of the frame was divided into the ten prescribed positions by strings and the alternating portions were determined merely by placing the quadrat in the 0.1 square-meter compartment so that it filled either the inside or the outside half.

The quadrat frame, 20 x 25 cm. in size, was made of plexiglass strips 1/8 inch thick and one inch wide. On each 25 cm. side, three notches were filed, dividing the side into four quarters. Two sets of brass pins, 15 inches long, 3/32 inch in diameter, connected by 12 inches of fine, linen cord, were also used in the counting procedure.

The counting procedure was as follows: (1) the quadrat was placed on the ground in the pre-determined position within the square-meter being sampled; (2) one set of brass pins was pushed into the ground next to the first set of notches and the string stretched taut across the quadrat; (3) the plants in the first quarter were then counted; (4) the second pair of pins was put into the ground next to the second set of grooves, and counts were made in the second quarter of the quadrat; (5) the first set of pins was then moved to the third set of grooves, and the plants in the third and fourth quarters of the quadrat were counted. The string and pins also served to hold the quadrat frame tightly to the ground and to maintain a constant inside area during the counting. This method proved to be a very effective way of counting the stunted or diminutive vegetation characteristic of high Arctic regions.

The counts for each quarter-quadrat were kept separate on the data sheets for statistical reasons. Notes concerning the physical features of each quadrat were also recorded on the data sheets. One hundred quadrats were counted on the 100 square-meter transect area; thus, the sample was five percent of the total transect area.

Nomenclature of the higher plants mentioned in this paper is in accord with Hultén (1941--1949). Representative lichen collections were identified by Dr. John Thomson, and these were used as reference specimens for quadrat determinations.

Photographic Sampling

Because certain species presented growth forms that made it impossible to obtain actual density counts, a photographic sampling technique was devised to evaluate these species. A 4" x 5" Speed Graphic camera mounted on a sturdy tripod was used to photograph the 20 x 25 cm. quadrat from a position directly overhead. The photographs were made on Plus-X film, through a green X_1 filter, using a number 11 flashbulb at approximately two feet. The camera was focused so that the quadrat completely filled the ground glass. Twenty-five photographs were taken of quadrats located every fourth meter in the transect. The photographic sample was, therefore, a 1.25 percent sample of the total area of the transect. The prints of the quadrats were enlarged to make the quadrat on the photographic paper the same size as the original quadrat.

The quadrat size was scored on a plexiglass sheet, 1/8 inch thick, and 12 inches square. This area was divided into 100 compartments. Percentage cover was determined from the photographs for *Salix rotundifolia* and *Petasites frigidus* by the use of this plexiglass grid.

In determining the percentage cover for these species, the grid was placed on the photograph and each square containing a plant or a portion of a plant was counted as one unit. *Salix rotundifolia* cover values were determined because actual density could not be ascertained due to its prostrate, mat-like growth form. Cover values for *Petasites frigidus* were compared with actual density values for the quadrats that were photographed. The resulting data furnish a gauge of the effectiveness of cover values and their relationship to density.

Soil Sampling

Some of the differences in vegetational cover on natural areas are due to variations in soils and their physical and chemical makeup. Therefore, a series of trenches was dug at various points along the transect and soil samples were taken from the strata that were revealed. The soil samples were analyzed both chemically and mechanically, whenever possible. The mechanical analysis of the soil samples was made using the hydrometer method according to the procedure outlined by Bouyoucos (1936). The Soils Testing Department, Michigan State College, performed the active test for the elements in the chemical analysis.

Three times during the progress of the study, soil samples were collected from a stratum just below the vegetative mat for immediate pH analysis. The samples were analyzed with a Beckman pH meter, Model G. These samples were taken at stations ten meters apart along the transect.

Active layer depth measurements were also recorded several times during the summer at stations ten meters apart on the transect. A metal probe was pushed into the ground until the permafrost table was reached and then this depth was measured with a rule. Data for active layer transects in three different habitats are also considered in the discussion of soil and vegetation relationships.

TREATMENT OF DATA

Quadrat Data

In analyzing the quadrat data, three methods were used to describe the distribution of each species of lichen and flowering plant on the transect. The densities of the species occurring on this transect were determined by actual stem count. Density histograms were made for most of the species. Saxifraga caespitosa (six individuals in quadrat 45), Juncus biglumis and several lichen species were omitted. The histograms are included in Appendix Figures I to XXXI. On these histograms, the profile of the ridge was plotted and also the average pH value for the ten soil-sampling stations on the transect. The profile or elevation values are represented by the solid line while the pH values are symbolized by the dotted line. Each bar represents the number of individuals that occurred in the quadrat with the appropriate scale at the right of the histogram. The transect distance of one hundred meters is represented by the horizontal axis. Mean density of the species in the quadrats and the frequency of occurrence in the one hundred quadrats are also placed on the histogram.

The distribution of a particular species, whether it be aggregated or scattered uniformly, can be observed directly from these diagrams. The relationship of elevation and soil chemistry to species density is also evident. However, such factors as soil moisture, soil-frost phenomena (frost scars or "boils"), and hummocks which influence the micro-distribution of many of the species, cannot be reasonably portrayed.

The lichens presented an unusual growth form and densities do not have the same value when applied to them as when applied to the higher plants. However, for the purposes of denoting the quantitative changes that occurred on this beach ridge and transect, they can be used, although with certain reservations. Each distinct thallus, unconnected to another, was counted as one unit. The species present on the transect were not fragmented into minute pieces and, therefore, could easily be counted. This was especially true of Cetraria nivalis, C. islandica, Lobaria linita, Parmelia omphalodes and others.

In the case of such fruticose species as Cornicularia divergens, Sphaerophorus globosus, and Dactylina arctica clumps were counted. These species occurred in small clumps of thalli or lobes of a thallus and very likely these clumps represent individuals. The measurement of growth forms of this type is very difficult and any method used is subject to error. With the same observer doing all the counting, some of this error was minimized.

Flowering species such as Luzula nivalis also presented a problem in arriving at a stem count. This species grows in clumps of one to several rosettes of leaves. Each rosette was counted as an individual in this case, since it was theoretically capable of producing one or more flowering spikes. The rest of the flowering plants counted were easily recognized as individuals. Salix rotundifolia, as indicated before, was measured with the photographic method, in terms of percentage of the quadrat covered.

To study the distribution of the species on the transect and to evaluate this condition in terms of the relationship of the observed frequency distribution to the theoretical distribution expected for a random dispersion, the plates comparing these two distributions were prepared. Poisson's exponential binomial limit tables by Molina (1942) were used to plot the theoretical distribution line. Several of the lichen species have been omitted in this series of plates.

From these Appendix Figures (XXXII - LVIII), it can be seen that the distribution of few species approximates the random condition. The actual frequency class contributing the most to aggregation can be observed on the figures.

In addition to the frequency distribution figures, four statistical indices or measures of aggregation were computed for all the species. These four indices have been used by many investigators in phytosociology in an attempt to find a statistical measure that will effectively evaluate the aggregation occurring in plant distributions. These four measures are those proposed by McGinnies (1934), Clapham (1936), Fracker and Brischle (1944), and Whitford (1949).

All of these measures use the basic frequency-density relation, $F = 100(1-e^{-d})$. Clapham (1936) used a characteristic of the Poisson distribution, the equivalence of the variance of the distribution to the mean, and called this measure the relative variance. Blackman (1942) called this measure the coefficient of dispersion. The relative variance in the present paper is indicated by $s^2/\bar{x}$. Departure from unity (1) is the measure of non-randomness, within the limits imposed by sample size. McGinnies (1934) compared the actual densities with theoretical densities at the observed frequency level. This measure is represented by D/d in the tables. Fracker and Brischle (1944) used the relationship $D\text{-}d/d^2$ in describing the distributions of _Ribes_ and included a very helpful table that can be used to obtain the expected density at a given frequency level according to the frequency-density equation above. In both of the measures described above, _D_ represents the actual mean density of the species and _d_ represents the theoretical mean density expected at the observed frequency. Whitford's index employs the relationship between frequency and abundance (the ratio of the number of individuals found to the number of samples of occurrence). In the present paper, _A_ represents this index, which is equal to $100(D)/\text{frequency}^2$. The value _D_, again, is equal to the observed mean density. These phytosociological indices or measures were very well outlined and explained by Curtis (1950).

Tables listing these measures for individual species are found in the Appendix. The species are listed in the following categories: 1) grasses, sedges and rushes; 2) miscellaneous flowering plants; 3) and lichens.

In order to ascertain the effect of quadrat size upon these measures of aggregation, the data for two quadrat sizes were compared. For convenience of discussion and comparison, the one-hundred 0.05 square-meter quadrats were designated as Transect III. The counts for each

0.05 square-meter quadrat were recorded by quarters on each data sheet and, by using the counts for the first two quarters of each quadrat, data for a 0.025 square-meter quadrat size were obtained. These smaller quadrats were designated as Transet IIIb.

It was the intention at the beginning of the study to make a similar transect on an area adjacent to this high portion of the ridge so that the quantitative and the qualitative differences in vegetation might be observed. Because of a shortened field season, a transect as detailed as the original transect (III) could not be completed. Therefore, a transect (designated as I) was made approximately 1/8 mile north of Transect III on the same beach ridge. The number of samples in Transect I was reduced to 21 quadrats, 0.05 square-meter in size; these were spaced in every fourth meter-unit of the transect. The total area of Transect I was the same as Transect III, that is, 100 square meters.

To provide a basis for comparison of these two transects, a comparable series of quadrats was separated from the original transect (III) and designated as Transect IIIa. The quadrats selected for this purpose were from every fourth meter on the transect area.

The data concerned in these comparisons are listed in the Appendix Tables. Appendix Tables 1 and 2 contain the basic data for Transects III and IIIa. These data were used in making the computations for the succeeding tables. The comparisons of Transects III and IIIa involving mean density, frequency, and the four measures of aggregation are contained in Appendix Tables 3 to 7. In Appendix Table 8, Transects IIIa and I are compared. Comparisons between the 0.025 and the 0.05 square-meter quadrats (Transect IIIb and III) are listed in Appendix Tables 9 to 14.

DISCUSSION AND ANALYSIS OF DATA

Comparison of Quadrat Numbers

Density and frequency. From the comparison of Transect III and IIIa in Appendix Table 3, it can be seen that in the grasses, rushes, and sedges there is some shifting of the relative densities of certain species, e.g., Eriophorum schuechzeri; but the two grasses showing the greatest relative density have retained their same position. Eriophorum scheuchzeri drops from third place in Transect III to fifth place in Transect IIIa, which consisted of only 21 quadrats. This can be explained by the restricted distribution of E. scheuchzeri which evidently was not sampled as effectively by the smaller number of quadrats and therefore, is under-represented. The tiny rush, Juncus biglumis, was not recorded in the 21 quadrat transect. The frequencies of several species remain the same for both series of samples.

In the case of the miscellaneous flowering plants in Appendix Table 3, the same five species are retained as the five densest species with the usual shifting among the more sparsely represented species. Saxifraga cernua dropped from the most dense species on Transect III to the fourth most dense species on Transect IIIa. An inspection of the histogram for this species (Appendix Figure VIII) shows that it occurred on the transect at three places which are correlated with relatively moister soil conditions. Of the miscellaneous flowering plant species, Saxifraga cernua had the most discontinuous distribution. The distributions of Eriophorum scheuchzeri and Saxifraga cernua can be termed micro-distributions and it is evident that the reduced number of samples was not sensitive enough to record the actual density conditions for these species.

The lichens appear to be more effectively sampled by the reduced number of quadrats than the flowering plants since the comparison in Appendix Table 3 shows little disagreement, and then only in the minor or less conspicuous elements of the lichen flora.

These comparisons indicate that the 21-quadrat transect produced nearly the same results in regard to mean density and frequency as the larger sample. Poor representation is noted in the case of contagiously distributed species.

Measures of aggregation. In analyzing the distributions of the species on the transect according to the measures of aggregation, tables comparing the effect of both quadrat number and quadrat size upon these measures have been prepared. Appendix Tables 4 to 7 are concerned with the comparison of the effect of the number of quadrats upon these measures.

In Appendix Table 4, the species of grasses, rushes, and sedges are arranged in decreasing order of non-randomness, according to the four measures of aggregation. All of the measures, except Whitford's index (A), give values that indicate a definite non-random condition. Fracker and Brischle's index, $D-d/d^2$, showed the least difference in the arrangement of the species between the two transects. This index placed Poa arctica as the second most random species while according to the other three measures, this species is indicated to be either the second or the third most aggregated.

A consideration of the histograms (Appendix Figures I - VII) for the grass, rush, and sedge species indicates that the relative order of non-randomness according to $D-d/d^2$ is the most sensitive and best describes the distributions of these species. Luzula confusa, indicated the third most aggregated by $D-d/d^2$, exhibited a sporadic distribution of densities which are correlated with its tussock type of growth form. Eriophorum angustifolium and E. scheuchzeri clearly show the most aggregation on the histograms.

All of the measures and both of the transects reveal the same general order of species, except for the instances mentioned, and indicate, as did the mean density and frequency comparisons, that the 21-quadrat sample was nearly as efficient as the 100-quadrat sample.

Appendix Table 5 lists the computations of the same four measures of aggregation for the miscellaneous flowering plants. There is not the agreement in this comparison between the measures and quadrat number, as there was in the grasses, rushes, and sedges. It is possible that the 0.05 square-meter quadrat was too small to evaluate these species with the measures of aggregation. However, when the species indicated as the most aggregated or contagious by the measures of aggregation are examined on the histograms, the order of species in Appendix Table 5 appears to agree with the actual conditions. Again $D-d/d^2$ agrees very closely with the relationships indicated by the histograms. Whitford's measure (A) also approximates quite closely these relationships.

Vaccinium vitis-idaea is indicated to be the most non-random species by the indices $D-d/d^2$ and A. Its distribution, confined to the hummock tops in the upper portion of the transect, would seem to warrant this position. Potentilla emarginata, the most random species according to $D-d/d^2$, has mean density almost the same as that of Vaccinium vitis-idaea, but its frequency is twice as large. One of the characteristics of aggregated species is that for any given density, the frequency value is lower than would be expected. Petasites frigidus is another species with a high mean density and a low frequency and is indicated to be very contagiously distributed by all of the measures. As with the grasses, rushes, and sedges, the more sensitive of the four measures are apparently $D-d/d^2$ and A. The smaller number of quadrats, however, did not maintain the same relationships of the measures that were indicated in the larger sample.

Appendix Tables 6 and 7 compare the effect of quadrat number upon the measures of aggregation for the lichen species. All of the measures, except the index D/d, indicate that Stereocaulon evolutoides is the most non-random species. The histogram (Appendix Figure XXIX) for this species shows that it occurred on only two portions of the transect. At both locations there was gravel at the surface of the ground. The high density in the first quadrat was associated with the gravel edge of the lower end of the transect. The relatively high density present on these micro-habitats was indicated by the measures in placing Stereocaulon evolutoides in the most aggregated position.

No explanation can be given for the disagreement of the index D/d in these comparisons. It is noticeable that for the smaller sample of 21 quadrats, D/d gives values which indicate Stereocaulon evolutoides the most non-random, which is in agreement with the values indicated by the other indices and the 100-quadrat transect.

Fracker and Brischle's index, $D\text{-}d/d^2$, does not show much agreement between transects, except that Stereocaulon evolutoides is assigned the most aggregated position in both samples. Parmelia omphalodes exhibited a distribution on the transect that can be correlated with the presence of bare earth. This lichen was found on the bare areas at the base of the transect, in and around the frost-boils found on the steeper portion (25 to 45 m.), and on the hummocks at the upper end. Evidently Parmelia omphalodes had a frequency which was high enough to lower the aggregation index and the localized distribution of this species is not indicated. The value of descriptive data like the histogram is realized in analyzing such distributions.

A repeated pattern of multimodal densities is evident on the histograms for the following lichen species: Cetraria islandica, C. nivalis, Dactylina arctica, Cladonia sp., Sphaerophorus globosus, Thamnolia vermicularis, and Cornicularia divergens. At each point where these species decreased or ceased to occur, a moist area was present. The line representing elevation shows a slight depression at each of these sites (20 m. and 75 m.). These lichen species were xerophilic in their distribution in the entire Barrow area, being found in their highest densities on polygon and hummock tops, and on the beach ridges, both recent and old.

It is believed that Cetraria richardsonii was limited to the lower portion of the transect (See Appendix Figure XXXI) by the predominantly northeasterly winds. The wind struck the beach ridge and the transect at the higher point and a slight lee effect was exerted by the 2.7 meter difference in elevation between the lower and upper ends of the transect. The large, strap-like thalli of this lichen were found loosely tangled among the grass stems and offered the most wind resistance of any of the lichens.

The lichens are the most difficult of the plants to analyze according to ecological and phytosociological methods. The methods used in this study could hardly be used in temperate or even in boreal areas. The lush growths of lichens occurring in central Alaska and in some north temperate forests could not be analyzed using actual densities. But because of the stunted or reduced condition of the lichen flora in the Barrow area, and especially on this beach ridge, it was possible to use a sampling method such as list-quadrats. Wiggins (1951) remarked that large areas densely covered with either Sphagnum or lichens were uncommon in the immediate vicinity of Point Barrow.

Even under these conditions, it is realized that an arbitrary method has been used but the correlations that have been observed seem to warrant the use of this method. Density counts of such life forms, although they could not represent the actual numbers of individuals present, serve as an index or gauge of abundance which otherwise might not be measureable. The application of photographic techniques may solve part of the problem of evaluating life forms such as lichens and mosses.

Summary. The effect of the number of quadrats upon the values of density, frequency, and measures of aggregation was described in this section. It was found that density and frequency were represented reasonably well in the smaller sample. However, when a species was aggregated in respect to some micro-habitat feature, the smaller number of quadrats was liable to inaccurately represent the relative status of the species.

In phytosociologial studies, concerned with these micro-distributional relationships, the larger sample of the total area is desirable. If sampling merely to record the dominants of an area, the smaller number of quadrats appears to produce essentially the same results as the larger, more detailed sample. The 21-quadrat transect was a 1.25 percent sample of the total transect area while the 100-quadrat transect was a 5 percent sample.

In these comparisons, it can be seen that the effectiveness of the measures of aggregation is dependent upon the number of quadrats and the distributional factors present in the habitat. The measures when applied to the grasses, rushes, and sedges gave comparable results for both series of quadrats. In the miscellaneous flowering plants and the lichens, there was a tendency for the order of the species to be significantly changed when the smaller number of quadrats was employed. The species most commonly misrepresented in degree of non-randomness were those exhibiting relationships to micro-distributional features.

Therefore, if a study is concerned with the phytosociological characteristic of aggregation or contagion, the level of sampling should be high enough to compensate for micro-distributional effects. It appears from this study of tundra vegetation, where habitat differences occur in relatively short distances, that a 1.25 percent sample of the total area was not detailed enough to describe accurately the distributional aspects of the vegetation. The dominant species, however, could be determined from the smaller number of quadrats.

Comparison of Quadrat Size

Appendix Tables 10 to 14 are concerned with the comparison of quadrat sizes. As described previously, the quadrat size was halved and the resulting data were used in exactly the same manner as the original transect data. Mean density, frequency, and the four measures of aggregation were computed. Appendix Table 9 merely lists the data for the 100-quadrat transect, using the quadrat size of 0.025 square-meter. This transect is designated as Transect IIIb in the Appendix Tables.

Density and frequency. In Appendix Table 10, the density and frequency values for the two quadrat sizes were compared. Among the grasses, rushes, and sedges there was no disagreement at all. The means ($\bar{x}$) seemed to be approximately halved in the smaller quadrat data. When density is considered as the number of individuals per quadrat, it becomes directly proportional to quadrat size. The high mean, low frequency condition of Eriophorum scheuchzeri was repeated in the smaller quadrat but the difference between density and frequency was not as large as in the larger quadrat.

Curtis (1950) and Evans (1952) both stated that estimates of relative frequency are affected by the size of the quadrat employed while density values are proportional. Apparently Eriophorum scheuchzeri represents this condition since the density value was almost halved, yet the frequency dropped only one percent in the smaller quadrat data. The resulting discrepancy in the measures of aggregation for this species illustrates the significance of this condition and will be discussed in the analysis of the measures of aggregation. Saxifraga cernua, in the comparison in Appendix Table 10, dropped to fourth most abundant species. Of the miscellaneous flowering plants, S. cernua had the most discontinuous distribution on the transect. The histogram (Appendix Figure VIII) for this species showed three density modes coinciding with relatively moister soil conditions. This species was also poorly represented in Transect IIIa, in which the number of quadrats was reduced. It was evident that the smaller quadrat size did not record the actual density conditions for this species as well as it did for the other species which did not have such a discontinuous distribution.

Curtis (1950) found in his studies on artificial populations that there is some indication that highly contagious species are over-represented by relatively small quadrats. The unusually high frequencies indicated for *Saxifraga cernua* and *Eriophorum scheuchzeri* in the smaller quadrat data appear to illustrate this condition since these species were contagiously distributed.

The rest of the density values for the miscellaneous flowering species showed a very good agreement in the order of the species, especially among the less dense species.

The lichen densities showed little variation between the two quadrat sizes so that the species maintained their same relative positions in each transect. The proportional relationship of quadrat size and density seemed to apply to the lichens as well as the flowering plants. The frequency relationships of the flowering plants were also repeated in the lichen species, with high frequencies indicated in the smaller quadrats. *Cetraria islandica* had a frequency of 86 percent in the 0.05 square-meter quadrats and 83 percent in the 0.025 square-meter quadrats.

Measures of aggregation. Appendix Tables 11 to 14 compare the measures of aggregation for the species in the two transects, using the two different quadrat sizes. The index $D-d/d^2$ showed the most sensitivity in Appendix Table 11 where the grasses, rushes, and sedges are listed. It was noticed in the comparison of the densities and frequencies that *Eriophorum scheuchzeri* had an unusually high frequency in the smaller quadrat data. In Appendix Table 11, according to $D-d/d^2$, the relative position of *E. scheuchzeri* drops to fifth most aggregated species. In the 0.05 square-meter quadrat data, *E. scheuchzeri* had been considered as the most non-random, or the second most non-random.

A consideration of the histogram (Appendix Figure III) for this species indicates that Eriophorum scheuchzeri does exhibit a highly contagious distribution. It is evident that the high frequency observed in the smaller quadrat data results in a more random condition being indicated by the measure, $D\text{-}d/d^2$, than actually exists. The three other measures in Appendix Table 11 apparently are not sensitive enough to record this condition and show little disagreement between the two quadrat sizes.

The various measures of aggregation for the miscellaneous flowering species are listed in Appendix Table 12. Saxifraga cernua, as noted previously, shows an unusually high frequency in the smaller quadrat. Fracker and Brischle's index, $D\text{-}d/d^2$, indicates a more random condition for S. cernua in the smaller quadrat data. The unusually high frequency and the resulting discrepancy in the measures of aggregation revealed in the values for Eriophorum scheuchzeri seem to be repeated in the values for Saxifraga cernua. On the basis of the effect of quadrat size upon the measures of aggregation for these two species, the assumption of Curtis (1950) that contagious species are over-represented in relatively small quadrats appears to be substantiated.

Appendix Tables 13 and 14 are concerned with the measures of aggregation computed for the lichen species, using the two quadrat sizes. The relative variance ($s^2/\bar{x}$) in this comparison is affected the most by the smaller quadrat size while $D\text{-}d/d^2$, the most sensitive of the measures when applied to the flowering plants, showed little disagreement between the two quadrat sizes. Whitford's measure, A, also shows close agreement between quadrat sizes in this comparison. The measure used by McGinnies, D/d, does not appear to be affected by the change in quadrat size but the order of the species in degree of non-randomness is actually not as indicated by this index.

The high frequency for Cetraria islandica in the 0.025 square-meter quadrats has not resulted in the usual change in the relative randomness. If a change were to occur, it would be expected in the $D-d/d^2$ values, which indicated this change in the flowering plants. It is possible that lichen distributions cannot be measured by these indices, even though individuals can be arbitrarily delimited and density values obtained. The asexual methods of reproduction (especially in the Arctic species), the means of dissemination, and many other characteristics of the lichens, may produce distributional effects that render this type of data ineffective.

Summary. From these various comparisons, from which the most conspicuous examples have been drawn, it can be concluded that density, when it is defined as the number of individuals per quadrat, is affected by change in quadrat size in a directly proportional manner. Frequency exhibits more complex relationships, especially when the species is contagiously distributed. Variations in frequency are related to the effect of quadrat size upon the measures of aggregation. The misrepresentation of the degree of aggregation shown by a species is often the result of relatively small quadrats being used. Whenever randomness is indicated in plant populations, while at the same time it is apparent that micro-distributional influences are present, more than one quadrat size should be used. In this case, an increase in quadrat size would be in order because of the tendency of smaller quadrats to misrepresent the degree of aggregation. The use of nested quadrats, or counting the quadrats in sections and keeping the count separate for each section, are methods which can be used to record data for several quadrat sizes simultaneously.

Since populations have been shown to commonly occur in aggregated distributions, and random dispersions are seldom found, it would seem that investigators in phytosociology should consider the employment of several quadrat sizes an indespensible part of their technique. The nature of contagious distributions has been studied by several biometricians and phytosociologists. Neyman (1939), Cole (1946) Archibald (1948, 1950), Thomas (1949), Thomson (1952) and Beall and Rescia (1953) have developed or modified statistical distributions which can be fitted to the observed frequency distributions found in biological populations.

Comparison of Transects

Transect I was established on a lower or more mesic area on the beach ridge to provide a basis of comparison with the higher portion sampled by Transect III. Transect I was located 1/8 mile north of Transect III on the same beach ridge. The same sampling procedure was used to study both transects. Only 21 quadrats were counted on Transect I, but they were spaced every fourth meter. The area sampled in this transect was the same so that in Transect IIIa which comprised 21 quadrats selected as previously mentioned from Transect III.

Comparable data from these two transects are summarized in Appendix Table 8. Several differences are observable in this comparison. The relative densities of several grasses and sedges vary significantly. Luzula nivalis and L. confusa occurred in reduced densities on the moister area (I). These two species were found in the more xeric sites in the entire Barrow area. Alopecurus alpina was present in moderately high densities on Transect I, sharing co-dominance with Poa arctica and Arctagrostis latifolia. Gelting (1934) observed that Alopecurus alpina occurred especially in bogs and other damp places in East Greenland, where it is often dominant with Arctagrostis latifolia. Alopecurus alpina was absent from Transect IIIa which was evidently too xeric for this species. The comparatively higher density of Carex aquatilis on Transect I, was indicative of the higher moisture requirements of this species. Carex aquatilis occurred in highest densities in the polygonal ditches and trough and was decidedly hydrophilic in its distribution in the Barrow area.

The absence of several species of miscellaneous flowering species from Transect I also indicated the influence of a more hydric habitat. Vaccinium vitis-idaea, Cassiope tetragona, Saxifraga flagellaris, S. oppositifolia (not in quadrats), were all characteristic of the higher area (IIIa) but were absent on Transect I.

Certain lichen species such as Cetraria nivalis, Cornicularia divergens, Sphaerophorus globosus, and Cladonia gracilis occurred in considerably lower densities in Transect I than in Transect IIIa. These same species showed density maxima in the more xeric sites on Transect IIIa. Further evidence of their xeric tendency was provided by their distribution in the Barrow area on polygon tops, hummocks, and other beach ridges.

On the basis of the species present in Transect III, of which Transect IIIa was a part, this higher area can be considered to represent a more xeric habitat. The soil data further confirm the condition that was noticed at the beginning of the study on the basis of vegetational characteristics.

Discussion of Photographic Sampling

As noted previously, Salix rotundifolia and Petasites frigidus were sampled using a photographic method. Text Figures I and II are based on the resulting data.

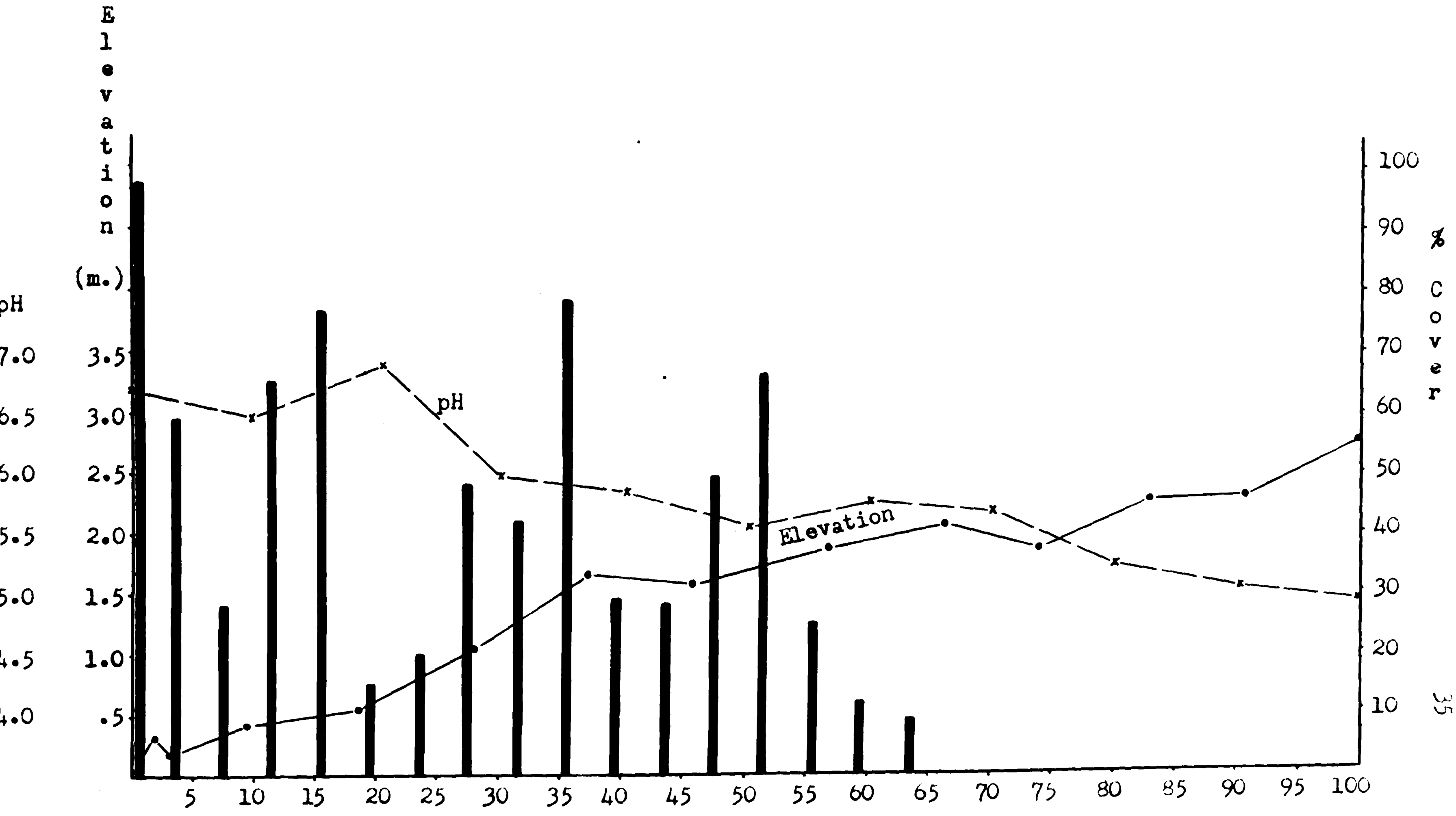
The cover values of Salix rotundifolia indicate that this species has a rather wide tolerance of moisture conditions. Reduced cover values, however, were noted in extremely wet areas. The low cover values in the 20 - 25 m. area (Text Figure I) were related to the seepage occurring at the 20 meter station and the soil-frost activity on the steeper portion of the slope (25 m.). The absence of this species in the upper portion of the transect (80 to 100 m.) is explained partially by the soil-frost activity in the hummock area. The polygonal trough at 75 m. was evidently too moist and, in addition, competition with grasses and sedges was greater there.

The quadrat frequency of *Salix rotundifolia* was 64 percent which agrees reasonably well with the 68 percent obtained in the photographic sample.

The density-cover relationship of *Petasites frigidus* is graphically represented in Text Figure 11. It was possible to obtain both density and percentage cover values for this species. The relationship of density and percentage cover varies as indicated by the text figure. The discrepancies, where they occur, are believed to be related to the micro-habitats present in the area where *Petasites frigidus* occurred. The pattern of hummocks in this area presented a mosaic of soil and relief conditions upon which this species was distributed. The varying conditions of the micro-habitat were expressed in the vigor of the plant and hence its vegetative growth. Plants on hummocks that were not affected by soil-frost activity as much as others had larger vegetative parts (leaves) and hence possessed a greater cover value. Because of these and similar factors in the environment, densities will not agree at all times with cover values.

Percentage cover as determined from 4" X 5" photographs

<u>Salix</u> <u>rotundifolia</u> Trautv.



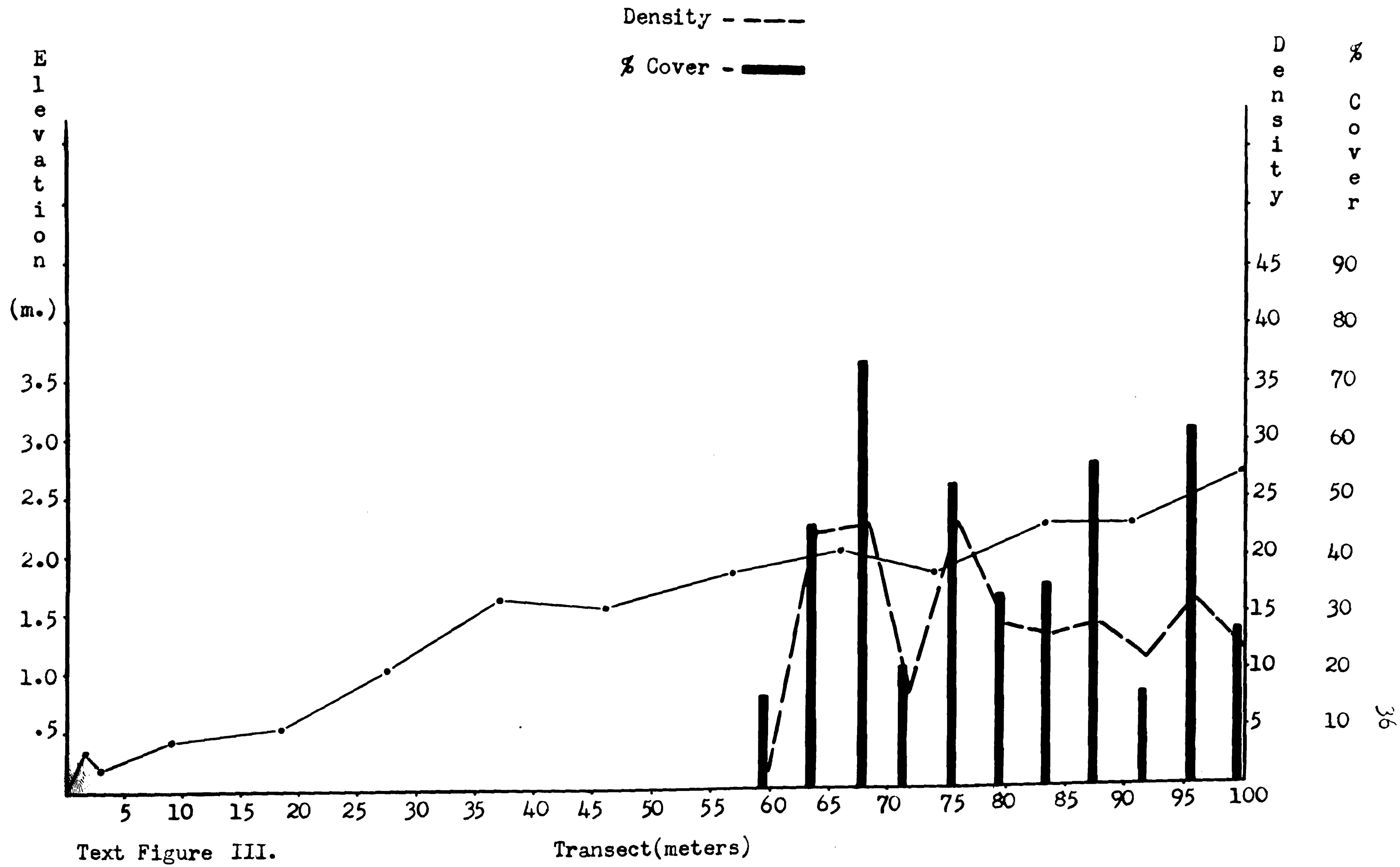
Text Figure II.

Transect(meters)

Transect III

Density-Cover Relationship

<u>Petasites</u> <u>frigidus</u> (L.) Fries.



Text Figure III.

Discussion of Soil-Vegetation Relationships

The beach ridge has been described previously as representing a more xeric site in comparison with the polygonal and marsh habitats. The most evident reasons for this condition were the gravel substratum and the slight elevation. Active layer measurements were made at ten stations on Transect III and I several times during the summer (Text Figure III and IV). These measurements were made with a metal probe. It was possible to feel the presence of gravel with the probe and as each depth reading was made, the presence or absence of gravel was noted.

At the base of the beach ridge, the lowest point on the transect, the active layer was the deepest with a definite stratum of gravel, six inches thick, occurring just above the permafrost. The gravel was felt at all the stations up to the sixty meter area. In the trench at 60 meters, the gravel was present in a 2 to 3 inch stratum directly over the permafrost table. Approximately 17 inches of weakly stratified soils were superimposed upon the gravel layer at this station. At 65 meters, however, the gravel disappeared and could not be felt with the probe in the remaining upper portion of the ridge. A trench dug at the 100 meter station failed to disclose any gravel on the permafrost table. It is possible that the gravel layer in the upper 30 meters of the ridge was absorbed into the permafrost. The average active layer depth at the 100 meter station was slightly over 30 inches.

From the active layer readings made with the probe and the trenches dug at various points on the transect, it is known that a gravel substratum existed under a major part of the ridge and that it occurred just above the permafrost table.

Müller (1947) stated that percolation of ground water takes place upon permafrost gradients. From Text Figure III, the gradient of the permafrost table on Transect III can be seen to be quite steep, especially from 70 meters to the base of the transect. From field notes, taken while the trenches were being dug, a phenomenon can be described which illustrates the percolation of ground water on the permafrost table.

As the trench at the 30-meter station was being dug, an upwelling of water occurred as soon as the gravel layer was entered. A similar upwelling took place in the trench at the 20-meter station. The water in both trenches appeared to be under a slight hydrostatic pressure. The trench at 20 meters soon filled and remained filled for the entire summer. The 30-meter trench eventually drained and did not fill again. Water was not encountered in any of the other trenches above the 60-meter trench or below the 20-meter trench. In the trench dug at the 0-meter station, i.e., the base of the transect, an active layer of 22 to 31.5 inches was noted with approximately six inches of loose gravel upon the permafrost table. The gravel was slightly damp and plant roots had penetrated into this layer. There was no water in this trench at the time of digging nor did it fill with ground water at anytime during the summer.

The reason for the lack of water in the lowest trench at 0 meters was very likely the "hump" in the permafrost table that occurred between

20 meters and the base of the transect. In every series of active layer readings, this area (10 m.) had a shallower active layer than the one either above or below it. This bulge upward in the permafrost table exerted a damming effect upon the percolation of ground water. The area from 18 to 21 meters was a very moist site and this saturation could be reasonably attributed to the damming of ground water just below the 20-meter station.

The comparatively shallower active layer beneath the 10-meter area could be easily correlated with the thicker vegetative mat occurring at this zone. Wiggins (1951) found that areas of bare ground had deeper active layers than areas with a thick vegetative mat. Salix rotundifolia shows high cover values on this area; Poa arctica, Arctagrostis latifolia Luzula nivalis, and L. confusa are present in moderate to high densities here. The histograms for these species in the Appendix Figures from I to VII show the actual densities on this area. The mosses also constituted a very important part of the vegetative mat on this area. Ceratadon purpureus, Tomenthypnum nitans, Drepanocladus uncinatus, Distichum flexicaule, and Oncophorus polycarpus were the most abundant species of mosses. Thalli of the alga, Nostoc commune, were also found in this moist area from 10 to 20 meters.

The diagram of active layer depths for Transect III (Text Figure III) shows a pronounced deeper layer during the whole summer on the area from 20 to 50 meters. The steepest gradient and also the most bare ground on the whole transect occurred in the area between 20 and 50 m..

The bare ground was in the form of frost "boils" or "scars". Text Figure V shows ten-meter cumulative values for the frost "boils" and hummocks in the transect. The associated vegetation of this area was typical of bare earth habitats where pioneer species are apt to be found. Continued frost action on this area very likely kept the species from ever establishing a vegetative mat and hence this area is always in a colonizing stage.

Hopkins and Sigafoos (1950) concluded that the concept of climax vegetation must be modified when applied to tundra vegetation. They stated that the tundra differs from climax assemblages in that bare areas, and those covered by pioneer plants, are intimately mixed among areas covered by vegetation representing the highest stage in the succession.

Most of the flowering species either dropped in density on this area (20 to 40 m.) or they did not occur here at all. Such species as _Luzula nivalis_, _L. confusa_, _Potentilla emarginata_, _Papaver radicatum_, _Draba glabella_, _Saxifraga foliolosa_, _S. punctata_, _S. caespitosa_, _Stellaria laeta_, and _Cassiope tetragona_ are found on this area. _Poa arctica_ and _Arctagrostis latifolia_ occurred here in reduced density. _Saxifraga cernua_ was virtually absent from this area and appeared to occur in highest densities when in moister conditions. The histograms indicate the distributions of these species in regard to this area (Appendix Figures I to XV). _Cassiope tetragona_ and _Papaver radicatum_ were present in the quadrats from 25 to 35 meters. They were represented by only one or two individuals.

