RESPONSE OF PLANT SPECIES TO GRAZING IN THE FOREST REGION OF SASKATCHEWAN

A Thesis

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by

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INTRODUCTION

Vast areas of central Saskatchewan are occupied by aspen groves, aspen forest and mixed-wood (Rowe, 1959). A part of the aspen forest has been cleared and is now utilized as pastures. These pastures may be referred to as 'wooded', 'bushland' or 'northern wooded' pastures. Though, historically, the utilization of the wooded pastures can be traced back to the times of early settlers, their development as government sponsored pasture dates back to the early 1940's. While the first government community pasture in the grassland zone was established in 1922 at Matador (Moen, 1964), it was not until 1941 that a community pasture was set up at Beaver Hills in the forest zone.

By the early 1950's it became obvious that the livestock industry was being greatly hampered by insufficient grazing facilities. The pastures in the grassland region could not cope with the increasing demand for grazing needs due to low carrying capacity as a result of frequent droughts. In the northern fringe of settlement there were still present vast areas of unutilized submarginal lands under aspen forest. The soil under aspen forest is podzolic, often low in fertility, of sandy texture, stony and poorly drained in low lying areas so that its tillage for cereal crops was not feasible.

The importance of wooded pastures would further increase with the rising demand of beef production. Haase (1964) has outlined the need and importance of increased forage production in Canada. He suggested that an additional 15 million acres of improved land would be needed by 1980. The investigators in various fields discussed effectively the problems and needed fields of study in the establishment of northern wooded pastures in a meeting on "The development of pasture from bushlands in western Canada" under the auspecies of Canada Department of Agriculture in 1964. Perhaps, the most important aspect of the problems that were discussed at the meeting, was the need for understanding the response of vegetation, native as well as seeded, to grazing.

The present study was undertaken primarily to consider the effect of grazing on herbaceous vegetation in wooded pastures. This involved the selection and study of comparable grazed and ungrazed stands under three different 'habitat' types: forest; forest, cleared; and forest, cleared, ploughed and seeded. The study sites were located in areas, potentially capable of supporting aspen forest on podzolic, degraded black or grey wooded soil. Populus tremuloides is the dominant tree species and Fragaria vesca, Lathyrus venosus, Vicia americana, Aster ciliolatus, Galium septentrionale, Thalictrum dasycarpum, Bromus ciliatus, Agropyron subsecundum and Schizachne purpurascens are the common herb species in undisturbed sites. Poa pratensis and Poa palustris are the dominant grasses in cleared areas while Bromus inermis, Agropyron cristatum and Medicago sativa are the most common species in seeded areas.

LITERATURE REVIEW

The present review is in no way a complete review of the literature on grazing studies. It includes only selected studies which are pertinent to the general principles and methods involved in this study.

A review of the available literature reveals that the vegetation in northern wooded pastures in the Prairie Provinces has been scarcely investigated. It was not until 1948 that a first survey report appeared on grazing resources of wooded pastures in Saskatchewan (Coupland and Van Haerlem, 1948). In 1957, a study was started by the Department of Plant Ecology, University of Saskatchewan, to obtain data concerning the effect of grazing of various native and seeded forage species. The present project was undertaken as a continuation of the above in 1963.

Several grazing studies have been carried out in different forest types in North America. Lutz (1930) studied the effect of grazing in a hemlock-beech stand in northwestern Pennsylvania and concluded that grazing brings about a decrease in canopy-cover, basal area and sapling density. Herbs and shrubs are more severely affected and the understory vegetation usually shifts towards a xerophytic type. Den Uyl (1947) in Indiana, Day and Den Uyl (1932) in Ohio and Steinbranner (1951) in southern Wisconsin have studied the effect of grazing on the deterioration of vegetation of the farmwoods. Tisdale (1960) described the effect of grazing of forest lands in Idaho and British Columbia. All these studies have been pointing to the basic interest of conservation of forest vegetation.

Cawley (1960) carried on a phytosociological study of the effect of grazing on southern Wisconsin woodlots. He used 'indicator' and 'ordination' techniques to study the behaviour of species under grazing. He found that deterioration of vegetation under excessive grazing was a downward curve from climax vegetation and was composed of a series of continuous changes in the relative amount of decreasers, increasers and invaders. He further concluded that there is no reversal in species behaviour to grazing with change in moisture factor. He is of the opinion that invaders are better indicators than increasers and decreasers of grazing conditions.

Although the above is a consideration of rather infrequent studies in relation to response of native vegetation to grazing in the forest environment in North America, even less attention has been paid to the adaptability of introduced forage species to grazing in these areas. The results of the reviewed studies can not be applied directly to the present area of study but some general principles and methods involved can be applied to study of the vegetation in wooded pastures in Saskatchewan. The work done on introduced species has mostly been concentrated in the grassland zone. Various studies have been carried on the effect of clipping and other environmental factors, fertilizers and irrigation on some of native and introduced forage species. Pond (1961) reported that high intensities of clipping results in low dry matter production. Lawrence and Troelsen (1961) published on the forage values of 15 grasses for the prairie region of south-western Saskatchewan. The use of fertilizers and irrigation result in increased productivity (Doran <u>et al</u>., 1963 and Hubbard and Nicholson, 1963).

The study of Pellet and Roberts (1963) showed that high temperatures retarded the growth of Kentucky bluegrass. Moline and Wedin (1963) evaluated that the date of cutting affects the yield and nutritive value of alfalfa appreciably. Buglass (1964) remarked that the use of fertilizers tend to increase seed production but the response is limited by moisture conditions. Fribourg (1962) brought out that dalapon can effectively be used in the renovation of fescue pasture. Roshal (1963) concluded that there was a sufficient manifestation of the effect of trace elements like Cu, Co and Mb in pastures on peat bogs in Ukrainian SSR. Leigh (1961) studied the resistance of some varieties of pasture grasses to invasion by other species and concluded that it varied with the species and varieties.

DESCRIPTION OF STUDY AREA

Most of the study sites were located in the east-central part of Saskatchewan (Fig. 1). The location and legal description, soil type and topography of the sites is presented in Table 1.

The climate of the general region has been classified as C_1 climatic type, a dry subhumid microthermal climate, by Sanderson (1948). The annual precipitation is approximately 16 inches. Mean total snowfall is 50 inches and the variability in the annual precipitation is 25 percent. The mean January temperature ranges from 0 to -5^{o}F, mean April from 32 to 35^{o}F, mean July from 60 to 65^{o}F and mean October from 35 to 40^{o}F. The mean minimum annual temperature has been recorded as -50^{o}F and mean maximum as 95^{o}F. The length of the frost-free period varies from 80 to 100 days and mean annual length of the growing season is approximately 120 days (Atlas of Canada, 1957).

The topography of the area is variable, from gently sloping to gently rolling. The whole area has been glaciated and surface material are deep tills and glacio-lacustrine deposits. The subsurface rock deposit is Lea Park of cretaceous epoch (Edmunds, 1950). The soils have been classified as transition soils (black degraded) and have grey podzolic profile characters in undisturbed sites. The soil texture varies from fine sandy, sandy loam to clay loam.

Figure 1. Location of study sites. Site locations are illustrated by dots.

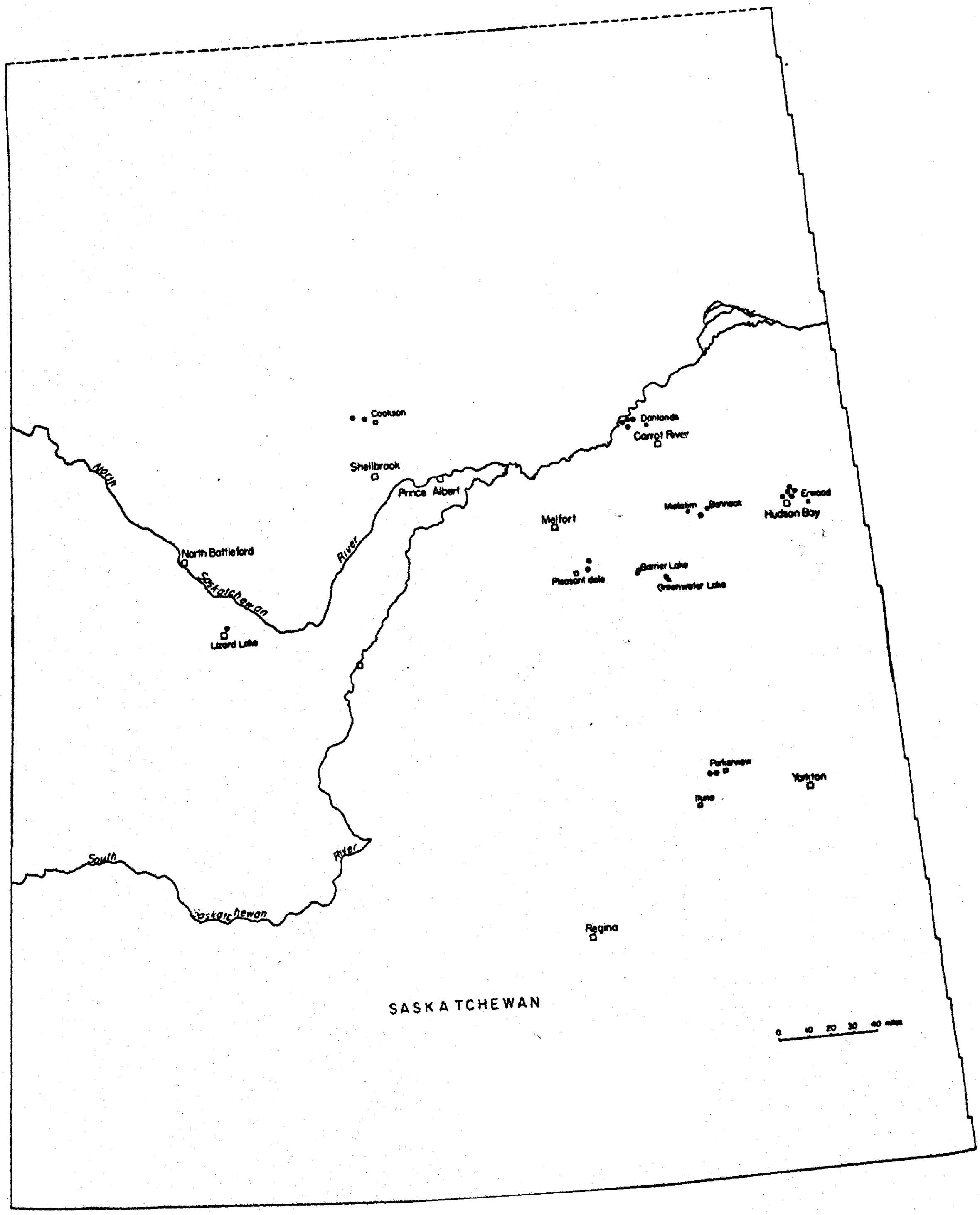

Cookson
Shellbrook
Prince Albert
North Battleford
Lizard Lake
North Saskatchewan River
South Saskatchewan River
Melfort
Carrot River
Erwood
Hudson Bay
Barrier Lake
Greenwater Lake
Pleasant dale
Yorkton
Regina
SASKATCHEWAN
0 10 20 30 40 miles

Table 1. Description of study sites in the wooded community pastures (C.P.).

Site	Legal description	Soil zone	Soil type	Topography	Land use
Barrier Lake C.P.					
Site 1	NW25-41-14 W2	Transition (Black degraded) soil zone.	Light loam to sandy loam.	Gently to moderately undulating.	Forest, cleared and seeded to brome, creeping red fescue, timothy, crested wheat, and alfalfa.
Site 2	NE24-41-14 W2	Transition (Black degraded) soil zone.	Light loam to sandy loam.	Gently to moderately undulating.	Seeded to brome, crested wheat, creeping red fescue, and alfalfa.
Beaver Hills C.P.					
Site 1	SW32-26-10 W2	Black soil zone.	Medium textured light loam.	Undulating to gently rolling.	Forest, cleared.
Site 2	NE26-26-10 W2	Black soil zone.	Medium textured light loam.	Undulating to gently rolling.	Seeded to brome, crested wheat and creeping red fescue.

Cont'd ...

Table 1 concluded. Description of study sites in the wooded community pastures (C.P.).

Site	Legal description	Soil zone	Soil type	Topography	Land use
Site 2	NE3-41-12 W2	Transition (Black degraded) soils.	Sandy loam.	Gently to moderately undulating.	Seeded to brome, crested wheat, alfalfa and red fescue.
Mistatim C.P.					
Site 1	NE34-44-9 W2	Transition (Black degraded) soils.	Clay loam.	Gently to moderately undulating.	Seeded to brome, crested wheat, alfalfa, red fescue and white clover.
Site 2	SE34-44-9 W2	Transition (Black degraded) soils.	Clay loam.	Gently to moderately undulating.	Seeded to brome, crested wheat, alfalfa, red fescue and white clover.

METHODS

Selection Of Stands

The study was planned to utilize sites where ungrazed and grazed stands could be located in pairs, and the only difference between the two units being grazing. The stands were selected using the following criteria:

(1) They should be distributed in locations where the undisturbed 'habitat' was judged to be capable of supporting aspen forest. While a majority of the sites were located in the forest zone, some were in the aspen grove or northern mixed prairie regions, but occurred at elevations sufficiently higher than the surrounding terrain that forest occurred. Lowlands, which occupy a considerable area within these regions, were thus excluded.

(2) All ungrazed stands must not show any signs of disturbance subsequent to protection.

(3) Stand partners must lie on the same soil type separated by a fence, thus insuring that both partners had received identical treatment before separation.

(4) They should have a visual homogeneity of vegetation and physiography.

(5) They may represent one of the three habitat types; forest, cleared forest, and forest cleared, ploughed and seeded. In the text these three habitats will be referred to as "forest", "cleared" and "seeded", respectively.

While originally the study was designed to have a uniform number of stands on each of the three habitat types, this was not possible because of scarcity of one or two types in some areas. During the course of two summers' study it was possible to find 49 pairs of stands which satisfied all criteria: 7 pairs of forest stands, 11 pairs of cleared stands and 31 pairs of seeded stands. The stand size varied from .07 to .20 acres.

Sampling Methods

The methods were selected to collect the maximum information in regard to the differences in abundance of each species in grazed and ungrazed vegetation. It was necessary to employ two methods - one a plot (area) method, the other a distance method.

List quadrats were used to measure the frequency of species. Curtis and McIntosh (1950) showed that the most suitable size of quadrat is one which will give frequencies of approximately 86 percent for the most common species. In the present study 0.5 m x 0.5 m quadrat size was used to sample the frequency of herbs, shrubs and tree seedlings. While this resulted in some species regularly occurring with frequencies above 86 percent, the small size required to achieve adequate level for dominant species would have required a very large number to sample relatively uncommon species. In this connection, it is important to consider that some of the grasses were seeded and had regular distribution because of uniform distribution of seed. In such cases the use of smaller quadrats would still have resulted in 100 percent frequency of dominant grasses, but poorer sampling of rarer species.