Several lichen species exhibit density maxima on this bare earth area. Most of the fruticose species occurred densely here, while the foliose species such as Lobaria linita and Peltigera canina were more hydrophilic.

As indicated on the diagram of the active layer depths for Transect III (Text Figure III) a consistently deeper active layer was also present at the upper end of the transect. Again this feature can be related to the presence of bare ground in the hummock area which occurred from 80 to 100 meters. This site was a poorly developed polygonal area with many small hummocks. The tops of most of the hummocks were bare except for a few plants of Arctagrostis latifolia, Poa arctica, Vaccinium vitis-idaea and lichens which did not form a continuous vegetative cover. The lack of turf, the exposure to winds, and the absence of snow cover all favored the formation of hummocks in this area. The low site at 75 meters represented a polygonal trough with possibly a melting ice wedge supplying the moisture which made it more hydric. The distribution of Eriophorum angustifolium on the histogram (Appendix Figure VII) is to be noted with respect to this feature. This species was commonly found in areas much moister than the beach ridge.

The pH values recorded for ten stations each on Transect III and Transect I are diagrammed in Text Figure VII. The more acidic condition consistently found on the upper portion of Transect III was very likely related to the increase in elevation and the leaching associated with the local drainage conditions. The soil in the hummocks, which were present in the area from 80 to 100 meters, was a light yellow-brown color and the pH range was usually from 4.6 to 4.8. The troughs between the hummocks, with slightly darker soil, did not have pH values of much over 5.0 so that the entire micro-relief of the site was decidedly acid in reaction.

The distribution of Vaccinium vitis-idaea on the transect is an example of the acidophilic tendency of a species which was related to the micro-relief present on the hummocks previously described. This species was entirely restricted to the upper portion of the transect (III) where it occurred only on the hummock tops.

In Text Figure VII, the pH values for Transect III and I are compared. Although these transects were located at least 1/8 mile apart, a repetition of the high pH values is apparent at the same points on both transects. The active layer depths for Transect I were not as deep as on the higher area (Transect III) but this would be expected since the vegetative cover was more continuous and denser on Transect I. At the 20 meter station, an unusually high pH of 7.4 was recorded twice during the summer. In the trench that was dug at this station, a well-defined stratum of fine, blue-gray, clayey-sand was discovered just above the permafrost table. This layer was approximately two to three inches thick. When tested with HCl, this soil effervesced indicating free lime. The chemical analysis of this soil (Sample #4, Text Table 1) shows a comparatively high potash and calcium content. The soil sample was examined for Foraminiferan tests but only unidentifible fragments were found. It is possible that this stratum of fine, compacted clayey-sand was an organic deposit laid down beneath a pool or pond. Pools of this type commonly form on the backslopes of beach ridges and were seen on the present beach ridges of the Arctic Ocean in the vicinity of Point Barrow.

Whatever its formation, this stratum evidently created a rich soil habitat in the lower portion of the transect. Saxifraga flagellaris occurred on the lower or alkaline portion of the transect between 0 and 45 meters. This species was consistently found on the lower part of the beach ridge for several hundred yards on either side of the transect. Gelting (1934), in his studies on the vascular plants of East Greenland, considered this species to be calciphilic. He found this plant especially numerous on the raised marine terraces in company with Saxifraga caespitosa. Six specimens of S. caespitosa were present in the quadrat at 45 meters.

The soil samples from the trenches were analyzed chemically by active tests and mechanically for sand, silt, and clay. The results of these tests are given in Text Table 1.

It was not possible to analyze every stratum that was found; therefore characteristic strata were analyzed from several trenches. For example, a light brown sandy loam was present on most of the transect just beneath the dark humic layer associated with the vegetation. Samples #1 and #10 in Text Table 1 were from this layer and showed little difference except in pH. Sample #10, from the 100-meter station, was lighter in color which was possibly an indication of the degree of leaching.

In the 20 to 45 meter area, this sandy loam was mixed with the gravel stratum which appeared here at the surface. The soil in this area was very homogeneous and did not show the stratification apparent in the other portions of the transect. This was expected, since the area from 20 to 50 meters had the largest number of frost "boils" of any portion of the transect, and these features are an indication of the churning (congeliturbation) occurring in a soil. Sigafoos (1951) stated that the formation of frost scars or "mud spots" was the initial result of congeliturbation on most sites.

Sample #4 was from the blue-gray clayey-sand in the trench at 20 meters. The chemical analysis of this stratum correlated with the high pH values obtained at this point.

Sample #3 was a sample of the dark-brown humic layer associated with the vegetative mat. It was present, either in an unbroken or broken form, on most of the transect. This layer varies from pH 6.6 at the base of the transect to pH 4.8 at the 100-meter station. Compared to a sample eight inches below in the sandy loam, this dark-brown humic layer had twice as much potash and calcium.

The possibility that some of these soil conditions were present over a large area on the beach ridge was indicated by the similarity of the pH patterns for both transects, I and III.

The trench at the 100-meter station yielded several interesting samples which are possibly related to the history of the beach ridge.

The gravel layer was not found in the trench at 100 meters but, as stated previously, it was possible for this layer to have been absorbed into the permafrost. A narrow stratum of dark-brown peat, one to two inches thick, was found on top of the permafrost table in this trench. Sample #9, from a 15 inch depth in the trench at 100 meters, showed a noticeable increase in phosphorus, potash, calcium, and manganese. The color of the soil at this depth was gray. The light brown layer, previously described, and this deeper gray stratum very likely represent two periods in the development of the beach ridge. Rex (1953) considered these beach ridges in the Point Barrow area as being loess-covered. Evidently the upper layer, light brown in color, represented the eolian deposition while the deeper, gray layer was associated with the earlier, marine history of the beach ridge. Eolian deposition of similar material was common in Alaska where deep deposits have been laid down in relatively short periods.

The peat layer (pH - 5.2) present on the permafrost table at the 100-meter station represented the remains of the initial vegetation of beach ridge. The 0.5 ppm of iron recorded in sample #8 was associated with the peat layer.

In connection with certain ecological studies conducted in the Point Barrow area by Thompson (1953), active layer depth transects were established in three distinct habitats (Text Table II). One of the

TEXT TABLE 1

SOIL DATA

Mechanical Analysis

Constituents(%)	#1 0-meters 8" depth	#3 0-meters 2" depth	#4 20-meters 15"depth	#7 100-meters 10" depth	#9 100-meters 15" depth	#8 100-meters 18" depth
	Soil Samples					
Sand	39	-	63	45.6	44.4	-
Silt	37.8	-	4.2	28.4	34.6	-
Clay	23.2	-	32.8	25.9	21.0	-

Chemical Analysis*

Test	#1	#3	#4	#7	#9	#8
pH	6.5	6.6	7.8	4.8	5.1	5.2
Phos. Act.	1/8	1/8	1/4	1/8	1/4	1/4
Potash	4.5	10.0	39.0	5.0	10.5	10.2
Mg	6.25	6.25	6.25	5.0	4.0	5.0
Ca	37.5	75.0	175.0	40.0	75.0	62.5
Mn	0	0	0	0	5.0	3.75
Fe	0	0	0	0	0	.5

* All values in parts/million, except pH

habitats was the beach ridge concerned in this study and the other two areas were adjacent to the beach ridge. The central marsh readings were made in the basin that was enclosed by the beach ridge, and the polygonal area readings were made just north of the beach ridge. These data illustrate some of the particular conditions presented by the beach ridge.

The active layer on the beach ridge was consistently deeper than either the marsh or polygonal areas. The readings made on the beach ridge in these data were from an area comparable to Transect I. From Text Figure III, the higher portion of the ridge (Transect III) can be seen to have an even deeper active layer than any of the readings in this table.

The refreezing of the active layer was observed to commence between the 17th of August and the 2nd of September, according to the data in Text Table 2. In the same period, the active layer readings on Transects I and III began to decrease.

The snow depth readings were inserted here to present another of the factors effective in the distribution of Arctic plants. The early removal of snow by melting and resulting water supply were influential in producing the unique vegetational complex observed on the beach ridge. The southern exposure of the beach ridge was very important in the early disappearance of the snow and the beginning of the vegetative period. Gelting (1934) noted that several species exhibited unfailing association with snow patches either because of the protection from dessicating winds or the moisture supplied by thawing.

TEXT TABLE 2

SNOW RETREAT
IN VARIOUS HABITATS,
POINT BARROW, ALASKA

Habitat	Depth of Snow (inches)*		
	25 May 53	2 June 53	10 June 53
Central Marsh	12.2	10.3	3.1
Beach Ridge	7.5	4.5	0
Polygonal Area	8.7	5.6	0

* Mean of ten readings

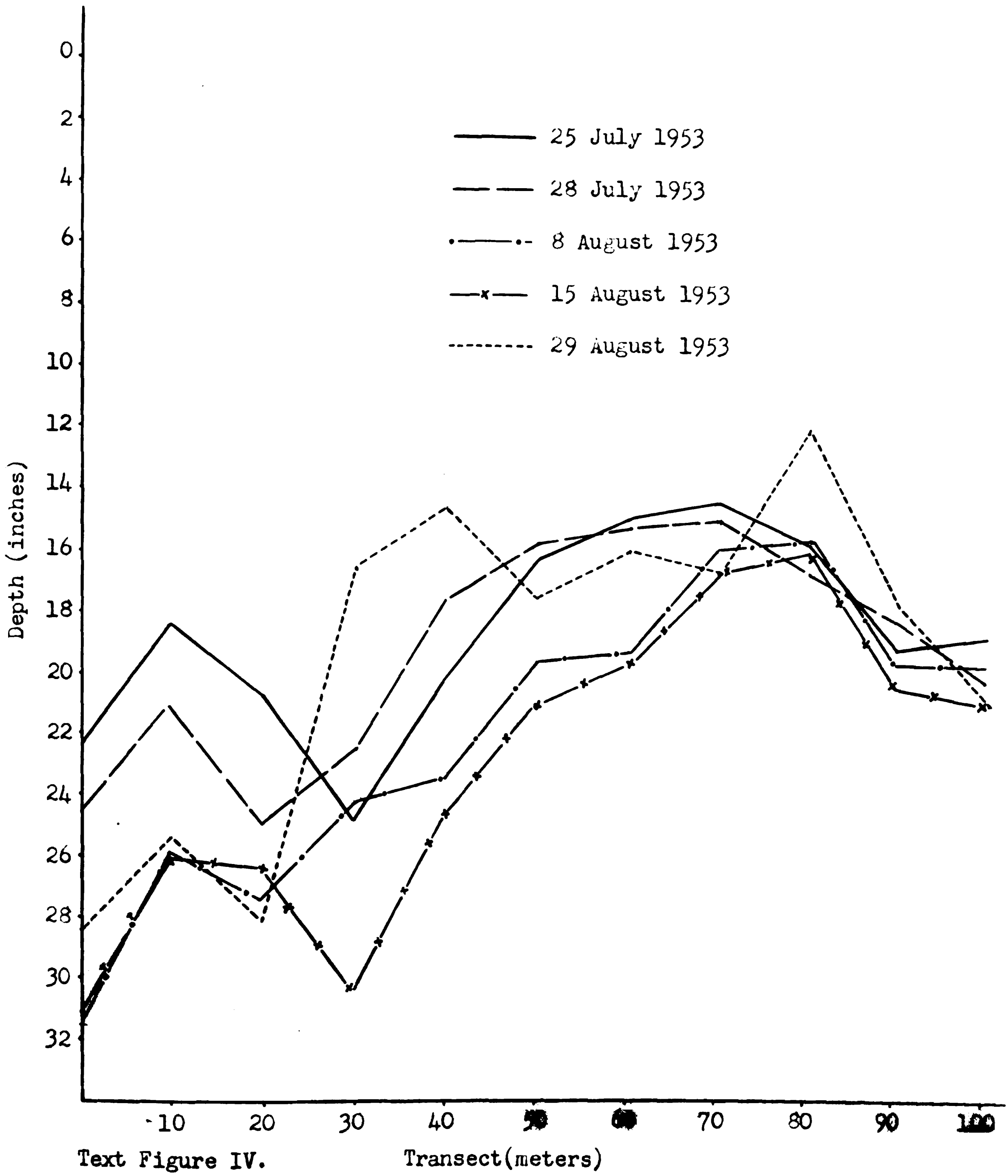
DEPTH OF ACTIVE ZONE TRANSECTS
POINT BARROW, ALASKA

Habitat	25 June	6 July	17 July	24 July	7 Aug	17 Aug	2 Sep
Polygonal Area	4.9*	6.2	7.5	9.7	11.1	12.0	11.0
Central Marsh	3.1	4.3	4.9	7.5	8.7	9.3	8.6
Beach Ridge	6.1	9.6	10.2	13.1	14.7	15.6	13.9

* In inches, a mean of 20 measurements

Active Layer Depths

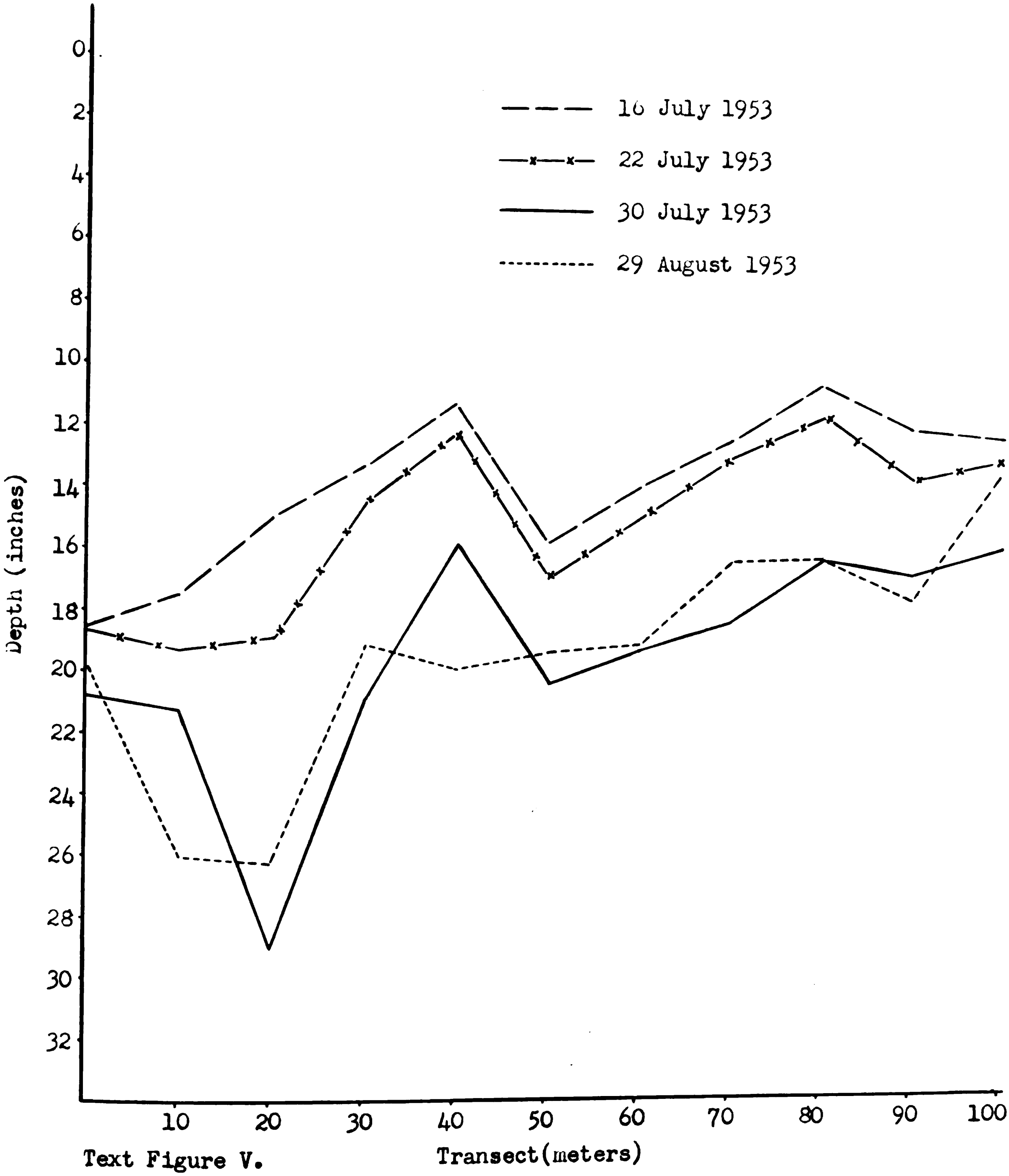
During Summer - Transect III



Text Figure IV.

Active Layer Depths

During Summer - Transect I



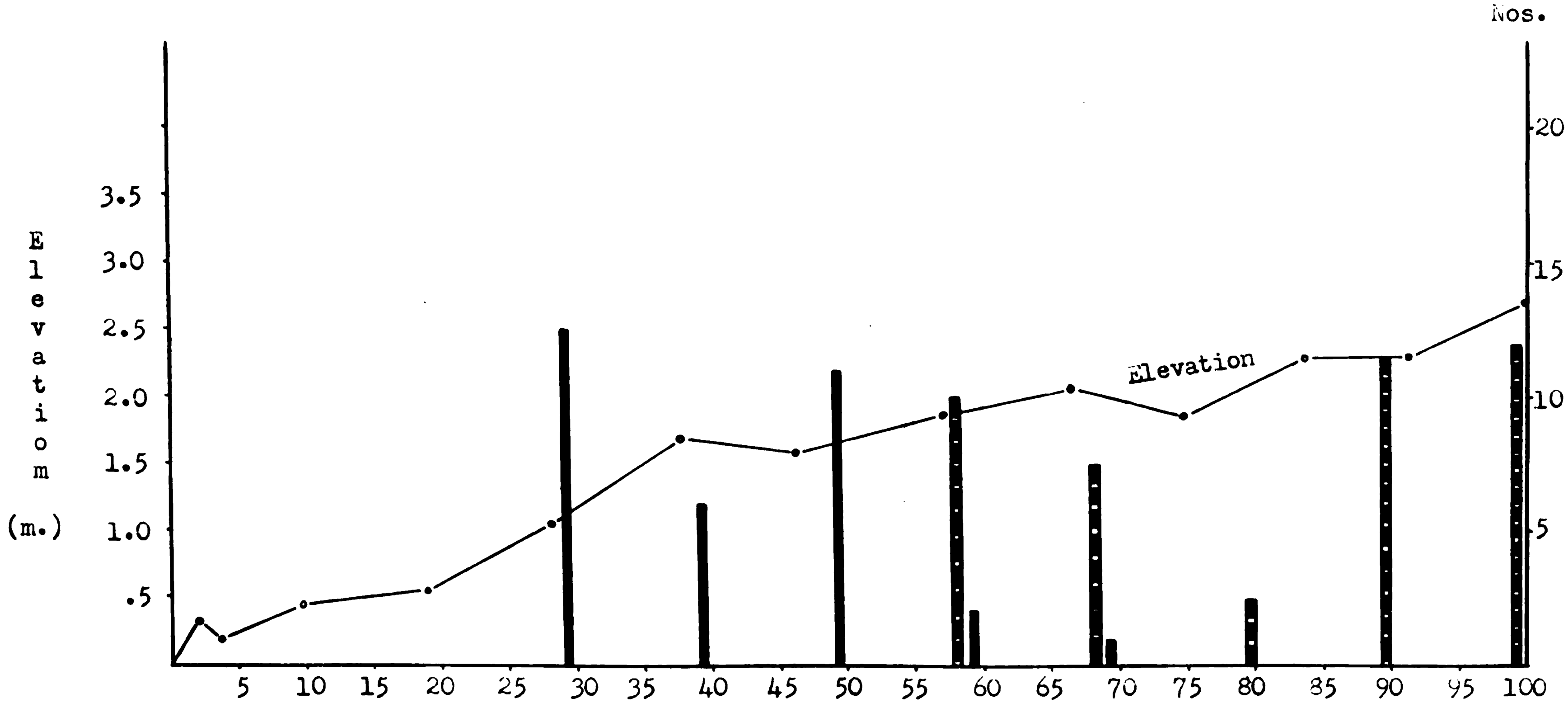
Text Figure V.

Histogram of Hummock and Frost Boil Occurrence

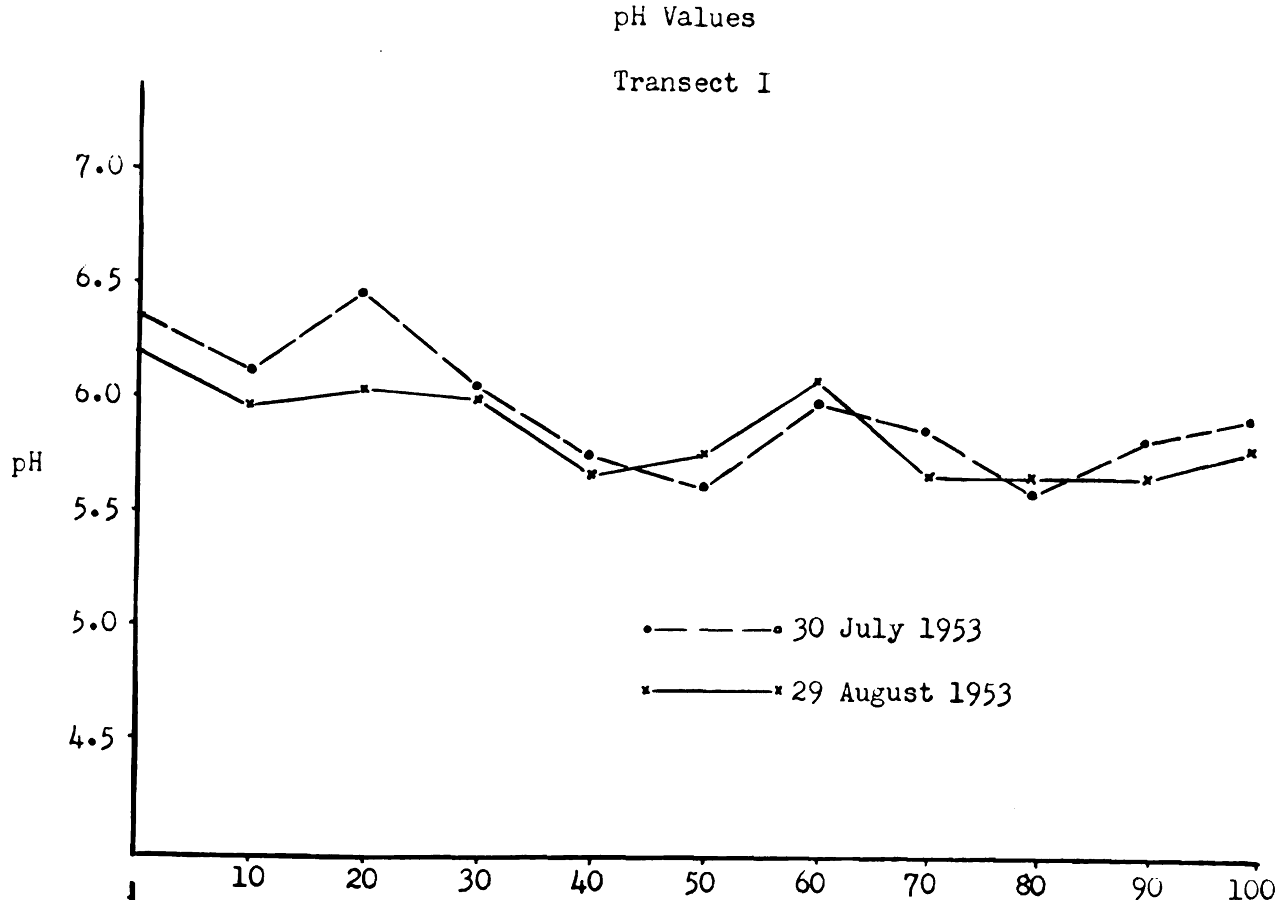
Transect III

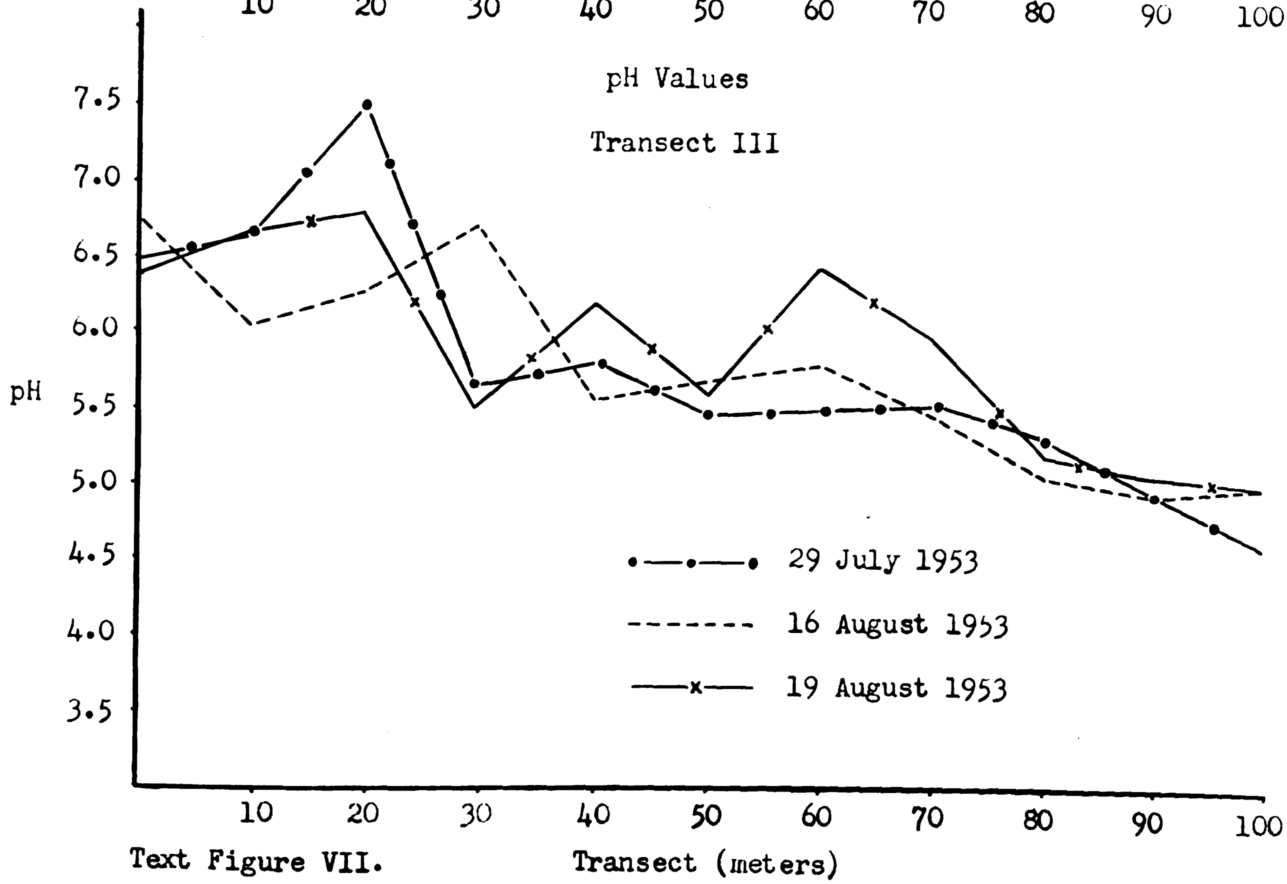
Actual number of "frost boils" in 1 m. X 100 m. transect area -

Actual number of hummocks in 1 m. X 100 m. transect area ------



Text Figure VI.





Text Figure VII.

SUMMARY

This phytosociological study concerns the vegetation of an uplifted marine beach ridge on the Arctic Coastal Plain, near Point Barrow, Alaska. The vegetational complex on the beach ridge was sampled quantitatively by list-quadrats placed randomly in a belt-transect.

These quantitative data were evaluated by three statistical methods:

(1) Comparisons of the observed frequency distribution with the Poisson series.

(2) Density histograms -- which diagrammed the actual number of individuals occurring in each quadrat.

(3) Measures of aggregation -- statistical indices which evaluate the amount of aggregation in the distribution of a species.

Few species were found to have distributions that approximated the Poisson distribution. The density histograms revealed relationships existing between the contour of the beach ridge and soil pH. The histograms also furnished a basis of comparison for evaluating the measures of aggregation.

The measures of aggregation were found to agree with the distributions of the species as indicated by the histograms.

The effect of the number of quadrats and the size of the quadrat upon density, frequency, and the measures of aggregation was analyzed.

Twenty-one quadrats were found to be as effective a sample as 100 if the object of the sampling was merely to determine the dominant species. If phytosociological relationships were to be investigated, a larger sample was recommended. The relative order of the species in regard to the degree of aggregation was affected by the number of quadrats used, especially when micro-distributional factors were present.

It was shown that density was proportional to quadrat size, when density was defined as the number of individuals per quadrat. Frequency, however, did not react to quadrat size in the same manner. The degree of aggregation apparently influenced the change of frequency that occurred when the quadrat size was reduced.

The measures of aggregation were also affected by quadrat size and tended to misrepresent the degree of aggregation when the smaller quadrats were used. This was especially evident when the species were distributed very contagiously.

A comparison was made of two transects, which represented distinct areas on the beach ridge. On the basis of species alone, the higher area could be identified as a more xeric site.

The measurement of percentage cover was accomplished by a photographic method for two species, Salix rotundifolia and Petasites frigidus. Salix rotundifolia was shown to exhibit low cover values on extremely moist sites and on areas affected by soil-frost activities. The frequency of Salix rotundifolia in the photographic sample was approximately

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The relationship of percentage cover to density was determined for Petasites frigidus. The effects of micro-habitat were analyzed in relation to percentage cover and density and found to be related.

Variations in the vegetational pattern were found to be correlated primarily with soil-frost phenomena, structure of the ridge, and chemistry of the soil. Climatic factors such as exposure to wind, and snow cover were also effective.

An analysis of the structure of the beach ridge and the component soils revealed several correlations with vegetative characteristics. Soil-frost phenomena were shown to create a habitat which possibly excluded a species but which, more often, merely caused a reduction in density. The particular conditions of active zone depth and snow cover were discussed briefly. The beach ridge was found to have a deeper active layer than either the marsh or polygonal habitats. The early withdrawal of snow cover was also indicated by the series of readings made in several sites.

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APPENDIX

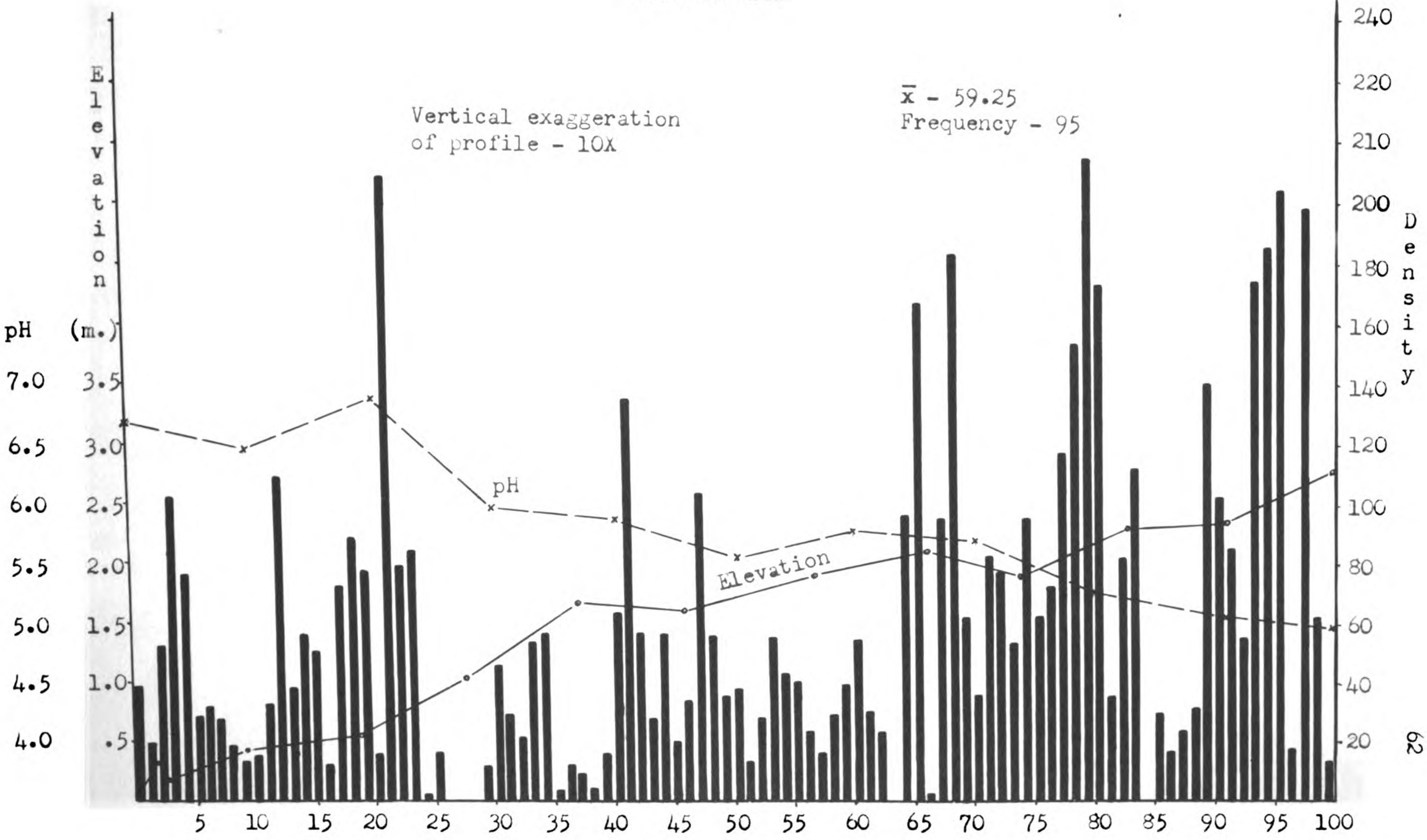
Histograms

Frequency Distribution Figures

Tables

Density Histogram of <u>Poa</u> <u>arctica</u> R.Br.

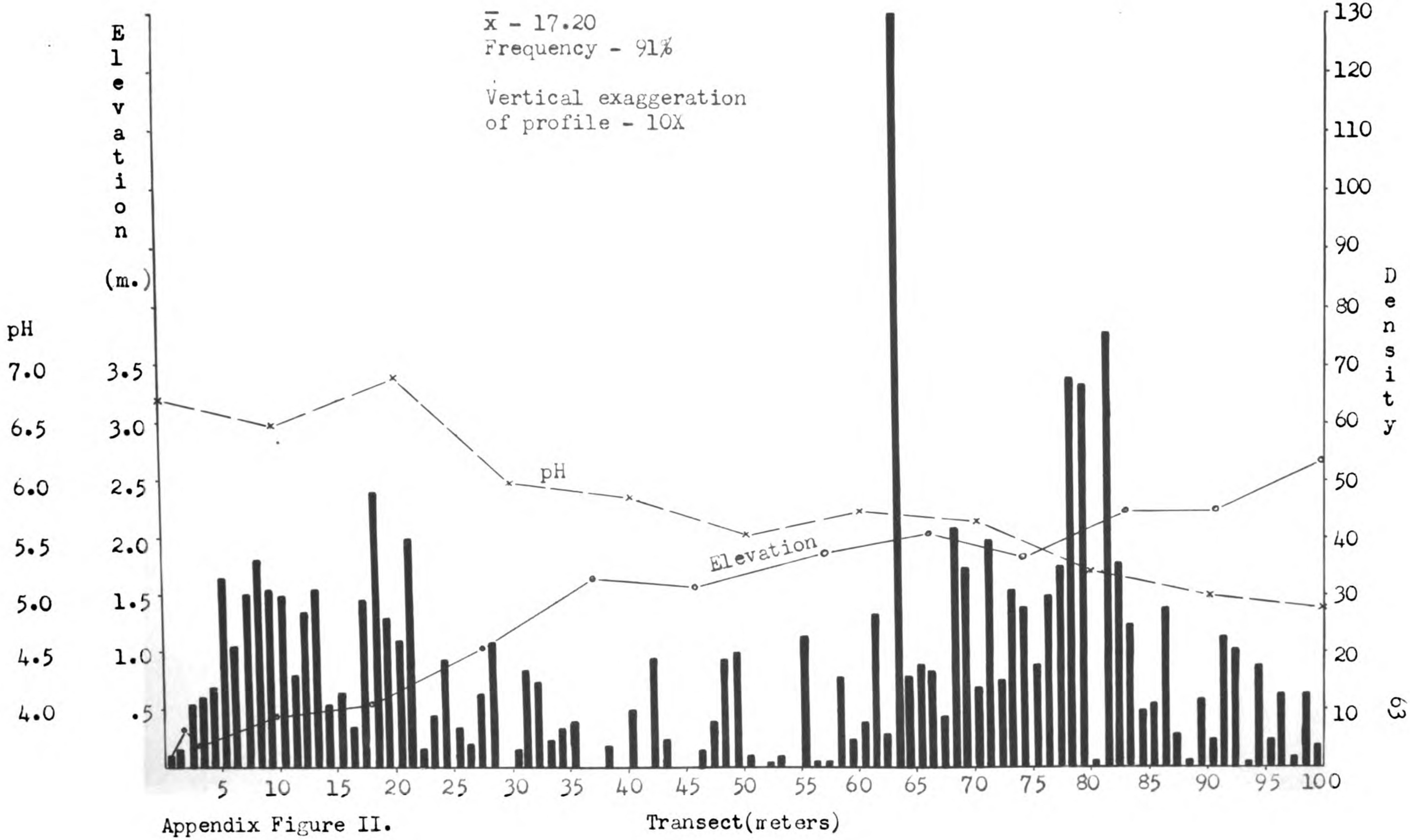
Transect III



Appendix Figure I.

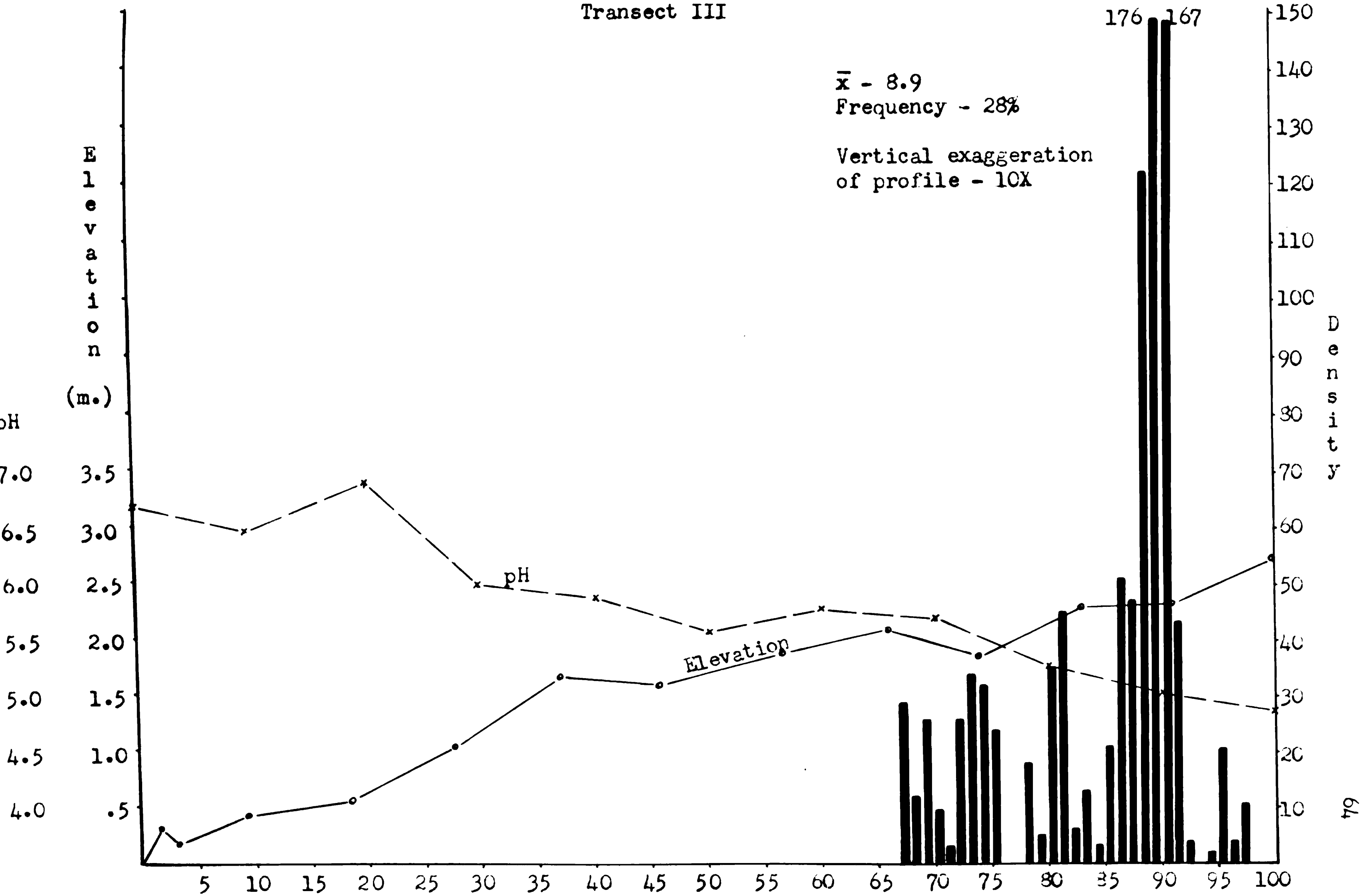
Density Histogram of <u>Arctagrostis</u> <u>latifolia</u> (R.Br.) Griseb.

Transect III



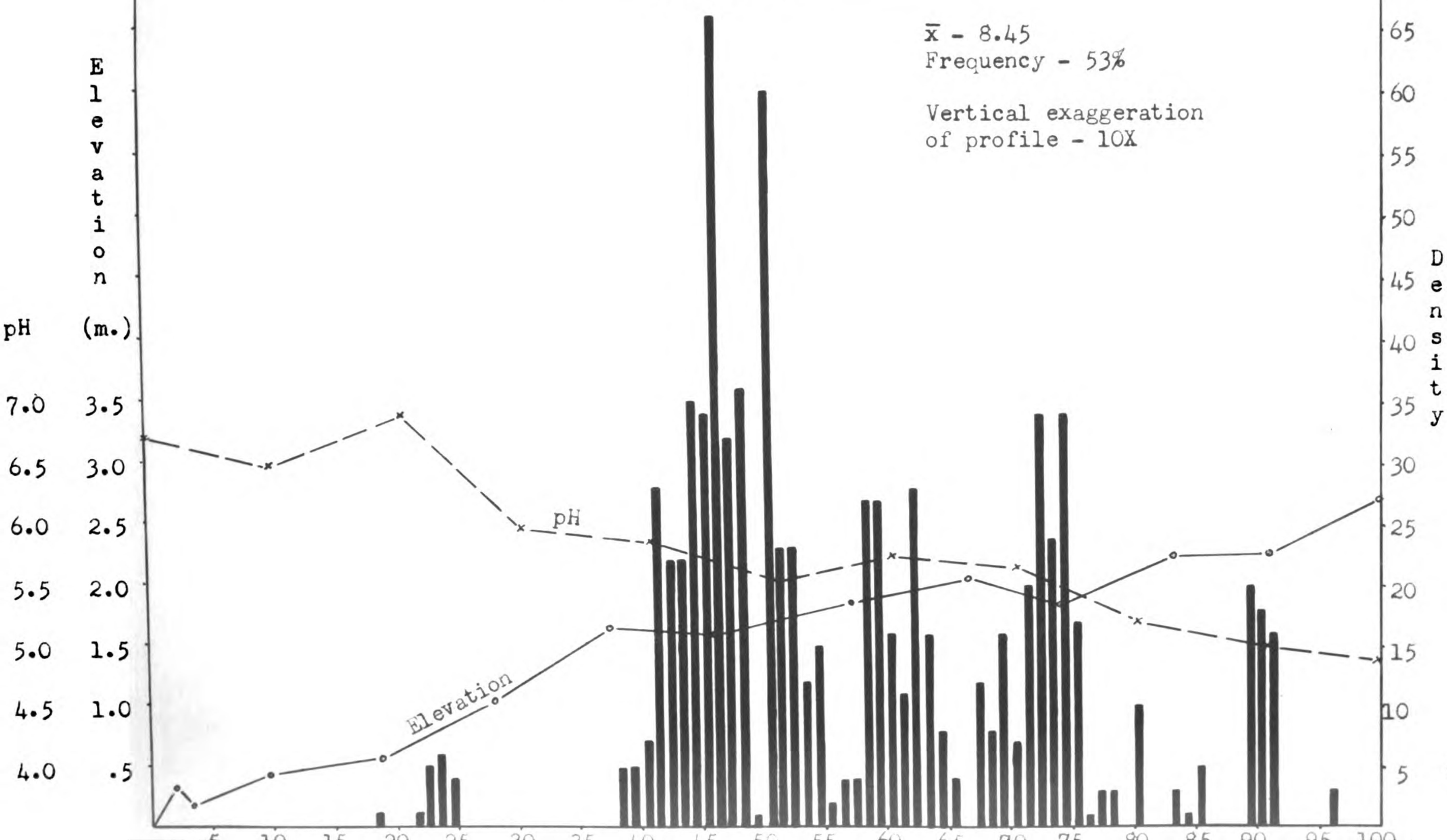
Appendix Figure II.

Density Histogram of <u>Eriophorum scheuchzeri</u> Hoppe



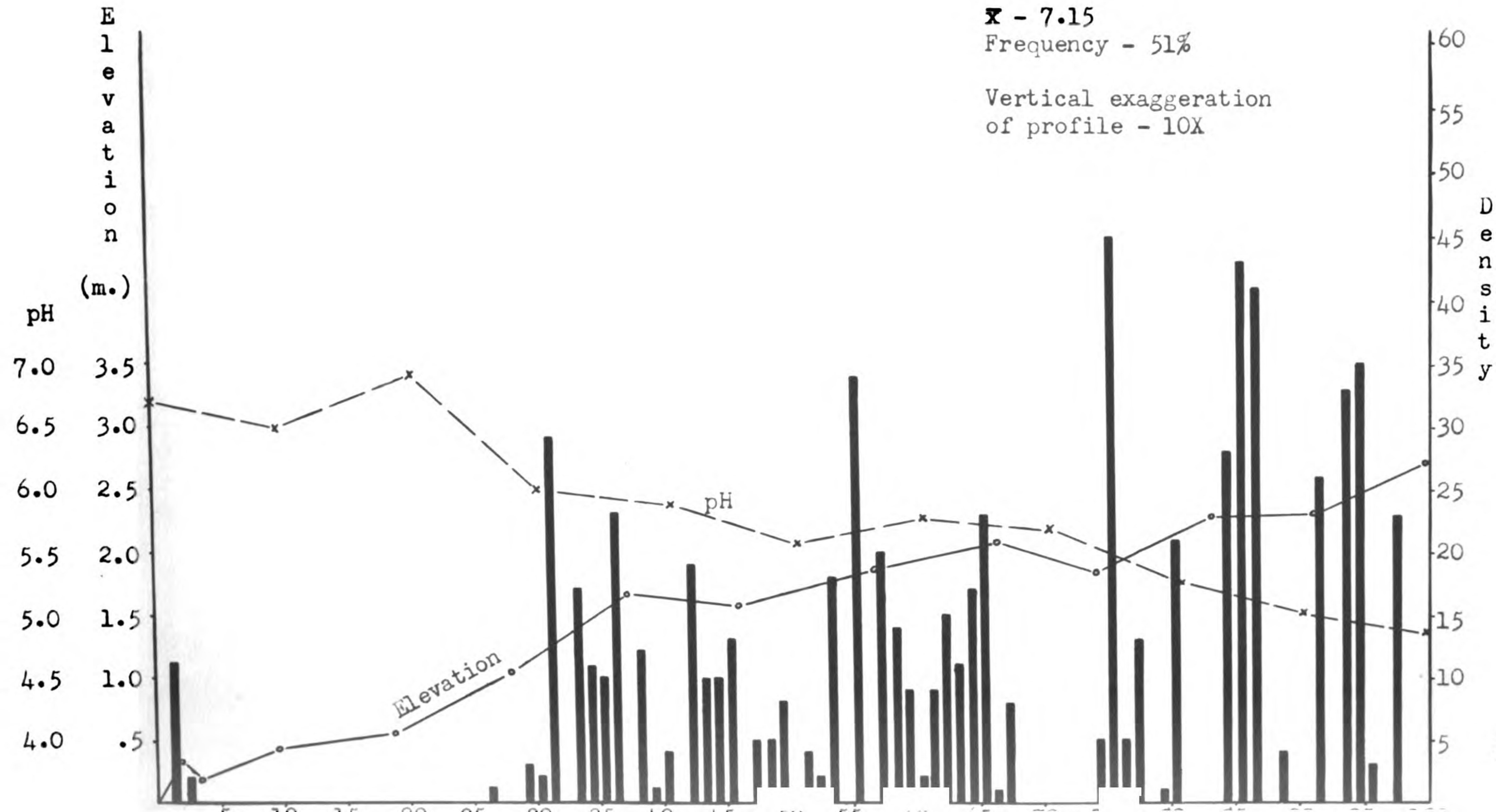
Appendix Figure III.

Density Histogram of <u>Carex</u> <u>aquatilis</u> Wahl.
Transect III



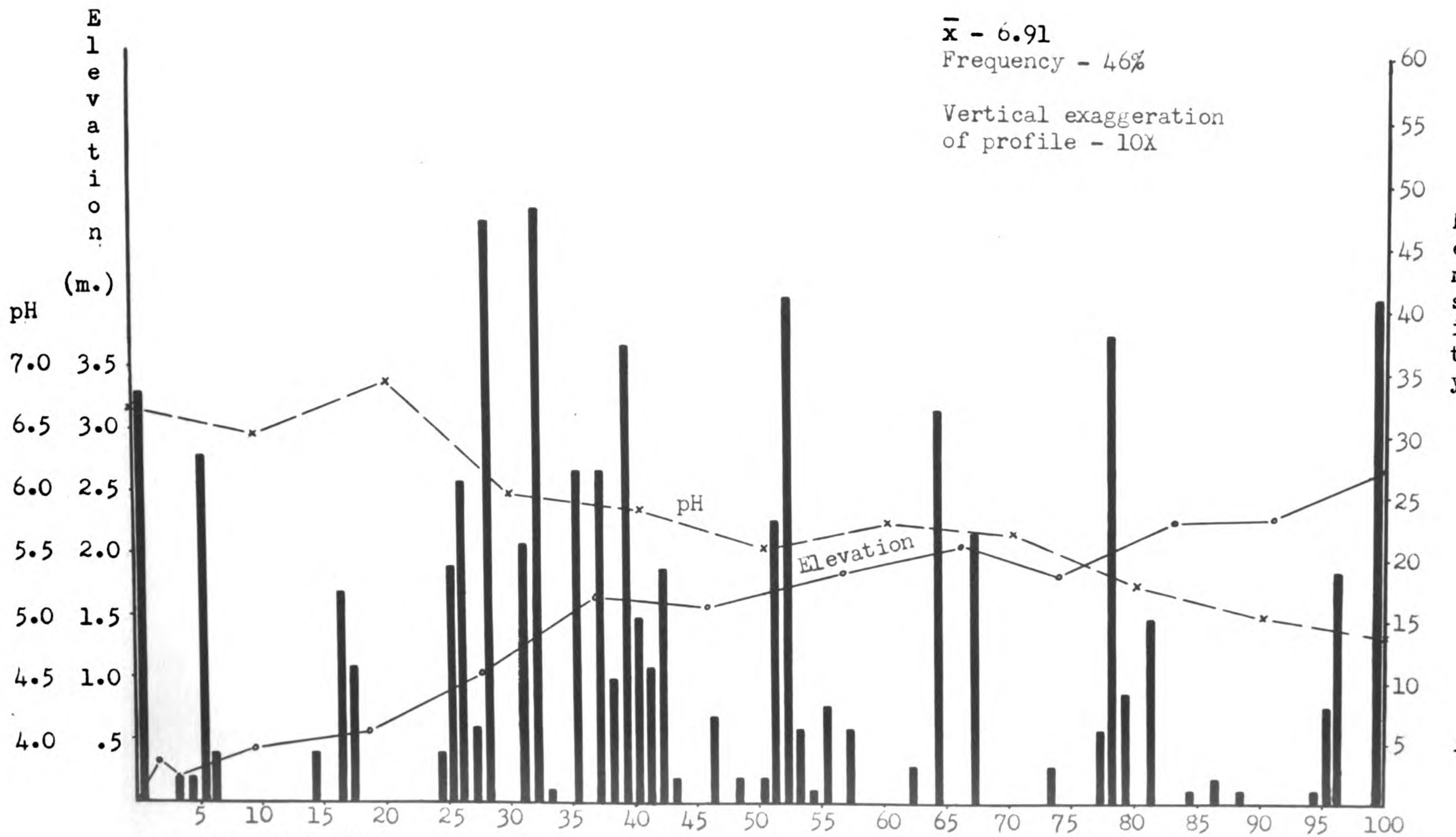
Density Histogram of Luzula nivalis (Laest.) Beurl. var. latifolia (Kjellm.) Sam.

Transect III



Density Histogram of <u>Luzula</u> <u>confusa</u> Lind.

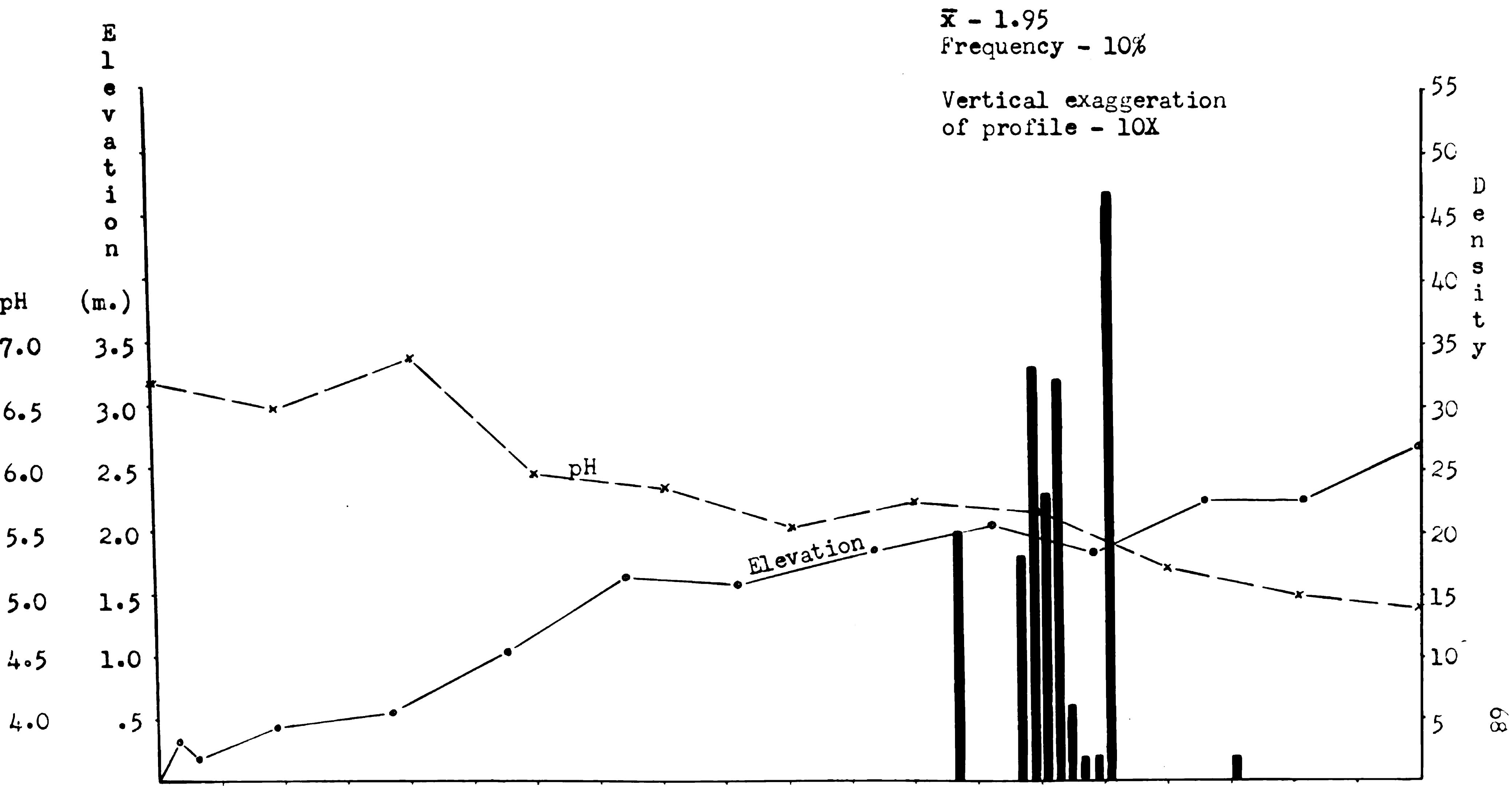
Transect III



Appendix Figure VI.

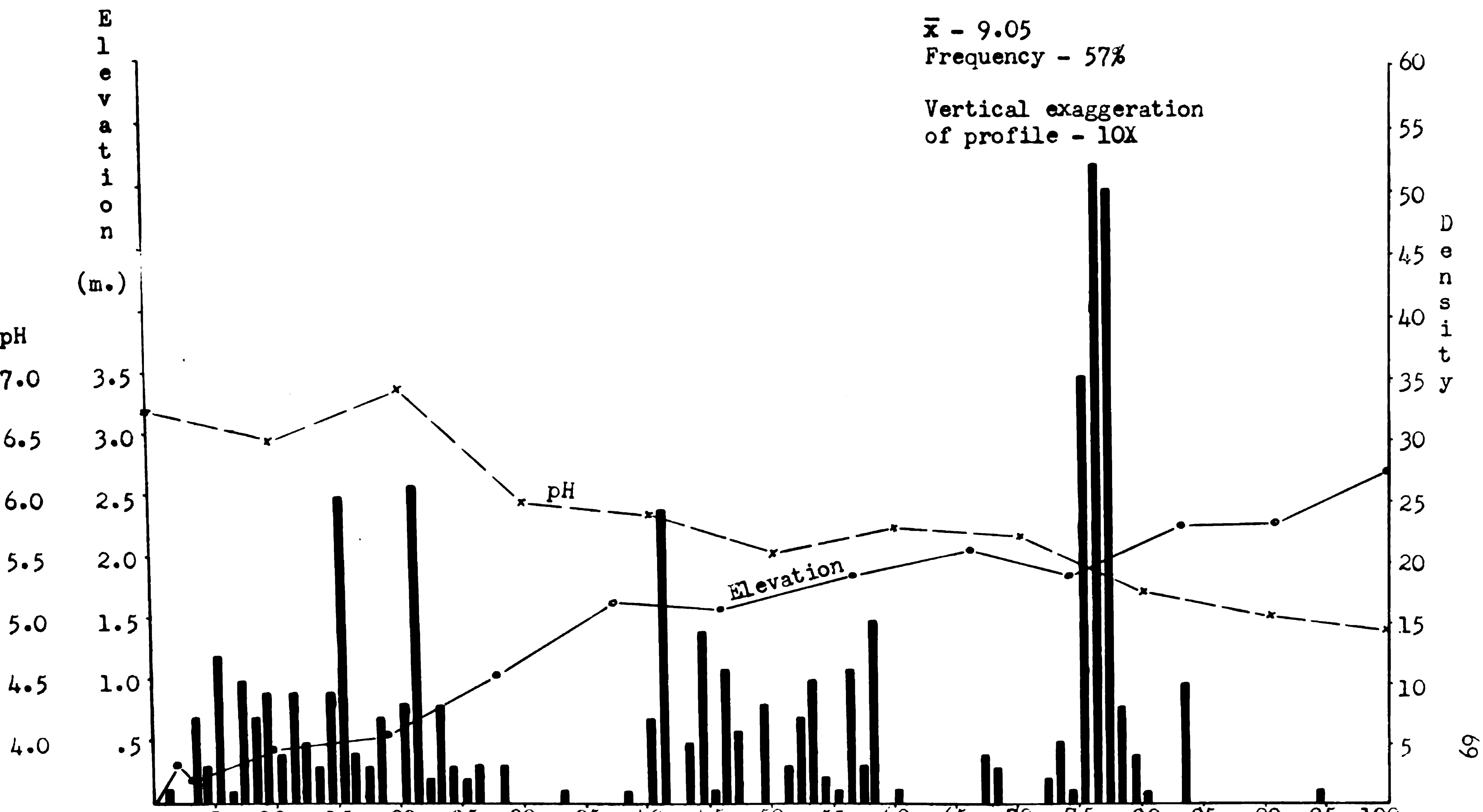
Density Histogram of Eriophorum angustifolium Honcheny.

Transect III



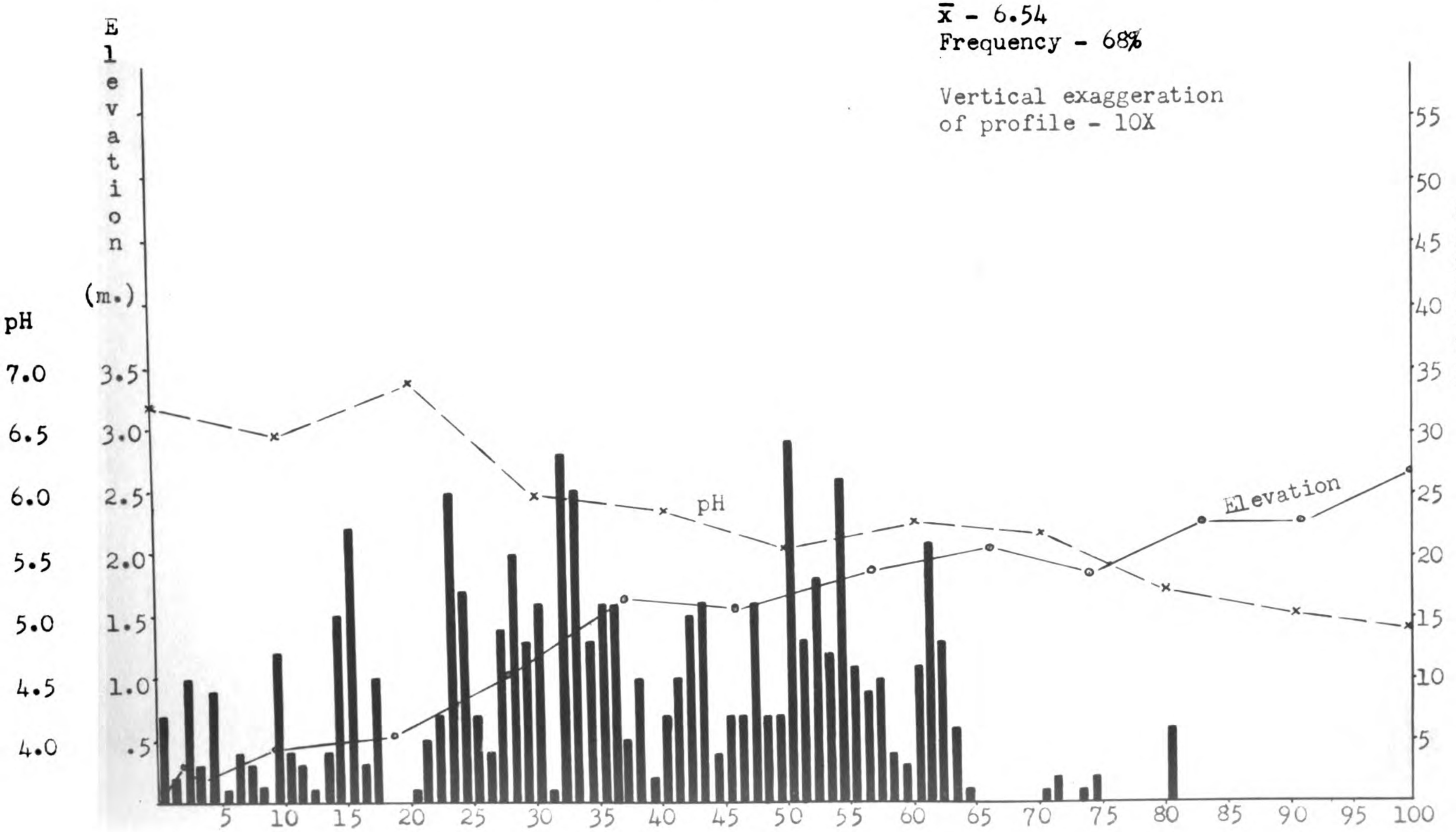
Density Histogram of Saxifraga cernua L.

Transect III



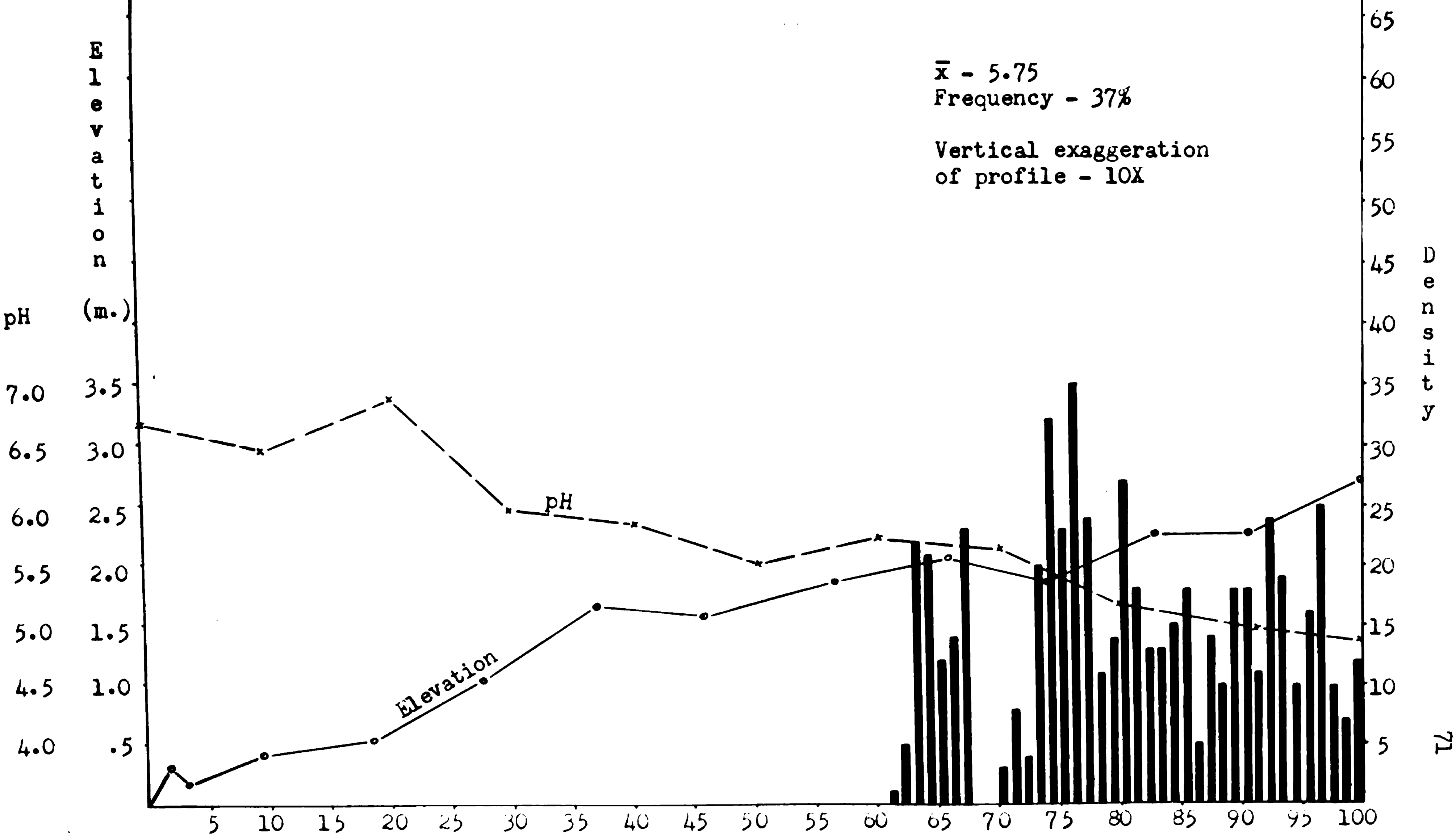
Density Histogram of Stellaria laeta Richards.

Transect III



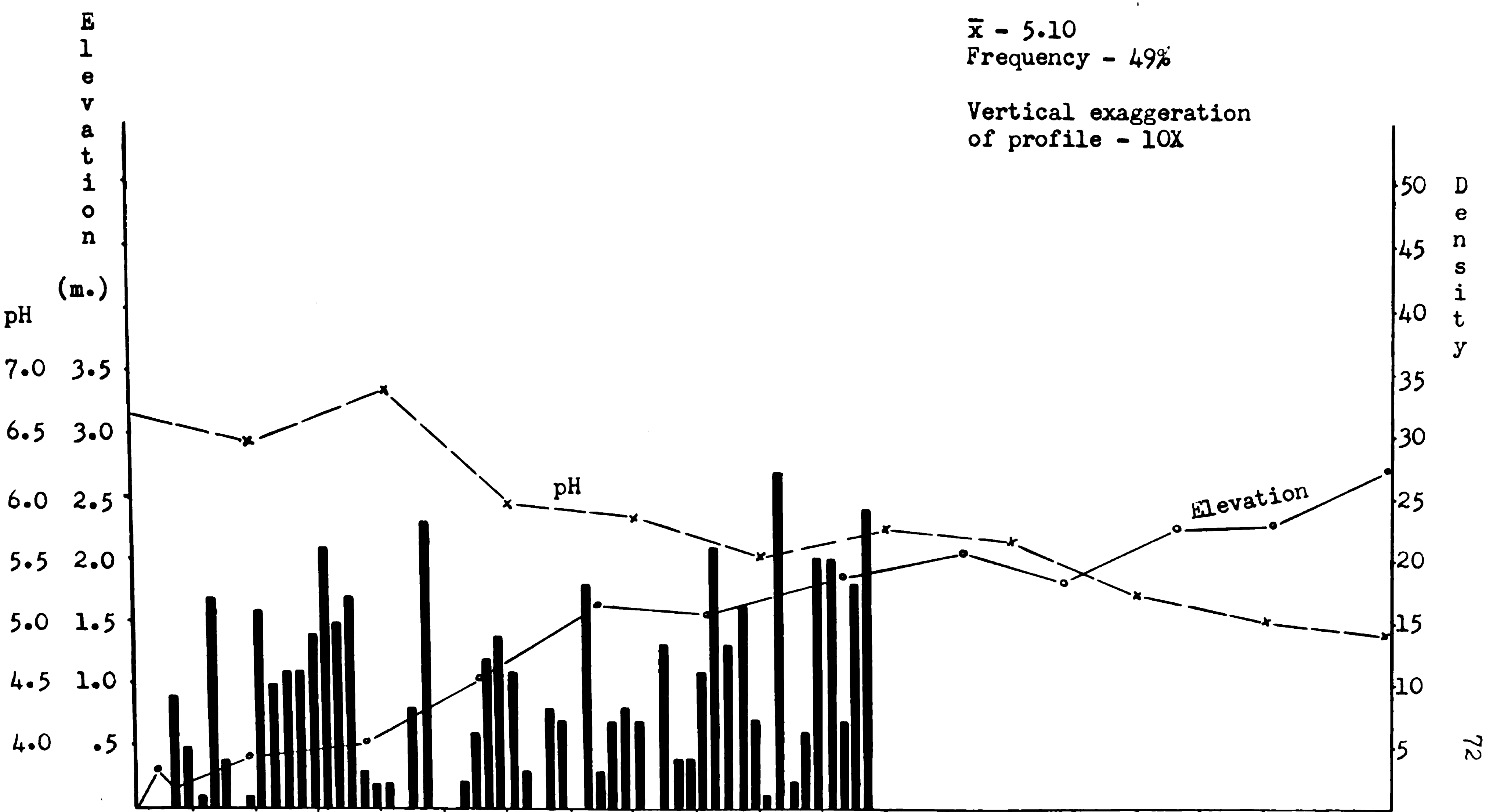
Density Histogram of Petasites frigidus(L.) Fries.

Transect III



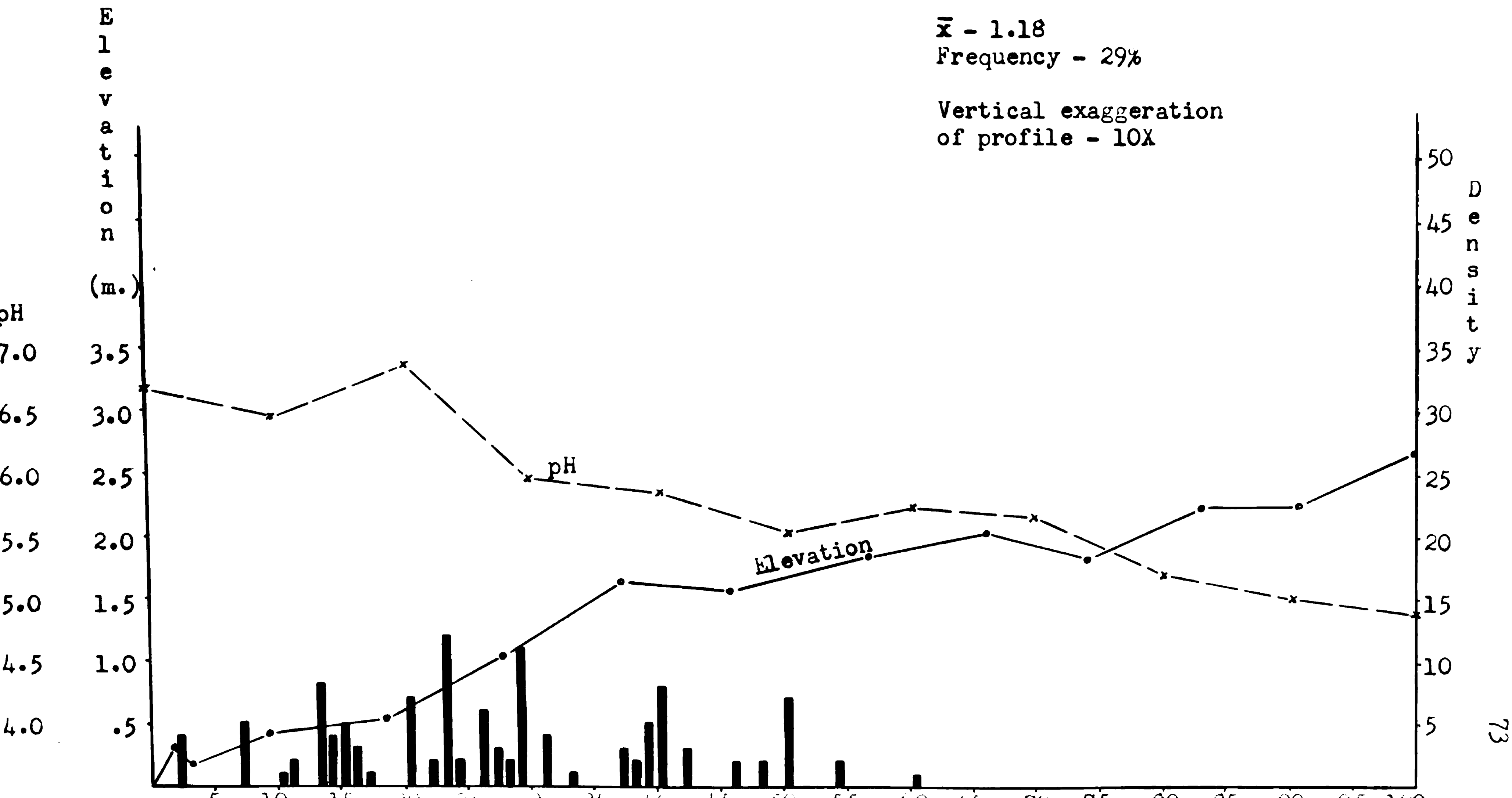
Density Histogram of <u>Senecio atropurpureus</u> (Lebed.) Fedtsch.

Transect III



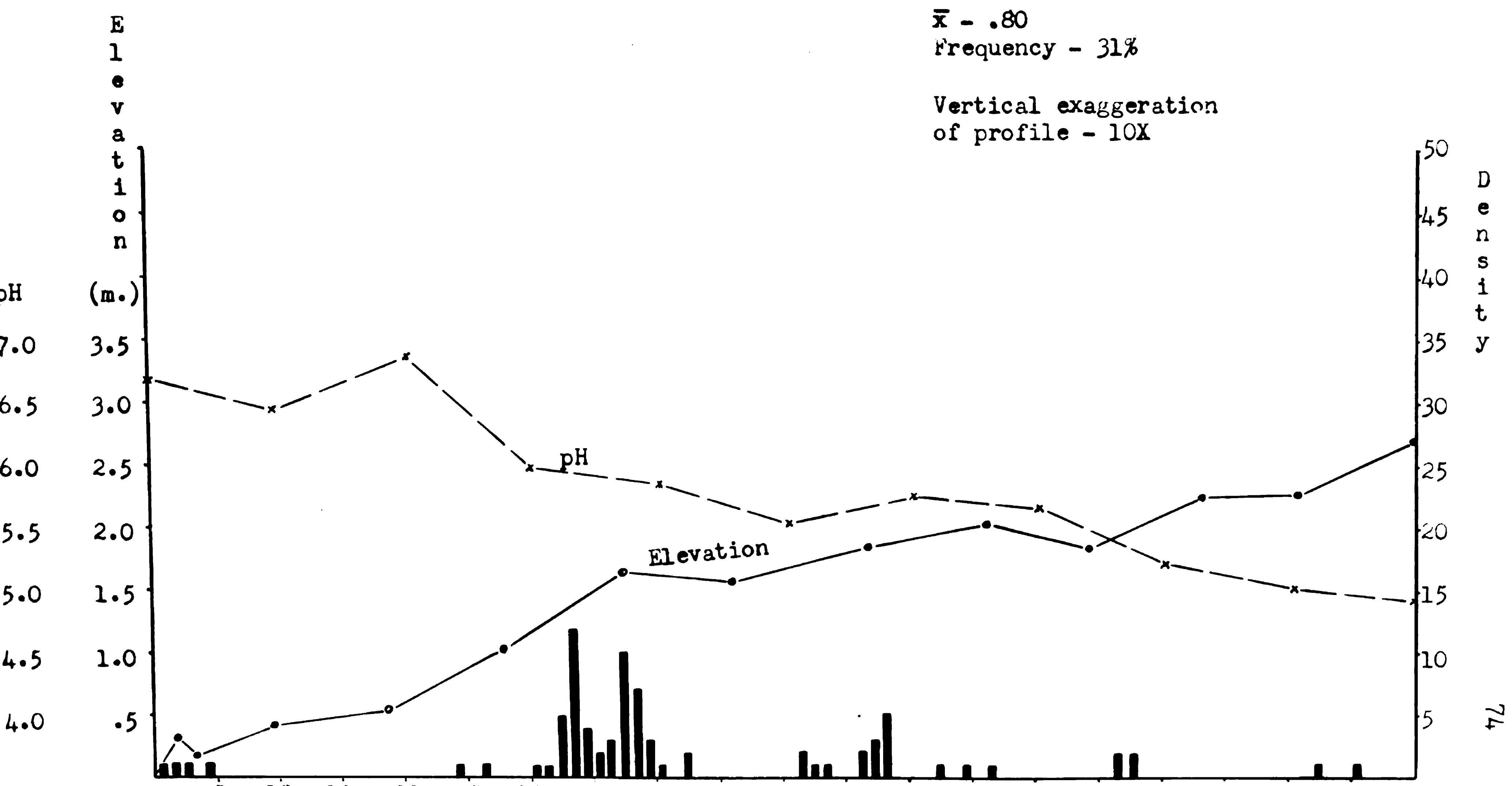
Density Histogram of Saxifraga punctata L. subsp. nelsoniana (D.Don.) Hult.

Transect III



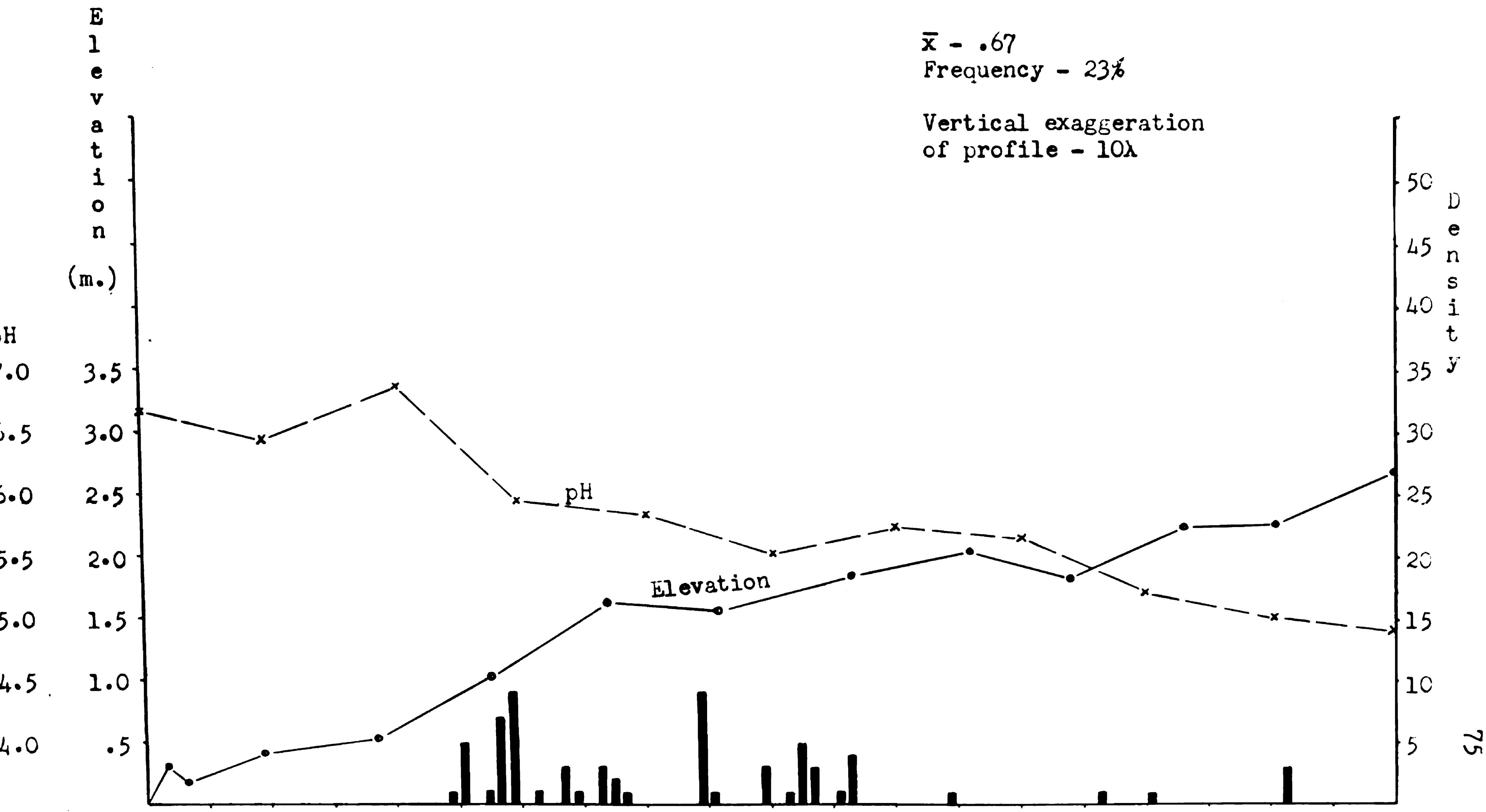
Density Histogram of <u>Potentilla</u> <u>emarginata</u> Pursh.