To ascertain the number of quadrats required for an adequate sample, six pairs of stands were sampled in the beginning of the study using 40 quadrats in each stand. On examination of the data it was found that a sample larger than 20 quadrats did not result in modifying the data for species having frequencies of 40 percent or greater. On this basis it was decided to use 30 quarter square meter quadrats under all the habitat types so as to have comparable results for species which occurred under all the three conditions.

It has been pointed out in a number of studies that frequency is related to density. However, at very high frequencies a difference in density between two treatments may be reflected little or not at all in frequency. Since the seeded species in this study have a high frequency because of even distribution of seed, therefore it is assumed that this relationship between frequency and density is affected. Thus the list quadrats were considered inefficient for measuring the frequency differences due to grazing for very common species, particularly those that had been seeded. In such cases the differences due to grazing were measured in terms of density or plant cover using the point-centered quarter method.

The point-centered quarter method was introduced for forest sampling by Cottam and Curtis (1956) and was employed for the analysis of grasslands by Dix (1961). Penfound (1963) remarked that the method provides excellent data on frequency and density but furnished no data on either cover or weight. The method can be used to obtain relative and absolute density of a species. In application a single pin is placed vertically into the soil at random throughout the stand. The area around each point is then divided into four quarters by drawing two imaginary lines through the pin. One line is drawn parallel to the direction of the line of sampling (traverse), while the second is at right angles to the first. Within each quarter of the sampling unit, the distance from the point to the closest shoot is measured to the nearest centimeter. Thus each sampling unit consists of four shoots and four measured distances. Relative and absolute densities are calculated using the following formulae:

$$\text{Mean distance} = \frac{d_1 + d_2 + d_3 + d_4 \, \ldots\ldots\ldots \, d_n}{4 \times \text{number of points}}$$

$$\text{Mean area} = (\text{Mean distance})^2$$

$$\text{Total density in terms of shoots per square meter} = \frac{10{,}000}{\text{Mean area}}$$

$$\text{Relative density of a species (R.D.)} = \frac{\text{No. of nearest shoots of a species}}{\text{Total no. of shoots}} \times 100$$

$$\text{Absolute density of species} = \text{Total number of shoots} \times \frac{\text{R.D.}}{100}$$

To test the applicability of this distance method to the present study, measurements of density were made of all species together and each of the dominant species separately at three sites. Thirty or 40 points were laid along parallel lines equally distant (5 to 10 ft.) from the fence on grazed and ungrazed stands. The interval between any two points was a fixed distance.

After calculations two difficulties were faced: (1) species when measured together gave higher density values (calculated from relative densities) compared to densities obtained when each species was measured separately. The disparity in the results from the two procedures was magnified with decrease in the relative frequency of species. In comparing the same species under ungrazed and grazed conditions this would presumably result in an error whenever the density was affected by grazing. For this reason it was decided to measure the density of each species separately to have comparable levels of sampling for the two treatments. The use of the method was limited to very abundant species. (2) The second difficulty faced was that the method undervalued the density of clumped grasses (bunch and loosely tufted grasses) in relation to the sod-formers. This was related to differences in dispersion of shoots between species. In the seeded as well as the native species, the clumps of clumped species tend to be less frequently distributed as compared to the individual shoots of the non-clumped grass species. Not uncommonly in sampling of grasslands by the point-centered quarter method, when the species are of equal abundance in number of shoots, the possibility of occurrence of shoots of non-clumped species nearest to the point is much more compared to the tendency of the clumps to occur nearest to the point. Thus in measuring the nearest shoot and calculating the density based on measurement of all species together, the calculated density of clumped species is very low in comparison to the number of shoots actually present. Inferences drawn from density measurements by the point-centered quarter method using all species together may thus overshadow the degree of influence of the clumped grasses under natural conditions. This also points out the inefficiency of the method for measuring all species together under these conditions. In order to overcome this discrepancy between turf grasses and bunch grasses, the basal area occupied by bunch grasses was considered in sampling.

The density of clumped grasses was measured in terms of basal cover per square meter following the method used by Misra (1964). Three measurements of diameter were taken for each of the nearest clumps for calculating the average diameter. The average diameters were converted into average areas before calculating the average mean area per clump. The number of clumps per unit area and basal cover per unit area can be calculated by using the formulae:

$$\text{Mean distance to centre of clump} = \frac{d_1 + d_2 + d_3 \ldots\ldots d_n}{\text{Number of points} \times 4}$$

$$\text{Mean area} = (\text{Mean distance})^2$$

$$\text{Number of clumps (of average mean area) per square meter} = \frac{10{,}000}{\text{Mean area}}$$

$$\text{Average mean area of clump} = \frac{\text{Sum areas of clumps}}{\text{No. of points} \times 4}$$

$$\text{Cover}/m^2 = \text{No. of clumps} \times \text{Average mean area of clump}$$

The number (n) of distances required for adequate sample at the 10 percent level of variation was calculated to be 34 to 52 distance ($n = \left(\frac{s}{.1\bar{x}}\right)^2$, where $\bar{x}$ = mean distance, s = standard deviation and n = number of distances). Thus the maximum number of points needed for adequate sampling was 13 (4 distances per point). To cover variation from site to site and stand to stand and also to have a constant sized sample for species, it was decided to sample 30 points in each stand for each species for which the density measurements were required.

The species records were mainly based on field identifications but unidentifiable species were collected and later identified in the laboratory. Hitchcock (1950) was followed for nomenclature of grasses and Scoggan (1957) for all other species. The species list includes both species that occurred in quadrats and species present in the stands. Voucher specimens are lodged in W. P. Fraser Herbarium of the University of Saskatchewan, Saskatoon.

RESULTS AND TREATMENT OF DATA

Since the sampling included forest, cleared forest, and cleared, ploughed and seeded land, the data collected under each type have been treated separately. The data were analyzed to ascertain, firstly, the kind and degree of change in abundance of each species to grazing, and secondly, species behaviour along a grazing gradient.

Response Of Individual Species To Grazing

In order to determine the effect of grazing on each species, its frequency in quadrats or its measured density was compared in all pairs of stands in which it was present in one or both units. Because averaged values obscured the differences among stands that represented a wide range of environmental conditions, as well as various degrees of grazing, and because it was difficult to assess the significance of numerous individual values by inspection, a means of diagramatical representation of these differences was sought.

The method decided upon was plotting in a scatter-diagram on a graph in which the X-axis represented the ungrazed and the Y-axis the grazed condition. Thus each stand pair was positioned in the diagram by plotting on the X-axis the number of quadrats (of 30 listed) in which it occurred on the ungrazed condition and on the Y-axis the number in which it was found under grazing. The position of each stand pair depends on the frequency (or density) of a species on both grazed and ungrazed stands. If a species occurs more frequently under protection, stand position tends to lie towards the X-axis, and if its frequency is more under grazing, the point of reference would be positioned towards the

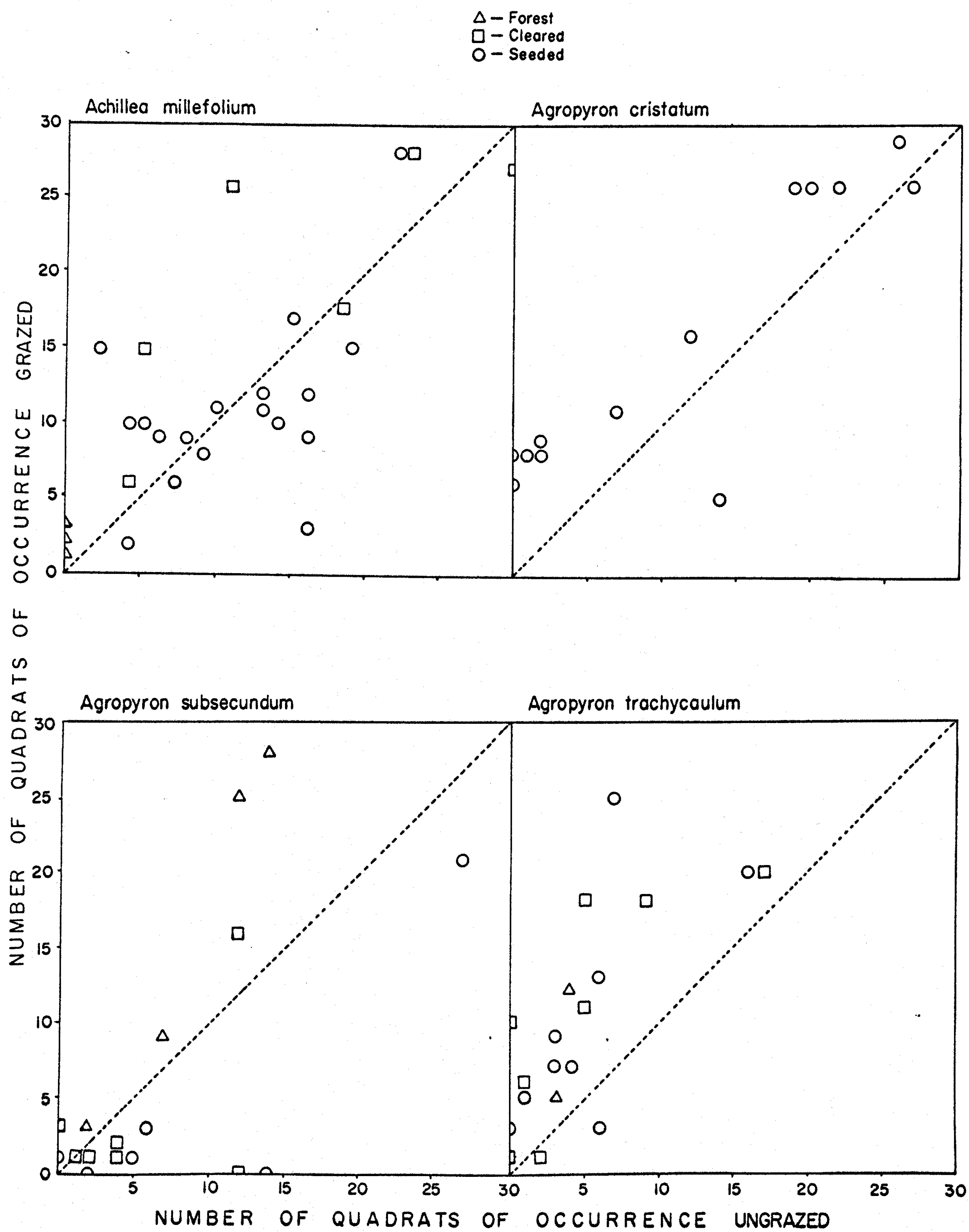
Y-axis. Therefore if a species is susceptible to grazing, the majority of plotted points will be located in the lower right position of the diagram, while for a species favoured under grazing the majority of the points will be in the upper left. Points lying along the diagonal through the origin show no effect of grazing. The frequency or density of the species does not affect the position of each reference point in relation to the diagonal because its position is determined by differences of frequencies (or densities) under grazing and protection. Each stand pair was identified to habitat type by symbols so as to permit identification of responses to grazing of the same species under different environments. Densities were used in seeded species which were so distributed that frequencies regularly approached 100 percent regardless of density.

Scatter-diagrams were drawn for species which had a frequency of 40 percent or more in at least one of the stands and occurred in at least five pairs of stands of the same 'habitat' type. Forty-eight species fulfilled these criteria (Figs. 2 to 13).

In grazing studies in forest and grasslands, it has been customary to allot each species to one of the three classes on the basis of their response to grazing: increasers, decreasers and invaders (Smith, 1940; Weaver and Hansen, 1941; Dyksterhuis, 1948; Voigt and Weaver, 1951; Moomaw, 1957 and Cawley, 1960). Vogl (1964) listed two additional classes to the three mentioned above; neutrals and retreaters. His classification pertained to the effect of fire on muskeg in northern Wisconsin and a five percent level of average percent frequency difference was used to delimit neutrals from decreasers and increasers. In the present study the species were

Figure 2. Scatter-diagrams showing response of *Achillea millefolium*, *Agropyron cristatum*, *Agropyron subsecundum* and *Agropyron trachycaulum* in 'forest', 'cleared' and 'seeded' habitats. Their response as indicated in the diagram is summarized below.

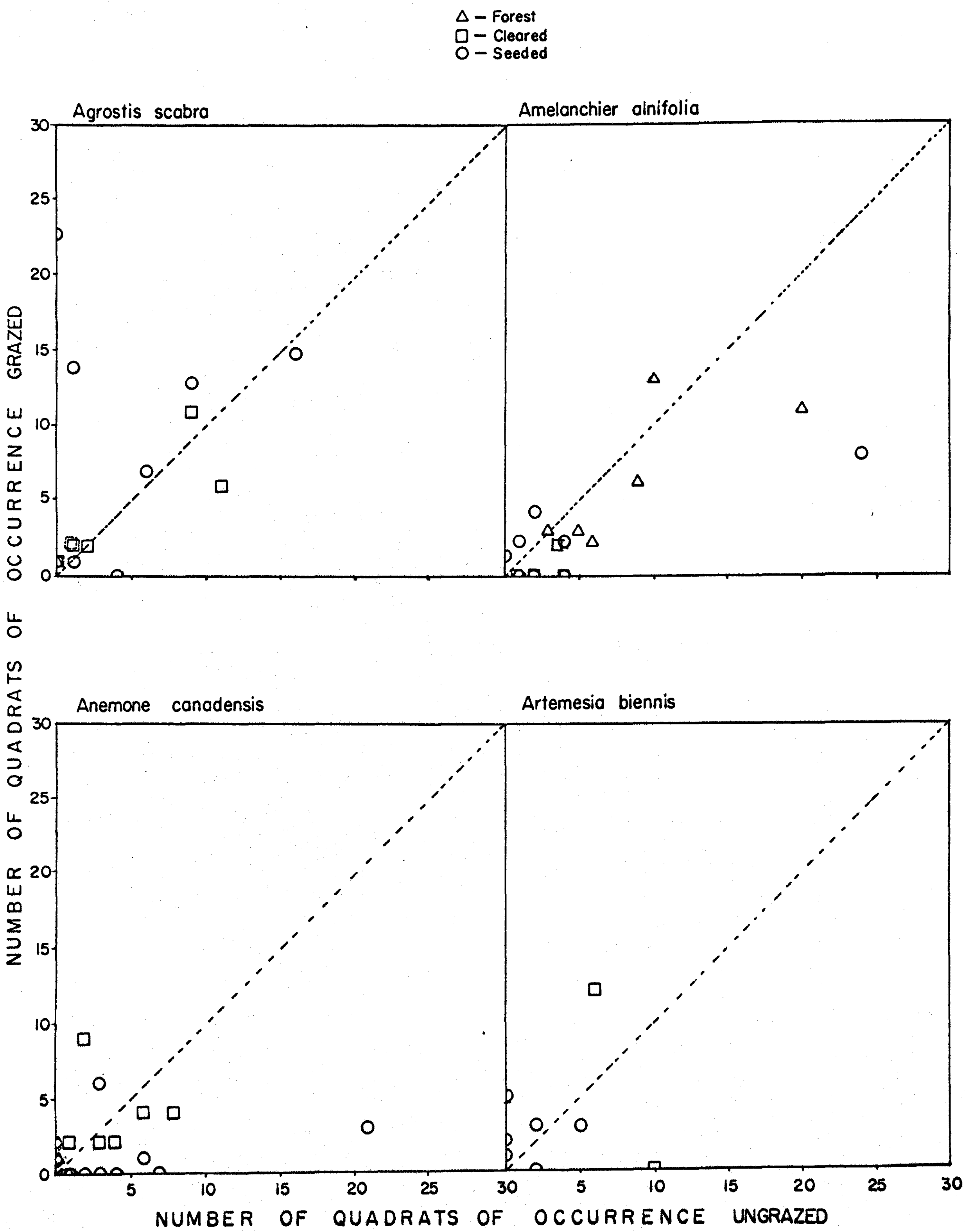
Species	Response to grazing		
	Forest	Cleared	Seeded
Achillea millefolium	Invader	Increaser	Increaser
Agropyron cristatum	-	-	Increaser
A. subsecundum	Increaser	Decreaser	Decreaser
A. trachycaulum	Increaser	Increaser	Increaser



Δ — Forest
□ — Cleared
○ — Seeded
Achillea millefolium
Agropyron cristatum
Agropyron subsecundum
Agropyron trachycaulum
NUMBER OF QUADRATS OF OCCURRENCE GRAZED
NUMBER OF QUADRATS OF OCCURRENCE UNGRAZED
0
5
10
15
20
25
30

Figure 3. Scatter-diagram showing response of Agrostis scabra, Amelanchier alnifolia, Anemone canadensis, and Artemisia biennis, in 'forest', 'cleared' and 'seeded' habitats. Their response as indicated in the diagram is summarized below.