Transect III



Density Histogram of <u>Saxifraga</u> <u>foliolosa</u> R.Br.

Transect III



Density Histogram

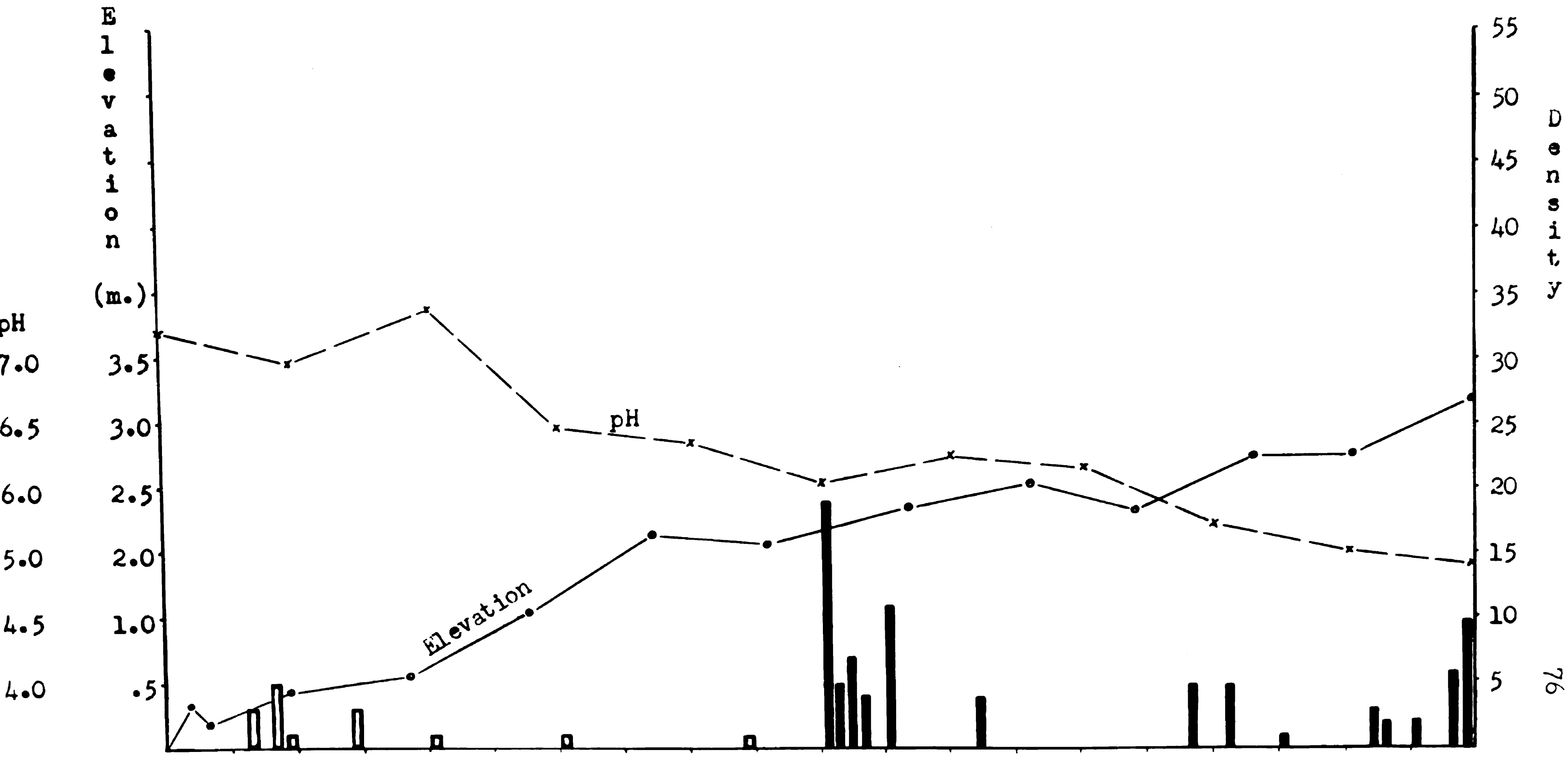
<u>Saxifraga</u> <u>flagellaris</u> Willd. ex Sternb.

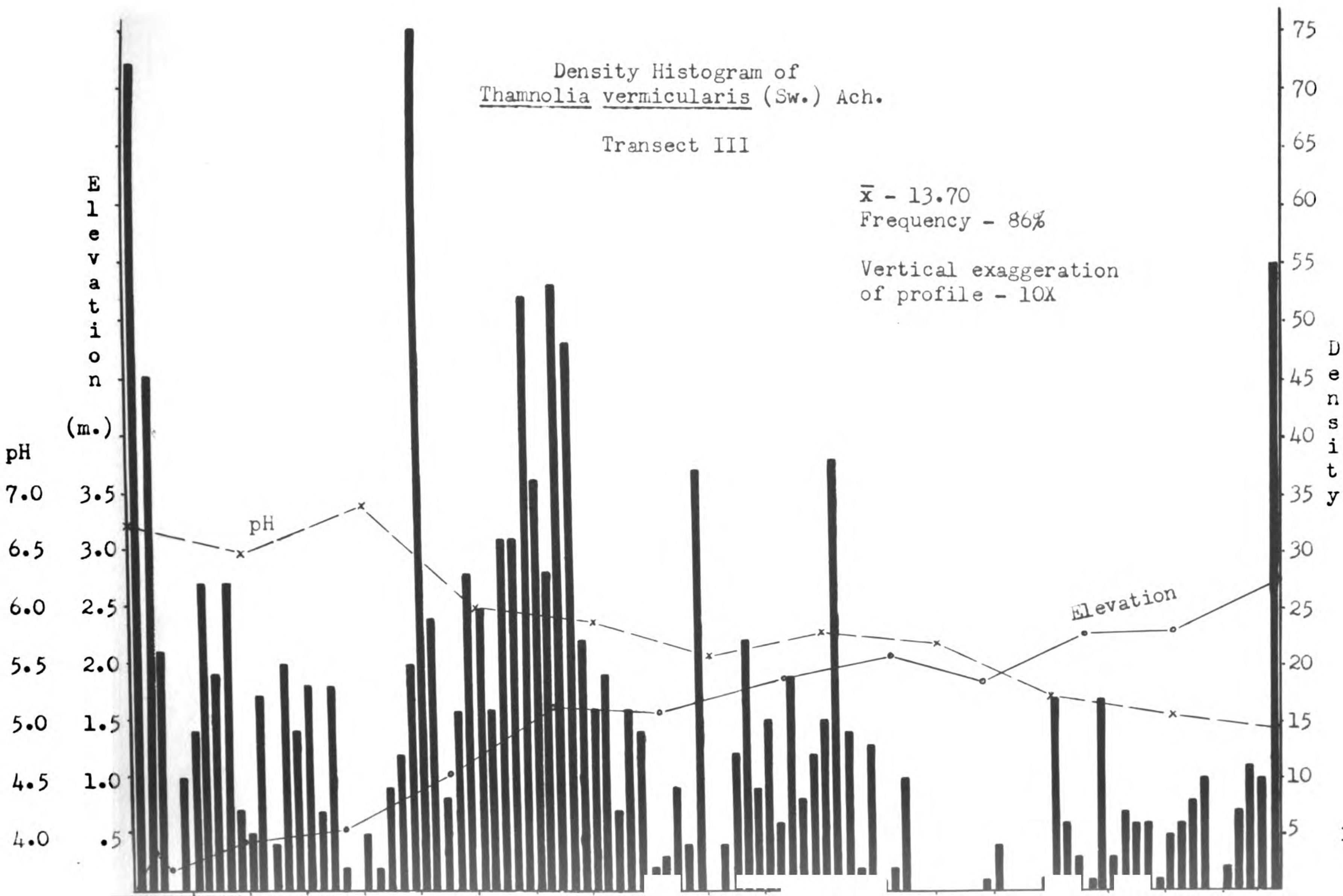
$\bar{x}$ - .15
Frequency - 7%

<u>Vaccinium</u> <u>vitis-idaea</u> L. subsp. <u>minus</u> (Lodd.)Hult.

$\bar{x}$ - .84
Frequency - 15%

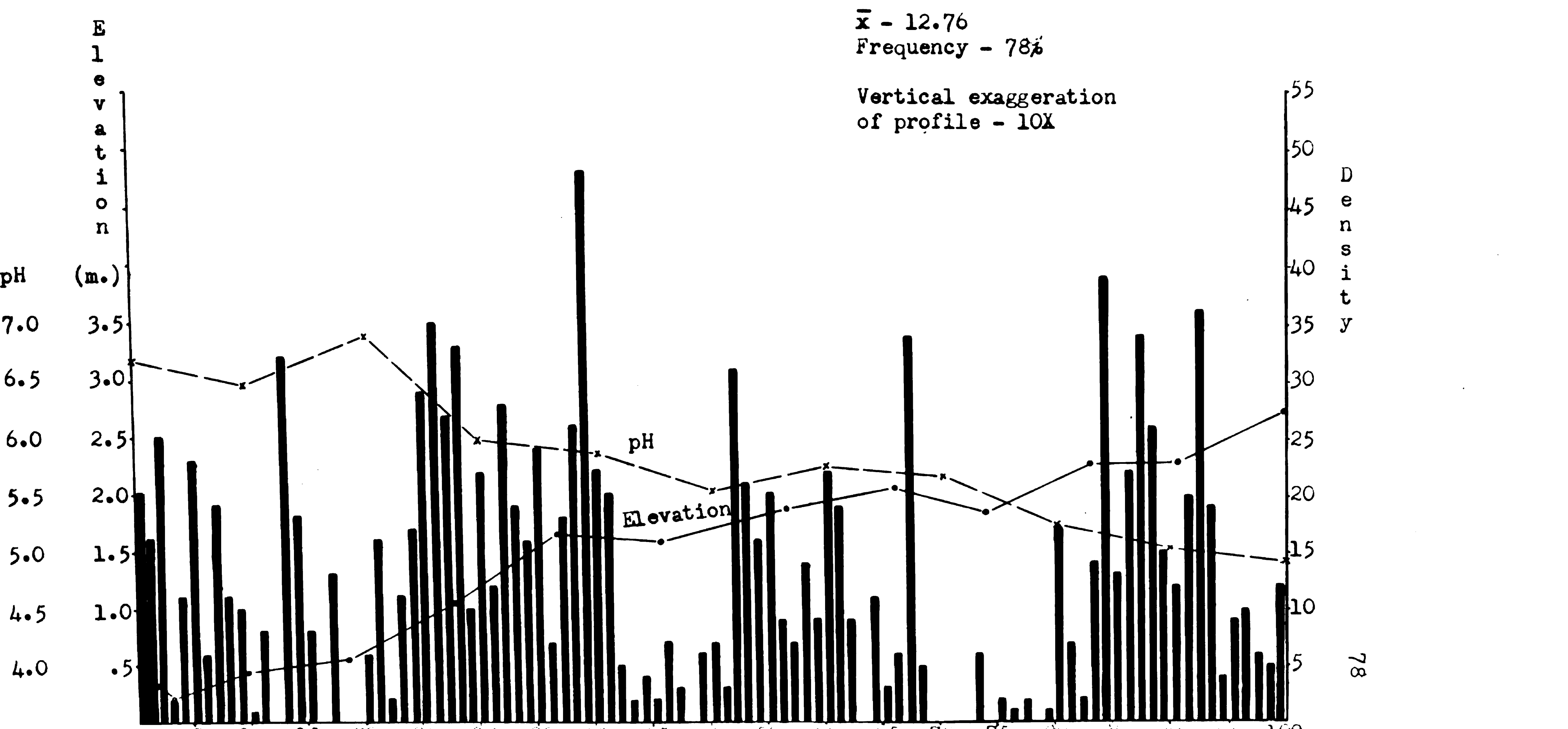
Vertical exaggeration
of profile - 10X




Density Histogram of
Thamnolia vermicularis (Sw.) Ach.
Transect III
$\overline{x}$ - 13.70
Frequency - 86%
Vertical exaggeration
of profile - 10X
pH
Elevation
Elevation (m.)
3.5
3.0
2.5
2.0
1.5
1.0
.5
pH
7.0
6.5
6.0
5.5
5.0
4.5
4.0
Density
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5

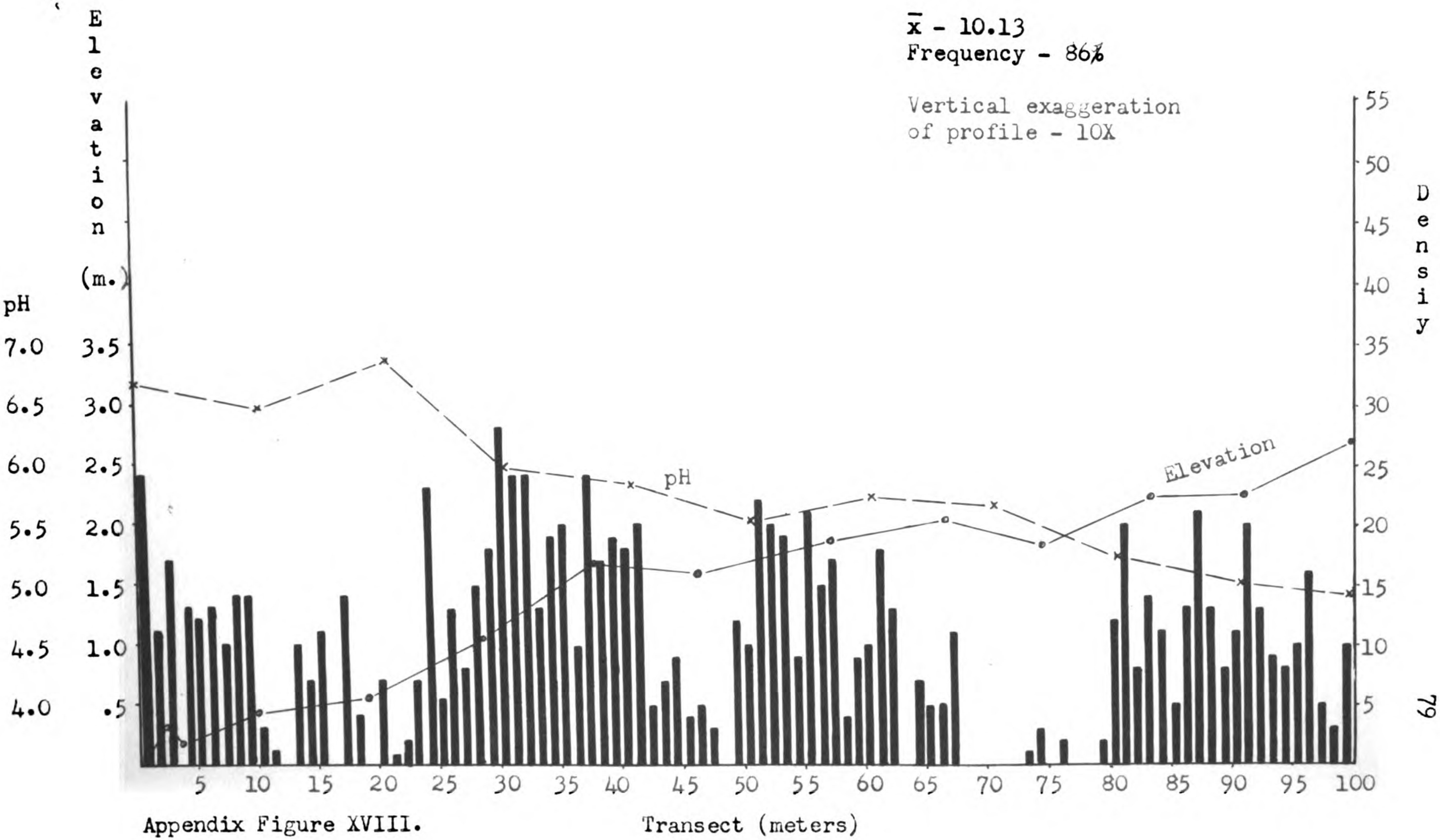
Density Histogram of <u>Dactylina arctica</u> (Hook.) Nyl.

Transect III



Density Histogram of Cetraria islandica (L.) Ach.

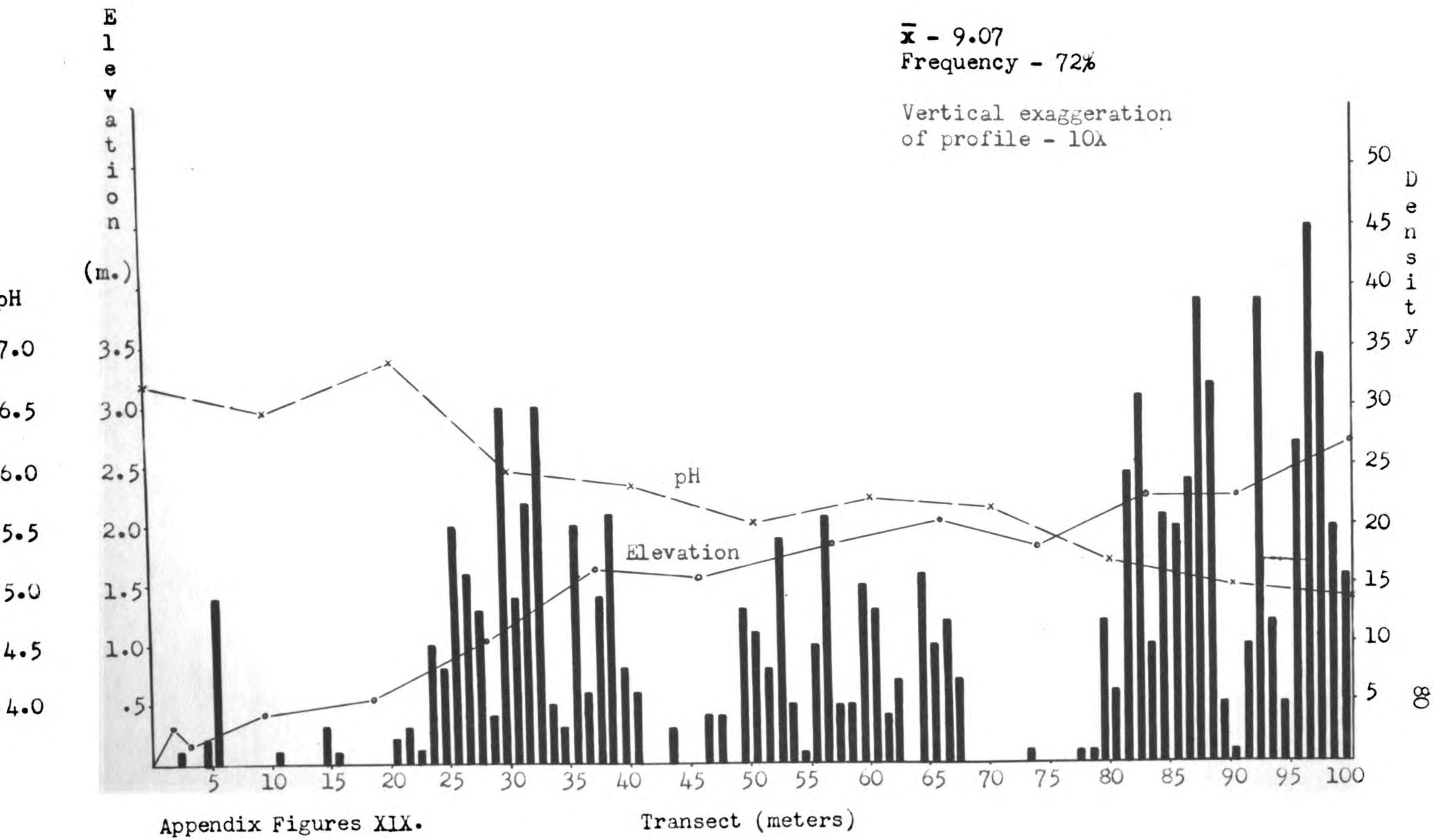
Transect III



Appendix Figure XVIII.

Density Histogram of <u>Sphaerophorus globosus</u> (Huds.) Vain.

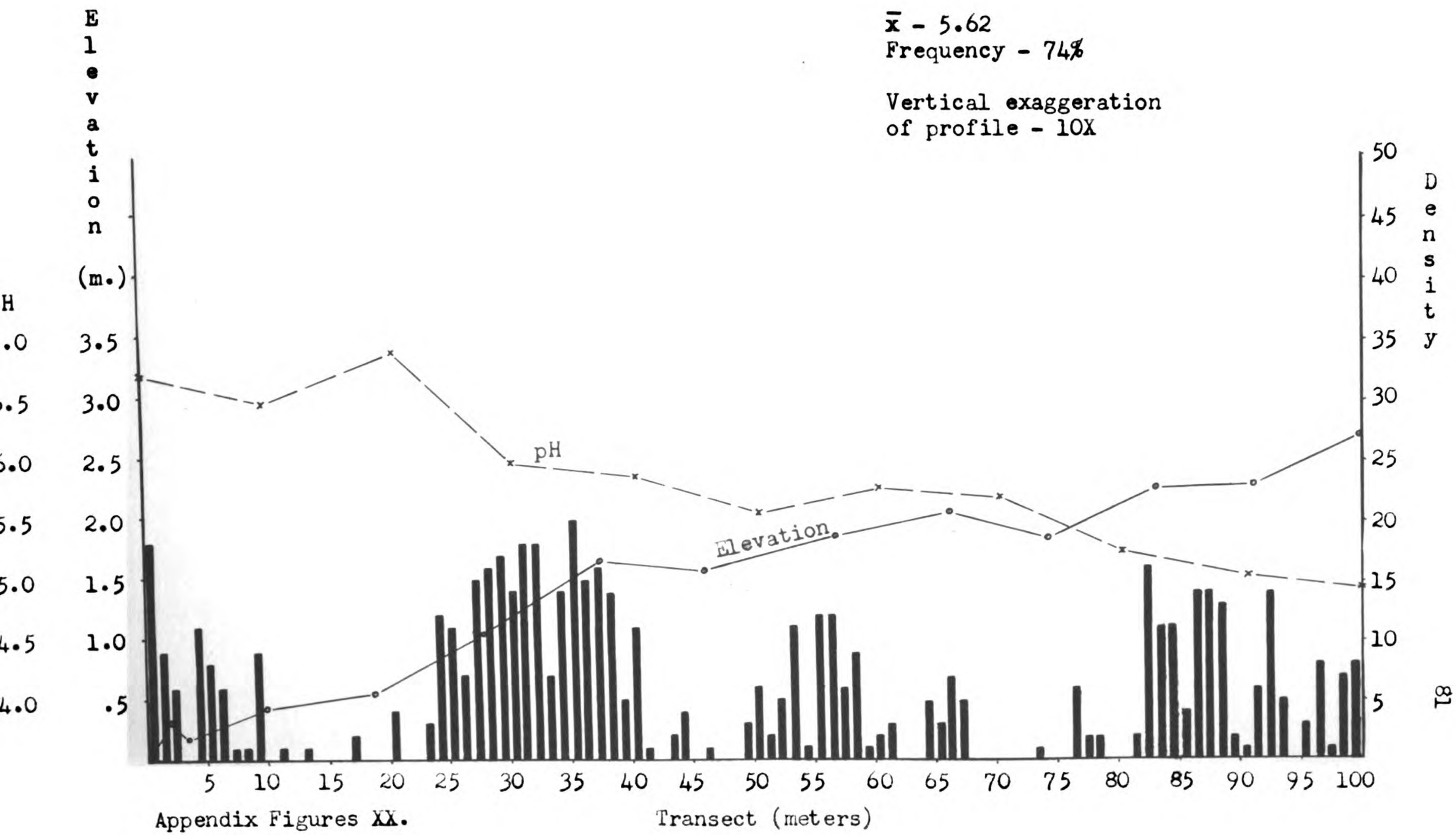
Transect III



Appendix Figures XIX.

Density Histogram of <u>Cornicularia divergens</u> Ach.

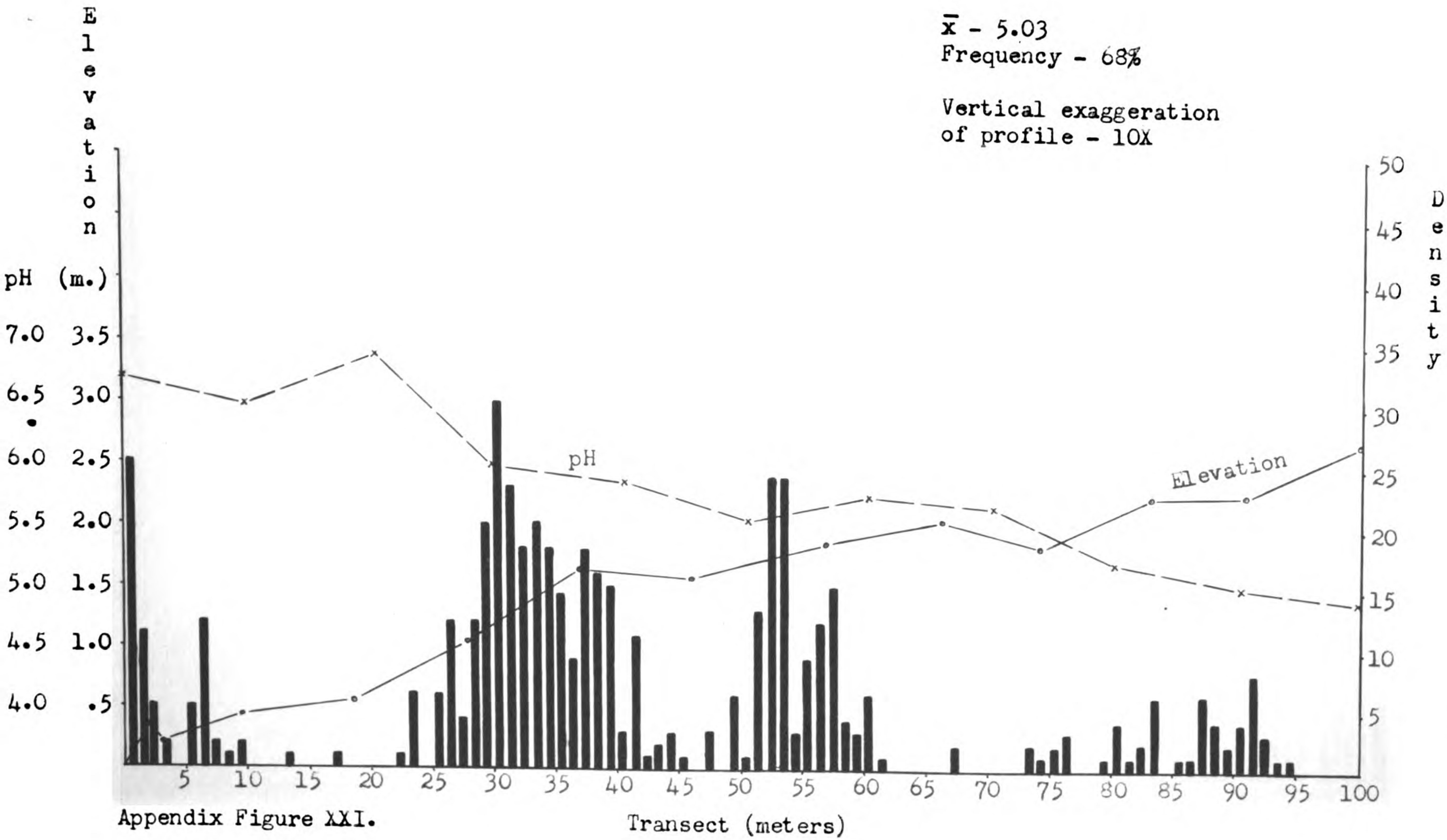
Transect III



Appendix Figures XX.

Density Histogram of Cetraria nivalis (L.) Ach.

Transect III



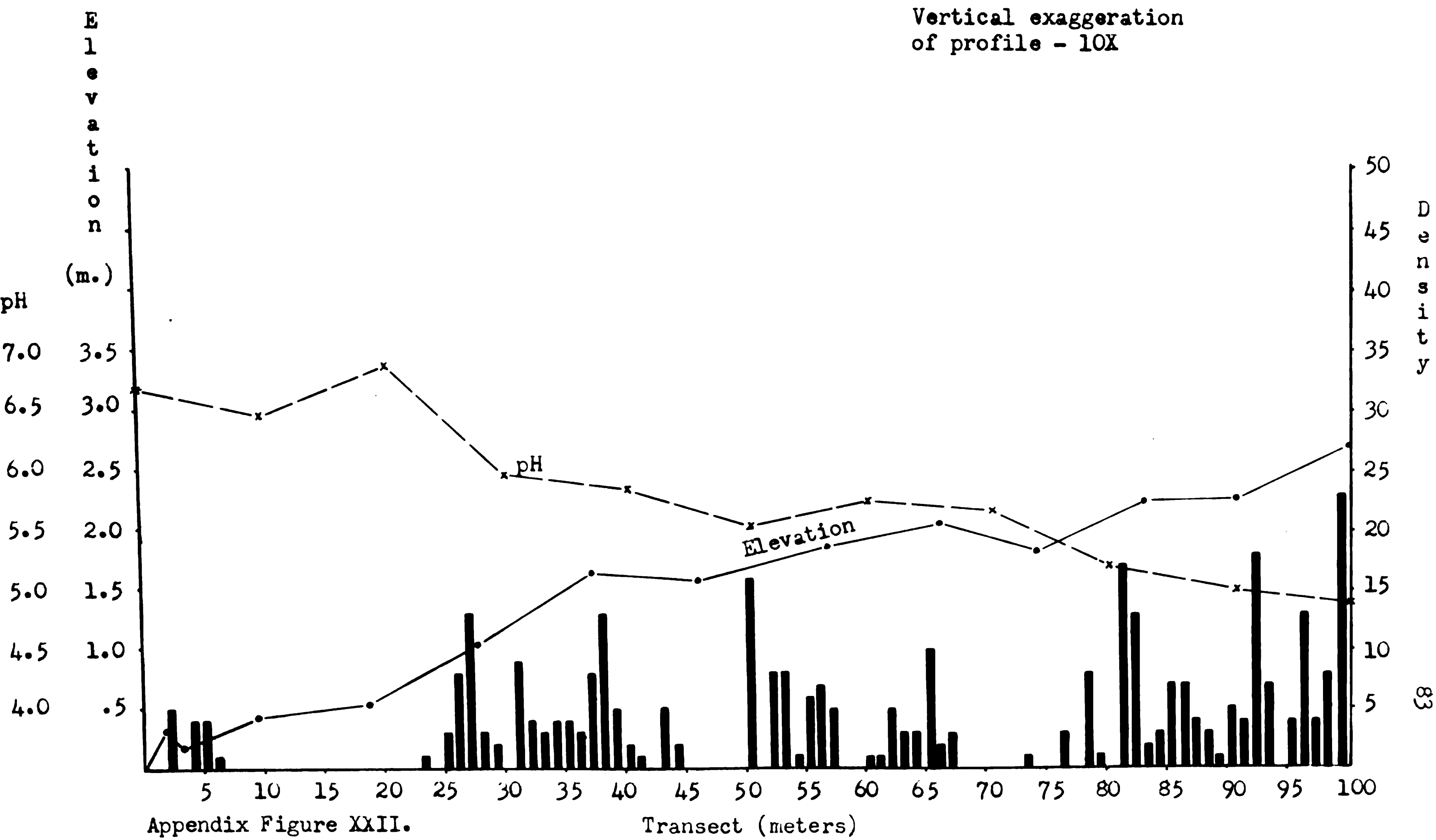
Appendix Figure XXI.

Density Histogram of <u>Cladonia</u> <u>sp</u>.

Transect III

$\bar{x}$ - 3.42
Frequency -60%

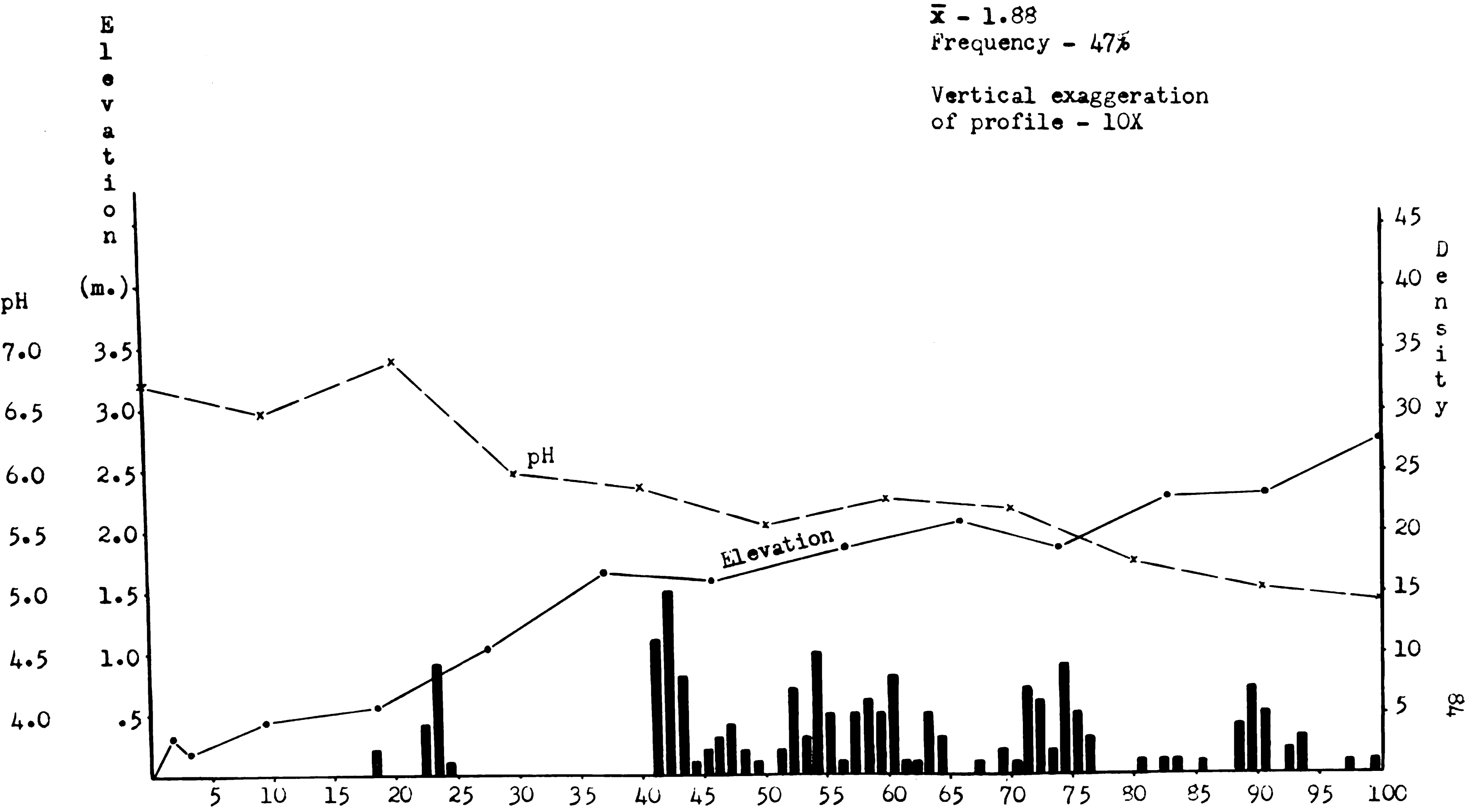
Vertical exaggeration
of profile - 10X



Appendix Figure XXII.

Density Histogram of <u>Peltigera canina</u> (L.) Willd.

Transect III



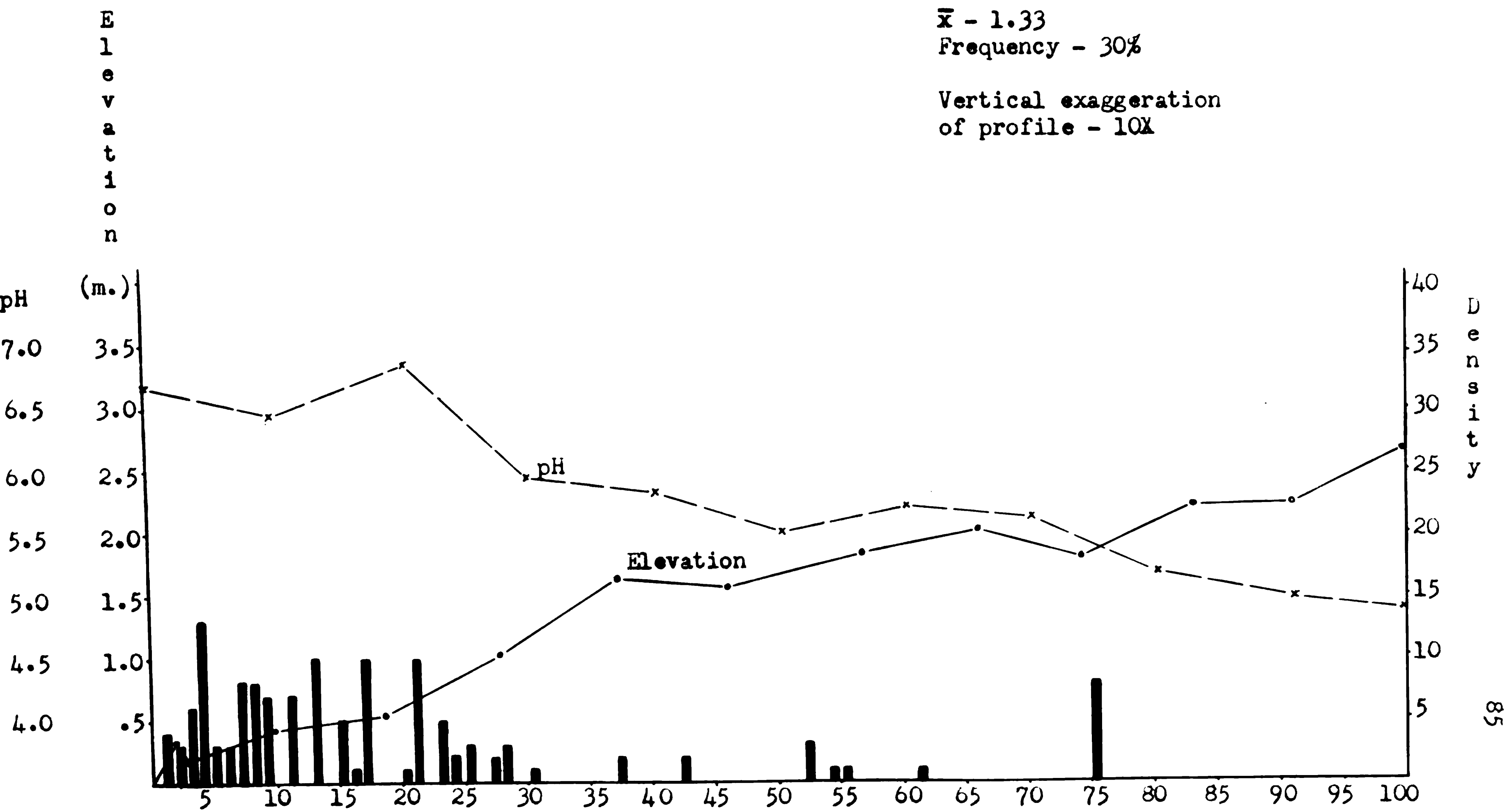
Appendix Figure XXIII.

Density Histogram of Lobaria linita (Ach.) Rabenh.

Transect III

$\bar{x}$ - 1.33
Frequency - 30%

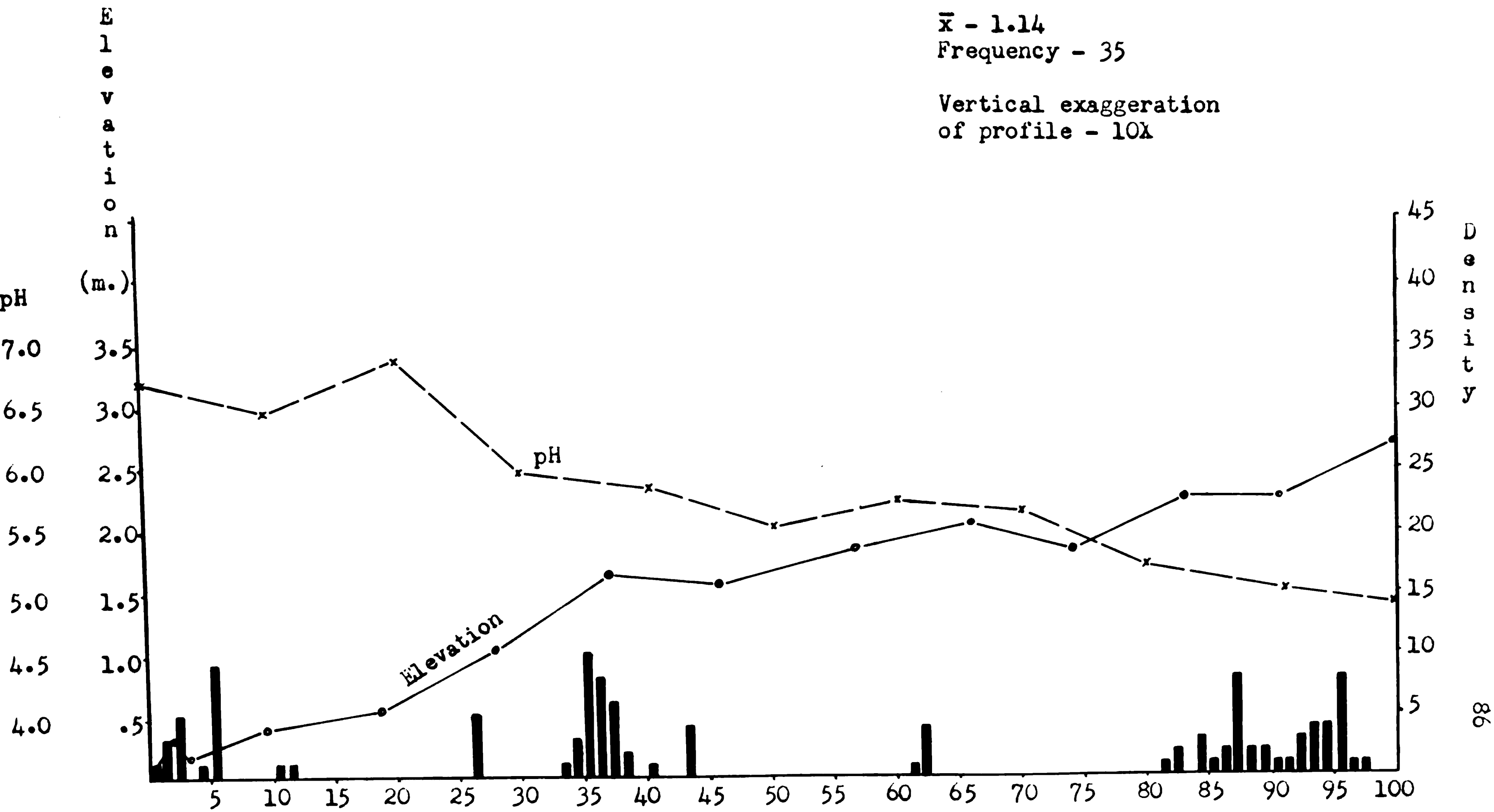
Vertical exaggeration of profile - 10X



Appendix Figure XXIV. Transect (meters)

Density Histogram of <u>Parmelia</u> <u>omphalodes</u> (L.) Ach.

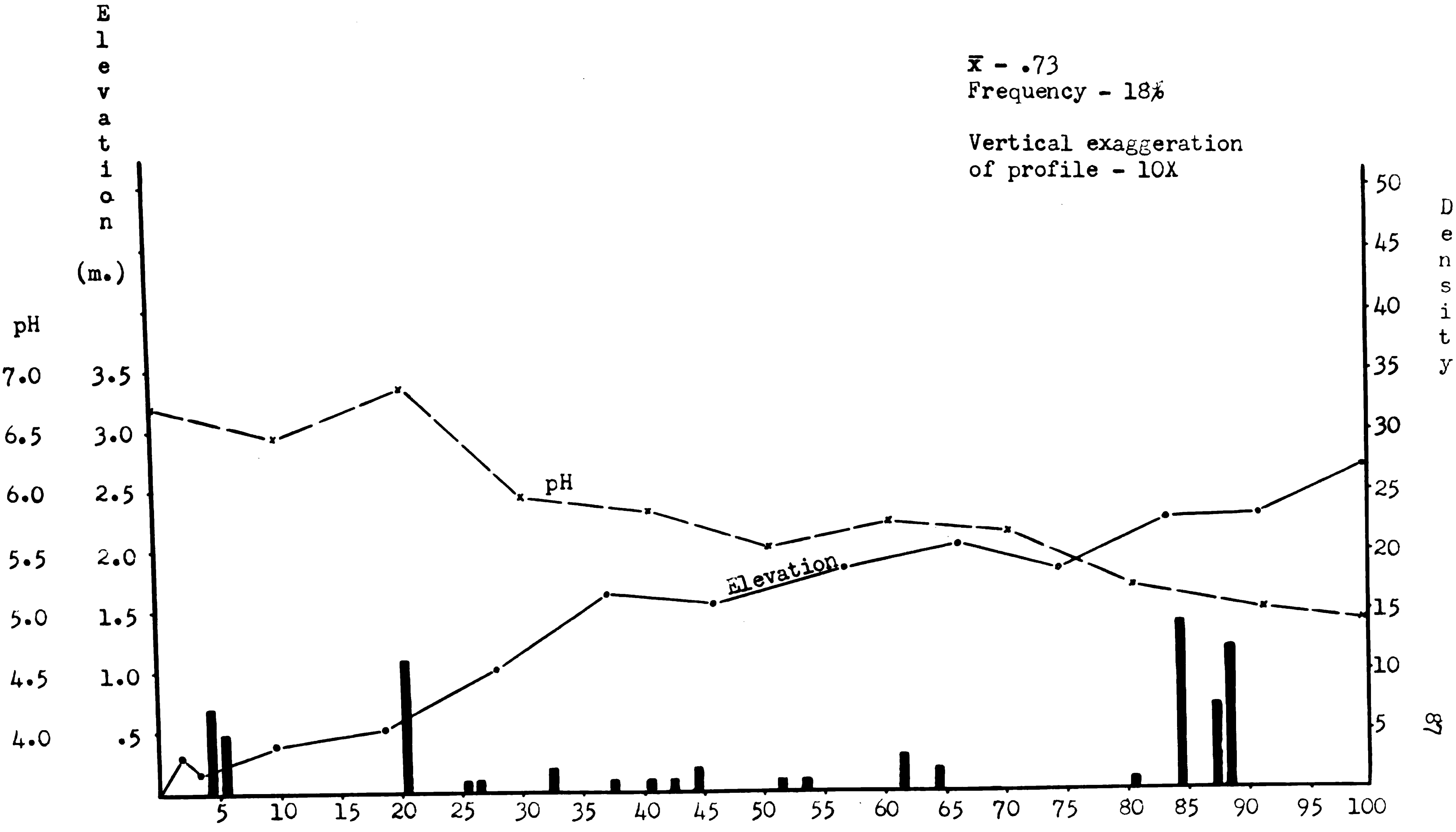
Transect III



Appendix Figure XXV.

Density Histogram of Cladonia uncialis (L.) web.

Transect III



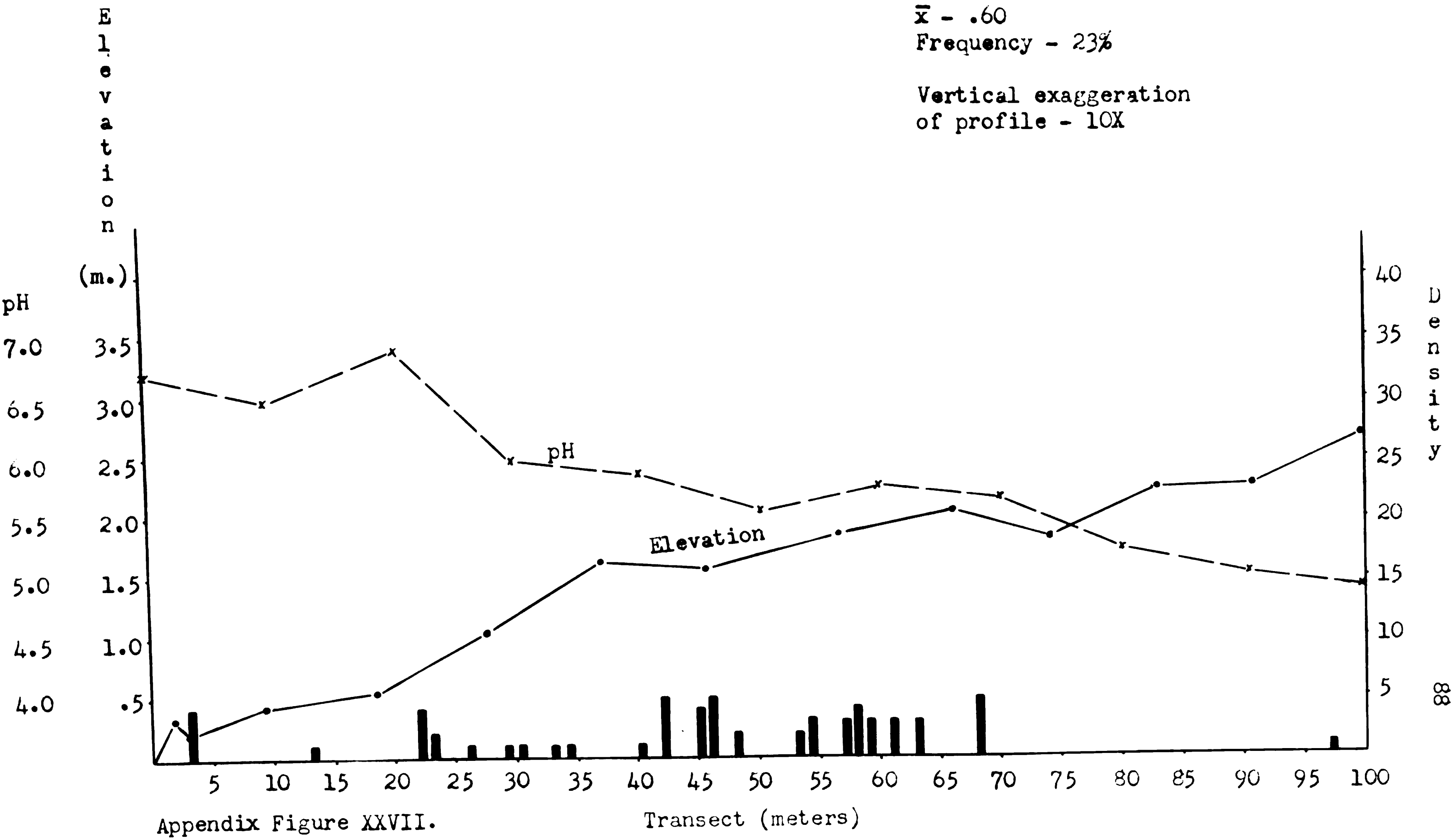
Appendix Figure XXVI.

Density Histogram of <u>Peltigera aphthosa</u> (L.) Willd.

Transect III

$\bar{x}$ - .60
Frequency - 23%

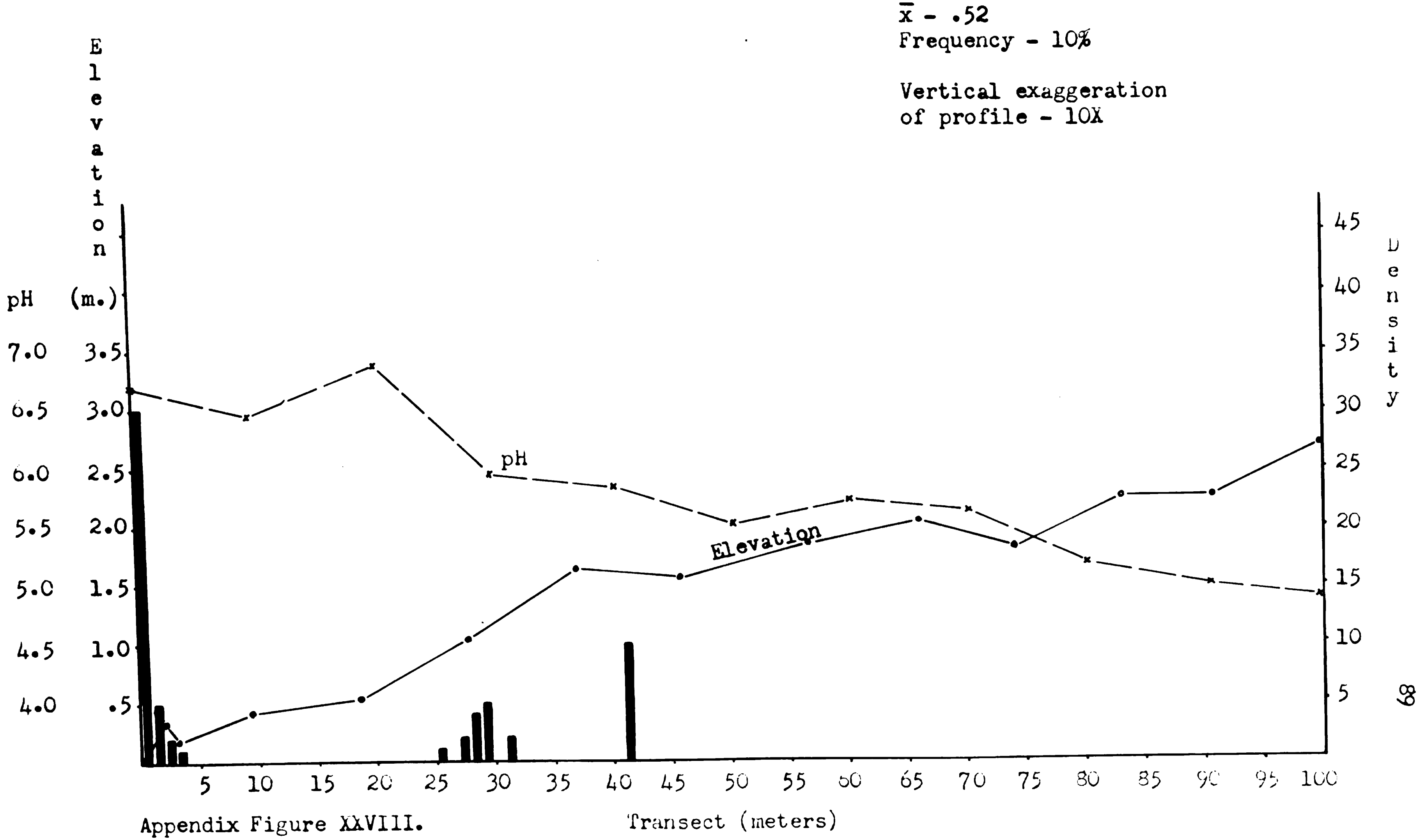
Vertical exaggeration
of profile - 10X



Appendix Figure XXVII.

Density Histogram of <u>Stereocaulon</u> <u>evolutoides</u> (Magn.) Frey

Transect III



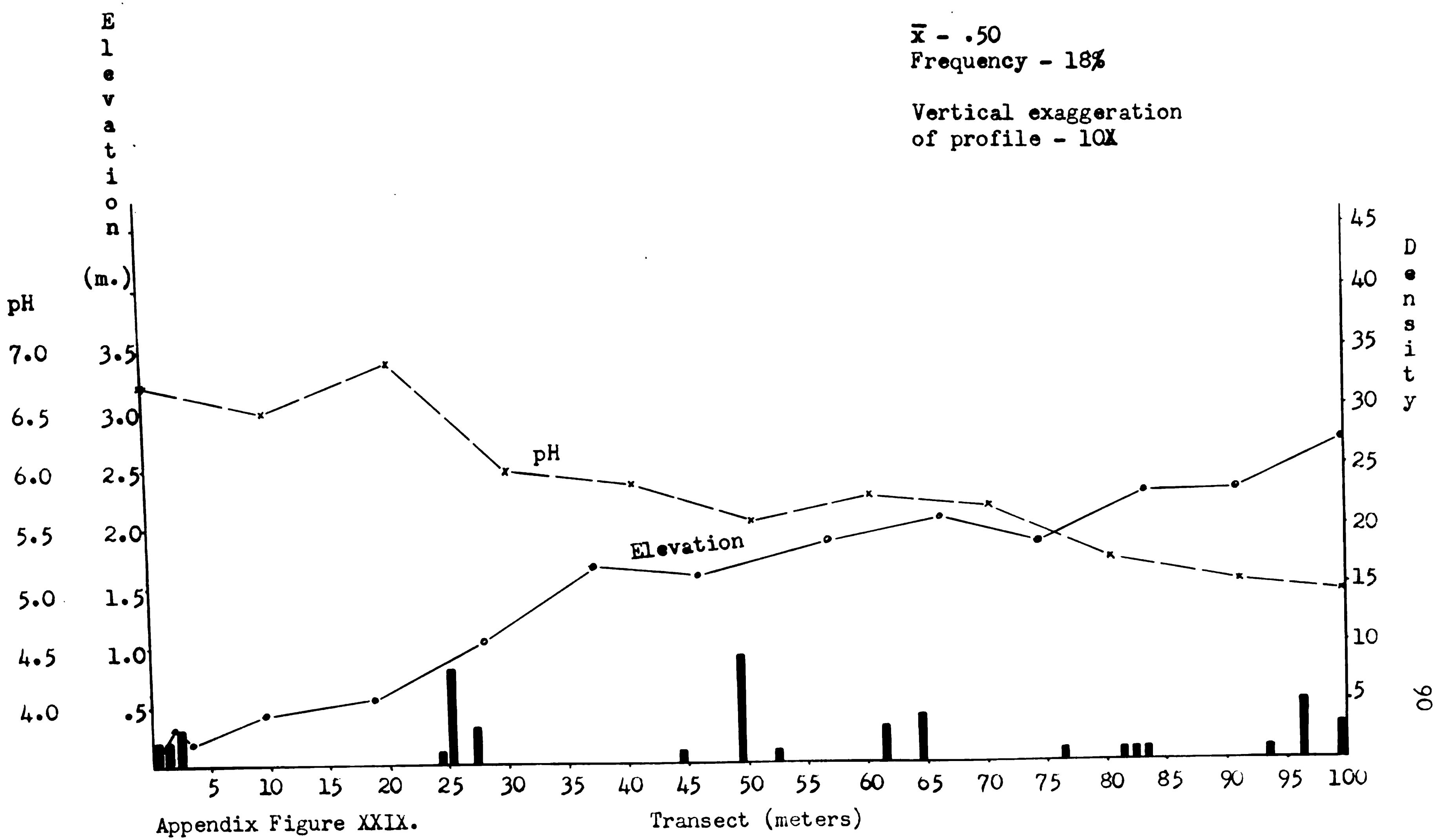
Appendix Figure XXVIII.

Density Histogram of <u>Caloplaca</u> <u>subolivacea</u> (Th.Fr.) Lynge

Transect III

$\bar{x}$ - .50
Frequency - 18%

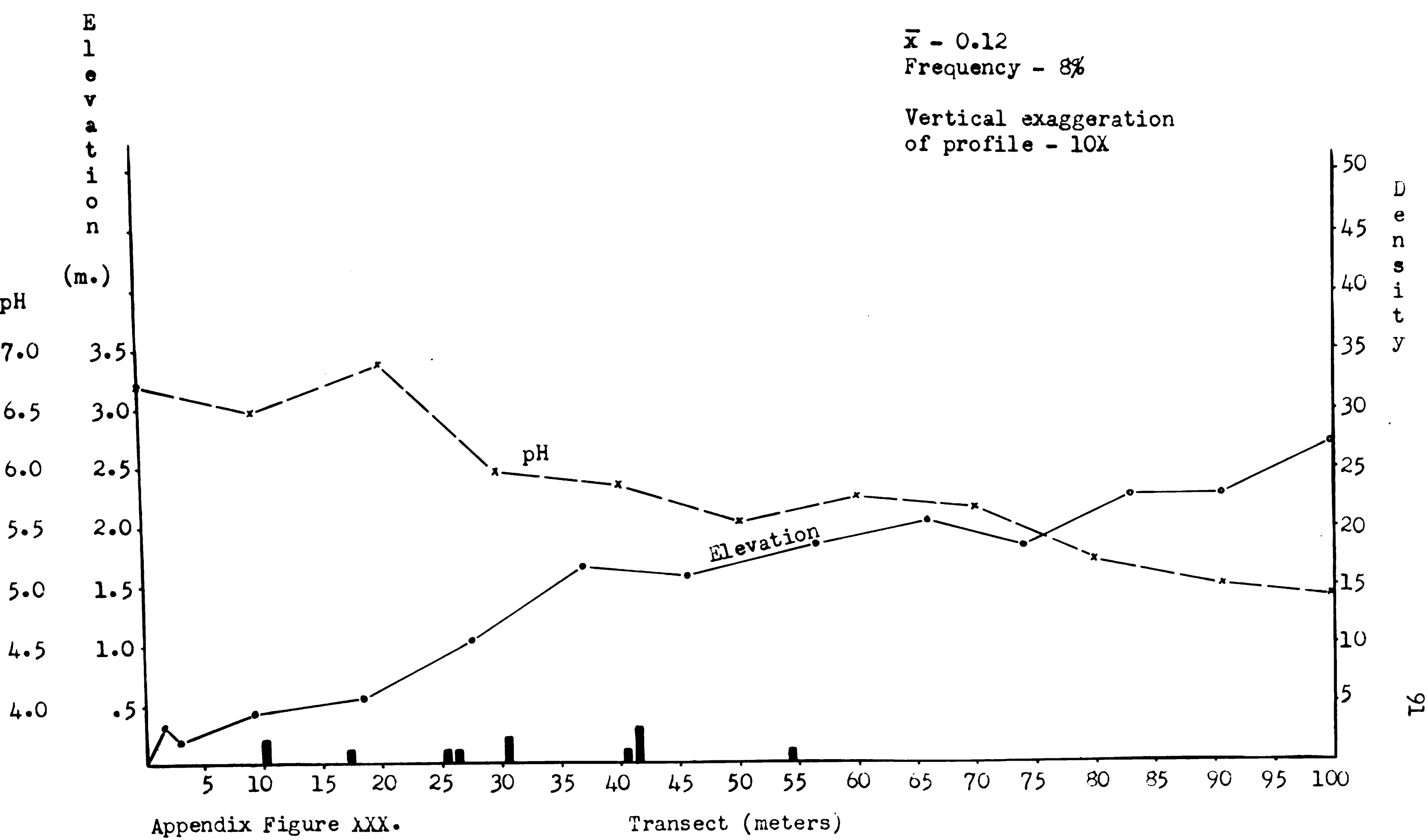
Vertical exaggeration
of profile - 10X



Appendix Figure XXIX.

Density Histogram of <u>Cetraria richardsonii</u> Hook.

Transect III



Appendix Figure XXX.

Transect III

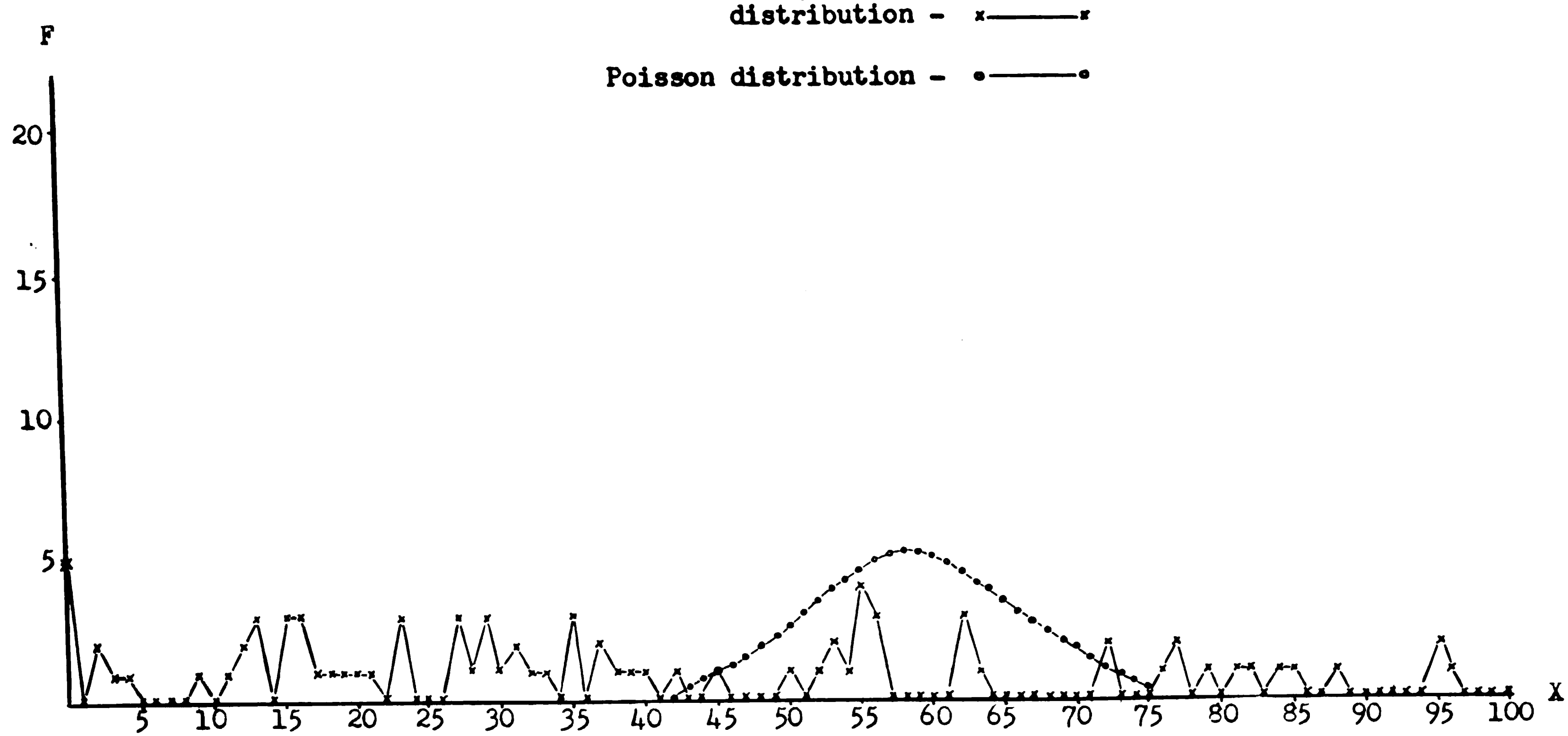
Frequency Distribution*

<u>Poa</u> <u>arctica</u> R.Br.

$\bar{x}$ - 59.25

Observed frequency distribution - x——x

Poisson distribution - •——•



* Fourteen frequencies above 100 omitted

Appendix Figure XXXI.

Transect III

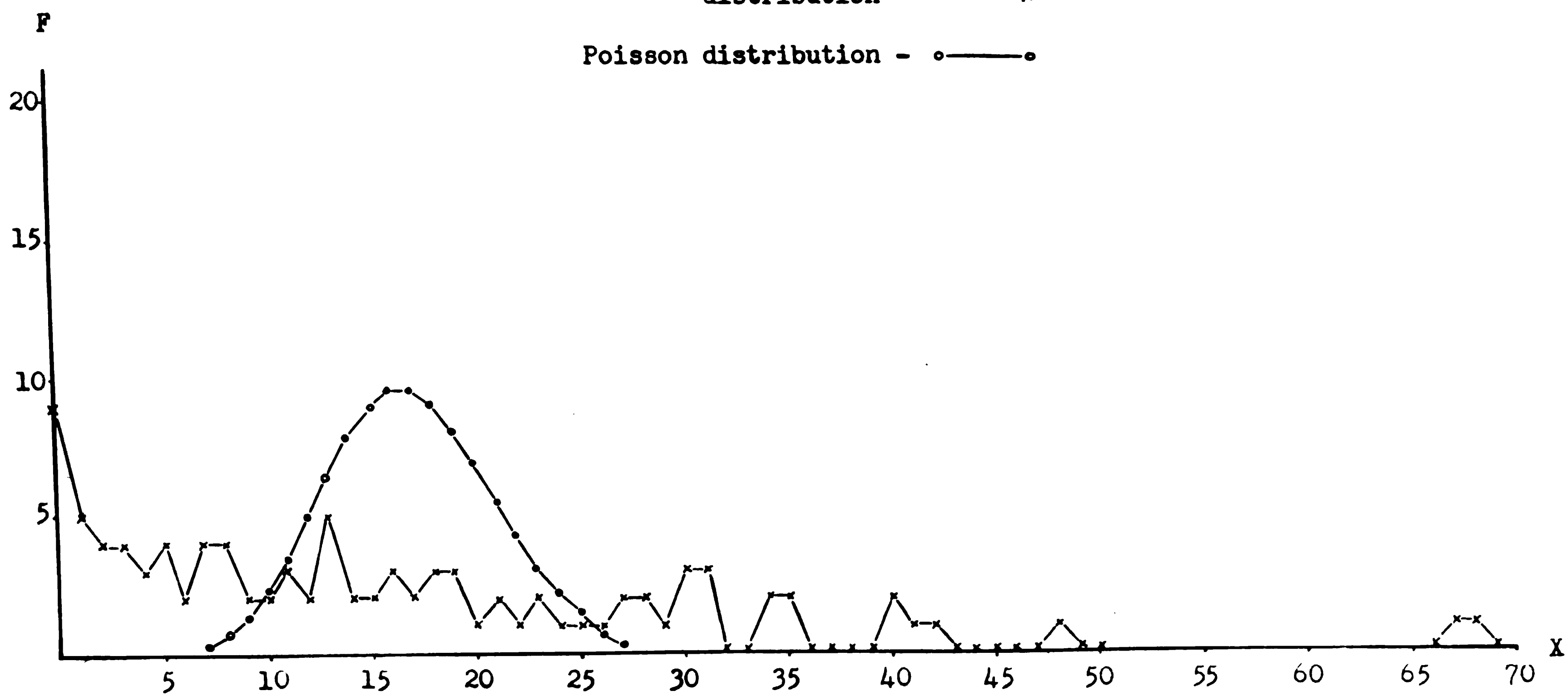
Frequency Distribution*

Arctagrostis latifolia (R.Br.) Griseb.

$\bar{x}$ - 17.20

Observed frequency distribution - x——x

Poisson distribution - o——o



* one frequency at 130 omitted.

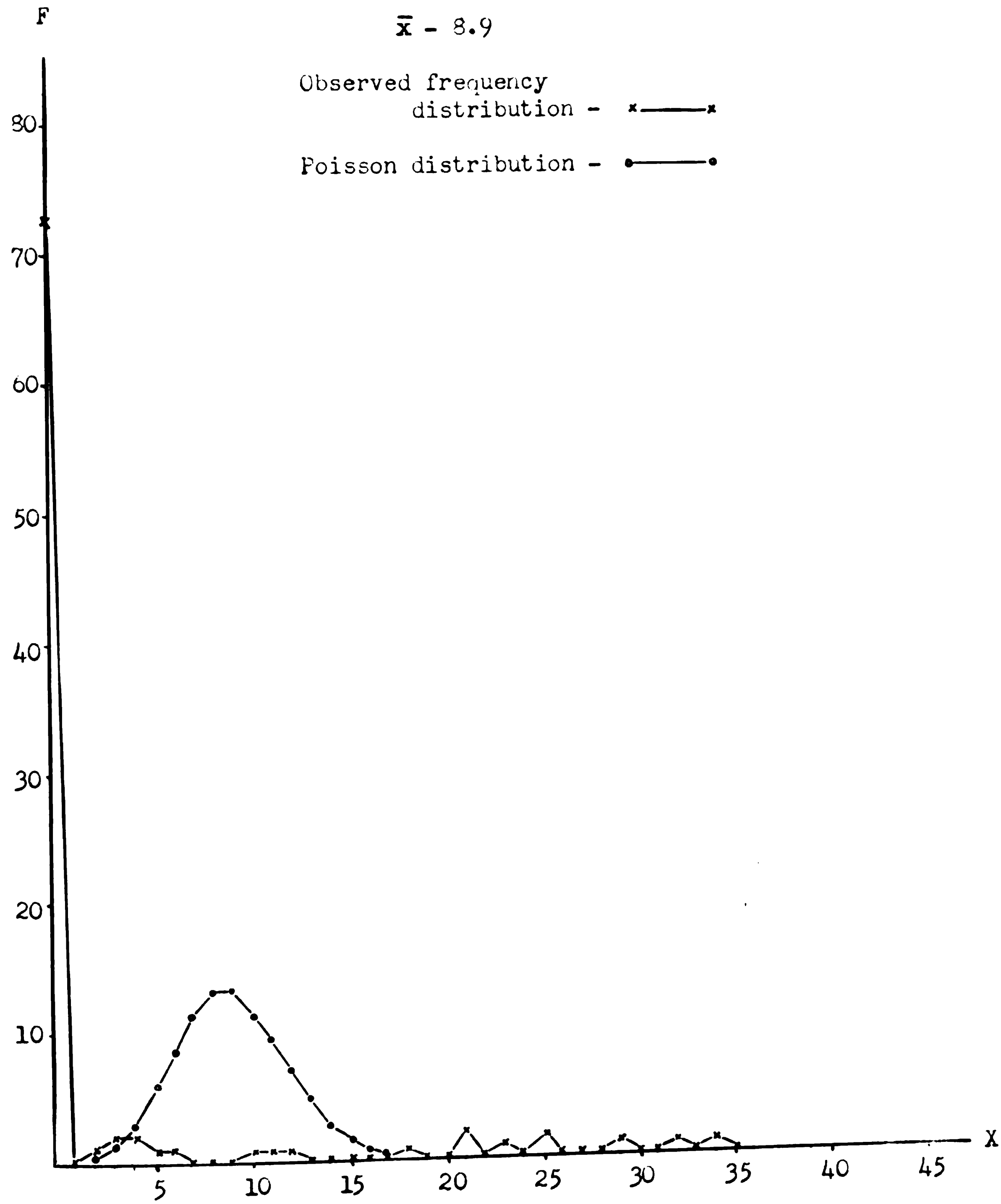
Appendix Figure XXXII.

Transect III

Frequency Distribution

Eriophorum scheuchzeri Hoppe

$\bar{x}$ - 8.9



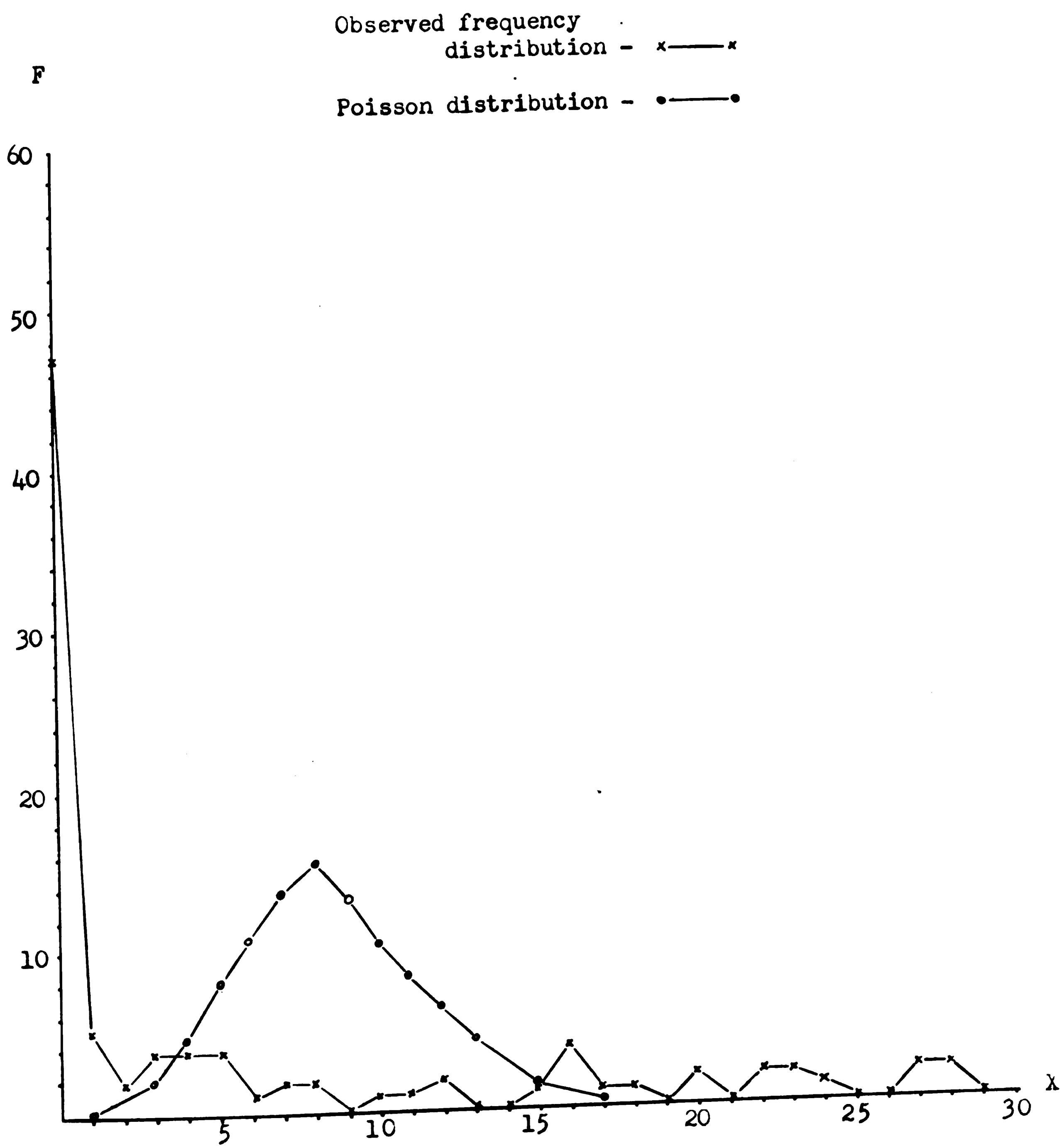
Appendix Figure XXXIII.

Transect III

Frequency Distribution

Carex aquatilis Wahl.

$\bar{x}$ - 8.45



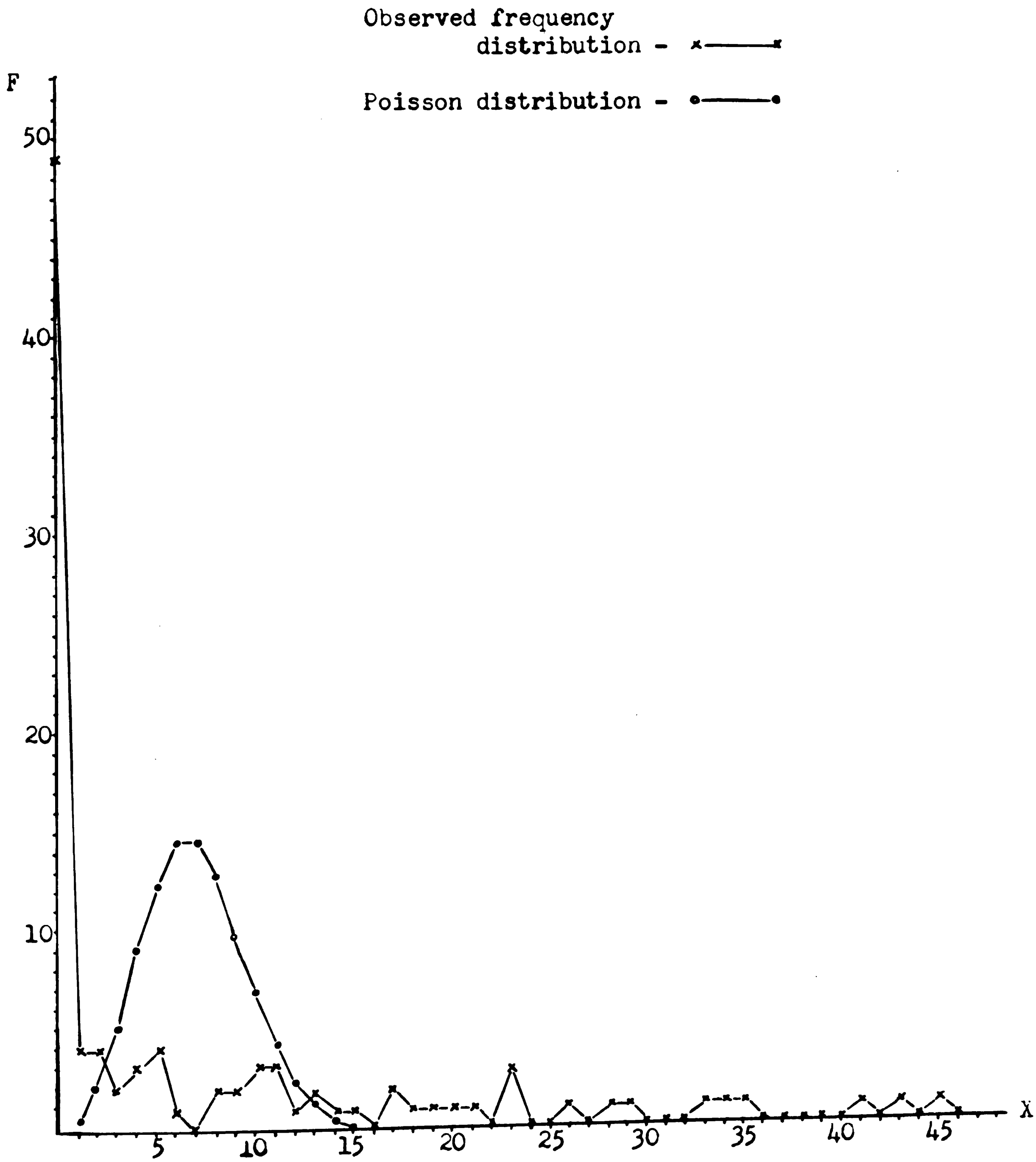
Appendix Figure XXXIV.