Species	Response to grazing		
	Forest	Cleared	Seeded
Agrostis scabra	Invader	Increaser	Increaser
Amelanchier alnifolia	Decreaser	Decreaser	Decreaser
Anemone canadensis	Invader	Neutral	Decreaser
Artemisia biennis	-	Decreaser	Increaser



△ — Forest
□ — Cleared
○ — Seeded
Agrostis scabra
Amelanchier alnifolia
Anemone canadensis
Artemesia biennis
NUMBER OF QUADRATS OF OCCURRENCE GRAZED
NUMBER OF QUADRATS OF OCCURRENCE UNGRAZED
0
5
10
15
20
25
30

Figure 4. Scatter-diagram showing response of *Aster ciliolatus*, *Bromus ciliatus*, *Calamagrostis canadensis*, *Carex trisperma* in 'forest', 'cleared' and 'seeded' habitats. Their response as indicated in the diagram is summarized below.

Species	Response to grazing		
	Forest	Cleared	Seeded
Aster ciliolatus	Increaser	Decreaser	Decreaser
Bromus ciliatus	Increaser	Decreaser	Retreater
Calamagrostis canadensis	Decreaser	Decreaser	Decreaser
Carex trisperma	Increaser	Decreaser	Decreaser

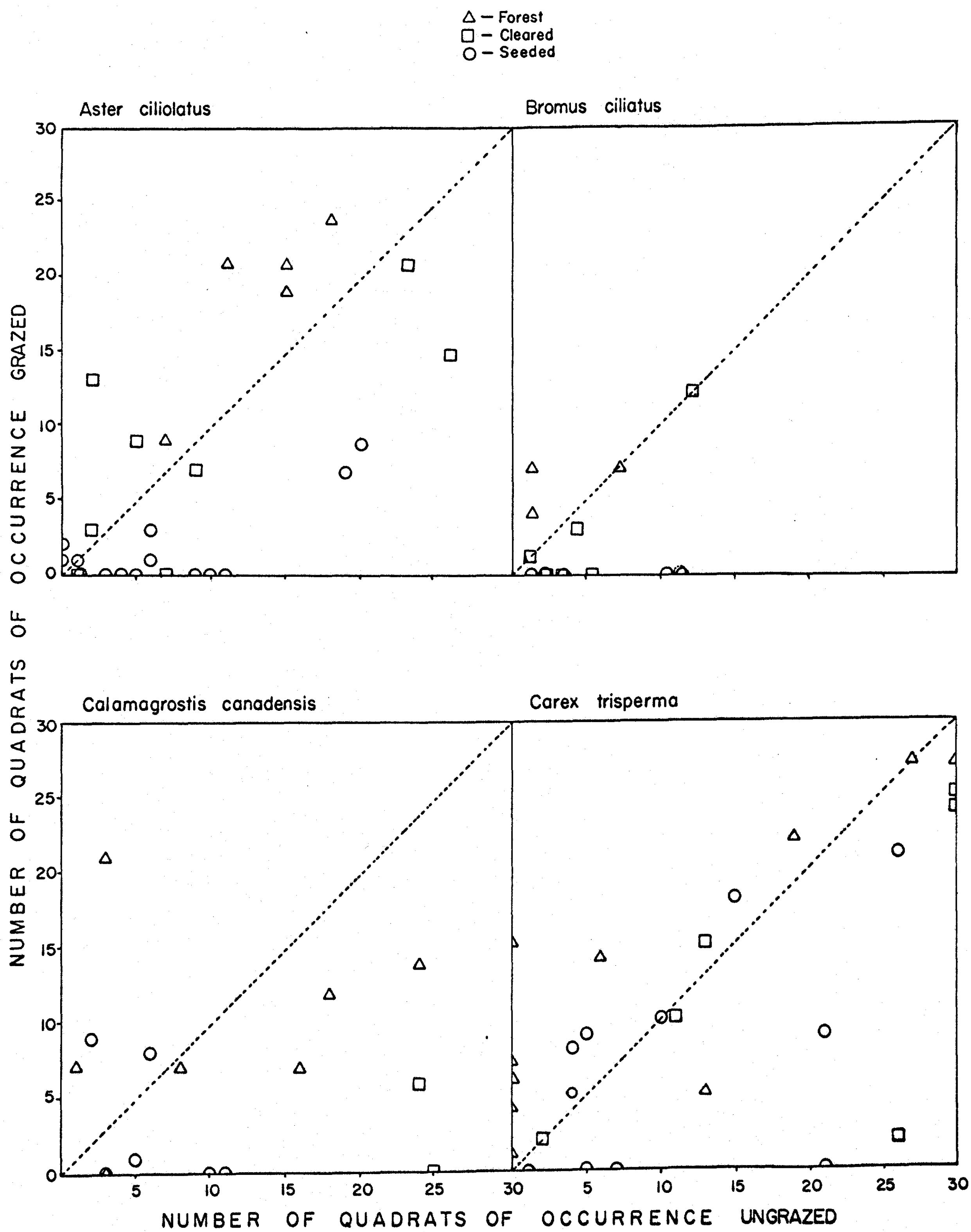
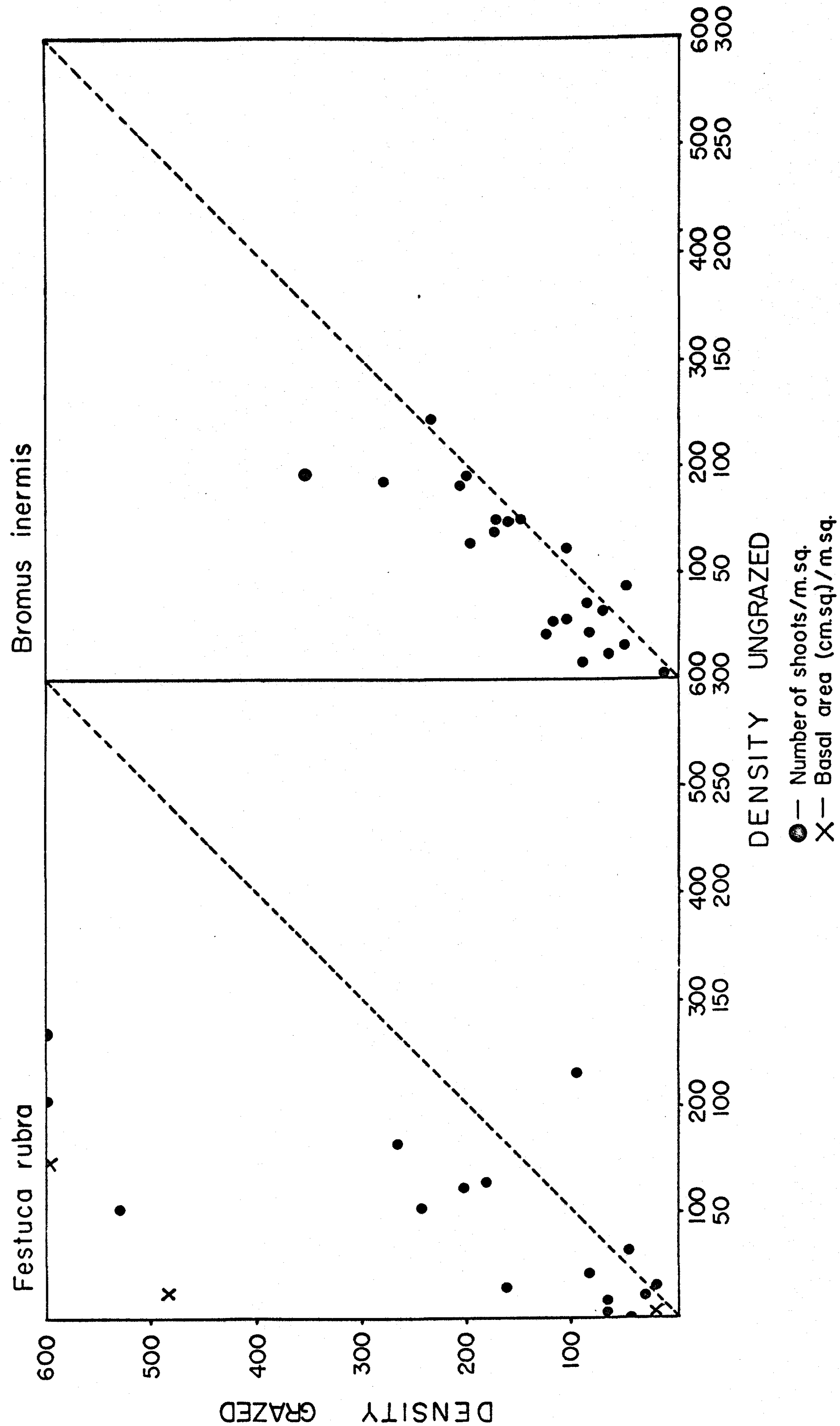

△ – Forest
□ – Cleared
○ – Seeded
Aster ciliolatus
Bromus ciliatus
Calamagrostis canadensis
Carex trisperma
NUMBER OF QUADRATS OF OCCURRENCE GRAZED
NUMBER OF QUADRATS OF OCCURRENCE UNGRAZED
0
5
10
15
20
25
30

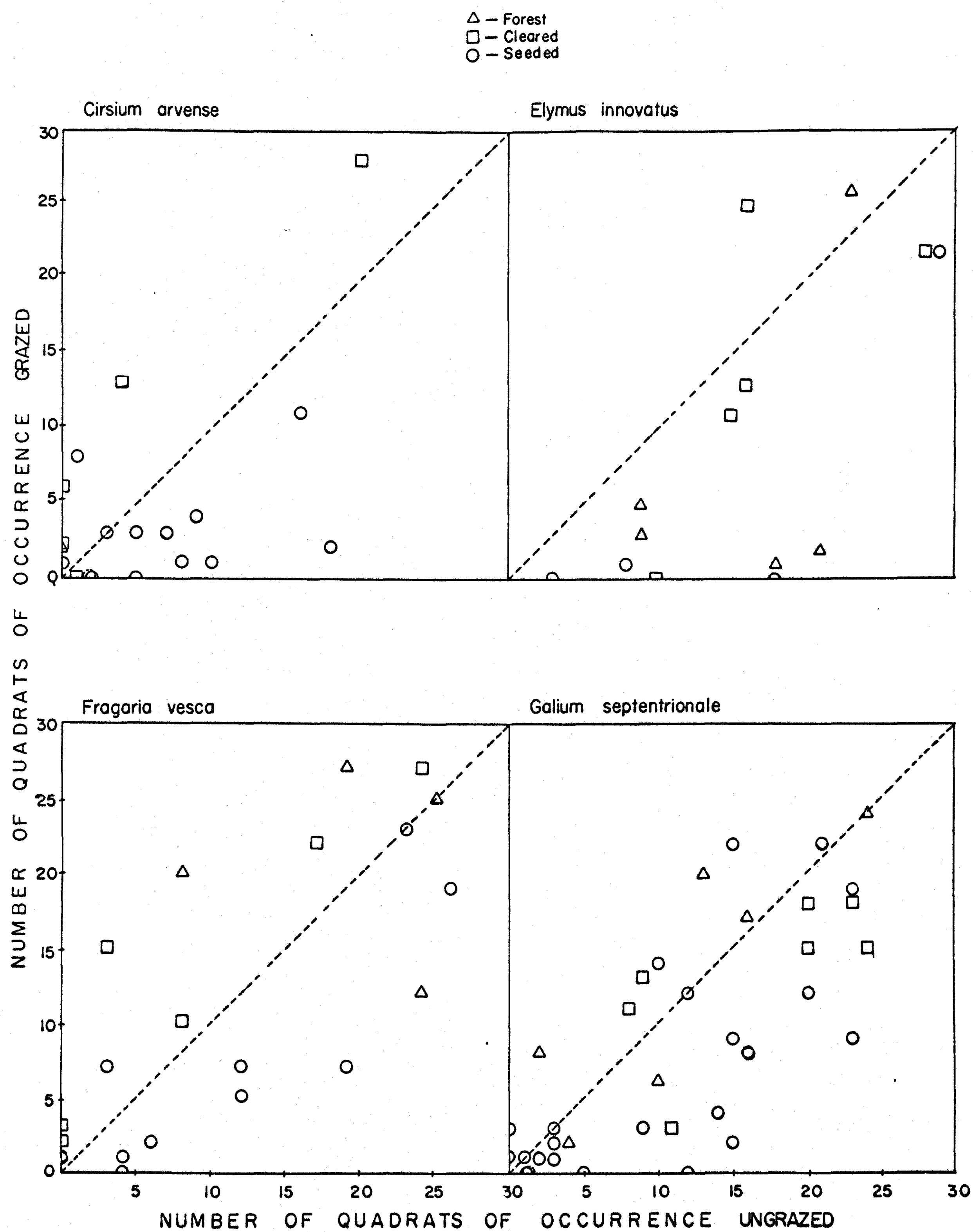
Figure 5. Scatter-diagram showing behaviour of *Bromus inermis* and *Festuca rubra* under grazing. Numbers in the upper line along the X-axis (100 - 600) refers to density in terms of no. of shoots/m^2 and numbers in the lower line along X-axis (50 - 300) correspond to basal cover (cm^2/m^2). Both species are denser under grazing.



Festuca rubra
Bromus inermis
DENSITY GRAZED
600
500
400
300
200
100
DENSITY UNGRAZED
100 50
200 100
300 150
400 200
500 250
600 300
●— Number of shoots/m.sq.
X— Basal area (cm.sq.)/m.sq.

Figure 6. Scatter-diagram showing response of *Cirsium arvense*, *Elymus innovatus*, *Fragaria vesca* and *Galium septentrionale* in 'forest', 'cleared' and 'seeded' habitats. Their response as indicated in the diagram is summarized below.