Transect III

Frequency Distribution

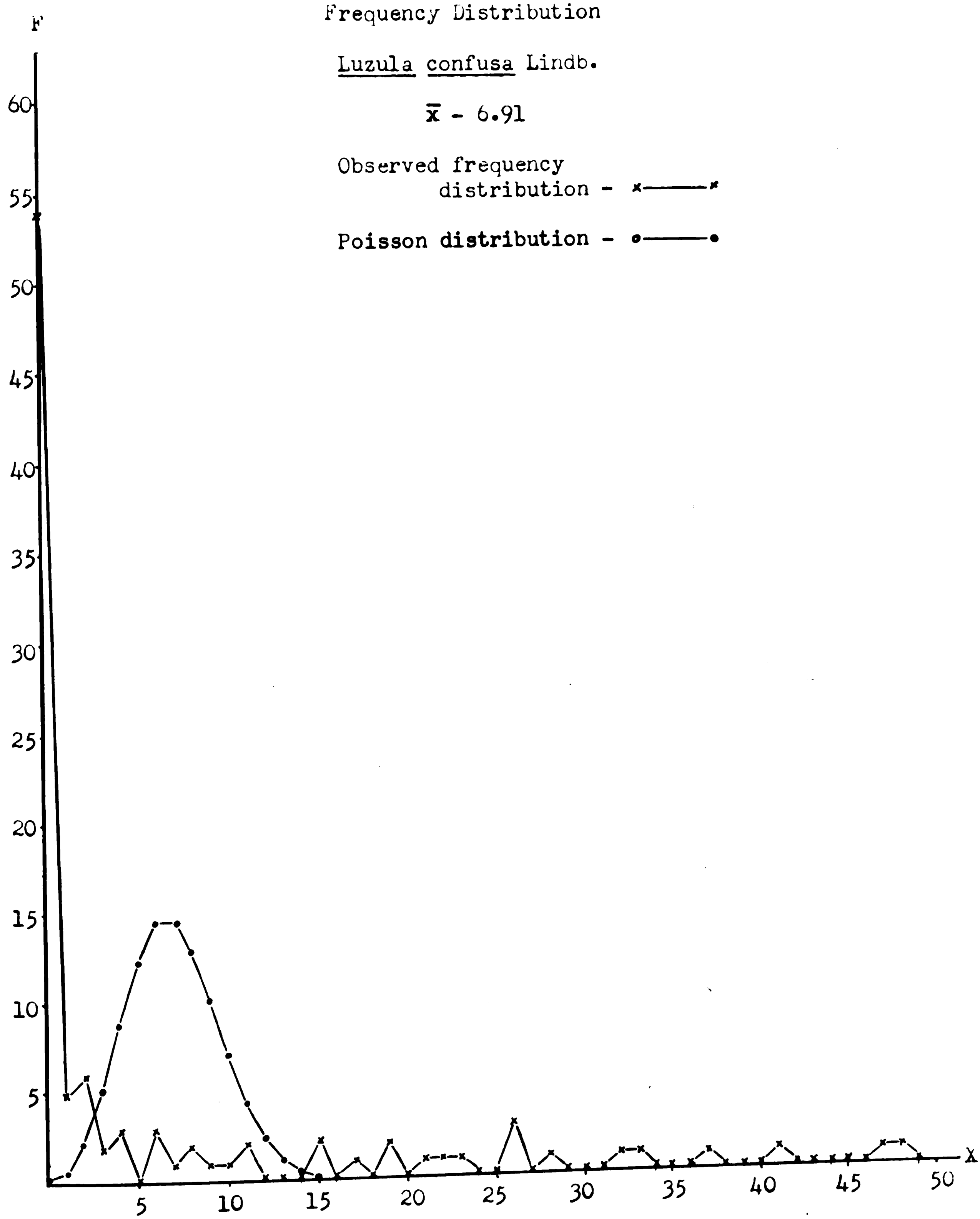
<u>Luzula</u> <u>nivalis</u> (Laest.) Beurl. var. <u>latifolia</u> (Kjellm.) Sam.

$\bar{x}$ - 7.15



Appendix Figure XXXV.

Transect 111



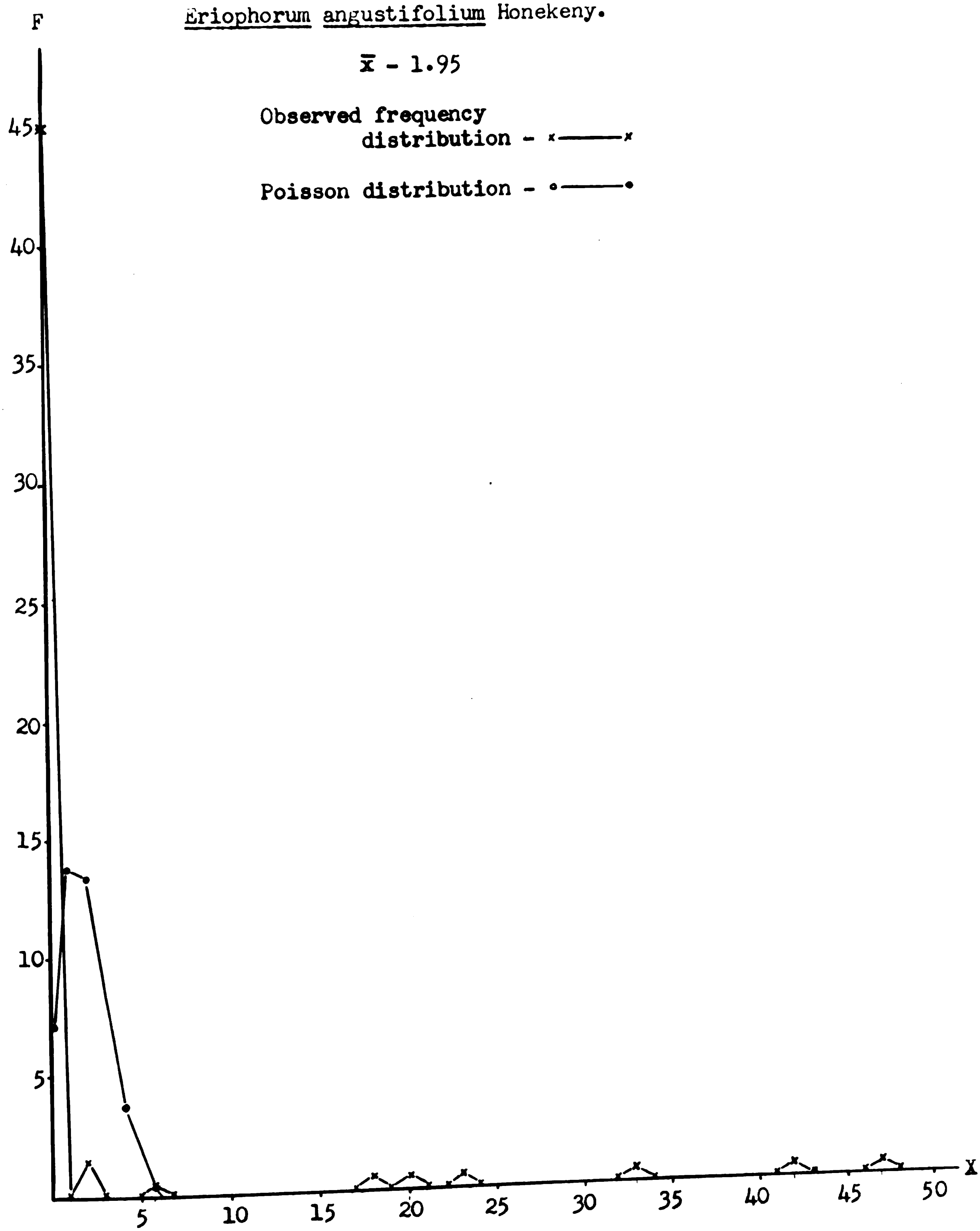
Appendix Figure XXXVI.

Transect III

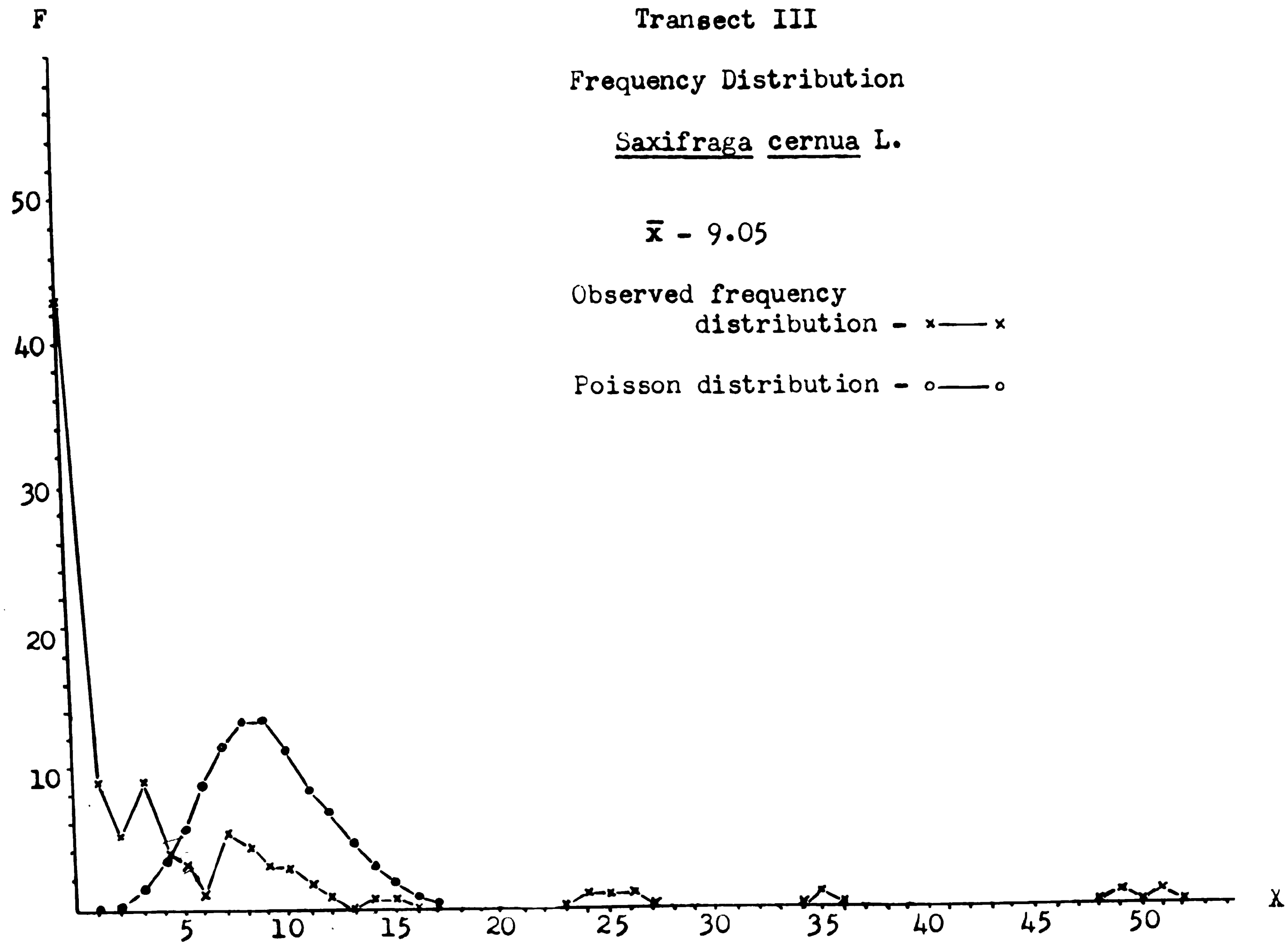
Frequency Distribution

Eriophorum angustifolium Honekeny.

$\bar{x}$ - 1.95



Appendix Figure XXXVII.



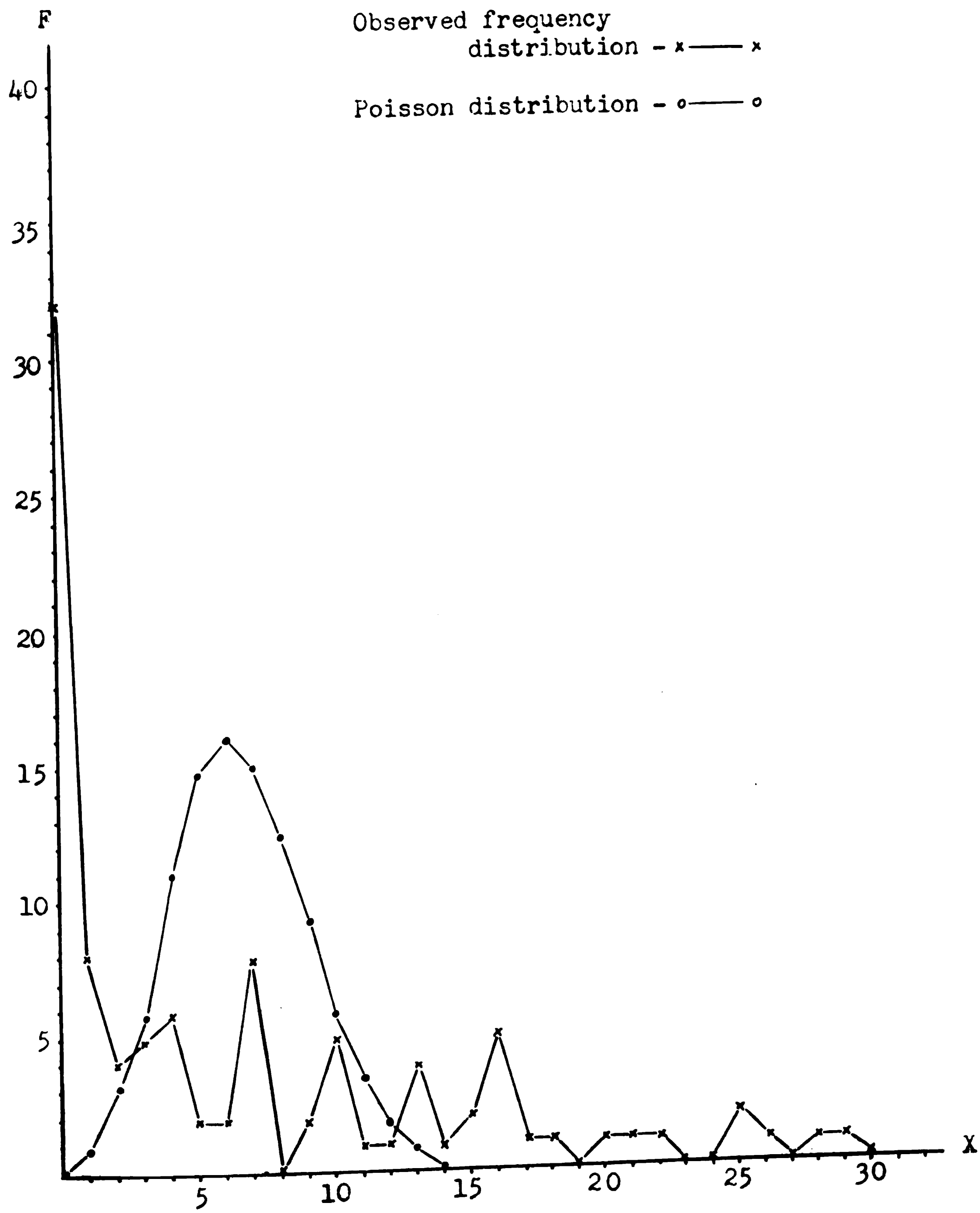
Appendix Figure XXXVIII.

Transect III

Frequency Distribution

Stellaria laeta Richards.

$\bar{x}$ - 6.54



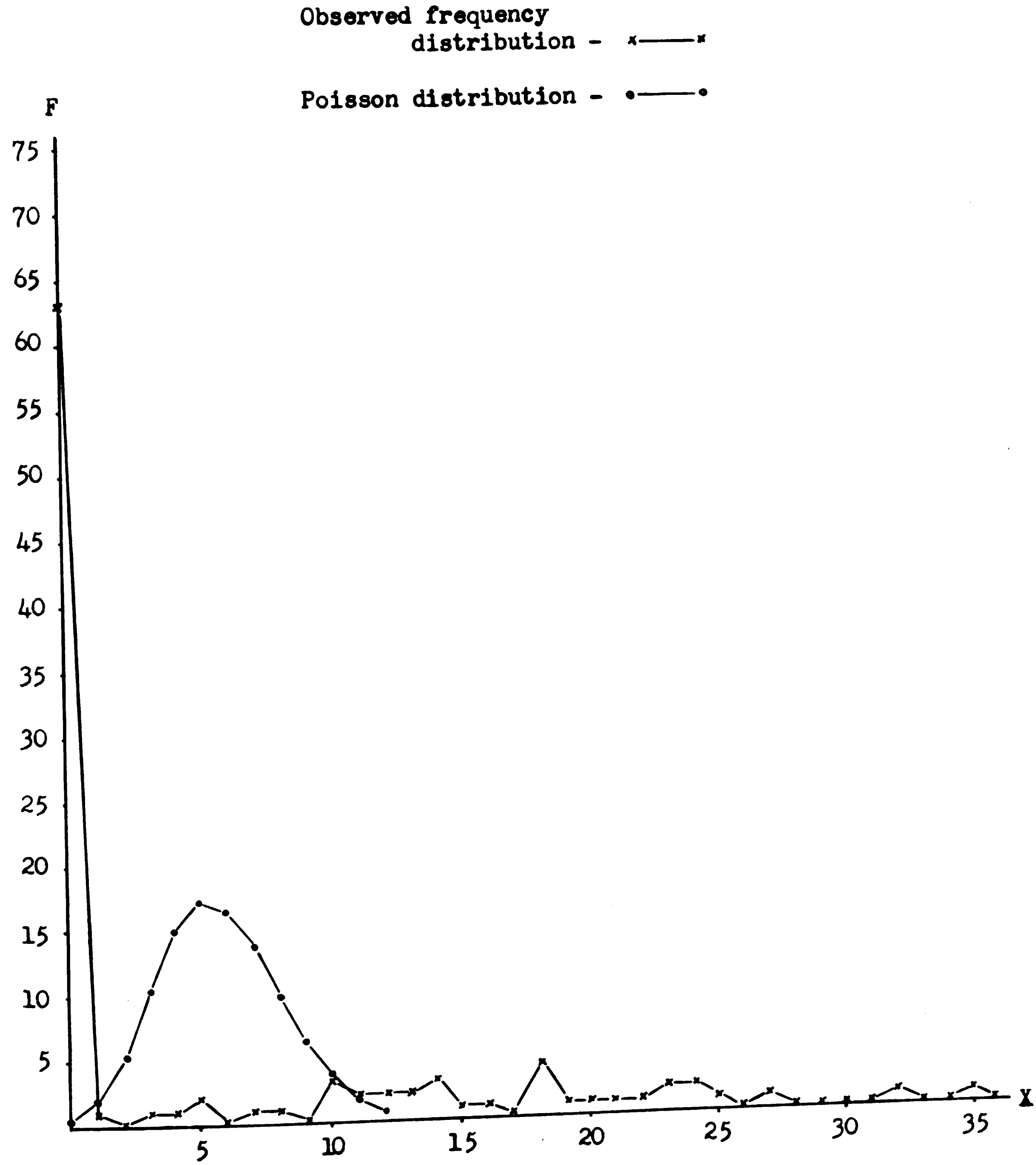
Appendix Figure XXXIX.

Transect III

Frequency Distribution

Petasites frigidus (L.) Fries.

$\bar{x}$ - 5.75



Appendix Figure XL.

Transect III

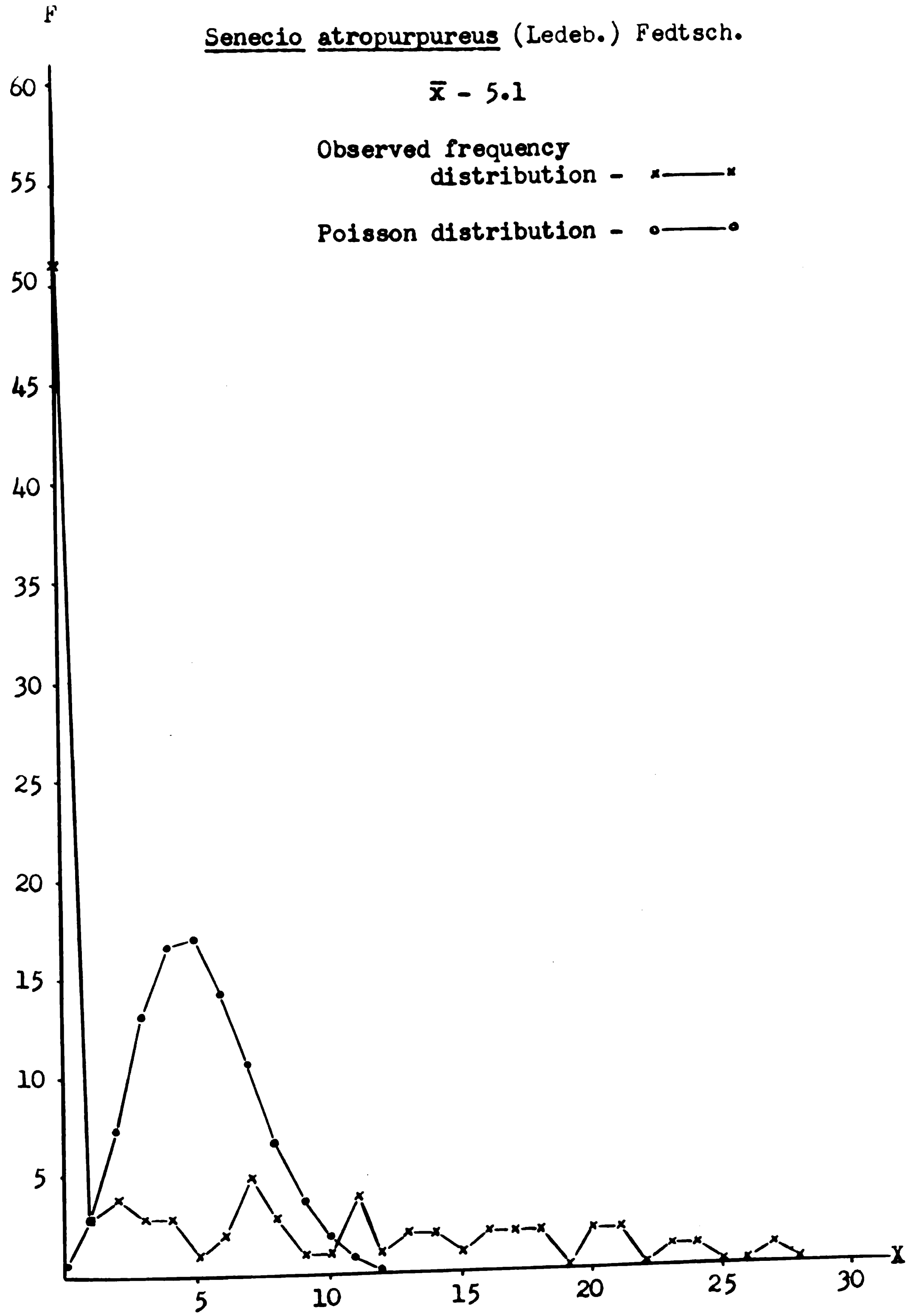
Frequency Distribution

<u>Senecio</u> <u>atropurpureus</u> (Ledeb.) Fedtsch.

$\bar{x}$ - 5.1

Observed frequency distribution - x——x

Poisson distribution - o——o



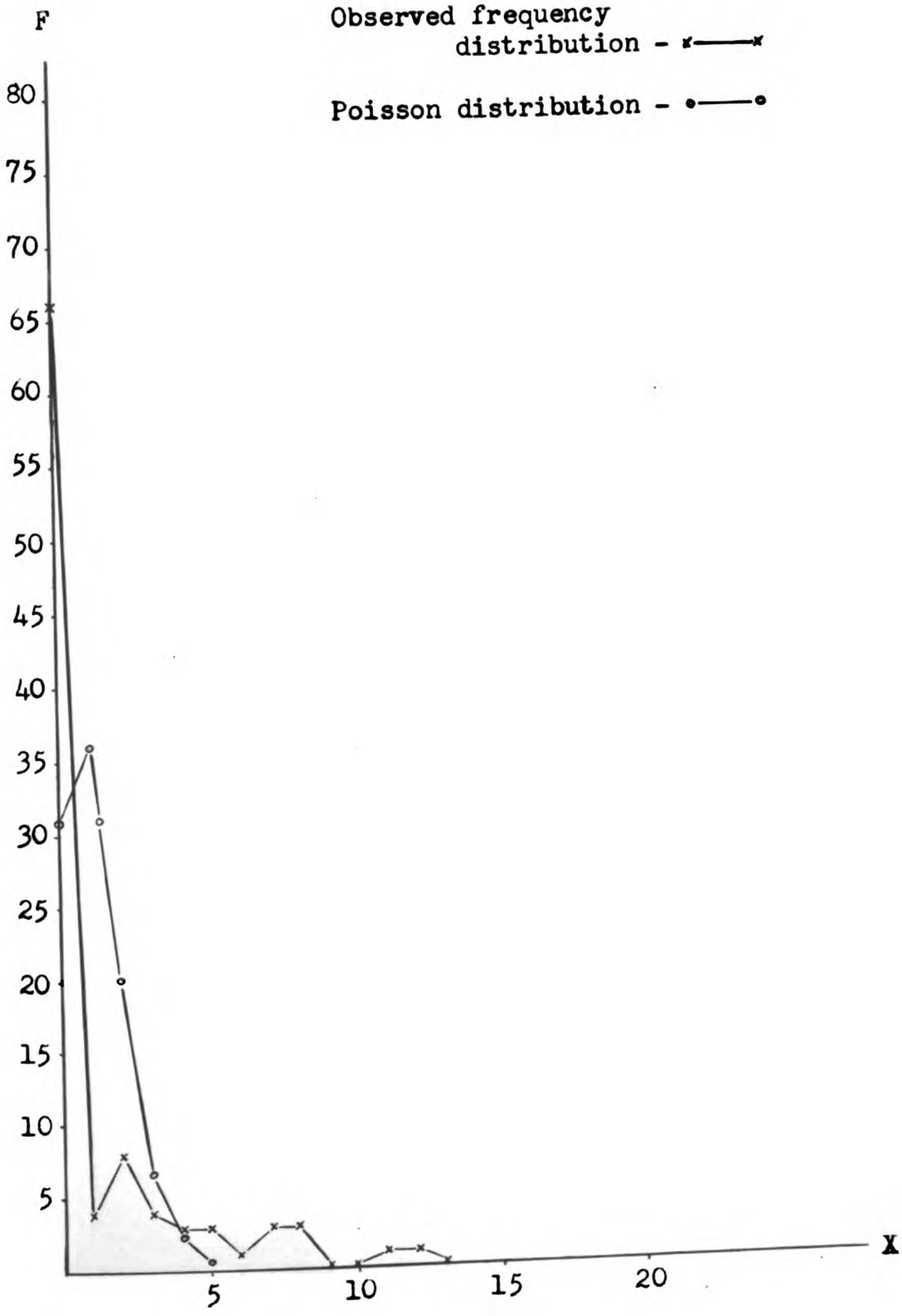
Appendix Figure XLI.

Transect III

Frequency Distribution

Saxifraga punctata L. ssp. nelsoniana (D.Don.) Hult.

$\bar{x}$ - 1.18



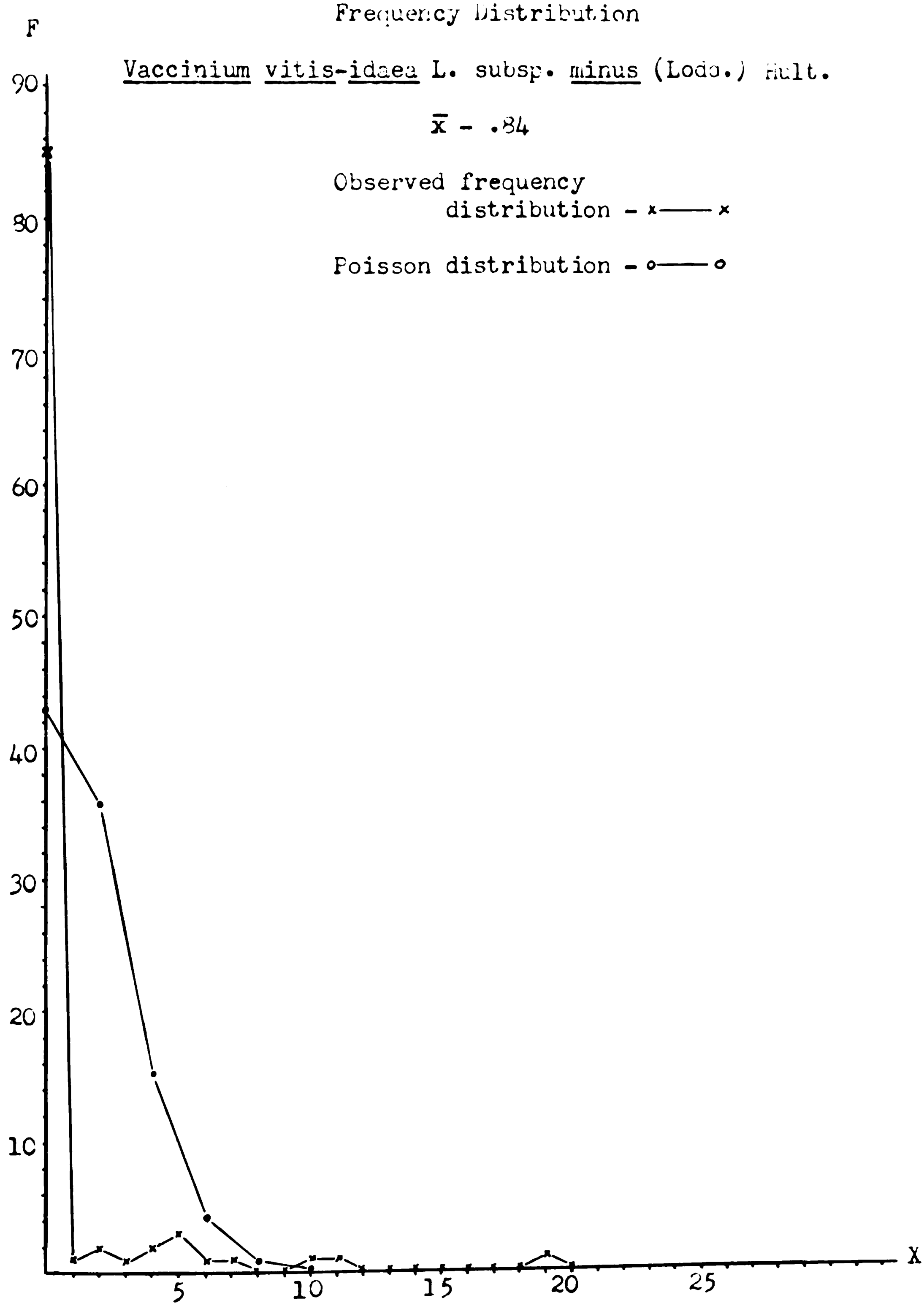
Appendix Figure XLII.

Transect III

Frequency Distribution

<u>Vaccinium</u> <u>vitis-idaea</u> L. subsp. <u>minus</u> (Lodd.) Hult.

$\bar{x}$ - .84



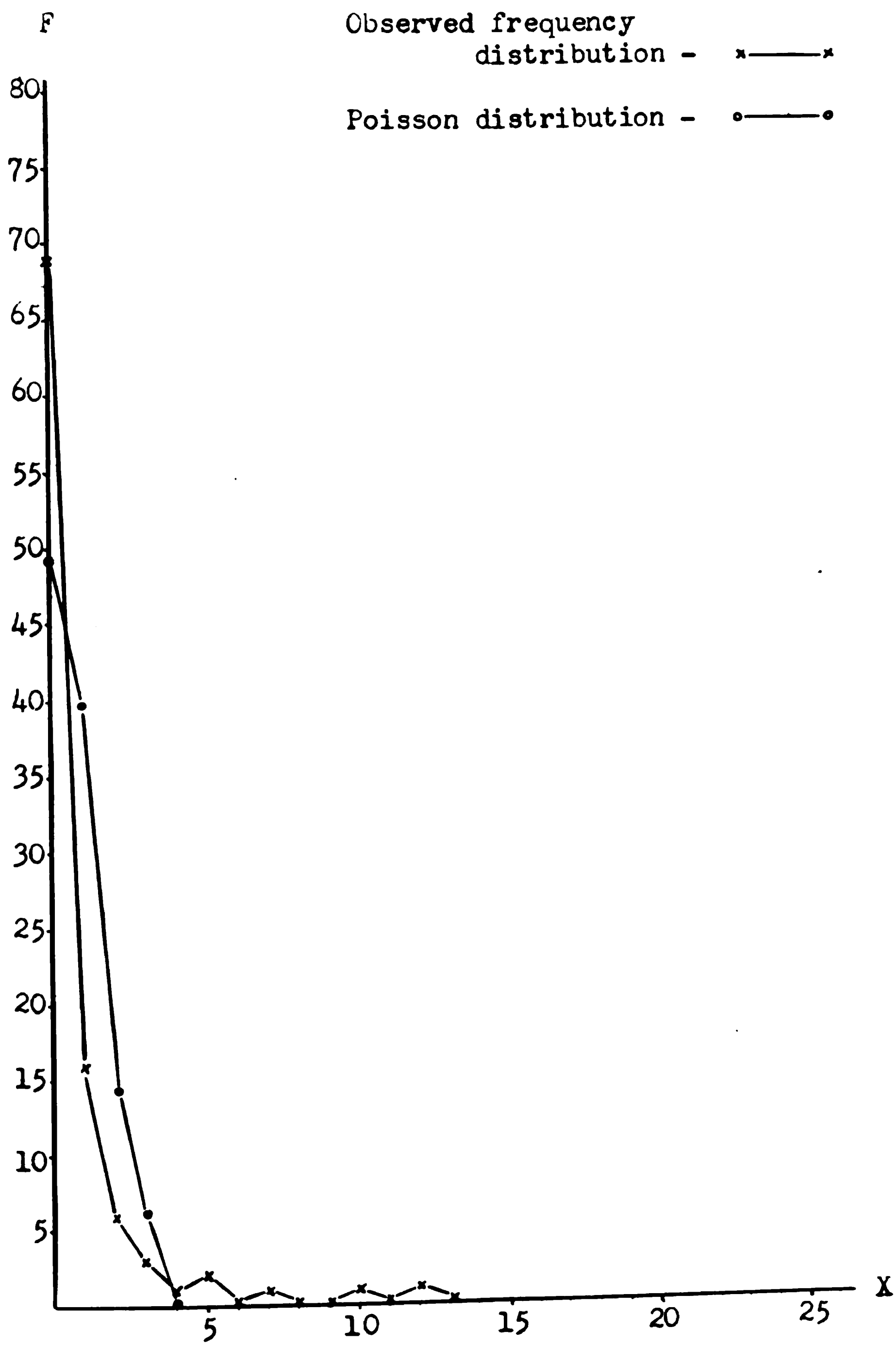
Appendix Figure XLIII.

Transect III

Frequency Distribution

Potentilla emarginata Pursh.

$\bar{x}$ - .80



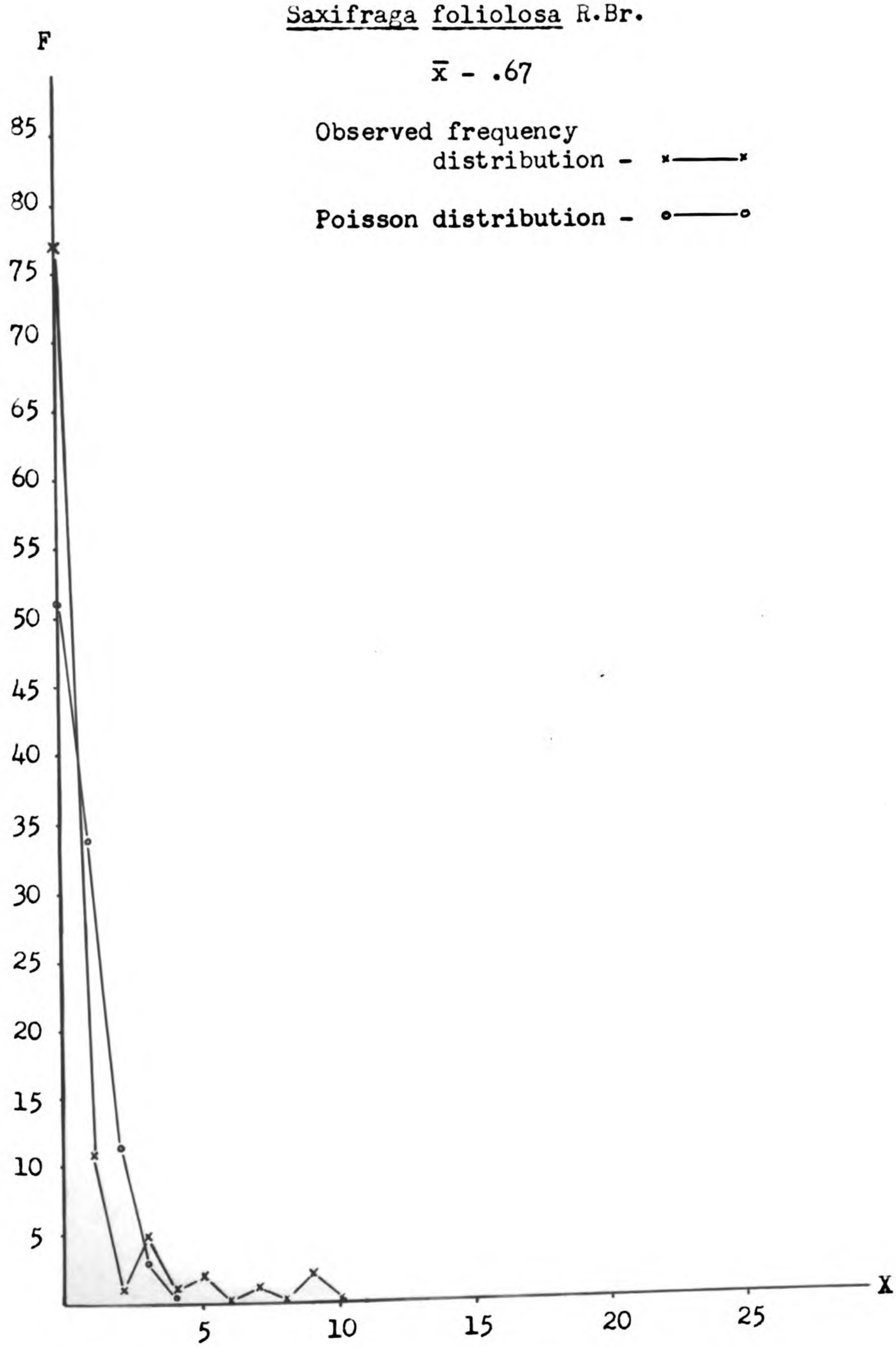
Appendix Figure XLIV.

Transect III

Frequency Distribution

<u>Saxifraga</u> <u>foliolosa</u> R.Br.

$\bar{x}$ - .67



Appendix Figure XLV.

Transect III

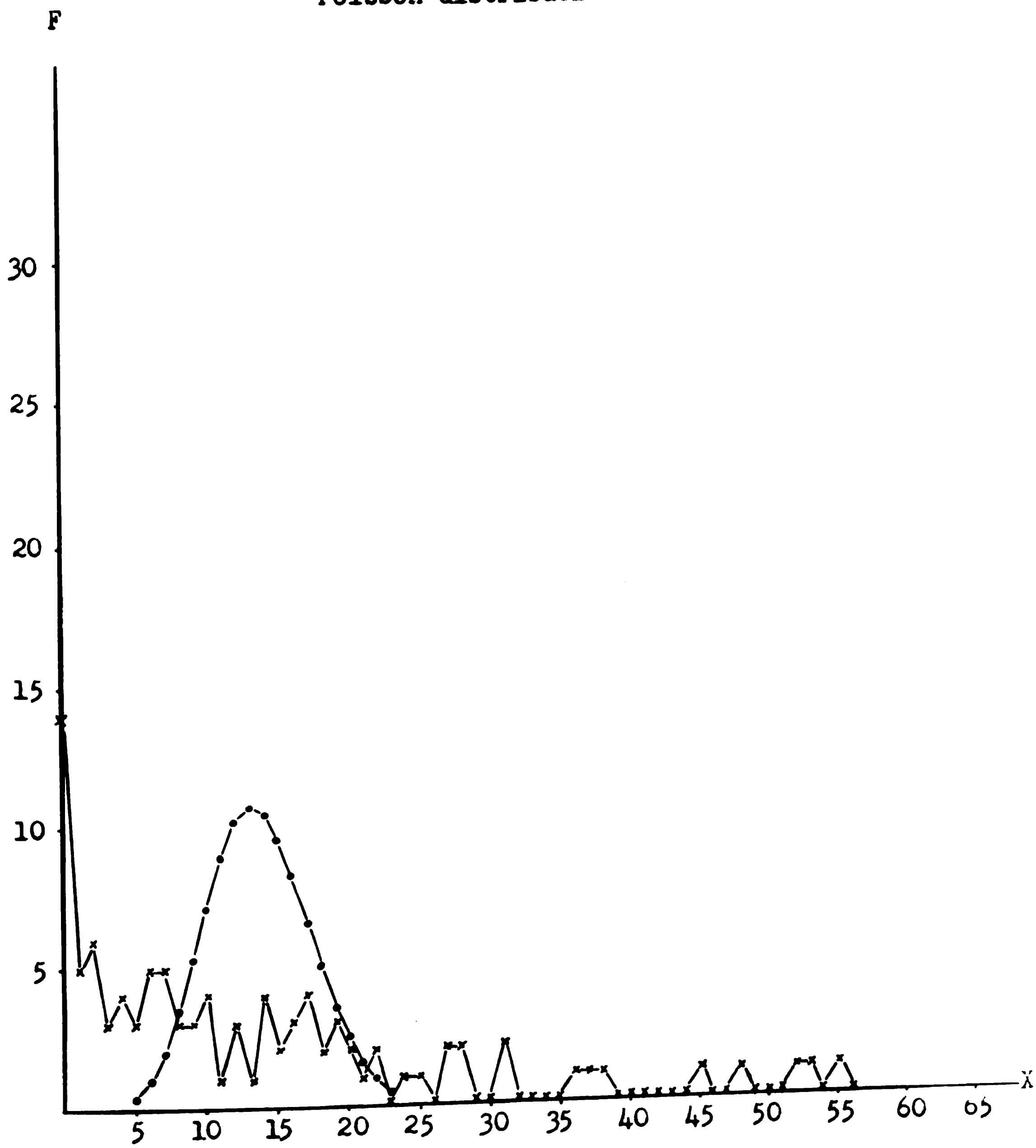
Frequency Distribution

Thamnolia vermicularis (Sw.) Ach.