Species	Response to grazing		
	Forest	Cleared	Seeded
Cirsium arvense	Invader	Increaser	Decreaser
Elymus innovatus	Decreaser	Decreaser	Decreaser
Fragaria vesca	Increaser	Increaser	Decreaser
Galium septentrionale	Increaser	Decreaser	Decreaser



△ — Forest
□ — Cleared
○ — Seeded
Cirsium arvense
Elymus innovatus
Fragaria vesca
Galium septentrionale
NUMBER OF QUADRATS OF OCCURRENCE GRAZED
NUMBER OF QUADRATS OF OCCURRENCE UNGRAZED
0
5
10
15
20
25
30

Figure 7. Scatter-diagram showing response of *Hordeum jubatum*, *Koeleria cristata*, *Lathyrus ochroleucus*, and *Lathyrus venosus* in 'forest', 'cleared', and 'seeded' habitats. Their response as indicated in the diagram is summarized below.

Species	Response to grazing		
	Forest	Cleared	Seeded
Hordeum jubatum	Invader	Increaser	Invader
Koeleria cristata	-	Increaser	Decreaser
Lathyrus ochroleucus	Decreaser	Retreater	Decreaser
Lathyrus venosus	Decreaser	Decreaser	Decreaser

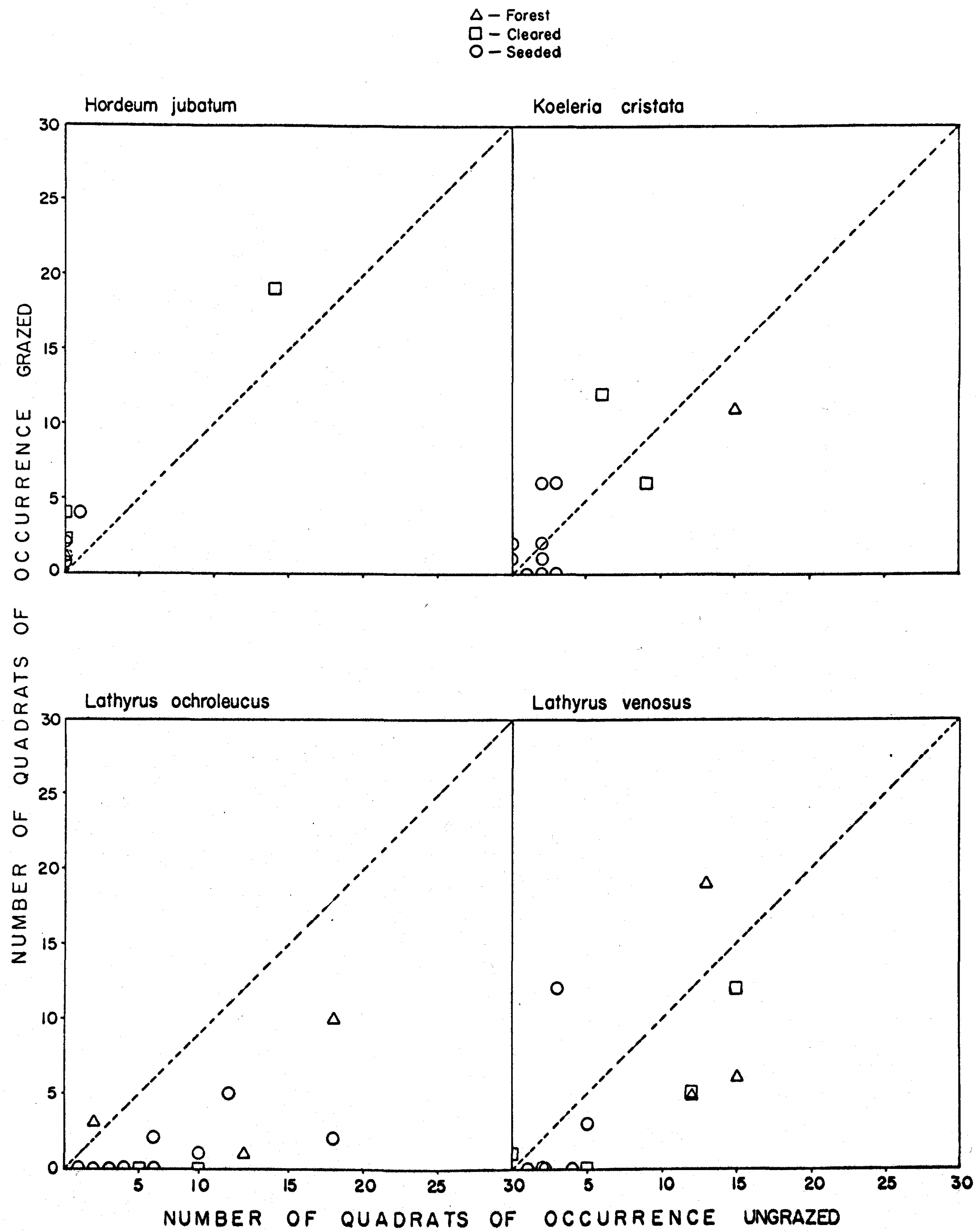

△ — Forest
□ — Cleared
○ — Seeded
Hordeum jubatum
Koeleria cristata
Lathyrus ochroleucus
Lathyrus venosus
NUMBER OF QUADRATS OF OCCURRENCE GRAZED
NUMBER OF QUADRATS OF OCCURRENCE UNGRAZED
0
5
10
15
20
25
30

Figure 8. Scatter-diagram showing response of *Medicago sativa*, *Phleum pratense*, *Poa compressa*, and *Poa palustris* in 'forest', 'cleared', and 'seeded' habitats. Their response as indicated in the diagram is summarized below.

Species	Response to grazing		
	Forest	Cleared	Seeded
Medicago sativa	-	-	Decreaser
Phleum pratense	-	-	Decreaser
Poa compressa	Invader	Increaser	Increaser
Poa palustris	Increaser	Increaser	Increaser

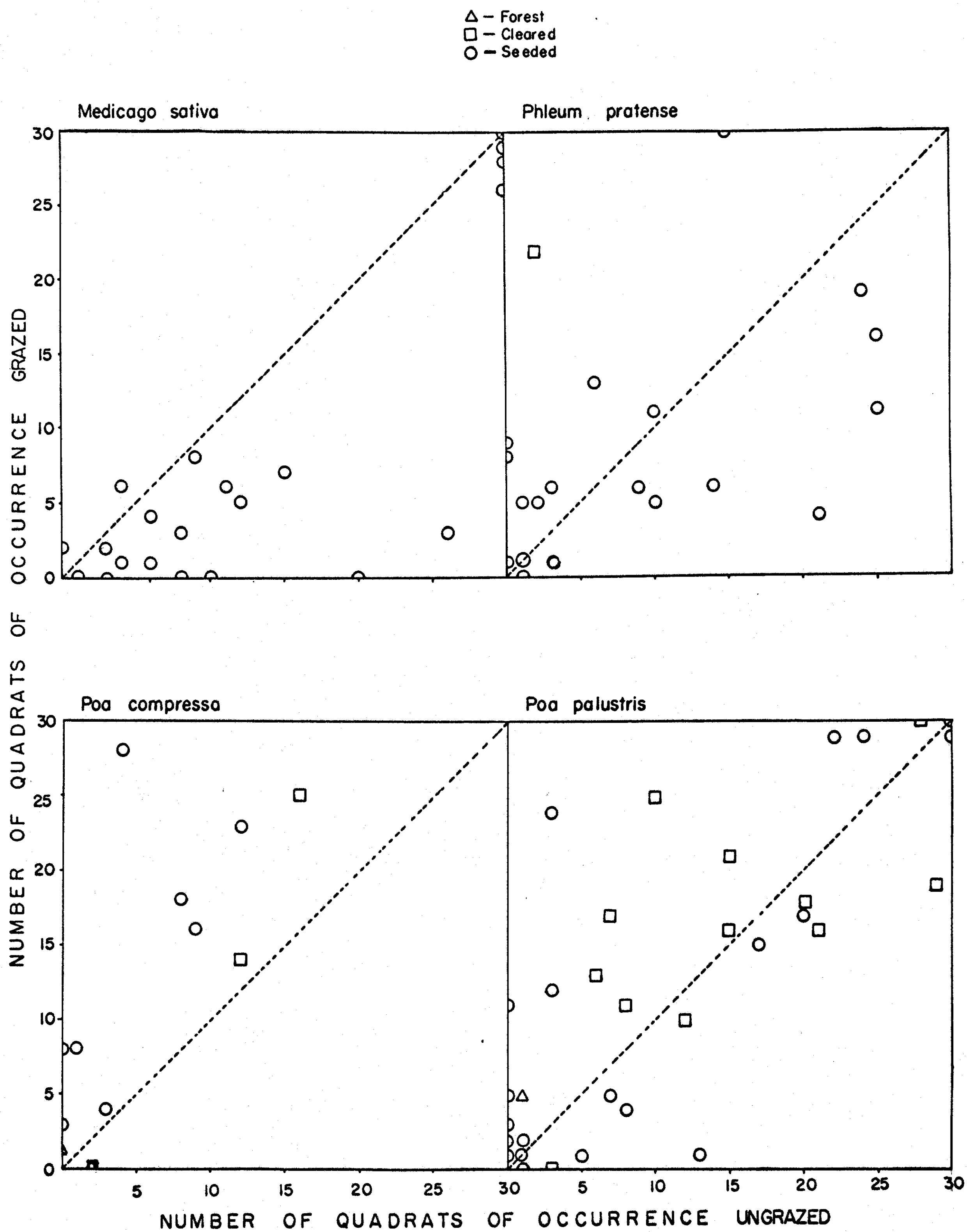
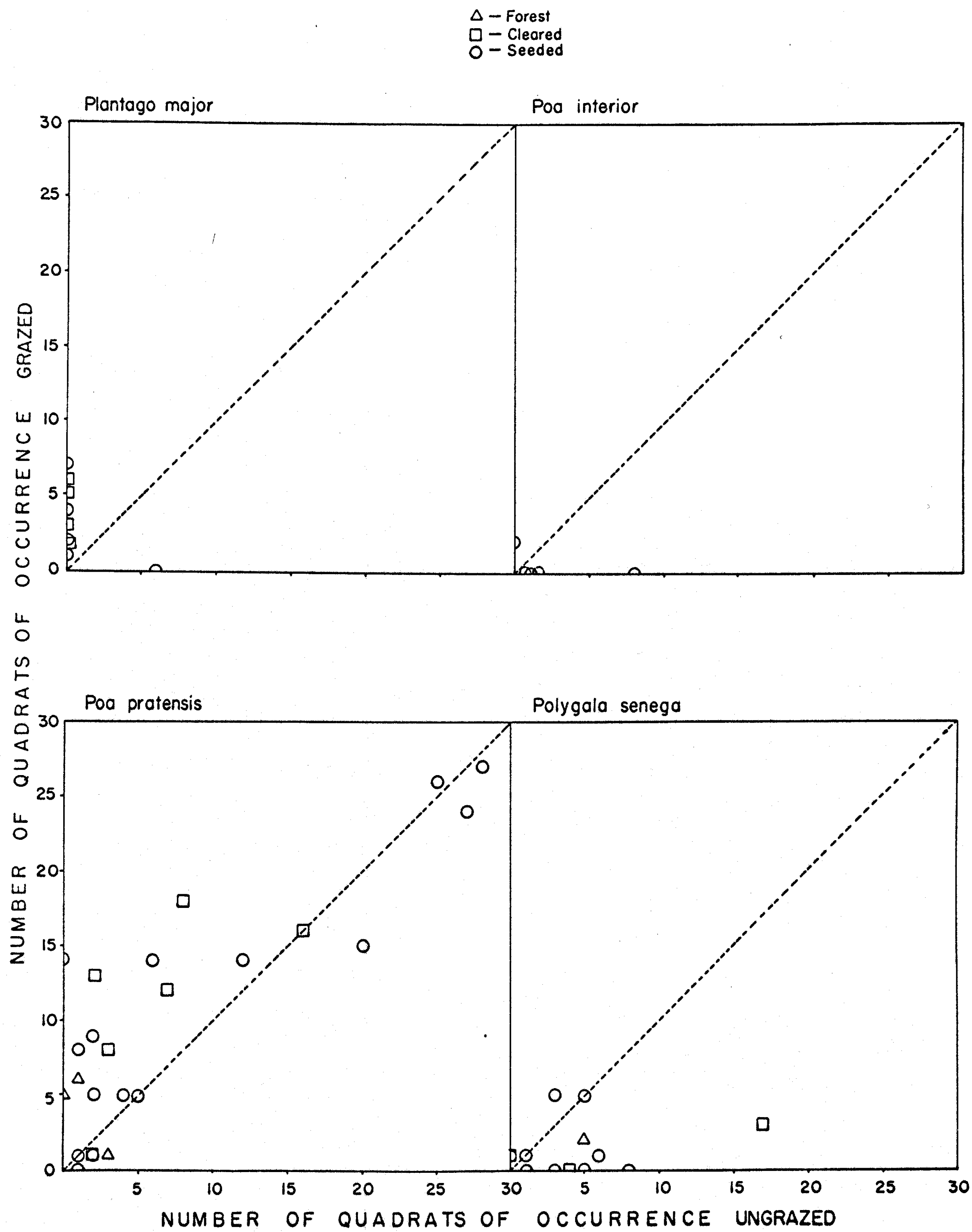

△ – Forest
□ – Cleared
○ – Seeded
Medicago sativa
Phleum pratense
Poa compressa
Poa palustris
NUMBER OF QUADRATS OF OCCURRENCE GRAZED
NUMBER OF QUADRATS OF OCCURRENCE UNGRAZED
0
5
10
15
20
25
30

Figure 9. Scatter-diagram showing response of _Plantago major_, _Poa interior_, _Poa pratensis_, _Polygala senega_ in 'forest', 'cleared', and 'seeded' habitats. Their response as indicated in the diagram is summarized below.

Species	Response to grazing		
	Forest	Cleared	Seeded
Plantago major	-	Invader	Increaser
Poa interior	-	-	Decreaser
Poa pratensis	Increaser	Increaser	Increaser
Polygala senega	Decreaser	Decreaser	Decreaser



△ — Forest
□ — Cleared
○ — Seeded
Plantago major
Poa interior
Poa pratensis
Polygala senega
NUMBER OF QUADRATS OF OCCURRENCE GRAZED
NUMBER OF QUADRATS OF OCCURRENCE UNGRAZED

Figure 10. Scatter-diagram showing response of *Populus balsamifera*, *Populus tremuloides*, *Rosa woodsii*, *Rosa acicularis* in 'forest', 'cleared', and 'seeded' habitats. Their response as indicated in the diagram is summarized below.

Species	Response to grazing		
	Forest	Cleared	Seeded
Populus balsamifera	-	Increaser	Increaser
Populus tremuloides	Decreaser	Decreaser	Decreaser
Rosa woodsii	Decreaser	Decreaser	Decreaser
Rosa acicularis	Decreaser	Decreaser	Decreaser

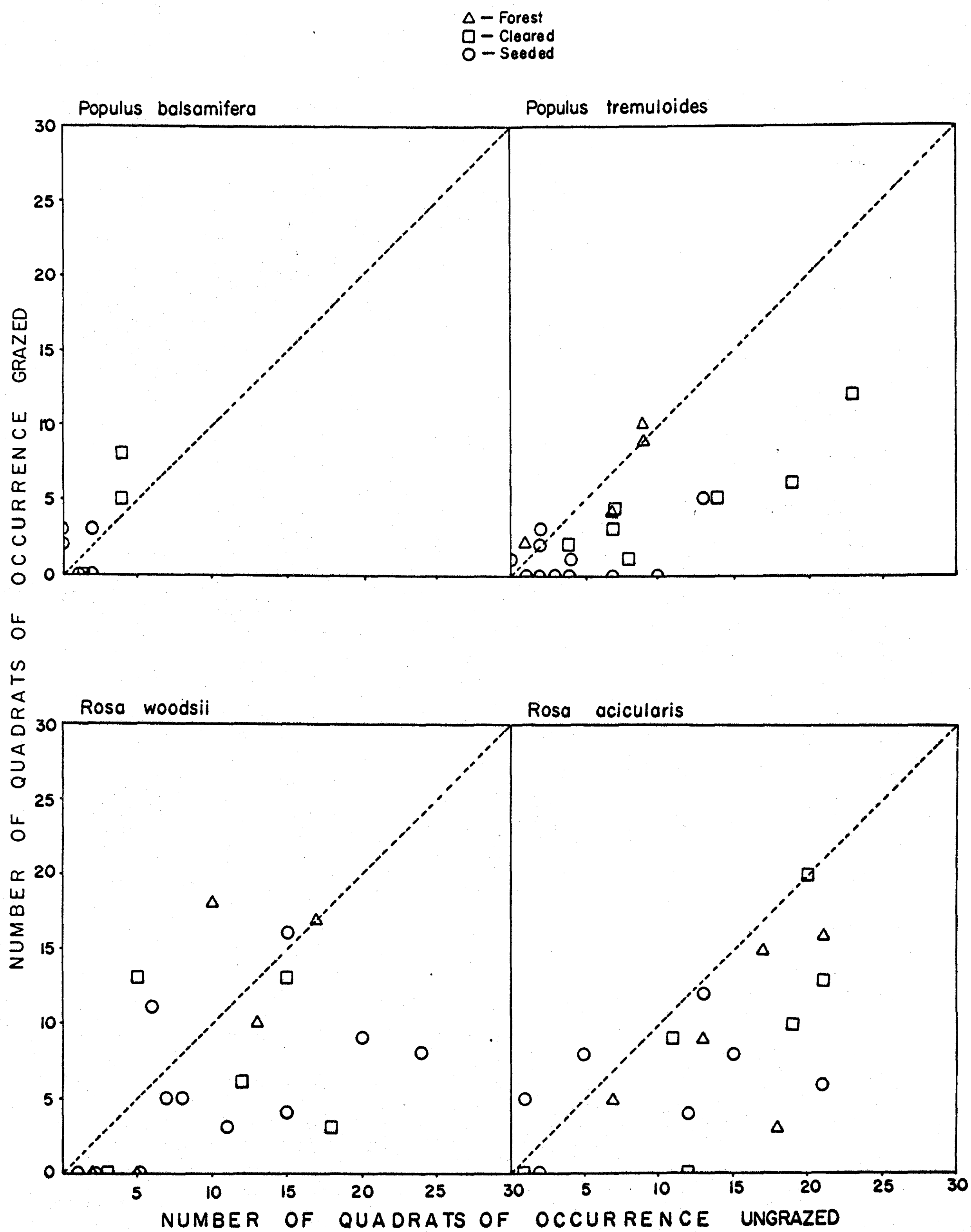

Δ — Forest
□ — Cleared
○ — Seeded
Populus balsamifera
Populus tremuloides
Rosa woodsii
Rosa acicularis
NUMBER OF QUADRATS OF OCCURRENCE GRAZED
NUMBER OF QUADRATS OF OCCURRENCE UNGRAZED
0
5
10
15
20
25
30

Figure 11. Scatter-diagram showing response of *Sanicula marilandica*, *Schizachne purpurascens*, *Sonchus asper*, and *Solidago canadensis* in 'forest', 'cleared', and 'seeded' habitats. Their response as indicated in the diagram is summarized below.

Species	Response to grazing		
	Forest	Cleared	Seeded
Sanicula marilandica	Decreaser	Increaser	Decreaser
Schizachne purpurascens	Decreaser	Increaser	Retreater
Sonchus asper	-	Decreaser	Decreaser
Solidago canadensis	Increaser	Decreaser	Decreaser

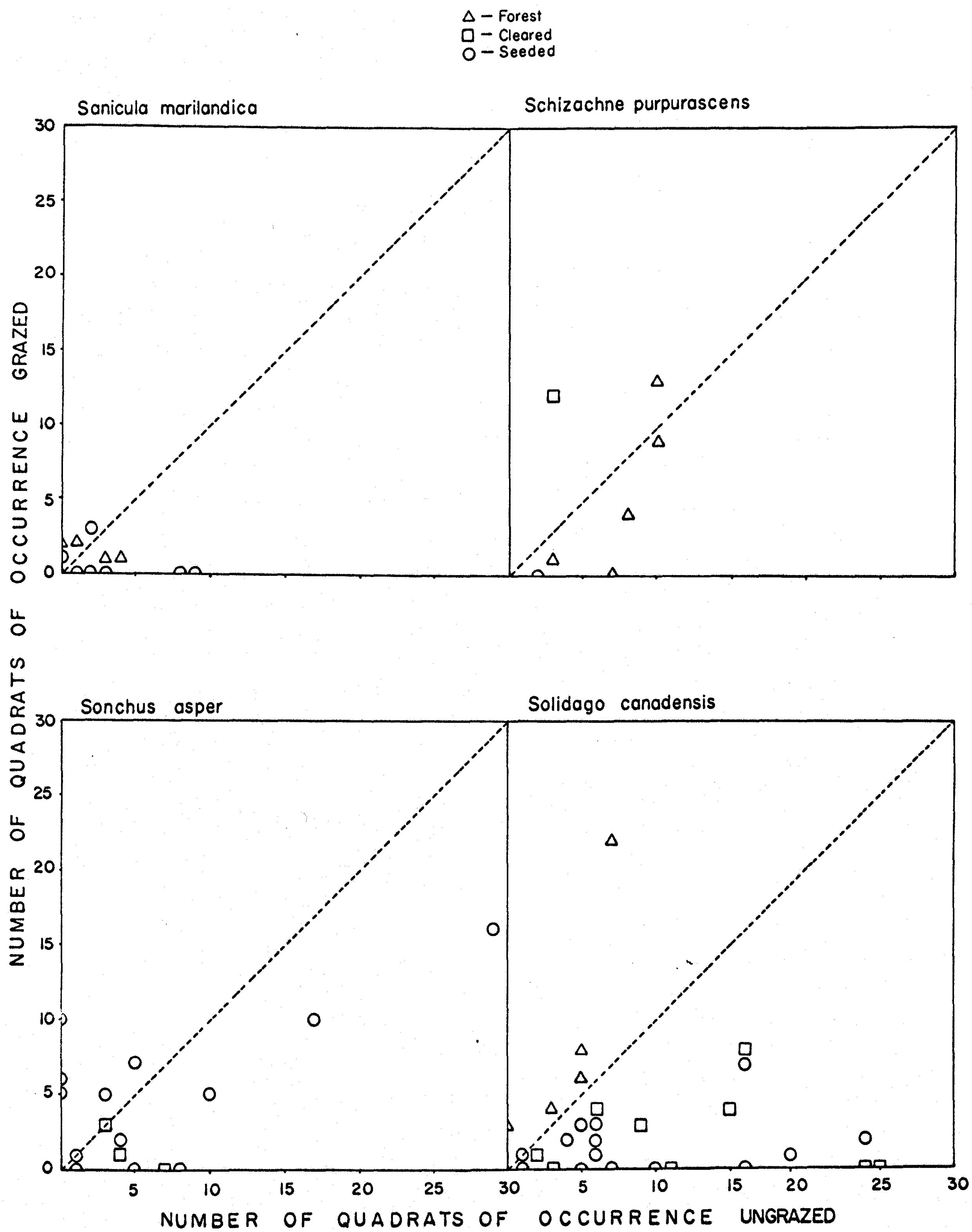

△ – Forest
□ – Cleared
○ – Seeded
Sanicula marilandica
Schizachne purpurascens
Sonchus asper
Solidago canadensis
NUMBER OF QUADRATS OF OCCURRENCE GRAZED
NUMBER OF QUADRATS OF OCCURRENCE UNGRAZED
0
5
10
15
20
25
30

Figure 12. Scatter-diagram showing response of Stachys palustris, Stellaria longipes, Taraxacum officinale, Symphoricarpus occidentalis in 'forest', 'cleared', and 'seeded' habitats. Their response as indicated in the diagram is summarized below.

Species	Response to grazing		
	Forest	Cleared	Seeded
Stachys palustris	Decreaser	Decreaser	Decreaser
Stellaria longipes	Neutral	Decreaser	Decreaser
Taraxacum officinale	Increaser	Increaser	Increaser
Symphoricarpus occidentalis	Increaser	Increaser	Decreaser

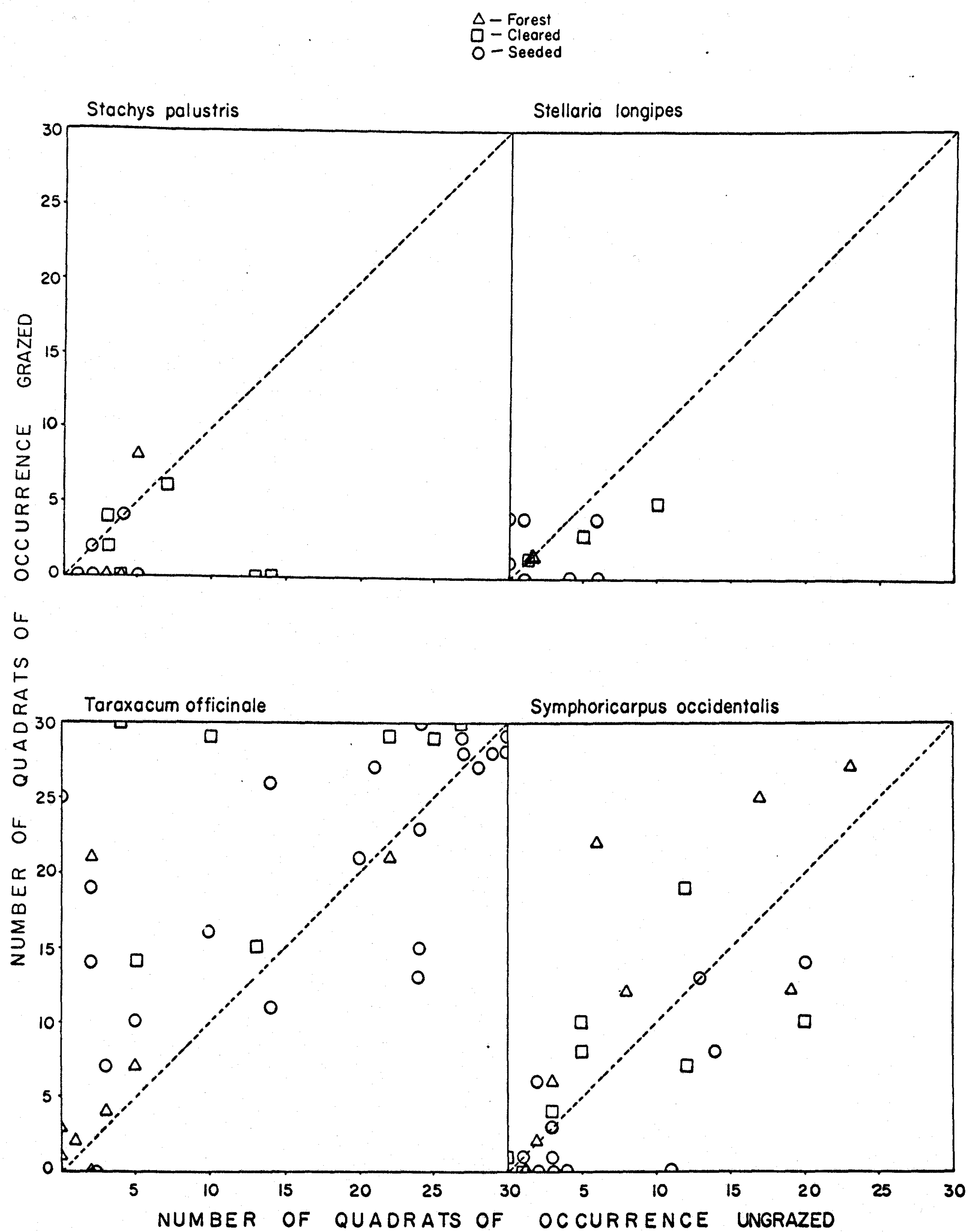
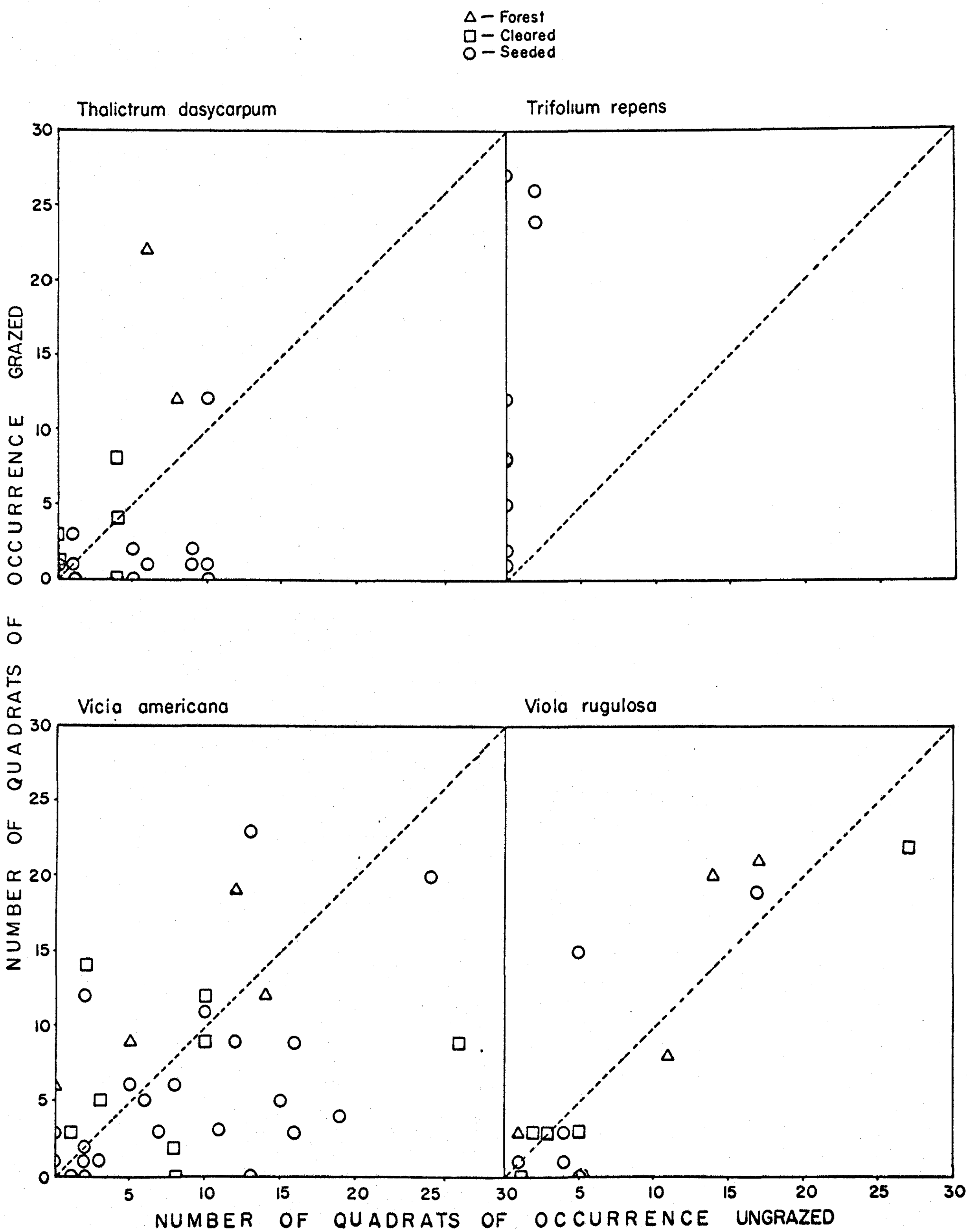