$\bar{x}$ - 13.70

Observed frequency
distribution - x——x

Poisson distribution - o——o



Appendix Figure XLVI.

Transect III

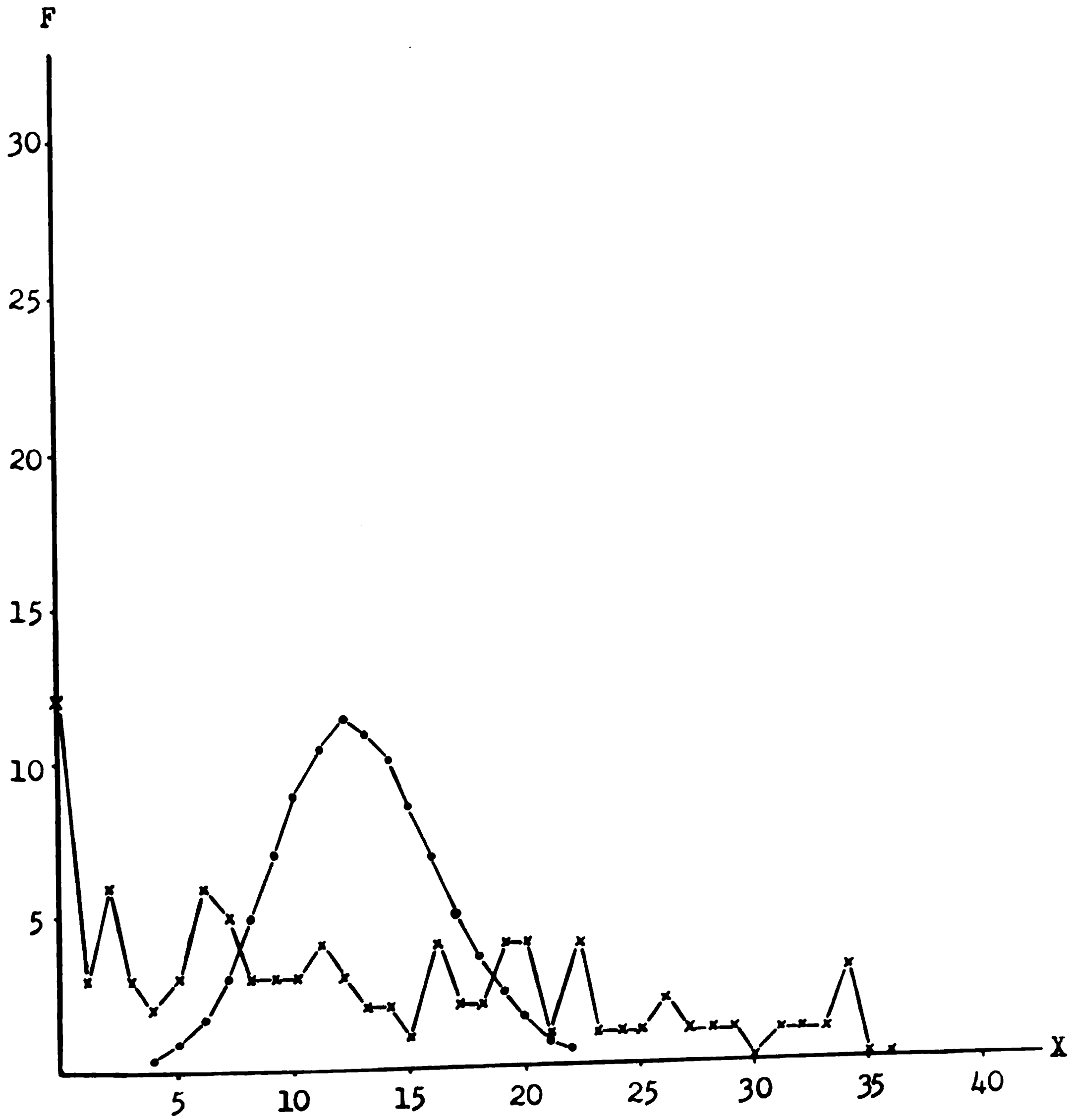
Frequency Distribution

Dactylina arctica (Hook.) Nyl.

$\bar{x}$ - 12.76

Observed frequency distribution - x———x

Poisson distribution - •———•



Appendix Figure XLVII.

Transect III

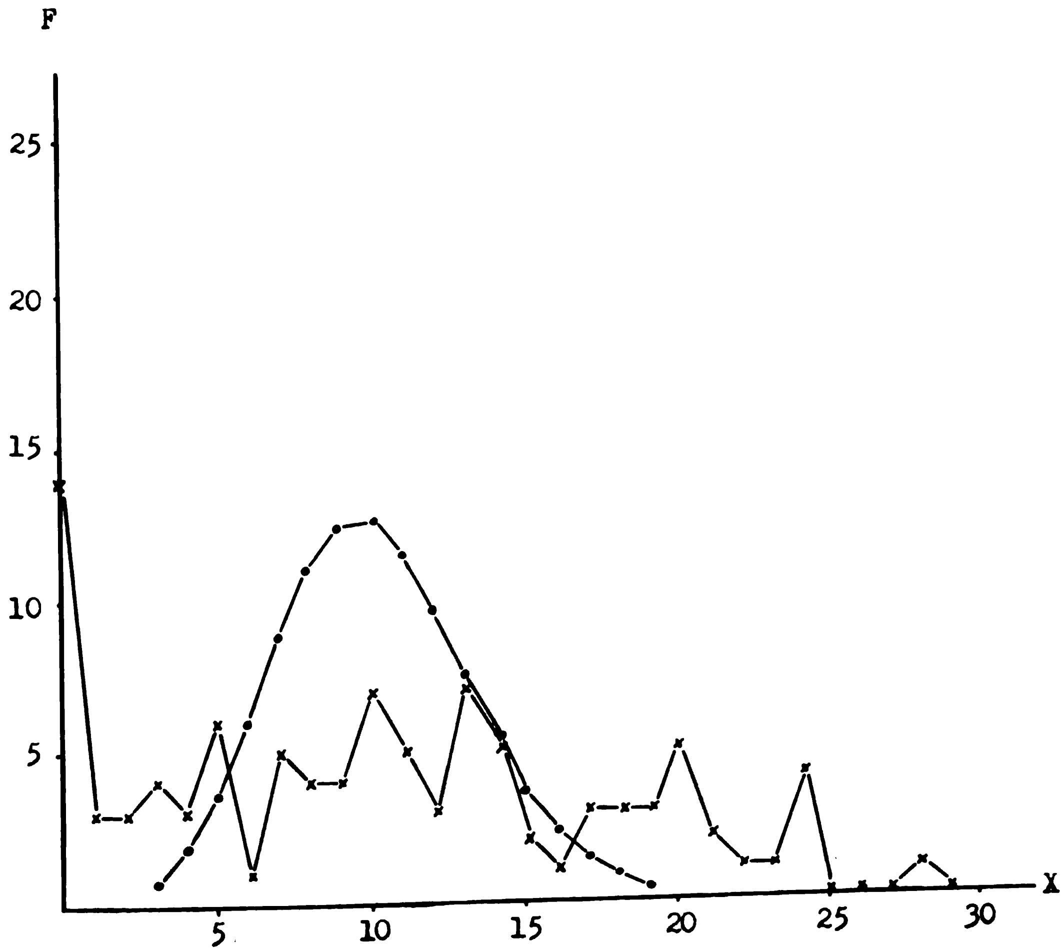
Frequency Distribution

<u>Cetraria</u> <u>islandica</u> (L.) Ach.

$\bar{x}$ - 10.13

Observed frequency distribution - x——x

Poisson distribution - •——•



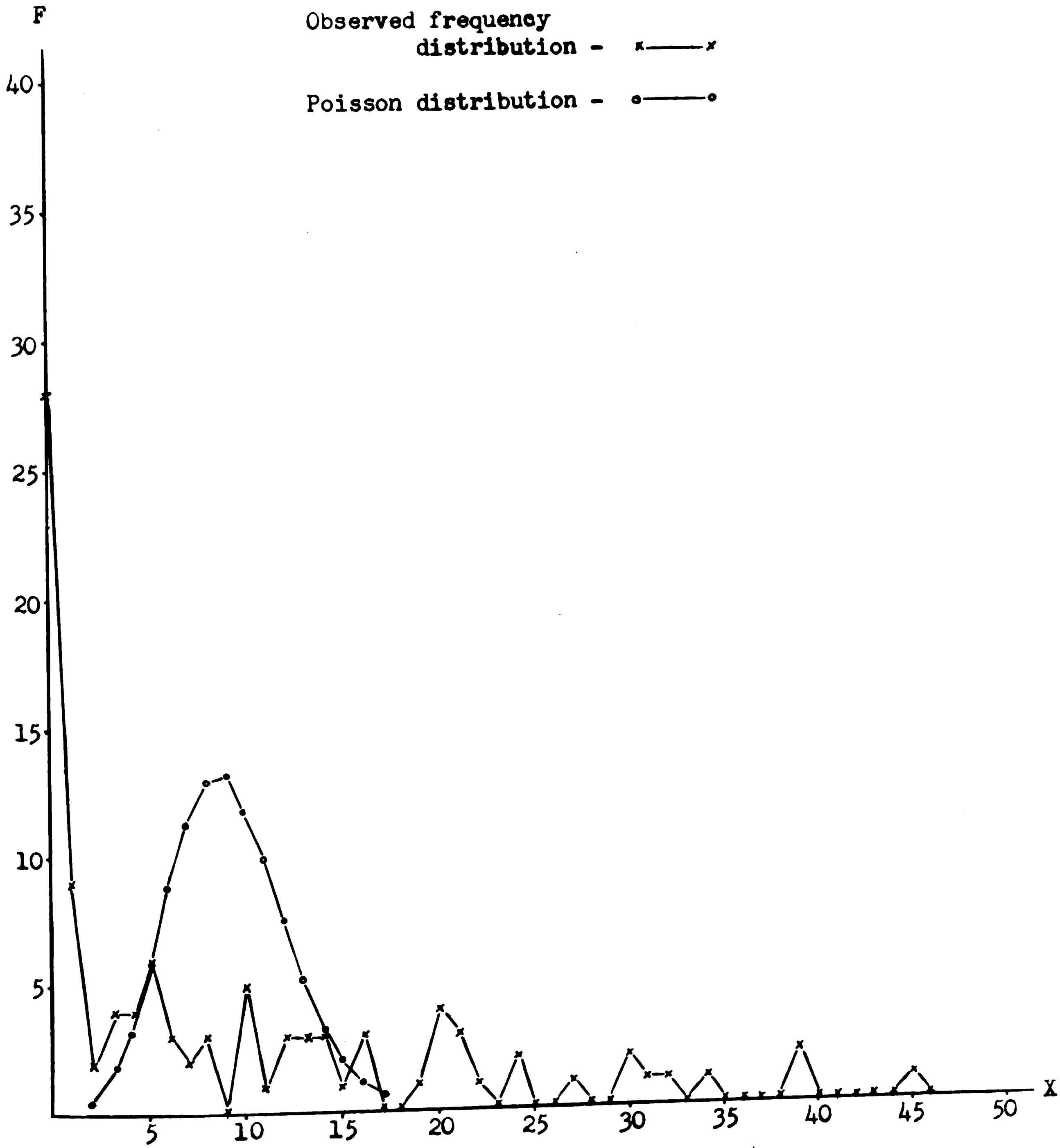
Appendix Figure XLVIII.

Transect III

Frequency Distribution

Sphaerophorus globosus (Huds.) Vain.

$\bar{x}$ - 9.07



Appendix Figure XLIX.

Transect III

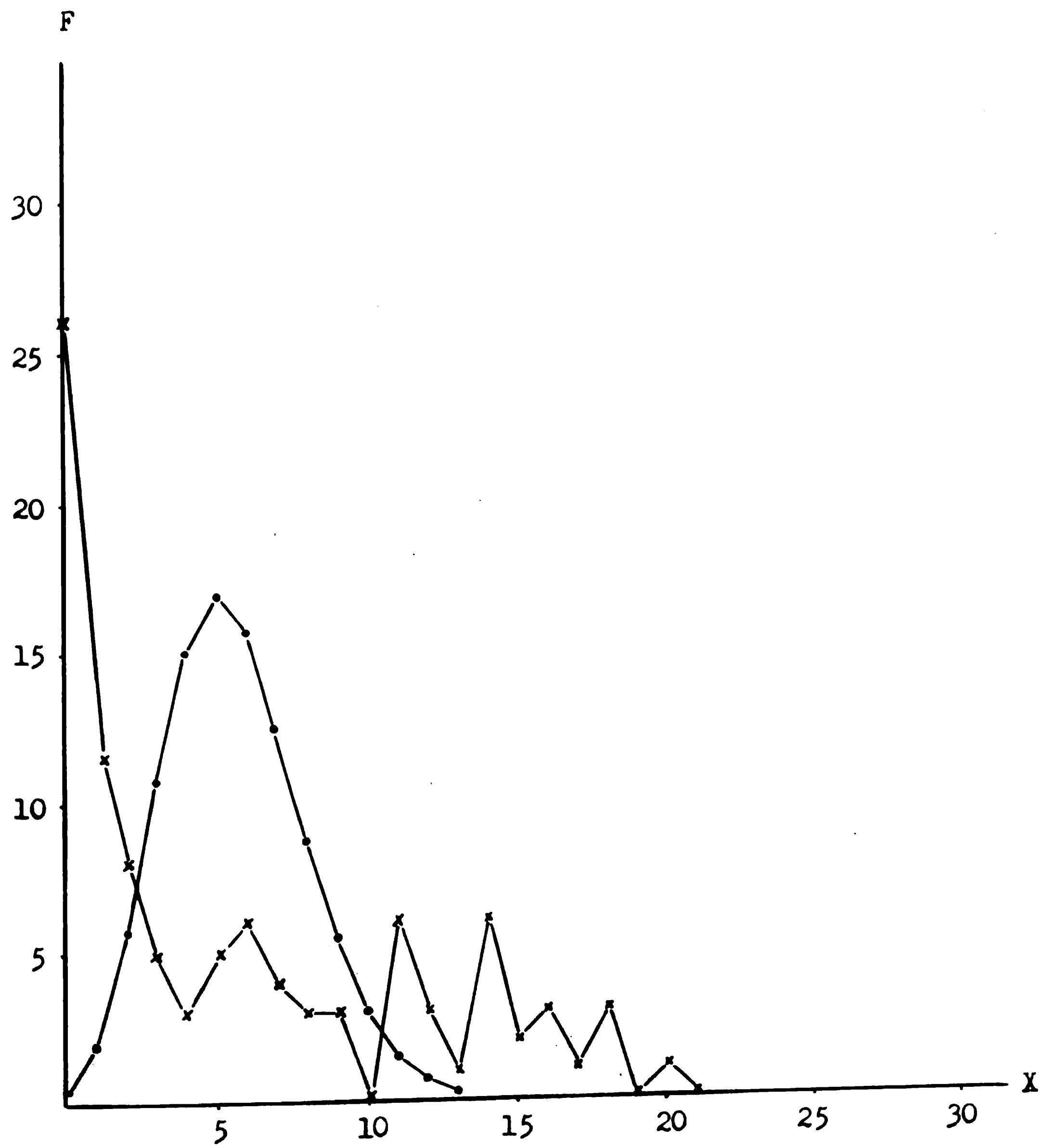
Frequency Distribution

Cornicularia divergens Ach.

$\bar{x}$ - 5.62

Observed **frequency distribution** - x——x

Poisson distribution - •——•



Appendix Figure L.

Transect III

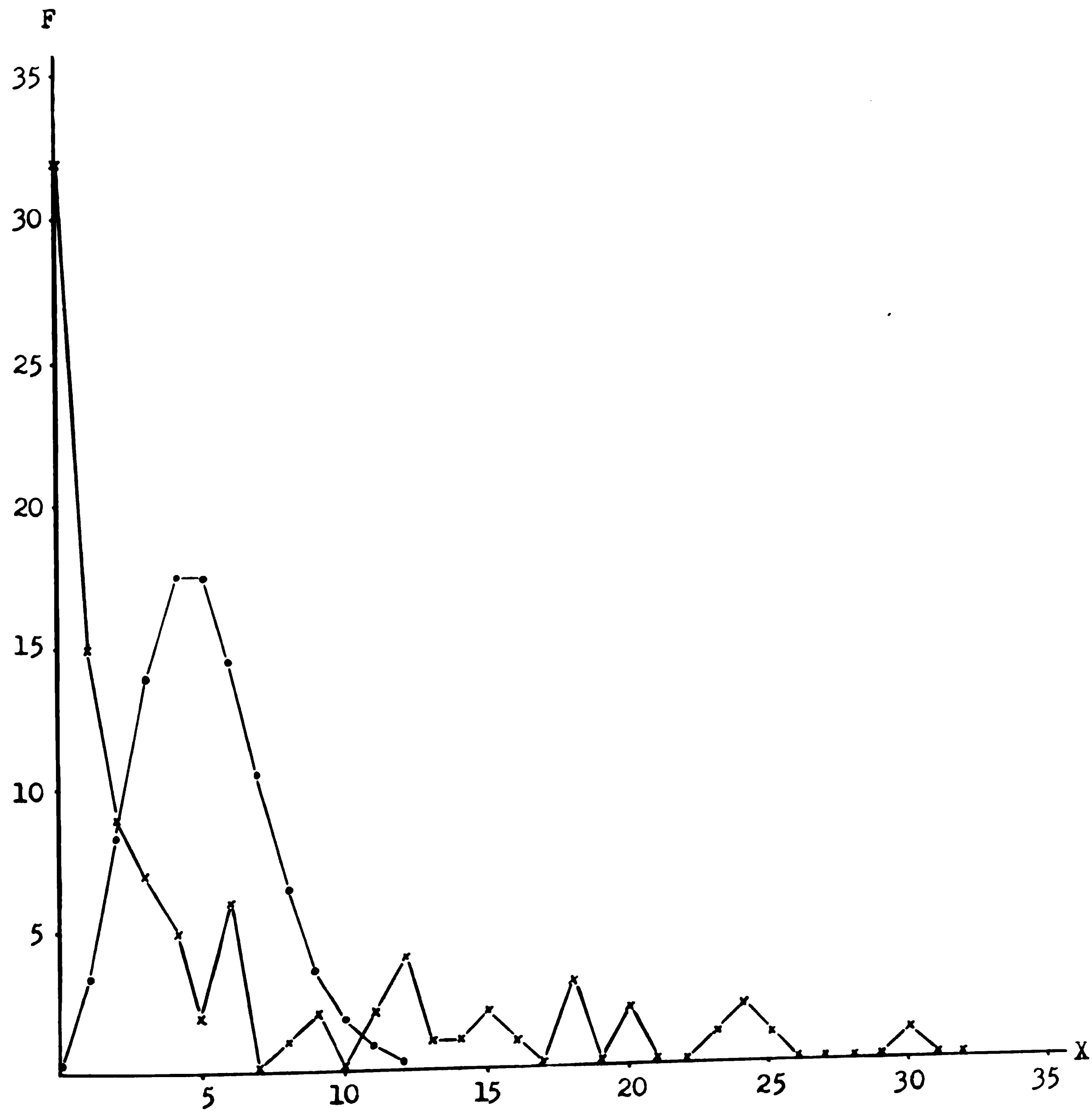
Frequency Distribution

Cetraria nivalis (L.) Ach.

$\bar{x}$ - 5.03

Observed frequency
distribution - x——x

Poisson distribution - •——•



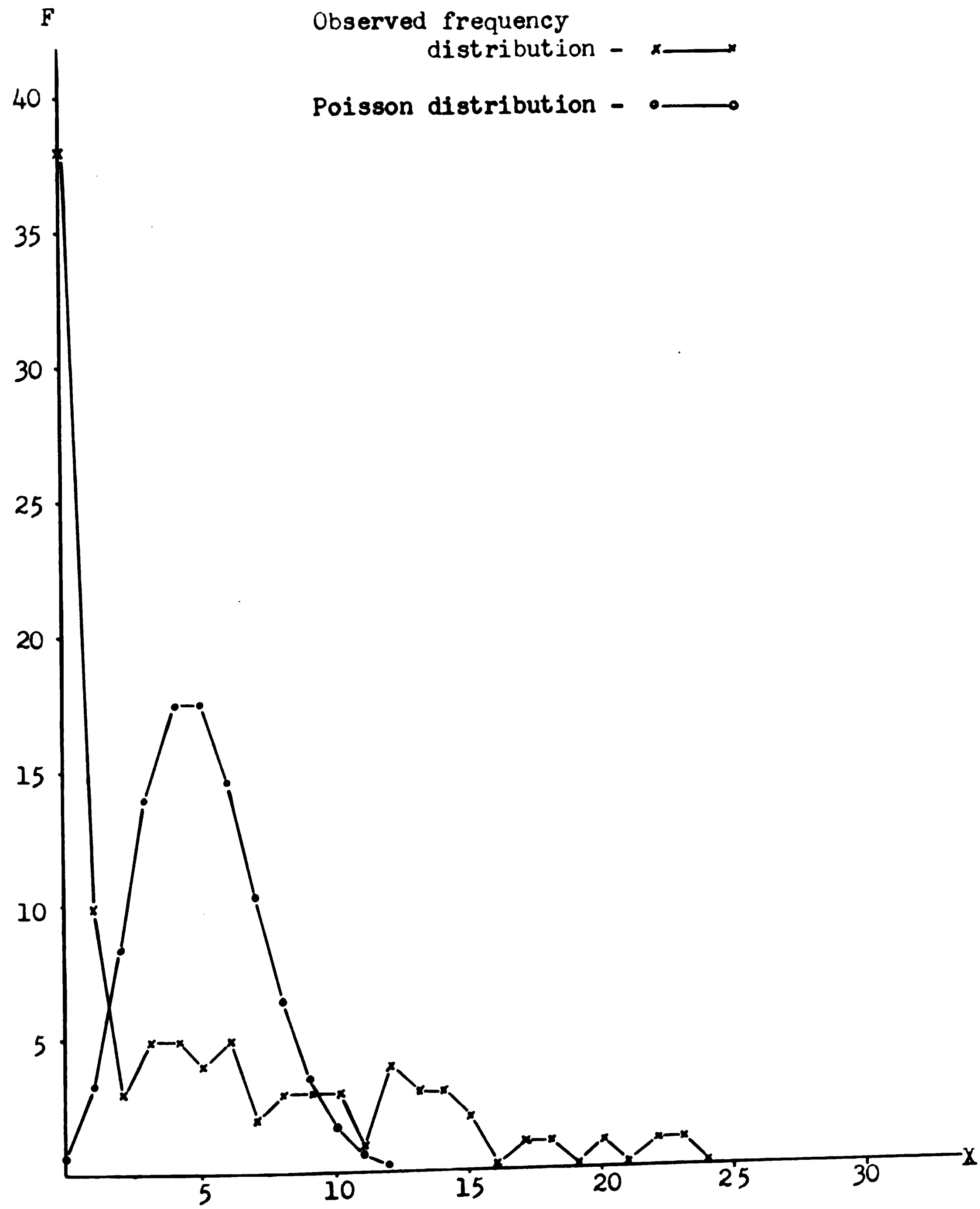
Appendix Figure LI.

Transect III

Frequency Distribution

Cladonia gracilis (L.) Willd.

$\bar{x}$ - 5.01



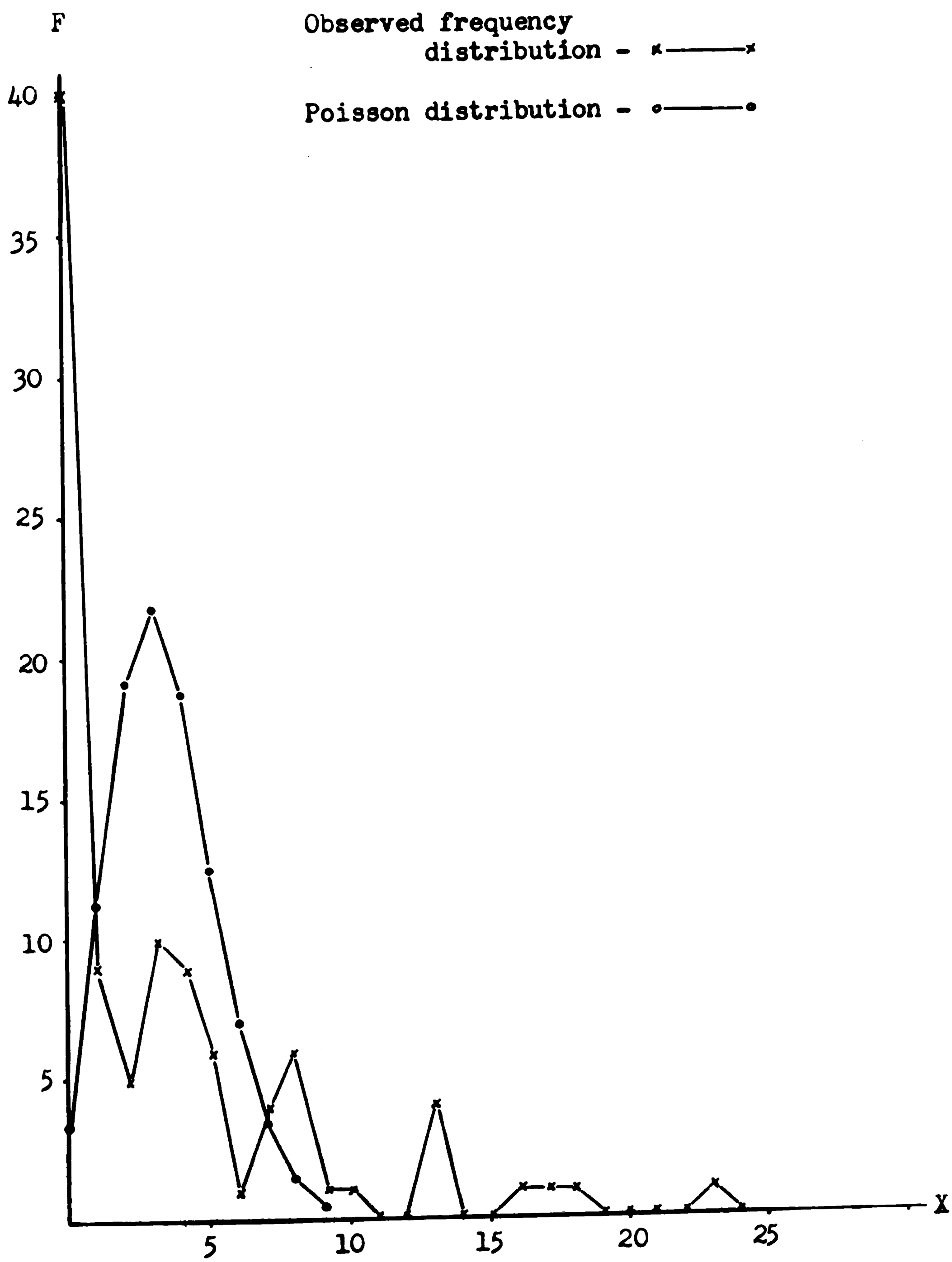
Appendix Figure LII.

Transect III

Frequency Distribution

Cladonia sp.

$\bar{x}$ - 3.42



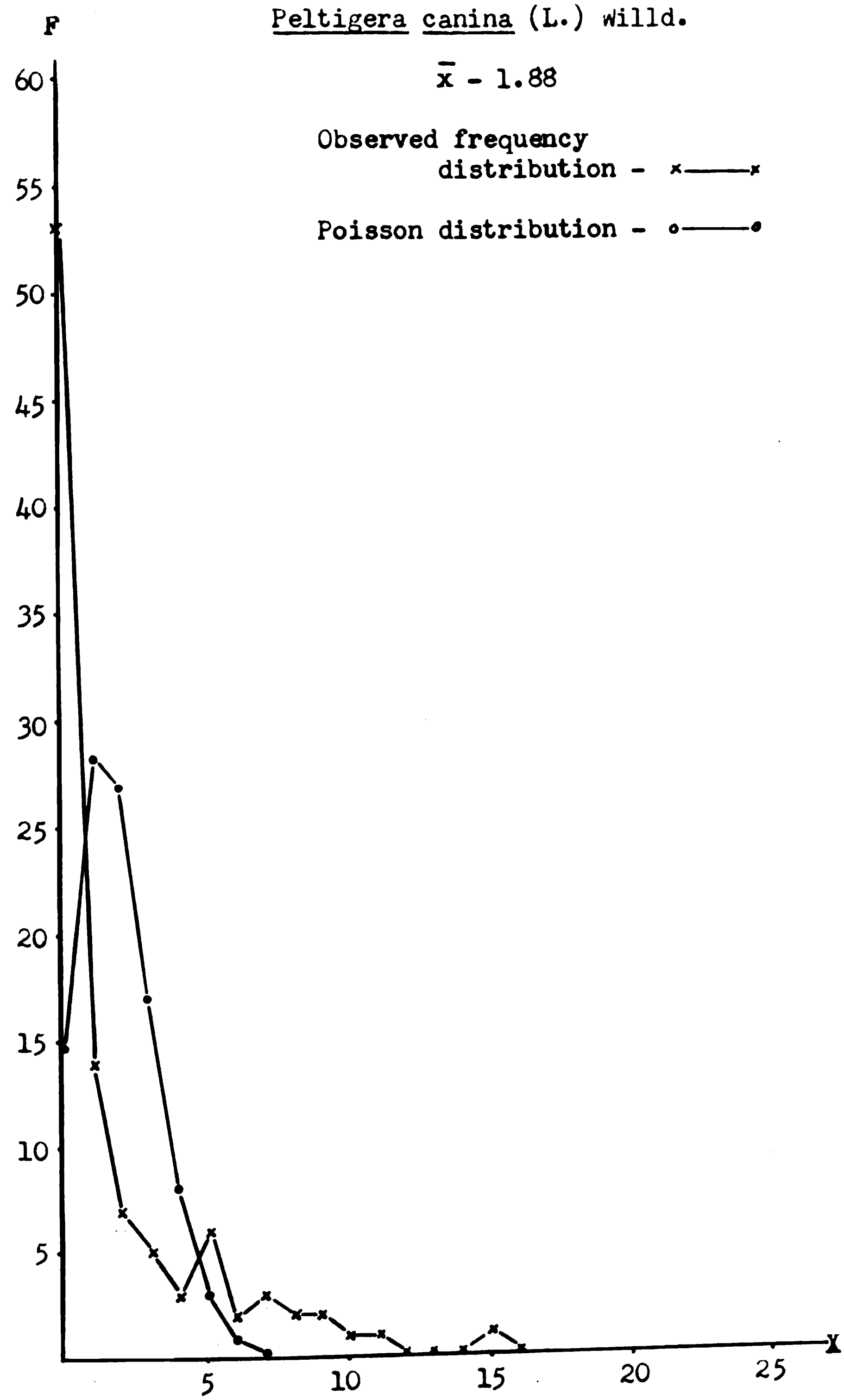
Appendix Figure LIII.

Transect III

Frequency Distribution

Peltigera canina (L.) Willd.

$\bar{x}$ - 1.88



Appendix Figure LIV.

Transect III

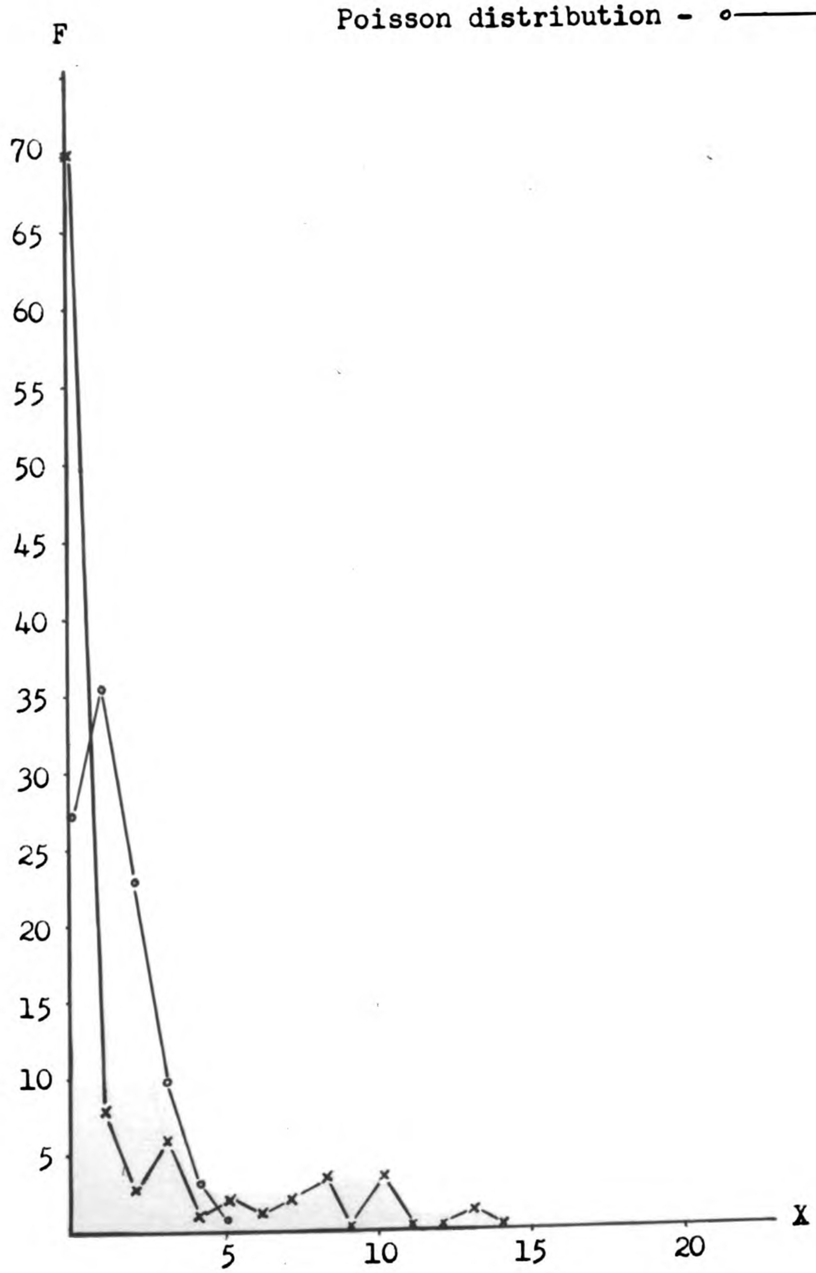
Frequency Distribution

Lobaria linita (Ach.) Rabenh.

$\bar{x}$ - 1.33

Observed frequency distribution - x———x

Poisson distribution - o———o



Appendix Figure LV.

Transect III

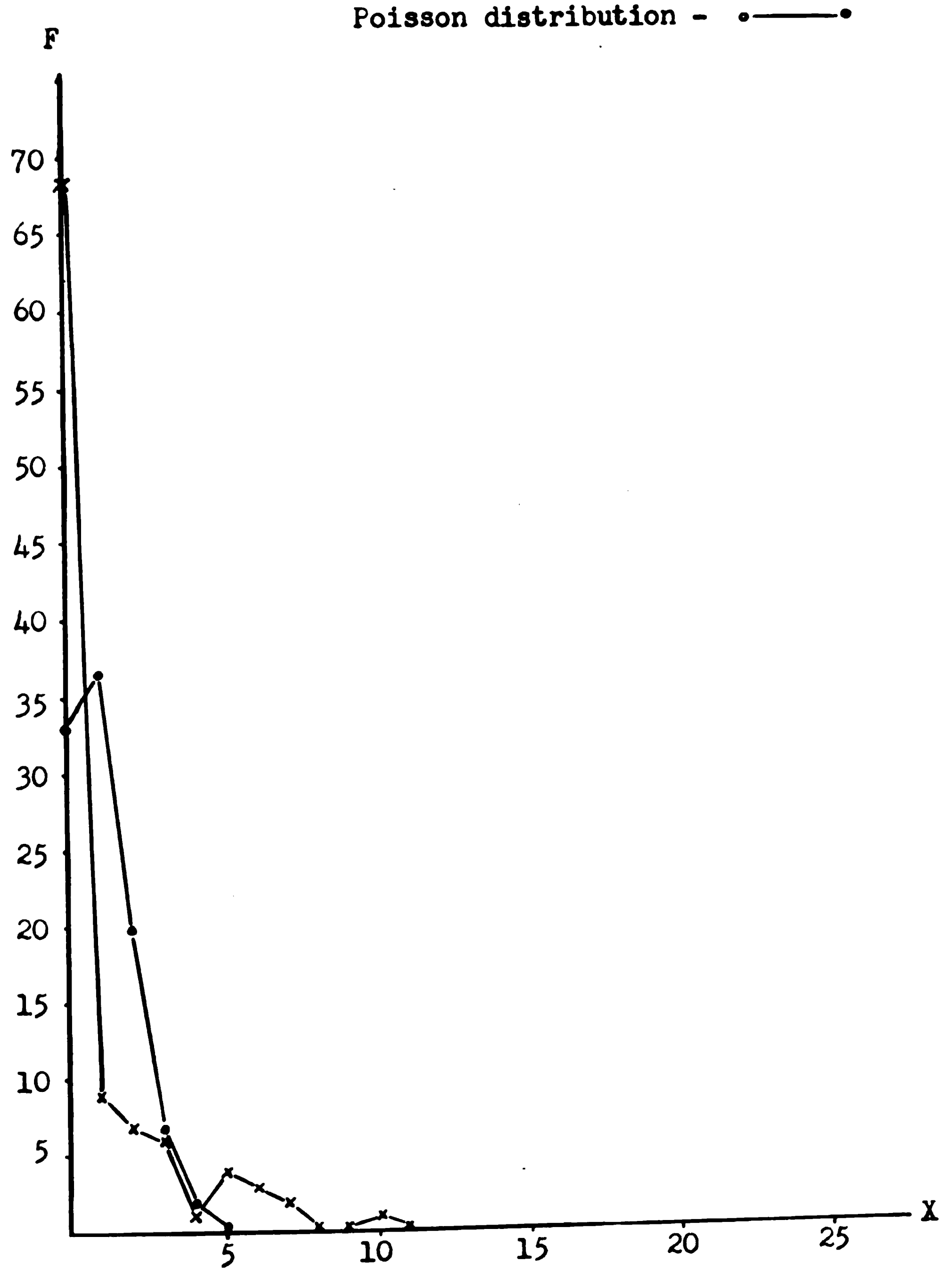
Frequency Distribution

Psoroma hypnorum (Dicks.) Hoffm.