△ — Forest
□ — Cleared
○ — Seeded
Stachys palustris
Stellaria longipes
Taraxacum officinale
Symphoricarpus occidentalis
NUMBER OF QUADRATS OF OCCURRENCE GRAZED
NUMBER OF QUADRATS OF OCCURRENCE UNGRAZED
0
5
10
15
20
25
30

Figure 13. Scatter-diagram showing response of *Thalictrum dasycarpum*, *Trifolium repens*, *Vicia americana* and *Viola rugulosa* in 'forest', 'cleared', and 'seeded' habitats. Their response as indicated in the diagram is summarized below.

Species	Response to grazing		
	Forest	Cleared	Seeded
Thalictrum dasycarpum	Increaser	Increaser	Decreaser
Trifolium repens	-	-	Increaser
Vicia americana	Increaser	Decreaser	Decreaser
Viola rugulosa	Increaser	Decreaser	Decreaser


Δ — Forest
□ — Cleared
○ — Seeded
Thalictrum dasycarpum
Trifolium repens
Vicia americana
Viola rugulosa
NUMBER OF QUADRATS OF OCCURRENCE GRAZED
NUMBER OF QUADRATS OF OCCURRENCE UNGRAZED
0
5
10
15
20
25
30

placed into five categories based on their response to grazing and the five percent level of mean percent difference was used to delimit the neutrals from increasers and decreasers. The mean percent difference was calculated using the formula:

$$\text{Mean percent difference} = \frac{\text{Sum frequencies (or densities) grazed} - \text{sum frequencies (or densities) ungrazed}}{\text{Sum frequencies (or densities) ungrazed}} \times 100$$

The five grazing categories have been defined as follows:

(a) Increasers: Increasers are those species which are favoured by grazing. The majority of the reference points for stand pairs lie towards the Y-axis and the average frequency is at least 5 percent more on the grazed than on the ungrazed stands.

(b) Decreasers: Decreasers are species which are reduced in abundance by grazing. The majority of the reference points of the stand pair are positioned towards the X-axis. They have an average frequency of at least 5 percent less on the grazed stands than on the ungrazed stands.

(c) Neutrals: The species belonging to this category do not have a consistent behaviour. They do not have a distinct distribution of majority of reference points towards either axis and do not fulfill the 5 percent difference requirement of average frequency between the grazed and ungrazed stands.

(d) Retreaters: These are species which are only present on the ungrazed stands. All the reference points for stand pairs lie on the X-axis.

(e) Invaders: These are species which are present only on the grazed stands. All reference points are located on the Y-axis.

The use of the term "invader" in the above sense deviates from its usual application, particularly in respect to cleared and seeded habitats. Usually this term is applied for those species that are not indigenous to the region. Because the native vegetation has been greatly modified by clearing, ploughing and seeding, many indigenous species do not survive in all habitat types, while the introduced species often occur in both ungrazed and grazed stands. Curtis (1959) in discussing this situation in Wisconsin observed that virtually all ground species on cleared areas are "invaders" because they would not have been there under the forest canopy. However, in the present study there are only a few species that occurred only on the grazed stands. The term in the present text has been applied strictly as defined in the text irrespective of whether a species was indigenous or introduced.

The difference or change in the abundance of species, that occurred in at least 5 pairs of stands under each habitat type, under grazing has been analyzed statistically by the paired 't' test method (Bailey 1959). The results are tabulated in Table 2.

The number of species in each of the five grazing categories were compared in each habitat type (Table 3). The proportion of total number of species, occurring in each habitat type, that are decreasers is at a maximum in seeded areas and at a minimum in the forest stands. In contrast, the proportion of increasers is highest in forest and lowest in seeded areas. The percentage of invaders is highest in cleared forest and much lower under forest and seeded stands.

Another means of calculating the average response of individual species to grazing, which also involves the comparison of the sum of frequencies (or densities) on grazed and ungrazed stands, was used by Dix (1959). A deviation of this method was applied to the present data. The method used in the present study deviates from the previously used method in that measurements of frequency (or measured density) were used instead of calculated densities from frequencies. Measured density values were utilized in the calculations of grazing resistibility numbers for only those species which did not show differences in frequencies under two treatments. The reasons for the changes that were made in the application of this method are described in Appendix A.

The mathematical comparison resulted in numerical values which objectively indicated the behaviour of species under grazing pressure. The sum of frequencies on ungrazed stands was subtracted from the sum of frequencies on the grazed stands. When the difference was positive it was divided by the sum on grazed stands and when negative, was divided by the sum on ungrazed stands. As these numerical values indicate the phytosociological behaviour of a species under grazing pressure, they have been termed grazing resistibility numbers (G.R.N.). To increase the proficiency of their use in calculation of stand indices, they have been multiplied by 10 and rounded to the nearest whole numbers. The procedure is summarized in the following formula:

$$\text{Grazing Resistibility Number (G.R.N.)} = \frac{\text{Sum frequencies grazed} - \text{Sum frequencies ungrazed}}{\text{Sum frequencies grazed (when numerator is positive} \quad \text{or} \quad \text{Sum frequencies ungrazed (when numerator is negative)}} \times 10$$

The grazing resistibility numbers for all species present in the list quadrats were calculated and are presented in Table 2. As the grazing resistibility numbers are dependent on the actual differences between the sum of frequencies (or densities) on grazed and ungrazed stands, it is rather immaterial whether a species has a low or high

Table 2 . Response of species to grazing in three habitat types as indicated by the mean percentage difference in frequency (or density) between grazed and ungrazed sites and by calculated grazing resistibility numbers (G.R.N.).

Species	Forest			Cleared			Seeded		
	General response	Mean % difference	G.R.N.	General response	Mean % difference	G.R.N.	General response	Mean % difference	G.R.N.
Achillea millefolium	X	+	+10	I	+22	+3	D	-8	-1
Agropyron cristatum	-	-	-	-	-	-	I	+34**	+3
Agropyron repens	-	-	-	-	-	-	I (sandy soil)	+48	+5
Agropyron subsecundum	I	+86*	+5	D	33	-3	D	-51*	-5
Agropyron trachycaulum	I	+101 I.S.	+6	I	+61*	+3	I	+33*	+3
Agrostis scabra	X	+	+10	I	+100	+5 I.S.	I	+50	+4
Alopecurus aequalis	-	-	-	N	[illegible]	0	-	-	-
Allium cernuum	-	-	-	X	+ I.S.	+10	R	-100 I.S.	-10
Amelanchier alnifolia	D	-27	-2	D	-14	-1	D	-60*	-6
Androsace septentrionalis	-	-	-	X	+ I.S.	+10	X	+ I.S.	+10
Anemone canadensis	X	+	+10	N	0	0	D	-85	-6
Anemone cylindrica	D	-62	-6	I	+100	+5	-	-	-
Arabis arenicola	-	-	-	-	-	-	N	0 I.S.	0
Arctostaphylos uva-ursi	-	-	-	-	-	-	N	0 I.S.	0
Artemisia biennis	-	-	-	D	-20	-2	I	+55	+3
A. ludoviciana	-	-	-	R	-100 I.S.	-10	I	+5	+1
Aster ciliolatus	I	37**	+3	D	-7	-1	D	-82**	-8
Axyris amaranthoides	-	-	-	I	+14 I.S.	+1	I	+235 I.S.	+8
Beckmannia syzigachne	-	-	-	X	+ I.S.	+10	-	-	-
Bromus ciliatus	I	+100 I.S.	+5	D	-7	-1	R	-100*	-10
B. inermis[1]	-	-	-	X	+	+10	I	+82**	+2
Calamagrostis canadensis	D	-8	-1	D	-60	-6	D	-68	-7
C. neglecta	-	-	-	R	-100	-10	D	-84	-8
Campanula rotundifolia	-	-	-	N	0 I.S.	0	D	-67	-7
Capsella bursa-pastoris	-	-	-	-	-	-	X	+ I.S.	+10
Carex atherodes	-	-	-	X	+ I.S.	+10	-	-	-
Carex aurea	R	-100 I.S.	-10	I	+333 I.S.	+8	I	+40 I.S.	+3
Carex doughlasii	-	-	-	I	+56 I.S.	+4	D	-83 I.S.	-8
Carex trisperma	I	+22	+2	D	-42	-4	D	-28	-3
Castilleja miniata	-	-	-	-	-	-	X	+ I.S.	+10
Cerastium arvense	-	-	-	-	-	-	I	+33	+3
Chenopodium album	-	-	-	X	+ I.S.	+10	I	+150 I.S.	+6
Cirsium arvense	X	+ I.S.	+10	I	+76	+2	D	-57*	-6
Cornus canadensis	I	+17 I.S.	+2	-	-	-	-	-	-
C. stolonifera	I	+50 I.S.	+3	D	-50 I.S.	-5	-	-	-
Crepis tectorum	-	-	-	-	-	-	R	-100 I.S.	-10
Deschampsia cespitosa	-	-	-	I	+55 I.S.	+5	I	+300 I.S.	+7
Descurainia sophia	-	-	-	-	-	-	R	-100 I.S.	-10
Elymus innovatus	D	-51	-5	D	-17	-2	D	-63	-6
Epilobium angustifolium	-	-	-	D	-50 I.S.	-5	D	-89 I.S.	-9
Equisetum arvense	D	-7	-1	I	+103 I.S.	+6	I	+16	+2
E. hyemale	-	-	-	I	+34 I.S.	+3	I	+32	+2

37

Cont'd...

Table 2 continued. Response of species to grazing in three habitat types as indicated by the mean percentage difference in frequency (or density) between grazed and ungrazed sites and by calculated grazing resistibility numbers (G.R.N.).

Species	Forest			Cleared			Seeded		
	General response	Mean % difference	G.R.N.	General response	Mean % difference	G.R.N.	General response	Mean % difference	G.R.N.
Erigeron canadensis	-	-	-	X	+ I.S.	+10	D	-14	-1
E. philadelphicus	-	-	-	-	-	-	R	-100 I.S.	-10
Festuca ovina	-	-	-	X	+ I.S.	+10	I	+233 I.S.	+7
F. rubra[1/]	-	-	-	-	-	-	I	+158**	+6
Fragaria vesca	I	+13	+1	I	+50*	+3	D	-34*	-3
F. virginiana	I	+8 I.S.	+1	N	-3	0	D	-78 I.S.	-8
Galium septentrionale	I	+10	+1	D	-20*	-2	D	-41**	-4
Gentiana amarella	R	-100 I.S.	-10	R	-100 I.S.	-10	R	-100*	-10
Geranium bicknellii	-	-	-	-	-	-	R	-100 I.S.	-10
Hackelia floribunda	-	-	-	-	-	-	X	+ I.S.	+10
Hedysarum alpinum	-	-	-	R	-100 I.S.	-10	D	-44 I.S.	-4
Hieraceum canadense	-	-	-	-	-	-	D	-80 I.S.	-8
Hordeum jubatum	X	+ I.S.	+10	I	+70 I.S.	+8	X	+ **	+10
Koeleria cristata	-	-	-	I	+20 I.S.	+1	D	-10	-1
Lathyrus ochroleucus	D	-54 I.S.	-5	R	-100 I.S.	-10	D	-86**	-9
L. venosus	D	-36 I.S.	-4	D	-52 I.S.	-5	D	-12	-1
Liatris linguistylis	-	-	-	R	-100 I.S.	-10	D	-50 I.S.	-5
Lilium philadelphicum	-	-	-	R	-100 I.S.	-10	R	-100 I.S.	-10
Lysimachia ciliata	-	-	-	R	-100 I.S.	-10	-	-	-
Maianthemum canadense	D	-77 I.S.	-8	R	-100 I.S.	-10	R	-100 I.S.	-10
Medicago sativa	-	-	-	-	-	-	D	-46**	-5
Melilotus alba	-	-	-	-	-	-	N	0	0
Mentha arvensis	X	+ I.S.	+10	I	+210	+6	R	-100 I.S.	-10
Orthocarpus luteus	-	-	-	R	-100 I.S.	-10	-	-	-
Oxytropis deflexa	-	-	-	N	0	0	I	+500 I.S.	+8
Phleum pratense	-	-	-	-	-	-	D	-7	-1
Plantago major	-	-	-	X	+ I.S.	+10	X	+ *	+10
Poa compressa	X	+ I.S.	+10	I	+19	+2	I	+230*	+7
Poa interior	-	-	-	-	-	-	D	-81	-8
Poa palustris	I	+400 I.S.	+8	I	+12	+1	I	+18	+2
Poa pratensis	I	+200 I.S.	+7	I	+47*	+4	I	+17	+2
Polygala senega	D	-60 I.S.	-6	D	-81 I.S.	-8	D	-53	-5
Polygonum interior	-	-	-	-	-	-	X	+ *	+10
Populus balsamifera	-	-	-	I	+30 I.S.	+2	I	+60	+4
Populus tremuloides	D	-16	-2	D	-52*	-5	D	-79*	-8
Potentilla fruticosa	R	-100 I.S.	-10	-	-	-	D	-30 I.S.	-3
Prunus virginiana	D	-30 I.S.	-3	D	-40 I.S.	-4	R	-100*	-10
Ribes lecustre	I	+75 I.S.	+4	X	+100 I.S.	+10	R	-100 I.S.	-10
Rubus idaeus	D	-70 I.S.	-7	I	+500 I.S.	+8	R	-100 I.S.	-10
Rubus pubescens	I	+200 I.S.	7	I	+200 I.S.	+5	-	-	-
Rosa acicularis	D	-37	-4	D	-37*	-4	D	-39	-4
Rosa woodsii	D	-10	-1	D	-31 I.S.	-3	D	-54*	-4
Rumex acetosella	-	-	-	X	+ I.S.	+10	D	-60 I.S.	-6
Salvia reflexa	-	-	-	N	0	0	-	-	-
Sanicula marilandica	D	-26 I.S.	-3	I	+50 I.S.	+3	D	-94	-9
Schizachne purpurascens	D	-27	-3	I	+300 I.S.	+7	R	-100 I.S.	-10

Cont'd ...

Table 2 concluded. Response of species to grazing in three habitat types as indicated by the mean percentage difference in frequency (or density) between grazed and ungrazed sites and by calculated grazing resistibility numbers (G.R.N.).

Species	Forest			Cleared			Seeded		
	General response	Mean % difference	G.R.N.	General response	Mean % difference	G.R.N.	General response	Mean % difference	G.R.N.
Sisyrinchium montanum	-	-	-	-	-	-	N	0	0
Smilacina stellata	I	+27 I.S.	+1	D	-81 I.S.	-8	-	-	-
Solidago canadensis	I	+89	+6	D	-76**	-8	D	-82**	-8
Sonchus asper	-	-	-	D	-71 I.S.	-7	N	-20	-2
Stachys palustris	D	-33 I.S.	-3	D	-73	-7	D	-67	-7
Stellaria longipes	N	0 I.S.	0	D	-43	-4	D	-27	-3
Symphoricarpus occidentalis	I	+14	+1	I	+8	+1	D	-40*	-4
Taraxacum officinale	I	+77**	+4	I	+63*	+4	I	+23	+2
Thalictrum dasycarpum	I	123 I.S.	+6	I	+23	+2	D	-64**	-6
Tragapogon dubius	N	0	0	D	-70 I.S.	-7	D	-90 I.S.	-9
Trifolium repens	-	-	-	-	-	-	I	+275**	+9
Urtica dioica	-	-	-	I	+100 I.S.	+5	R	-100 I.S.	-10
Vaccinium oxycoccus	D	-29	-3	-	-	-	-	-	-
Vicia americana	I	+46	+3	D	-20	-2	D	-29*	-3
Viola adunca	-	-	-	-	-	-	D	-10 I.S.	-1
Viola rugulosa	I	+21 I.S.	+2	D	-10	1	D	-8	-1
Zigadenus elegans	-	-	-	R	-100 I.S.	-10	D	-91 I.S.	-9
Zizia aptera	-	-	-	-	-	-	D	-94 I.S.	-9

D = Decreaser, I = Increaser, N = Neutral, R = Retreater, X = Invader.
* Differences due to grazing significant at .05 level of significance.
**Differences due to grazing significant at .01 level of significance.
I.S. Species occurred in less than 5 pairs of stand pairs and 't' test was not applied.
1/Measured density used for calculation of mean % difference and G.R.N.

Table 3 . Comparison of the relative number of species in each of the five categories in each habitat type.

Habitat type	Total number of species	Percent total number of species				
		Increasers	Decreasers	Invaders	Neutrals	Retreaters
Forest	49	43.0	35.0	12.0	4.0	6.0
Cleared	80	32.0	31.5	14.0	7.5	15.0
Seeded	95	25.3	46.3	7.3	5.1	16.0

frequency in a particular site. The G.R.N.'s vary from -10 to +10. Species previously defined as retreaters will have a G.R.N. of -10 and invaders will have a G.R.N. of +10. The decreasers can have any values from -9 to -1 and increasers from +1 to +9. The 0 values expressed for neutrals represents a range in calculated values of -0.5 to +0.5.

The grazing resistibility numbers derived in the present study are a measure of the ability of a species to withstand grazing. A high plus G.R.N. indicates that a species is favoured by grazing and a high minus G.R.N. implies that the particular species is hampered by grazing. Because the species behaviour differs under the three 'habitat' types having different environmental conditions, the grazing resistibility numbers for the species in different habitat types can not be applied interchangeably.

Comparison of the grazing resistibility numbers under three 'habitats' show that none of the species behave in exactly the same way in response to grazing. Only three of the 49 species from the forest stands have grazing resistibility number of zero. The status of 33 percent of the forest species is changed from having plus numbers under forest habitat to minus numbers under the cleared forest habitat. The change from cleared unseeded to seeded habitat is even more pronounced. Only 20 percent of the forest species with plus numbers retain their plus values under cleared seeded conditions and 80 percent of the forest species possess minus numbers under seeded conditions. From a comparison of species with plus numbers under forest habitat to their number under the cleared forest habitat, it is observed that 66 percent of forest species with positive G.R.N.'s have also plus numbers under forest cleared habitat. The forest species with plus numbers having consistent behaviour throughout the three habitat types tend to have lower numbers under cleared forest and seeded habitats. Forest species with minus grazing resistibility numbers show a consistent behaviour throughout the three habitat types and tend to have progressively higher minus numbers from forest through cleared to seeded habitats.

The comparison of grazing resistibility numbers shows that the sensitivity of such species which occur under all three habitat types, tends to increase under cleared and seeded conditions.

The total number of species occurring on forest cleared habitat is much higher than those in the forest habitat. The increase in number of species is due to invading species which come in just after clearing and species that come in as a result of grazing. Forty-eight percent of invading species having plus numbers under cleared habitat have minus numbers under seeded habitat while 48 percent continue to possess plus numbers with low values. Only 4 percent of these invading species are absent under seeded conditions.

The further increase in the total number of species under seeded habitat is due to 30 invading species, 53 percent of which have plus grazing resistibility numbers and 47 percent possess minus grazing resistibility numbers.

The grazing indicator value of a species with high grazing resistibility number (either positive or negative) is more as compared to the species with low grazing resistibility numbers. Similarly, species which are exclusive to one habitat type are better indicators of grazing as compared to species which occur in all the three habitat types.

Effect of Intensity Of Grazing On Vegetation

The scatter-diagrams and average numerical values do reflect the degree of change in abundance of each species in relation to grazing, but they do not measure its abundance in relation to the other plant species as they may be affected by the grazing factor. These methods also do not indicate whether a species behaves the same throughout the range of sampled sites.

Numerous studies have shown that intensity of grazing has a profound influence on the botanical composition. In the first few years of pasture use (native as well as seeded) the intensity of grazing can be estimated in terms of animal months per acre. With the passing of time the composition changes under environmental conditions created by grazing. It results in the increase or decrease of already present species and invasion of new species. Thus the time period is an important factor in addition to grazing in all pastures. The same intensity of grazing would have different effects at different periods in the establishment and development of a pasture. Therefore, the time factor should be given due consideration in determining the different intensities of grazing.

Two approaches have been followed to study the effect of intensity of grazing on vegetation; firstly, by establishing grazing indices for each stand, and secondly by positioning the individual stands along a phytosociological grazing gradient.

Establishment of Grazing Index Numbers

The first method involves allotting arbitrary ratings of degree of utilization to grazed stands and weighting of these arbitrary ratings with the number of years for which the site had been utilized. Arbitrary values ranging from 1 to 4 were assigned to each grazed stand using predefined criteria, while all ungrazed stands received a 0 value. Thus a scale was set up with five classes which described the degree of utilization at the time of sampling of the stands. The number of utilization rate allotted corresponded to the number of the class. The criteria used were as follows:

(a) number of acres per animal based on number recorded by pasture managers for previous and current years,

(b) abundance of bovine faeces,

(c) comparison of heights of plants and foliage cover under grazed and ungrazed conditions, and

(d) number and degree of use of cow paths.

The utilization classes recognized were:

Class 0 - ungrazed: All ungrazed stands were included in this class.

Class 1 - lightly grazed: In all grazed stands, included in this class less than the upper half of the plants had been removed, presence of faeces was sporadic, cow paths were not distinct, density of foliage cover was not much different on grazed and ungrazed stands, and plenty of undecomposed plant dry matter was present.

Class 2 - moderately grazed: In all grazed stands included in this class, more than the upper half of the plants had been grazed as compared to the height of plants on the ungrazed partner stand, faeces were common, cow paths were prominent but still occupied by occasional plants, basal cover was denser than that on the ungrazed stands, there was little or no accumulation of plant dry matter, and organic matter was present in moderate quantities.

Class 3 - heavily grazed: This included all grazed stands in which more than the upper three-quarters of the plant was grazed as compared to the height of plants on the ungrazed stands, bovine faeces were very common, cow paths were prominent without occupied by any plants, and there was no accumulation of plant dry matter.

Class 4 - very heavily grazed: This included all grazed stands in which plants were grazed to the ground level, faeces were very common, cow paths were wide and prominent, occasionally uprooted plants were present, foliage cover was sparse, there was no accumulation of plant dry matter, and there was tendency towards erosion.

To combine the effect of age of stands, utilization rating was multiplied by the number of years the stand had been used. The resulting value was termed the grazing index (G.I.) number for a stand. The grazing index numbers were calculated or each stand as shown in the following sample procedure:

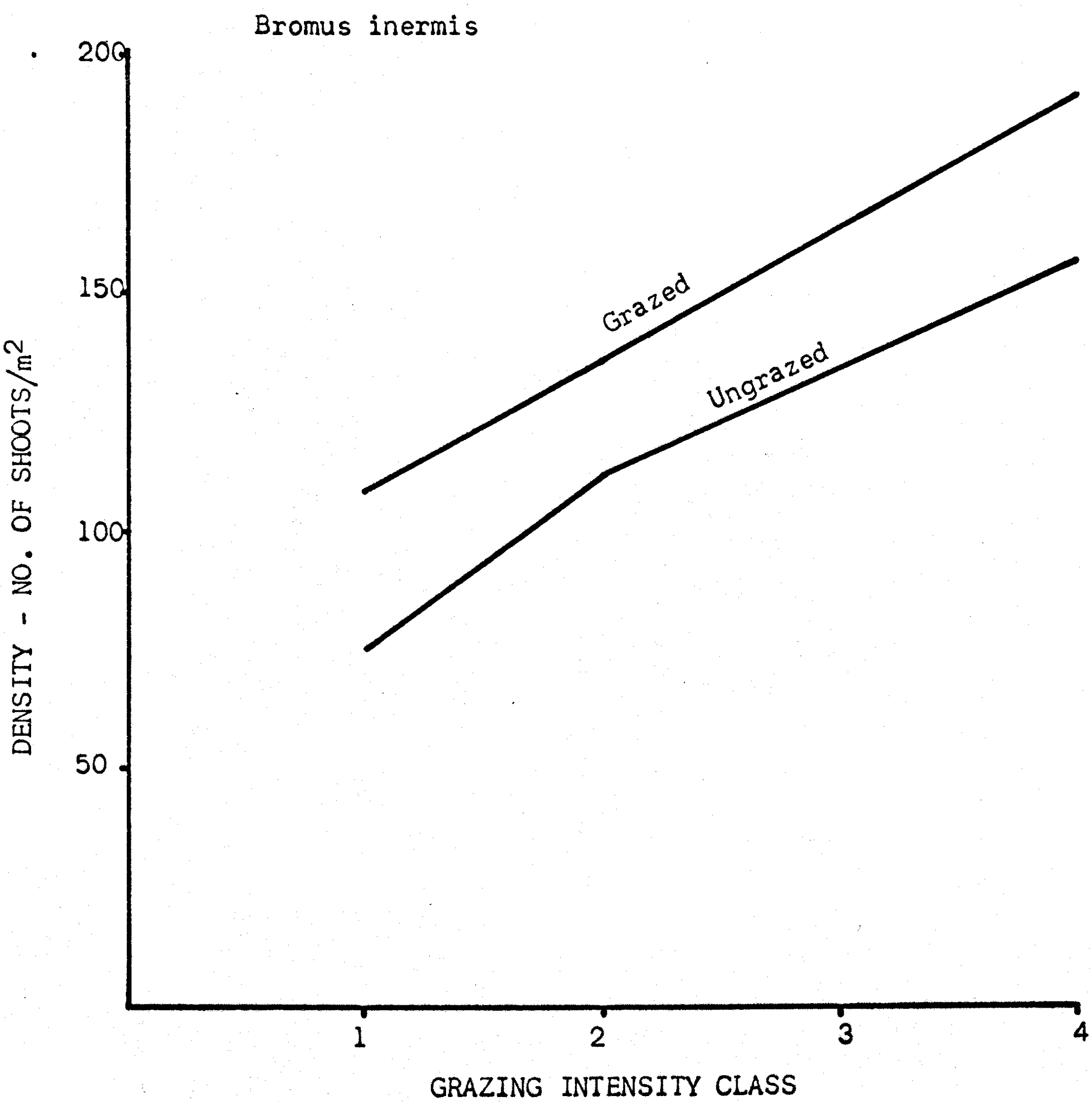
Site and stand number	Utilization rating	Number of years	Grazing index number
Beaver Hills C.P., BH - 2	2	24	48
Erwood C.P., EW - 13	4	6	24

It was decided to group the range of grazing indices under four groups in each habitat type. Then each stand was placed in one of the four groups depending on its grazing index. The frequency (or density) values for each group were averaged and these averages of individual species values for grazed and ungrazed stands were then plotted against each class and behaviour curves drawn (Fig. 14). The example of the procedure is illustrated for Bromus inermis:

Grazing class	Average density - shoot/m^2		Mean percent difference
	Ungrazed	Grazed	
1	75	108	+44
2	112	135	+20
3	-	-	-
4	156	191	+22

The method was applied to 15 most common species. Although certain trends were quite evident from behaviour curves, it was not thought feasible to apply this method for three reasons. Firstly, when stand indices were superimposed on the stand pair positions on scatter diagrams, there was no apparent pattern of stands. If the calculated indices were measures of grazing intensity, any difference in frequency or density of species due to differences in intensity of grazing should have resulted in some patterns. Secondly, species had a considerable variation in the mean frequency (or density) for the same species among the corresponding groups of ungrazed stands. When these average values for groups of corresponding ungrazed stands were plotted against grazing intensity classes, the curves showed trends similar to those when mean values of frequency (or density) were plotted for groups of grazed stands. For this reason, it was thought that the trends in the behaviour curves of species under four grazing intensity classes could have been due to original variation among the ungrazed stands. Also the grouping of stands was based on the arbitrary rating of the utilization of a stand which may not be considered as a very accurate measure of

Figure 14. Effect of intensity of grazing on density of *Bromus inermis*. Density values are average density values for all stands present in the grazing intensity class.


Bromus inermis
200
150
100
50
DENSITY - NO. OF SHOOTS/m2
Grazed
Ungrazed
1
2
3
4
GRAZING INTENSITY CLASS

the difference of stand due to grazing intensity. Thirdly, in some of the grazing intensity classes there were no stands or an insufficient number of stands to give a dependable average value of frequency (or density) for the grazing intensity class.