$\bar{x}$ - 1.07

Observed frequency distribution - x——x

Poisson distribution - •——•



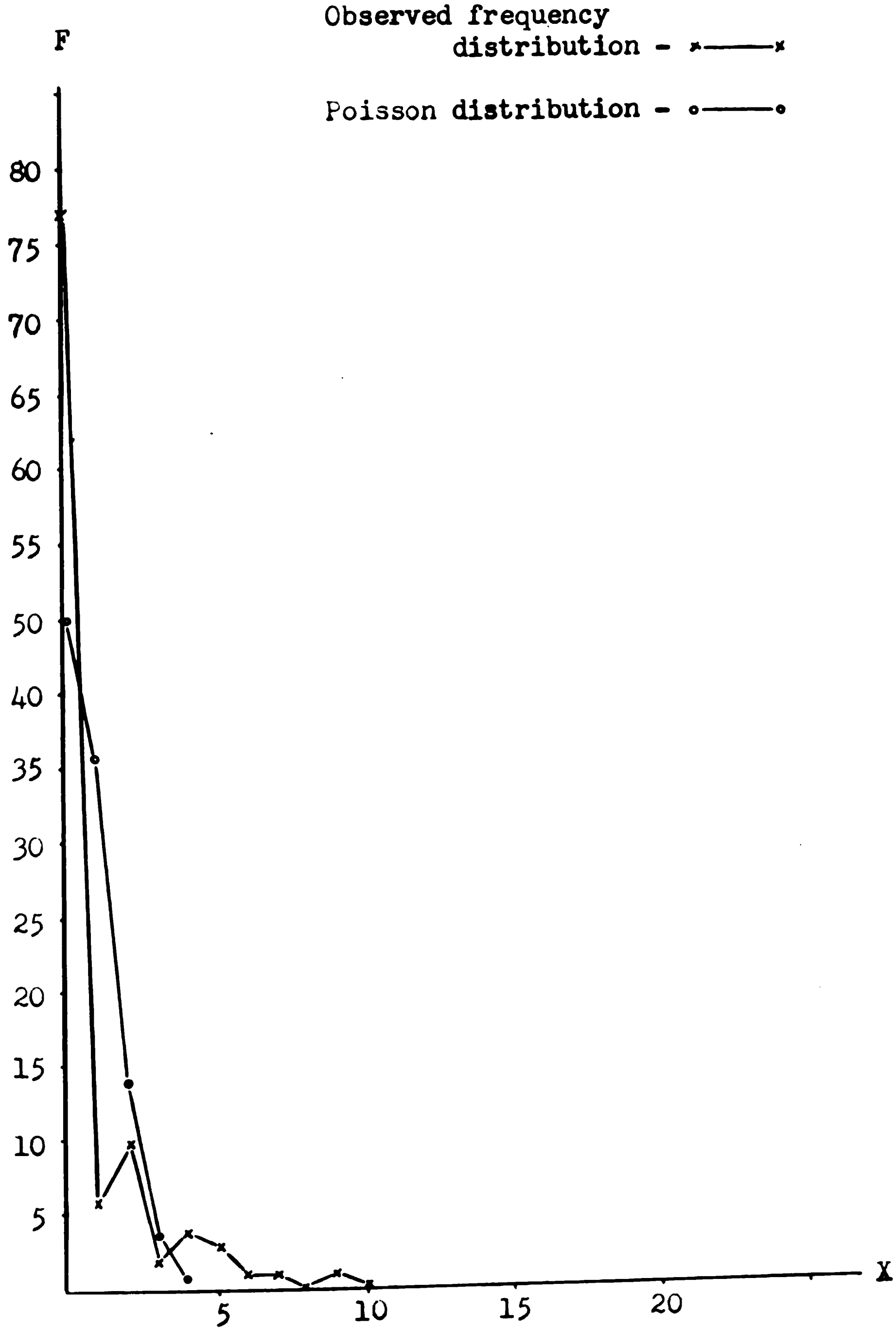
Appendix Figure LVI.

Transect III

Frequency Distribution

Cetraria delisei (Bory.) Th.Fr.

$\bar{x}$ - .85



Appendix Figure LVII.

APPENDIX TABLE 1

TRANSECT III - STATISTICS

Species	$\bar{x}$	Freq.	d	s^2
Poa arctica	59.25	95	2.99	1440.41
Arctagrostis latifolia	17.20	91	2.40	297.76
Eriophorium scheuchzeri	8.90	28	.32	649.19
Carex aquatilis	8.45	53	.75	172.71
Luzula nivalis	7.15	51	.71	121.03
Luzula confusa	6.91	46	.61	119.95
Eriophorum angustifolium	1.95	10	.10	60.43
Juncus biglumis	.06	2	.02	.25
Saxifraga cernua	9.05	57	.84	82.00
Stellaria laeta	6.54	68	1.13	56.71
Petasites frigidus	5.75	37	.46	76.67
Senecio atropurpureus	5.10	49	.67	50.90
Saxifraga punctata	1.18	29	.34	5.88
Vaccinium vitis-idaea	.84	15	.16	7.28
Potentilla emarginata	.80	31	.37	3.65
Saxifraga foliolosa	.67	23	.26	2.95
Saxifraga flagellaris	.15	7	.07	.45
Saxifraga caespitosa	.06	1	.01	.18
Thamnolia vermicularis	13.70	86	1.96	246.86
Dactylina arctica	12.76	78	1.51	122.52
Cetraria islandica	10.13	86	1.96	54.13
Sphaerophorus globosus	9.07	72	1.27	103.69
Cornicularia divergens	5.62	74	1.34	33.65
Cetraria nivalis	5.03	68	1.13	50.73
Cladonia gracilis	5.01	62	.96	36.91
Cladonia sp.	3.42	60	.91	21.35
Peltigera canina	1.88	47	.63	8.95
Lobaria linita	1.33	30	.35	7.65
Parmelia omphalodes	1.14	35	.43	4.82
Psoroma hypnorum	1.07	33	.40	4.02
Cetraria delisei	.85	28	.32	3.99
Cladonia uncialis	.73	18	.19	5.65
Peltigera aphthosa	.60	23	.26	1.69
Stereocaulon evolutoides	.52	10	.10	10.63
Caloplaca subolivacea	.50	18	.19	2.15
Cladonia rangiferina	.30	13	.13	1.74
Cetraria richardsonii	.12	8	.08	.20
Solorina crocea	.11	7	.07	.30
Dactylina ramulosa	.05	3	.03	.33

$\bar{x}$ - Observed mean density
Freq. - Frequency of occurrence in 100 quadrats
d - Theoretical mean density at the observed frequency
s^2 - variance of the observed frequency distribution

APPENDIX TABLE 2

COMPARATIVE TRANSECT IIIa

Species	$\bar{x}$	Freq.	d	s^2
Poa arctica	62.38	95	3.11	3224.74
Arctagrostis latifolia	15.66	81	1.63	251.28
Carex aquatilis	7.90	52	.73	139.29
Luzula confusa	7.85	52	.73	199.38
Eriophorum scheuchzeri	6.85	28	.33	375.36
Luzula nivalis	6.09	52	.73	199.38
Eriophorum angustifolium	1.66	10	.10	51.70
Stellaria laeta	6.24	67	1.07	53.39
Petasites frigidus	5.81	33	.39	87.26
Senecio atropurpureus	3.90	48	.63	34.19
Saxifraga cernua	2.57	48	.63	16.15
Saxifraga punctata	1.14	24	.26	7.13
Saxifraga foliolosa	1.14	40	.51	7.33
Potentilla emarginata	.52	29	.33	1.11
Vaccinium vitis-idaea	.47	5	.05	4.76
Saxifraga caespitosa	.28	5	.05	1.71
Saxifraga flagellaris	.19	10	.10	.46
Thamnolia vermicularis	18.33	86	1.93	405.93
Dactylina arctica	12.66	86	1.93	133.43
Cetraria islandica	10.71	90	2.35	47.21
Sphaerophorus globosus	7.52	71	1.23	67.66
Cetraria nivalis	5.95	67	1.08	63.24
Cornicularia divergens	5.52	71	1.23	34.76
Cladonia gracilis	5.52	57	.83	51.06
Cladonia sp.	2.52	62	.95	24.56
Peltigera canina	1.90	52	.63	9.79
Stereocaulon evolutoides	1.66	10	.10	43.33
Psoroma hypnorum	1.33	29	.33	7.93
Cladonia uncialis	1.24	24	.33	11.09
Lobaria linita	1.09	19	.16	9.89
Caloplaca subolivacea	.95	29	.33	4.64
Parmelia omphalodes	.66	29	.33	1.53
Peltigera aphthosa	.38	19	.16	0.84
Solorina crocea	.33	14	.15	1.23

$\bar{x}$ - Observed mean density
Freq. - Frequency of occurrence in 21 quadrats
d - Theoretical mean density at the observed frequency
s^2 - variance of the observed frequency distribution

APPENDIX TABLE 3

TRANSECT III AND TRANSECT IIIa COMPARISONS

Species III	$\bar{x}$	Freq.	Species IIIa	$\bar{x}$	Freq.
Poa arctica	59.25	95	Poa arctica	62.38	95
Arctagrostis latifolia	17.20	91	Arctagrostis latifolia	15.66	81
Eriophorum scheuchzeri	8.90	28	Carex aquatilis	7.90	52
Carex aquatilis	8.45	53	Luzula confusa	7.85	52
Luzula nivalis	7.15	51	Eriophorum scheuchzeri	6.85	28
Eriophorum angustifolium	1.95	10	Luzula nivalis	6.09	52
Juncus biglumis	.06	2			
Saxifraga cernua	9.05	57	Stellaria laeta	6.24	67
Stellaria laeta	6.54	68	Petasites frigidus	5.81	33
Petasites frigidus	5.75	37	Senecio atropurpureus	3.90	48
Senecio atropurpureus	5.10	49	Saxifraga cernua	2.57	48
Saxifraga punctata	1.18	29	Saxifraga punctata	1.14	24
Vaccinium vitis-idaea	.84	15	Saxifraga foliolosa	1.14	40
Potentilla emarginata	.80	31	Potentilla emarginata	.52	29
Saxifraga foliolosa	.67	23	Vaccinium vitis-idaea	.47	5
Saxifraga flagellaris	.15	7	Saxifraga caespitosa	.28	5
Saxifraga caespitosa	.06	1	Saxifraga flagellaris	.19	10
Thamnolia vermicularis	13.70	86	Thamnolia vermicularis	18.33	86
Dactylina arctica	12.76	78	Dactylina arctica	12.66	86
Cetraria islandica	10.13	86	Cetraria islandica	10.71	90
Sphaerophorus globosus	9.07	72	Sphaerophorus globosus	7.52	71
Cornicularia divergens	5.62	74	Cetraria nivalis	5.95	67
Cetraria nivalis	5.03	68	Cornicularia divergens	5.52	71
Cladonia gracilis	5.01	62	Cladonia gracilis	5.52	57
Cladonia sp.	3.42	60	Cladonia sp.	2.52	62
Peltigera canina	1.88	47	Peltigera canina	1.90	52
Lobaria linita	1.33	30	Stereocaulon evolutoides	1.66	10
Parmelia omphalodes	1.14	35	Psoroma hypnorum	1.33	29
Psoroma hypnorum	1.07	33	Cladonia uncialis	1.24	24
Cladonia uncialis	.73	18	Lobaria linita	1.09	19
Peltigera aphthosa	.60	23	Caloplaca subolivacea	.95	29
Stereocaulon evolutoides	.52	10	Parmelia omphalodes	.66	29
Caloplaca subolivacea	.50	18	Peltigera aphthosa	.38	19
Solorina crocea	.11	7	Solorina crocea	.33	14

Transect III - 100 quadrats, 1/20 square meter
Transect IIIa - 21 quadrats, 1/20 square meter, sampling the same area as Transect III

$\bar{x}$ - mean density
Freq. - Frequency of occurrence in either 100 or 21 quadrats.

APPENDIX TABLE 4

TRANSECT III AND TRANSECT IIIa COMPARISONS
MEASURES OF AGGREGATION
GRASSES, SEDGES, AND RUSHES

Species III	$s^2/\bar{x}$	Species IIIa	$s^2/\bar{x}$
Eriophorum scheuchzeri	74.06	Eriophorum scheuchzeri	54.70
Eriophorum angustifolium	30.98	Poa arctica	51.09
Poa arctica	24.31	Eriophorum angustifolium	31.14
Carex aquatilis	20.43	Luzula confusa	25.37
Luzula confusa	17.35	Carex aquatilis	17.62
Arctagrostis latifolia	17.31	Arctagrostis latifolia	16.04
Luzula nivalis	17.01	Luzula nivalis	7.54

Species III	D/d	Species IIIa	D/d
Eriophorum scheuchzeri	27.1	Eriophorum scheuchzeri	20.8
Poa arctica	19.7	Poa arctica	20.0
Eriophorum angustifolium	19.5	Eriophorum angustifolium	17.1
Luzula confusa	11.3	Carex aquatilis	10.8
Carex aquatilis	11.2	Luzula confusa	10.8
Luzula nivalis	10.0	Arctagrostis latifolia	9.6
Arctagrostis latifolia	7.2	Luzula nivalis	8.4

Species III	$D-d/d^2$	Species IIIa	$D-d/d^2$
Eriophorum angustifolium	167.7	Eriophorum angustifolium	174.3
Eriophorum scheuchzeri	79.7	Eriophorum scheuchzeri	60.9
Luzula confusa	16.9	Carex aquatilis	13.6
Carex aquatilis	13.6	Luzula confusa	13.5
Luzula nivalis	12.7	Luzula nivalis	10.2
Poa arctica	6.3	Poa arctica	6.1
Arctagrostis latifolia	2.6	Arctagrostis latifolia	5.3

Species III	A	Species IIIa	A
Eriophorum angustifolium	1.95	Eriophorum angustifolium	1.66
Eriophorum scheuchzeri	1.13	Eriophorum scheuchzeri	.87
Poa arctica	.65	Poa arctica	.69
Luzula confusa	.33	Carex aquatilis	.29
Carex aquatilis	.30	Luzula confusa	.29
Luzula nivalis	.27	Arctagrostis latifolia	.24
Arctagrostis latifolia	.21	Luzula nivalis	.22

$s^2/\bar{x}$ - relative variance Random - 1
D/d - Observed mean density/theoretical mean density Random - 1
$D-d/d^2$ - Fracker and Brischle measure Random - 0
A - 100(Observed mean density)/frequency^2 Random - 0-.3

APPENDIX TABLE 5

TRANSECT III AND TRANSECT IIIa COMPARISONS
MEASURES OF AGGREGATION
MISCELLANEOUS FLOWERING PLANTS

Species III	$s^2/\bar{x}$	Species IIIa	$s^2/\bar{x}$
Saxifraga cernua	17.01	Petasites frigidus	15.02
Petasites frigidus	13.33	Vaccinium vitis-idaea	10.00
Senecio atropurpureus	9.98	Senecio atropurpureus	8.75
Stellaria laeta	8.67	Stellaria laeta	8.55
Vaccinium vitis-idaea	8.67	Saxifraga foliolosa	6.50
Saxifraga caespitosa	5.81	Saxifraga cernua	6.28
Saxifraga punctata	4.98	Saxifraga punctata	6.23
Potentilla emarginata	4.56	Saxifraga ceaspitosa	6.00
Saxifraga foliolosa	4.40	Saxifraga flagellaris	2.42
Saxifraga flagellaris	3.01	Potentilla emarginata	2.11
Species III	**D/d**	**Species IIIa**	**D/d**
Petasites frigidus	12.5	Petasites frigidus	14.66
Saxifraga cernua	10.7	Vaccinium vitis-idaea	10.12
Senecio atropurpureus	7.6	Senecio atropurpureus	6.16
Saxifraga caespitosa	6.0	Saxifraga caespitosa	6.06
Stellaria laeta	5.7	Stellaria laeta	5.82
Vaccinium vitis-idaea	5.2	Saxifraga punctata	4.30
Saxifraga punctata	3.4	Saxifraga cernua	4.06
Saxifraga foliolosa	2.5	Saxifraga foliolosa	2.23
Potentilla emarginata	2.2	Saxifraga flagellaris	1.95
Saxifraga flagellaris	2.1	Potentilla emarginata	1.59
Species III	**$D-d/d^2$**	**Species IIIa**	**$D-d/d^2$**
Vaccinium vitis-idaea	26.5	Vaccinium vitis-idaea	214.5
Petasites frigidus	25.0	Saxifraga caespitosa	119.0
Saxifraga flagellaris	16.3	Petasites frigidus	34.7
Saxifraga cernua	11.6	Saxifraga punctata	12.5
Senecio atropurpureus	9.8	Saxifraga flagellaris	10.3
Saxifraga punctata	7.3	Senecio atropurpureus	8.2
Saxifraga foliolosa	6.1	Saxifraga cernua	4.8
Saxifraga caespitosa	5.0	Stellaria laeta	4.5
Stellaria laeta	4.2	Saxifraga foliolosa	2.4
Potentilla emarginata	3.1	Potentilla emarginata	1.8
Species III	**A**	**Species IIIa**	**A**
Petasites frigidus	.420	Vaccinium vitis-idaea	1.90
Vaccinium vitis-idaea	.373	Saxifraga caespitosa	1.14
Saxifraga flagellaris	.306	Petasites frigidus	.53
Saxifraga cernua	.278	Saxifraga punctata	.19
Senecio atropurpureus	.212	Saxifraga flagellaris	.19
Stellaria laeta	.141	Senecio atropurpureus	.16
Saxifraga punctata	.140	Stellaria laeta	.13
Saxifraga foliolosa	.126	Saxifraga cernua	.11
Potentilla emarginata	.083	Saxifraga foliolosa	.07
Saxifraga caespitosa	.060	Potentilla emarginata	.06

APPENDIX TABLE 6

TRANSECT III AND TRANSECT IIIa COMPARISONS
MEASURES OF AGGREGATION
LICHENS

Species III	D-d/d^2	Species IIIa	D-d/d^2
Stereocaulon evolutoides	42.00	Stereocaulon evolutoides	174.33
Cladonia uncialis	14.90	Lobaria linita	37.44
Caloplaca subolivacea	8.58	Psoroma hypnorum	9.39
Solorina crocea	8.16	Peltigera aphthosa	8.84
Lobaria linita	8.00	Cladonia uncialis	8.50
Peltigera aphthosa	5.02	Solorina crocea	8.31
Dactylina arctica	4.93	Cladonia gracilis	6.82
Sphaerophorus globosus	4.83	Caloplaca subolivacea	5.83
Cladonia gracilis	4.39	Thamnolia vermicularis	4.39
Psoroma hypnorum	4.18	Cetraria nivalis	4.18
Parmelia omphalodes	3.83	Sphaerophorus globosus	4.14
Peltigera canina	3.14	Peltigera canina	3.18
Thamnolia vermicularis	3.05	Parmelia omphalodes	3.15
Cetraria nivalis	3.05	Dactylina arctica	2.87
Cladonia sp.	3.03	Cornicularia divergens	2.82
Cornicularia divergens	2.38	Cladonia sp.	1.75
Cetraria islandica	2.12	Cetraria islandica	1.51

Species III	$s^2/\bar{x}$	Species IIIa	$s^2/\bar{x}$
Stereocaulon evolutoides	20.45	Stereocaulon evolutoides	26.00
Thamnolia vermicularis	18.01	Thamnolia vermicularis	22.14
Sphaerophorus globosus	11.43	Cetraria nivalis	10.62
Cetraria nivalis	10.08	Dactylina arctica	10.53
Dactylina arctica	9.60	Cladonia sp.	9.73
Cladonia uncialis	7.74	Cladonia gracilis	9.24
Cladonia gracilis	7.36	Lobaria linita	9.03
Cladonia sp.	6.24	Sphaerophorus globosus	8.99
Cornicularia divergens	5.98	Cladonia uncialis	8.95
Lobaria linita	5.75	Cornicularia divergens	6.29
Cetraria islandica	5.34	Psoroma hypnorum	5.95
Peltigera canina	4.76	Peltigera canina	5.14
Parmelia omphalodes	4.28	Caloplaca subolivacea	4.88
Caloplaca subolivacea	4.03	Cetraria islandica	4.40
Psoroma hypnorum	3.76	Solorina crocea	3.70
Peltigera aphthosa	2.82	Parmelia omphalodes	2.30
Solorina crocea	2.73	Peltigera aphthosa	2.22

D-d/d^2 - Fracker and Brischle measure   Random - 0

$s^2/\bar{x}$ - Relative variance, variance of observed frequency distribution/ observed mean density

APPENDIX TABLE 7

TRANSECT III AND TRANSECT IIIa COMPARISONS
MEASURES OF AGGREGATION
LICHENS

Species III	A	Species IIIa	A
Stereocaulon evolutoides	.555	Stereocaulon evolutoides	1.660
Cladonia uncialis	.225	Lobaria linita	.303
Solorina crocea	.224	Thamnolia vermicularis	.247
Sphaerophorus globosus	.174	Cornicularia divergens	.213
Caloplaca subolivacea	.154	Cladonia uncialis	.213
Lobaria linita	.147	Dactylina arctica	.171
Peltigera aphthosa	.113	Solorina crocea	.170
Cornicularia divergens	.102	Cladonia gracilis	.169
Psoroma hypnorum	.098	Sphaerophorus globosus	.149
Cladonia sp.	.095	Cetraria nivalis	.136
Parmelia omphalodes	.093	Cetraria islandica	.132
Peltigera canina	.085	Caloplaca subolivacea	.113
Dactylina arctica	.020	Peltigera aphthosa	.105
Thamnolia vermicularis	.018	Psoroma hypnorum	.083
Cetraria islandica	.013	Peltigera canina	.070
Cladonia gracilis	.013	Cladonia sp.	.065
Cetraria nivalis	.010	Parmelia omphalodes	.041
Species III	**D/d**	**Species IIIa**	**D/d**
Dactylina arctica	8.45	Stereocaulon evolutoides	17.17
Sphaerophorus globosus	7.14	Thamnolia vermicularis	9.49
Thamnolia vermicularis	6.98	Lobaria linita	6.88
Cladonia gracilis	5.21	Cladonia gracilis	6.65
Stereocaulon evolutoides	5.20	Dactylina arctica	6.55
Cetraria islandica	5.16	Sphaerophorus globosus	6.10
Cetraria nivalis	4.45	Cetraria nivalis	5.51
Cornicularia divergens	4.19	Cetraria islandica	4.55
Cladonia uncialis	3.80	Cornicularia divergens	4.48
Lobaria linita	3.80	Psoroma hypnorum	4.06
Cladonia sp.	3.75	Cladonia uncialis	3.77
Peltigera canina	2.98	Peltigera canina	3.00
Psoroma hypnorum	2.67	Caloplaca subolivacea	2.90
Parmelia omphalodes	2.65	Cladonia sp.	2.66
Caloplaca subolivacea	2.63	Peltigera aphthosa	2.38
Peltigera aphthosa	2.30	Solorina crocea	2.22
Solorina crocea	1.57	Parmelia omphalodes	2.02

A - 100(Observed mean density)/frequency^2 Random - 0-.3

D/d - Observed mean density/expected density at observed frequency
Random - 1

APPENDIX TABLE 8

COMPARISON OF TRANSECT I AND TRANSECT IIIa

Species IIIa	$\bar{x}$	Freq.	Species I	$\bar{x}$	Freq.
Poa arctica	62.38	95	Carex aquatilis	32.04	67
Arctagrostis latifolia	15.66	81	Poa arctica	16.95	86
Carex aquatilis	7.90	52	Alopecurus alpina	14.33	36
Luzula confusa	7.85	52	Arctagrostis latifolia	11.04	95
Eriophorum scheuchzeri	6.85	28	Eriophorum angustifolium	3.14	14
Luzula nivalis	6.09	52	Luzula nivalis	2.52	43
Eriophorum angustifolium	1.66	10	Eriophorum scheuchzeri	1.20	14
			Juncus biglumis	1.04	14
			Luzula confusa	.57	17
Stellaria laeta	6.24	67	Saxifraga cernua	3.95	48
Petasites frigidus	5.81	33	Stellaria laeta	2.95	57
Senecio atropurpureus	3.90	48	Senecio atropurpureus	2.57	57
Saxifraga cernua	2.57	48	Saxifraga foliolosa	1.28	48
Saxifraga punctata	1.14	24	Saxifraga punctata	.95	28
Saxifraga foliolosa	1.14	40			
Potentilla emarginata	.52	29			
Vaccinium vitis-idaea	.47	5			
Saxifraga caespitosa	.28	5			
Saxifraga flagellaris	.19	10			
Thamnolia vermicularis	18.33	86	Thamnolia vermicularis	8.09	90
Dactylina arctica	12.66	86	Cetraria islandica	5.00	71
Cetraria islandica	10.71	90	Dactylina arctica	3.80	57
Sphaerophorus globosus	7.52	71	Lobaria linita	2.09	48
Cetraria nivalis	5.95	67	Peltigera aphthosa	1.00	48
Cornicularia divergens	5.52	71	Caloplaca subolivacea	.95	19
Cladonia gracilis	5.52	57	Peltigera canina	.90	62
Cladonia sp.	2.52	62	Cladonia gracilis	.76	33
Peltigera canina	1.90	52	Stereocaulon evolutoides	.62	24
Stereocaulon evolutoides	1.66	10	Sphaerophorus globosus	.62	14
Psoroma hypnorum	1.33	29	Psoroma hypnorum	.33	14
Cladonia uncialis	1.24	24	Cornicularia divergens	.28	14
Lobaria linita	1.09	19	Cetraria nivalis	.28	19
Caloplaca subolivacea	.95	29			
Parmelia omphalodes	.66	29			
Peltigera aphthosa	.38	19			
Solorina crocea	.33	14			

$\bar{x}$ - Observed mean density
Freq. - Frequency of occurrence in 21 quadrats

Transect I - 21 quadrats, 1/20 square-meter, on comparative area

Transect IIIa - 21 quadrats, 1/20 square-meter, taken from quadrat data for transect of 100 quadrats, 1/20 square-meter

APPENDIX TABLE 9

TRANSECT IIIb - STATISTICS

Species	$\bar{x}$	Freq.	d	s^2
Poa arctica	28.78	93	2.66	624.31
Arctagrostis latifolia	8.30	81	1.66	74.57
Eriophorum scheuchzeri	4.61	27	.31	153.39
Carex aquatilis	4.20	44	.58	54.20
Luzula nivalis	3.60	33	.40	61.61
Luzula confusa	3.07	36	.44	35.54
Eriophorum angustifolium	1.16	9	.09	20.86
Stellaria laeta	2.89	57	.84	13.04
Petasites frigidus	2.84	36	.44	20.23
Senecio atropurpureus	2.56	41	.53	17.82
Saxifraga cernua	2.35	49	.67	23.22
Saxifraga punctata	.70	22	.25	2.55
Vaccinium vitis-idaea	.55	12	.13	4.03
Potentilla emarginata	.40	21	.23	1.21
Saxifraga foliolosa	.31	15	.16	.94
Saxifraga flagellaris	.09	5	.05	.22
Saxifraga caespitosa	.05	1	.01	.25
Thamnolia vermicularis	7.26	84	1.83	64.19
Dactylina arctica	6.67	83	1.77	40.58
Sphaerophorus globosus	4.56	65	1.05	30.71
Cetraria islandica	4.32	83	1.77	29.84
Cornicularia divergens	3.24	70	1.20	12.51
Cetraria nivalis	2.76	57	.84	17.74
Cladonia gracilis	2.47	50	.69	11.46
Cladonia sp.	1.92	50	.69	8.92
Peltigera canina	1.01	40	.51	2.47
Lobaria linita	.71	27	.31	2.13
Parmelia omphalodes	.67	27	.31	1.75
Psoroma hypnorum	.54	21	.23	1.80
Cetraria delisei	.51	24	.27	1.12
Cladonia uncialis	.40	14	.15	2.38
Peltigera aphthosa	.30	19	.21	.45
Stereocaulon evolutoides	.30	9	.09	1.44
Caloplaca subolivacea	.26	14	.15	.59
Cladonia rangiferina	.16	8	.08	.60
Dactylina ramulosa	.04	2	.02	.09
Solorina crocea	.03	3	.03	.03
Cetraria richardsonii	.03	3	.03	.03

$\bar{x}$ - Observed mean density
Freq. - Frequency of occurrence in 100 quadrats
d - Theoretical mean density at the observed frequency
s^2 - Variance of the observed frequency distribution

Transect IIIb - 100 quadrats, 1/40 square meter

APPENDIX TABLE 10

TRANSECT III AND TRANSECT IIIb COMPARISONS

Species III	$\bar{x}$	Freq.		$\bar{x}$	Freq.
Poa arctica	59.25	95	Poa arctica	28.78	93
Arctagrostis latifolia	17.20	91	Arctagrostis latifolia	8.30	81
Eriophorum scheuchzeri	8.90	28	Eriophorum scheuchzeri	4.61	27
Carex aquatilis	8.45	53	Carex aquatilis	4.20	44
Luzula nivalis	7.15	51	Luzula nivalis	3.60	33
Luzula confusa	6.91	46	Luzula confusa	3.07	36
Eriophorum angustifolium	1.95	10	Eriophorum angustifolium	1.16	9
Juncus biglumis	.06	2			
Saxifraga cernua	9.05	57	Stellaria laeta	2.89	57
Stellaria laeta	6.54	68	Petasites frigidus	2.84	36
Petasites frigidus	5.75	37	Senecio atropurpureus	2.56	41
Senecio atropurpureus	5.10	49	Saxifraga cernua	2.35	49
Saxifraga punctata	1.18	29	Saxifraga punctata	.70	22
Vaccinium vitis-idaea	.84	15	Vaccinium vitis-idaea	.55	12
Potentilla emarginata	.80	31	Potentilla emarginata	.40	21
Saxifraga foliolosa	.67	23	Saxifraga foliolosa	.31	15
Saxifraga flagellaris	.15	7	Saxifraga flagellaris	.09	5
Saxifraga caespitosa	.06	1	Saxifraga caespitosa	.05	1
Thamnolia vermicularis	13.70	86	Thamnolia vermicularis	7.26	84
Dactylina arctica	12.76	78	Dactylina arctica	6.67	83
Cetraria islandica	10.13	86	Sphaerophorus globosus	4.56	65
Sphaerophorus globosus	9.07	72	Cetraria islandica	4.32	83
Cornicularia divergens	5.62	74	Cornicularia divergens	3.24	70
Cetraria nivalis	5.03	68	Cetraria nivalis	2.76	57
Cladonia gracilis	5.01	62	Cladonia gracilis	2.47	50
Cladonia sp.	3.42	60	Cladonia sp.	1.92	50
Peltigera canina	1.88	47	Peltigera canina	1.01	40
Lobaria linita	1.33	30	Lobaria linita	.71	27
Parmelia omphalodes	1.14	35	Parmelia omphalodes	.67	27
Psoroma hypnorum	1.07	33	Psoroma hypnorum	.54	21
Cetraria delisei	.85	28	Cetraria delisei	.51	24
Cladonia uncialis	.73	18	Cladonia uncialis	.40	14
Peltigera aphthosa	.60	23	Peltigera aphthosa	.30	19
Stereocaulon evolutoides	.52	10	Stereocaulon evolutoides	.30	9
Caloplaca subolivacea	.50	18	Caloplaca subolivacea	.26	14
Cladonia rangiferina	.30	13	Cladonia rangiferina	.16	8
Cetraria richardsonii	.12	8	Dactylina ramulosa	.04	2
Solorina crocea	.11	7	Solorina crocea	.03	3
Dactylina ramulosa	.05	3	Cetraria richardsonii	.03	3

Transect III - 100 quadrats, 1/20 square meter
Transect IIIb- 100 quadrats, 1/40 square meter

APPENDIX TABLE 11

TRANSECT III AND TRANSECT IIIb COMPARISONS
MEASURES OF AGGREGATION
GRASSES, SEDGES, AND RUSHES

Species III	$s^2/\bar{x}$	Species IIIb	$s^2/\bar{x}$
Eriophorum scheuchzeri	74.06	Eriophorum scheuchzeri	33.27
Eriophorum angustifolium	30.98	Poa arctica	21.69
Poa arctica	24.31	Eriophorum angustifolium	17.98
Carex aquatilis	20.43	Luzula nivalis	17.11
Luzula confusa	17.35	Carex aquatilis	12.90
Arctagrostis latifolia	17.31	Luzula confusa	11.57
Luzula nivalis	17.04	Arctagrostis latifolia	8.98
Species III	**D/d**	**Species IIIb**	**D/d**
Eriophorum scheuchzeri	27.1	Eriophorum scheuchzeri	14.8
Poa arctica	19.7	Eriophorum angustifolium	12.8
Eriophorum angustifolium	18.5	Poa arctica	10.9
Luzula confusa	11.3	Luzula nivalis	9.0
Carex aquatilis	11.2	Carex aquatilis	7.2
Luzula nivalis	10.1	Luzula confusa	6.9
Arctagrostis latifolia	7.2	Arctagrostis latifolia	5.0
Species III	**$D-d/d^2$**	**Species IIIb**	**$D-d/d^2$**
Eriophorum angustifolium	167.7	Eriophorum angustifolium	133.7
Eriophorum scheuchzeri	79.7	Luzula nivalis	20.0
Luzula confusa	16.9	Luzula confusa	13.8
Carex aquatilis	13.6	Carex aquatilis	10.6
Luzula nivalis	12.7	Eriophorum scheuchzeri	4.5
Poa arctica	6.3	Poa arctica	3.7
Arctagrostis latifolia	2.5	Arctagrostis latifolia	2.4
Species III	**A**	**Species IIIb**	**A**
Eriophorum angustifolium	1.95	Eriophorum angustifolium	1.43
Eriophorum scheuchzeri	1.13	Eriophorum scheuchzeri	.63
Poa arctica	.65	Poa arctica	.33
Luzula confusa	.33	Luzula nivalis	.33
Carex aquatilis	.30	Luzula confusa	.23
Luzula nivalis	.27	Carex aquatilis	.22
Arctagrostis latifolia	.20	Arctagrostis latifolia	.13

$s^2/\bar{x}$ - relative variance Random - 1
D/d - Observed density/theoretical density Random - 1
$D-d/d^2$- Fracker and Brischle index Random - 0
A - 100(observed density)/frequency^2 Random - 0-.3

Transect III - 100 quadrats, 1/20 square meter
Transect IIIb- 100 quadrats, 1/40 square meter

APPENDIX TABLE 12

TRANSECT III AND TRANSECT IIIb COMPARISONS
MEASURES OF AGGREGATION
MISCELLANEOUS FLOWERING PLANTS

Species III	$s^2/\bar{x}$	Species IIIb	$s^2/\bar{x}$
Saxifraga cernua	17.01	Saxifraga cernua	23.22
Petasites frigidus	13.30	Petasites frigidus	20.23
Senecio atropurpureus	9.98	Senecio atropurpureus	17.82
Vaccinium vitis-idaea	8.67	Stellaria laeta	13.04
Stellaria laeta	8.67	Vaccinium vitis-idaea	4.03
Saxifraga caespitosa	5.81	Saxifraga punctata	2.55
Saxifraga punctata	4.98	Potentilla emarginata	1.21
Potentilla emarginata	4.56	Saxifraga foliolosa	.94
Saxifraga foliolosa	4.40	Saxifraga caespitosa	.25
Saxifraga flagellaris	3.01	Saxifraga flagellaris	.22
Species III	**D/d**	**Species IIIb**	**D/d**
Petasites frigidus	12.50	Petasites frigidus	6.45
Saxifraga cernua	10.70	Saxifraga caespitosa	5.00
Senecio atropurpureus	7.6	Senecio atropurpureus	4.83
Saxifraga caespitosa	6.0	Vaccinium vitis-idaea	4.22
Stellaria laeta	5.7	Saxifraga cernua	3.50
Vaccinium vitis-idaea	5.2	Stellaria laeta	3.44
Saxifraga punctata	3.4	Saxifraga punctata	2.80
Saxifraga foliolosa	2.5	Saxifraga foliolosa	1.93
Potentilla emarginata	2.16	Saxifraga flagellaris	1.80
Saxifraga flagellaris	2.14	Potentilla emarginata	1.73
Species III	**$D-d/d^2$**	**Species IIIb**	**$D-d/d^2$**
Vaccinium vitis-idaea	26.50	Vaccinium vitis-idaea	24.85
Petasites frigidus	25.00	Saxifraga flagellaris	16.00
Saxifraga flagellaris	16.32	Petasites frigidus	12.63
Saxifraga cernua	11.63	Saxifraga punctata	7.50
Senecio atropurpureus	9.36	Senecio atropurpureus	7.25
Saxifraga punctata	7.26	Saxifraga foliolosa	5.85
Saxifraga foliolosa	6.06	Saxifraga caespitosa	4.00
Saxifraga caespitosa	5.00	Saxifraga cernua	3.73
Stellaria laeta	4.23	Potentilla emarginata	3.40
Potentilla emarginata	3.14	Stellaria laeta	2.92
Species III	**A**	**Species IIIb**	**A**
Saxifraga caespitosa	6.00	Saxifraga caespitosa	5.00
Petasites frigidus	.42	Vaccinium vitis-idaea	.38
Vaccinium vitis-idaea	.37	Saxifraga flagellaris	.36
Saxifraga flagellaris	.30	Petasites frigidus	.22
Saxifraga cernua	.28	Senecio atropurpureus	.15
Senecio atropurpureus	.21	Saxifraga punctata	.14
Stellaria laeta	.14	Saxifraga foliolosa	.14
Saxifraga punctata	.14	Saxifraga cernua	.09
Saxifraga foliolosa	.13	Potentilla emarginata	.09
Potentilla emarginata	.08	Stellaria laeta	.08

APPENDIX TABLE 13

TRANSECT III AND TRANSECT IIIb COMPARISONS
MEASURES OF AGGREGATION
LICHENS

Species III	$s^2/\bar{x}$	Species IIIb	$s^2/\bar{x}$
Stereocaulon evolutoides	20.45	Thamnolia vermicularis	8.84
Thamnolia vermicularis	18.01	Cetraria islandica	6.91
Sphaerophorus globosus	11.43	Sphaerophorus globosus	6.73
Cetraria nivalis	10.08	Cetraria nivalis	6.43
Dactylina arctica	9.60	Dactylina arctica	6.08
Cladonia uncialis	7.74	Cladonia uncialis	5.95
Cladonia gracilis	7.36	Stereocaulon evolutoides	4.80
Cladonia sp.	6.24	Cladonia sp.	4.64
Cornicularia divergens	5.98	Cladonia gracilis	4.64
Lobaria linita	5.75	Cornicularia divergens	3.86
Cetraria islandica	5.34	Psoroma hypnorum	3.33
Peltigera canina	4.76	Lobaria linita	3.00
Parmelia omphalodes	4.28	Parmelia omphalodes	2.61
Caloplaca subolivacea	4.03	Peltigera canina	2.44
Psoroma hypnorum	3.76	Caloplaca subolivacea	2.26
Peltigera aphthosa	2.82	Peltigera aphthosa	1.50
Solorina crocea	2.73	Solorina crocea	.96
Species III	**D/d**	**Species IIIb**	**D/d**
Dactylina arctica	8.45	Sphaerophorus globosus	4.34
Sphaerophorus globosus	7.14	Thamnolia vermicularis	3.96
Thamnolia vermicularis	6.98	Dactylina arctica	3.76
Cladonia gracilis	5.21	Cladonia gracilis	3.57
Stereocaulon evolutoides	5.20	Stereocaulon evolutoides	3.33
Cetraria islandica	5.16	Cetraria nivalis	3.28
Cetraria nivalis	4.45	Cladonia sp.	2.78
Cornicularia divergens	4.19	Cornicularia divergens	2.70
Cladonia uncialis	3.80	Cladonia uncialis	2.66
Lobaria linita	3.80	Cetraria islandica	2.44
Cladonia sp.	3.75	Psoroma hypnorum	2.34
Peltigera canina	2.98	Lobaria linita	2.29
Psoroma hypnorum	2.67	Parmelia omphalodes	2.16
Parmelia omphalodes	2.65	Peltigera canina	1.98
Caloplaca subolivacea	2.63	Caloplaca subolivacea	1.73
Peltigera aphthosa	2.30	Peltigera aphthosa	1.42
Solorina crocea	1.57	Solorina crocea	1.00

$s^2/\bar{x}$ - relative variance Random - 1

D/d - Observed density/expected density at the observed frequency
Random - 1

APPENDIX TABLE 14

TRANSECT III AND TRANSECT IIIb COMPARISONS
MEASURES OF AGGREGATION
LICHENS

Species III	$D-d/d^2$	Species IIIb	$D-d/d^2$
Stereocaulon evolutoides	42.00	Stereocaulon evolutoides	25.92
Cladonia uncialis	14.90	Cladonia uncialis	11.11
Caloplaca subolivacea	8.58	Psoroma hypnorum	5.86
Solorina crocea	8.16	Caloplaca subolivacea	4.88
Lobaria linita	8.00	Lobaria linita	4.16
Peltigera aphthosa	5.02	Cladonia gracilis	3.78
Dactylina arctica	4.93	Parmelia omphalodes	3.74
Sphaerophorus globosus	4.83	Sphaerophorus globosus	3.19
Cladonia gracilis	4.39	Cetraria nivalis	2.74
Psoroma hypnorum	4.18	Cladonia sp.	2.61
Parmelia omphalodes	3.83	Peltigera aphthosa	2.04
Peltigera canina	3.14	Peltigera canina	1.92
Thamnolia vermicularis	3.05	Thamnolia vermicularis	1.62
Cetraria nivalis	3.05	Dactylina arctica	1.56
Cladonia sp.	3.03	Cornicularia divergens	1.41
Cornicularia divergens	2.38	Cetraria islandica	.81
Cetraria islandica	2.12	Solorina crocea	0
Species III	**A**	**Species IIIb**	**A**
Stereocaulon evolutoides	.520	Stereocaulon evolutoides	.370
Cladonia uncialis	.225	Solorina crocea	.333
Solorina crocea	.224	Cladonia uncialis	.204
Sphaerophorus globosus	.174	Caloplaca subolivacea	.132
Caloplaca subolivacea	.154	Psoroma hypnorum	.122
Lobaria linita	.147	Sphaerophorus globosus	.107
Peltigera aphthosa	.113	Thamnolia vermicularis	.102
Cornicularia divergens	.102	Cladonia gracilis	.098
Psoroma hypnorum	.098	Lobaria linita	.097
Cladonia sp.	.095	Dactylina arctica	.096
Parmelia omphalodes	.093	Parmelia omphalodes	.091
Peltigera canina	.085	Cetraria nivalis	.084
Dactylina arctica	.020	Peltigera aphthosa	.083
Thamnolia vermicularis	.018	Cladonia sp.	.076
Cetraria islandica	.013	Cornicularia divergens	.066
Cladonia gracilis	.013	Peltigera canina	.063
Cetraria nivalis	.010	Cetraria islandica	.062

$D-d/d^2$ - Observed mean density-expected mean density/(expected mean density)^2
Fracker and Brischle

A - 100(Observed density)/(frequency)^2 Whitford

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