Phyto-sociological Grazing Gradient

The relative abundance of increasers, invaders and decreasers depends on the intensity of grazing. If both degree of change in a species due to grazing and its relative abundance in a stand at a particular level of grazing are combined in a numerical value, it will be a more satisfactory estimate of change due to that level of grazing. Such a numerical value could be obtained for a species by the product of its grazing resistibility number, an estimate of average change in a species due to grazing, and its relative frequency, a measure of its relative abundance in a stand. In view of the fact that absence or change in relative abundance of species has occurred as a result of grazing, emphasis on one group of species while ignoring another group will not result in a good measure of change in vegetation as a result of grazing. For this reason, all species occurring in quadrats should be used in any estimate of change due to grazing. The sum of the above-mentioned numerical values (G.R.N. x R.F.) for all species occurring in a stand will give the estimation of change in each stand at a particular level of grazing.

The relative frequency for each species in each stand of the present study was calculated. The relative frequencies of all species occurring in a stand were multiplied by their corresponding grazing resistability numbers. The sum of all such products was considered as the stand index, a measure of the change in a stand as a result of a particular level of grazing. The stand index will be larger or smaller depending on the relative abundance of positive (increasers) and negative (decreasers) grazing resistibility numbers which in turn depends on the intensity of grazing. A virtually ungrazed forest or cleared stand without any invaders should have a maximum stand index of -1000 and very heavily grazed stand (without any of the originally existing species under ungrazed conditions) should have a value of +1000. Such extreme conditions are not commonly encountered. A sample calculation for the stand index is presented in Table 4.

Stands indices were calculated for all stands. The stands for each habitat type were then arranged separately in a linear order, using the stand indices. As this linear ordering of stands was a result of difference in species composition due to grazing intensities, the gradient is considered to be a grazing gradient. In all three habitat types, the grazed partner of each stand pair was always located to the right of the ungrazed partner on the grazing gradient.

Grazing gradient for forest stands

Thirteen out of the fourteen forest stands, grazed as well as ungrazed, had positive stand indices. This is because the stands were composed mostly of species with plus grazing resistibility numbers. The stand indices varied from minus 16 to plus 331. Stand positions on the grazing gradient are presented in Figure 15a. All grazed stands had stand indices of more than plus 100 and all ungrazed stands except one had a stand indices of less than plus 100. Under completely undisturbed conditions the forest floor is devoid of most of the herbaceous species which increase under grazing. The ungrazed stands

Table 4. Calculation of stand index using grazing resistibility numbers and relative frequencies of all species present in a stand.

Site and stand number	Species	Grazing resistibility number (G.R.N.)		Relative frequency (R.F.)	G.R.N. x R.F.	
Chaogness community pasture, CH 10A	Agropyron subsecundum	+5		2.0	+10	
	Aster ciliolatus	+3		14.0	+42	
	Amelanchier alnifolia		-2	7.0		-14
	Carex trisperma	+2		4.5	+ 9	
	Elymus innovatus		-5	17.0		-85
	Fragaria vesca	+1		8.0		
	Galium septentrionale	+1		1.3	+ 1	
	Lathyrus venosus		-4	12.5		-50
	Rosa acicularis		-3	3.0		-12
	Rosa woodsii	+1		6.7	+ 7	
	Schizachne purpurascens		-3	2.6		-8
	Solidago canadensis	+6		5.3	+32	
	Symphoricarpus occidentalis	+1		11.0	+11	
	Viola rugulosa	+2		5.1	+10	
				Total	+130	-169
				Stand index = -39		

in the study showed no evidence of present or recent use but in some instances had presumably been used by local farmers before the land was acquired for community pastures. The earlier disturbance favoured the greater abundance of species with plus grazing resistibility numbers resulting in positive stand index values for most of the ungrazed forest stands. Due to inadequate number of forest stands, the ungrazed segment of the gradient is probably not well represented.

Grazing gradient for cleared stands

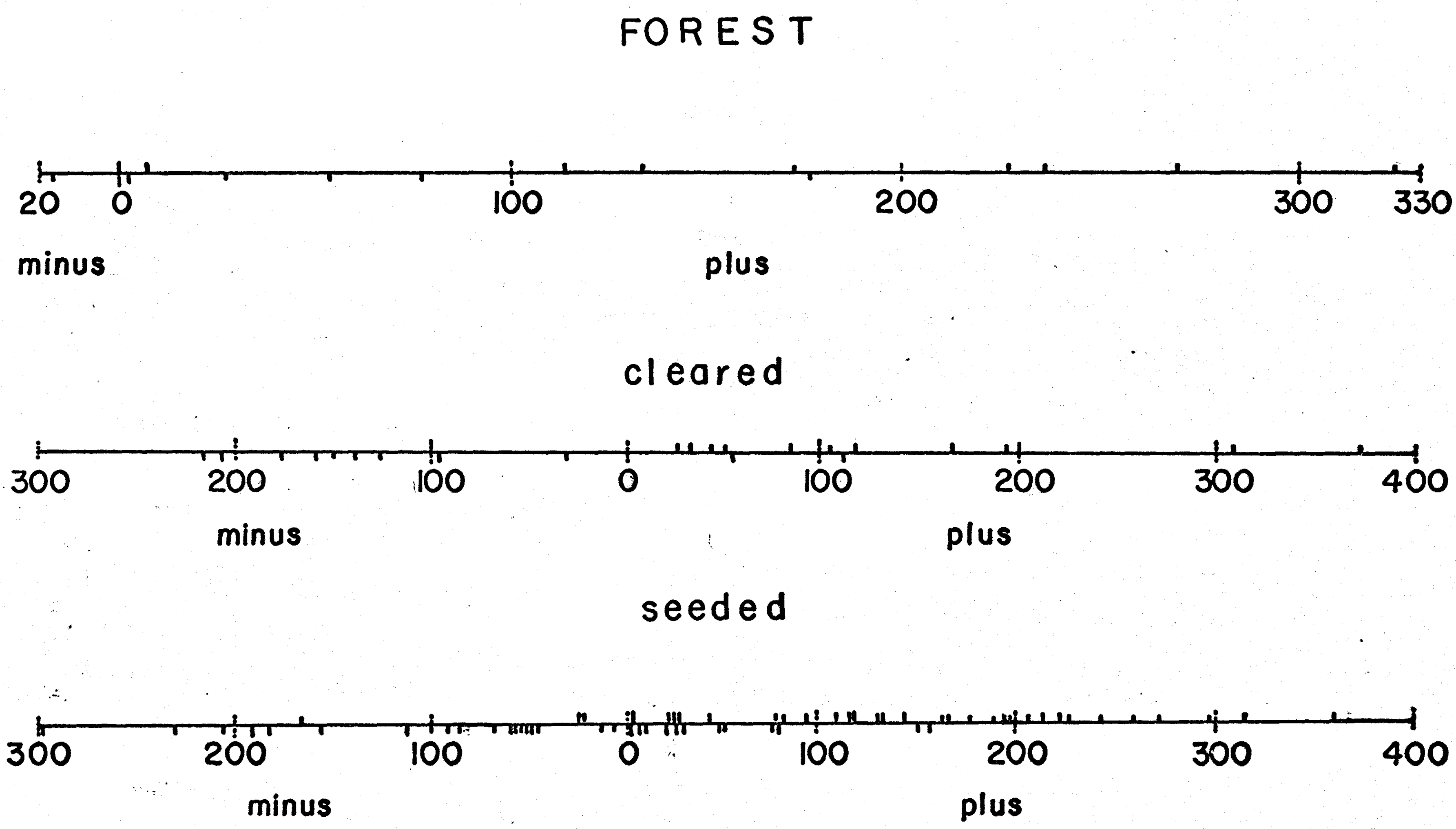
Twenty-two stands were ordered along the grazing gradient for this habitat type. The stand index values ranged from minus 215 to plus 370 (Fig. 15b). All ungrazed stands except two possessed minus index values and grazed stands had plus index numbers. Both of the "ungrazed" stands with unusual behaviour are older stands and have not been grazed for the last 8 years. The positive index values for the ungrazed stands may be explained by the fact that the possible disturbance prior to protection had resulted in the establishment of species which are favoured by grazing. In one of these two stands the relative frequency of *Poa pratensis* was very high resulting in a larger sum of plus values than the sum of minus values. The other stand was located at a position so that it received drainage and this resulted in prevalence of *Hordeum jubatum* and *Cirsium arvense*, both of which had high plus grazing resistibility number. This resulted in the plus index values for the ungrazed stands.

Grazing gradient for the seeded stands

Sixty-two stands were ordered along the grazing gradient. The stand indices varied from -297 to +360 and the order of the stands is presented in Figure 15c. All grazed stands, except two, had positive stand indices and 21 of the 27 ungrazed stands possessed negative stand indices. Both the grazed stands with negative index numbers are recently seeded stands and the ungrazed stands with positive indices are either old or very young stands. This is a complex situation because of the regular distribution and high abundance of the seeded species. This results in positive index numbers in most of the older ungrazed stands either because the native species have been crowded out by over-shading or the native species, especially the decreasers, have not yet grown to such an abundance that should result in negative index numbers of the ungrazed stannds.

In the grazed stands, with the minus indices, the total relative frequency of decreasers is higher than the total relative frequency of seeded species resulting in minus stand indices. The seeded species and the native increasers and invaders have not had time to affect the environment to the level that could be unfavourable for the growth of the native decreasers.

Figure 15. Grazing gradients showing arrangement of stands based on the stand index value, separately under each habitat type: (a) arrangement of forest stands, (b) arrangement of cleared stands, (c) arrangement of seeded stands. Marks below the base line represent the positions of the ungrazed stands and lines above the base line indicate the positions of the grazed stands.



GRAZING GRADIENTS

Species behaviour along the grazing gradient

When the stands had been arranged along the grazing gradient for each habitat type, the frequency or density for each species for all stands on the gradient were plotted and species behaviour curves drawn. The species behaviour curves were drawn only for species which had a frequency of 40 percent or more in at least one of the stands. Twenty-one species in forest, 32 in cleared and 37 in seeded habitats fulfilled this criterion. The procedure in drawing behaviour curves involved smoothening of the considerable variation in species frequency or density values in adjacent sites along the gradient. To draw the curves the gradient was divided into segments of 50 units in the case of forest habitat and 100 units in the case of cleared and seeded habitats. Because of the fewer number of stands under the forest habitat and also to have comparable number of points to draw the behaviour curves, the 50 units of the gradient were preferred for this habitat. Average frequency or measured density values were calculated for each segment to get average points for the behaviour curve for a species along the gradient.

A study of the behaviour of the species along the phyto-sociological grazing gradient supports the results from the methods used in the previous section in that all species behave differently in each habitat type and independently in the same habitat type. They have their maxima at different positions along the gradient. For convenience in discussion, species have been grouped according to their growth form (Tables 5, 6, 7) and grazing intensity terms were arbitrarily assigned to the different segments of the gradient; light to segment IV, moderate to segment V, heavy to segment VI, and very heavy to segment VII of the

Table 5 . Mean frequency (or density) of species in segments of the grazing gradient in forest sites. Only those species are included which occurred with a frequency of 40 percent or more in at least one stand. Each segment represents 50 units of the grazing gradient (-50 to +350).

Species	Mean frequency (or density) values							
	Segment I -50 to 0	Segment II +1 to +50	Segment III +51 to +100	Segment IV +101 to +150	Segment V +151 to +200	Segment VI +201 to +250	Segment VII +251 to +300	Segment VIII +301 to +350
Grasses and Sedges:								
Agropyron trachycaulum	6(1)[1/]	16(1)	--	39(2)	28(2)	86(2)[2/]	60(1)	50(1)
Schizachne purpurascens	33(1)	18(3)	--	3(1)	31(2)	42(1)	-	-
Calamagrostis canadensis	3(1)	28(3)	46(2)	26(2)	25(2)	-	-	-
Agropyron subsecundum	12(1)	15(1)	--	-	6(1)	-	-	-
Elymus innovatus	-	62(3)	6(2)	29(1)	10(2)	3(1)	-	-
Carex trisperma	-	33(3)	43(2)	70(2)	80(2)	30(1)	87(1)	-
Forbs:								
Introduced:								
Taraxacum officinale	10(1)	11(2)	-	15(2)	13(1)	11(2)	-	37(1)
Native:								
Galium septentrionale	3(1)	37(3)	-	43(2)	42(2)	63(2)	85(1)	79(1)
Aster ciliolatus	33(1)	60(3)	-	73(2)	41(2)	55(2)	95(1)	-
Fragaria vesca	63(1)	60(3)	-	72(2)	90(2)	89(2)	96(1)	84(1)
Thalictrum dasycarpum	-	12(2)	-	-	27(1)	40(1)	-	-
Vicia americana	-	24(3)	-	20(2)	40(1)	39(2)	17(1)	20(1)
Viola rugulosa	-	35(3)	-	70(1)	43(1)	40(2)	-	-
Solidago canadensis	17(1)	20(3)	-	76(1)	25(2)	15(2)	13(1)	17(1)
Lathyrus venosus	-	48(3)	-	20(1)	16(1)	-	-	-
L. ochroleucus	-	36(2)	-	10(1)	37(1)	15(2)	-	-
Shrubs:								
Symphoricarpus occidentalis	-	38(3)	-	14(2)	56(1)	10(2)	96(1)	-
Rosa acicularis	70(1)	39(3)	-	30(1)	56(1)	50(1)	-	-
R. woodsii	17(1)	35(3)	-	10(1)	-	56(1)	60(1)	-
Amelanchier alnifolia	30(1)	35(3)	-	8(2)	26(2)	24(2)	-	-
Tree seedlings:								
Populus tremuloides	22(1)	21(3)	8(2)	20(2)	30(2)	-	-	-
Number of stands	1	3	2	2	2	2	1	1

1/Numbers in parentheses denote the number of stands of occurrence.

2/Values underlined are maximum mean frequency values for the species along the grazing gradient.

Table 6 . Mean frequency (or density) of species in segments of the grazing gradient in 'cleared' sites. Only those species are included which occurred with a frequency of 40 percent or more in at least one stand. Each segment represents 100 units of grazing gradient (-300 to +400).

Species	Mean frequency (or density) values						
	Segment I -299 to -200	Segment II -199 to -100	Segment III -99 to 0	Segment IV +1 to +100	Segment V +101 to +200	Segment VI +201 to +300	Segment VII +301 to +400
Grasses and Sedges:							
Poa pratensis	40(1)[1]	10(2)	10(1)	55(4)	57(5)	-	100(1)[2]
Poa palustris	63(1)	53(3)	67(2)	61(4)	76(5)	-	93(1)
Hordeum jubatum	-	-	--	-	24(1)	-	63(1)
Koeleria cristata	-	30(1)	-	-	20(2)	-	40 (1)
Agrostis scabra	5(1)	20(5)	24(2)	44(3)	36(4)	-	37(2)
Agropyron trachycaulum	-	30(4)	23(2)	36(5)	22(3)	-	27(2)
Bromus ciliatus	-	25(3)	5(2)	40(2)	-	-	10(1)
Elymus innovatus	-	84(2)	57(1)	82(2)	42(1)	-	41(1)
Festuca ovina	-	-	-	83(1)	-	-	-
Poa compressa	-	74(2)	67(1)	78(3)	-	-	-
Calamagrostis canadensis	80(1)	80(1)	83(1)	24(2)	-	-	-
Schizachne purpurascens	40(1)	-	-	-	7(1)	-	-
Agropyron subsecundum	80(1)	22(3)	13(2)	30(2)	7(1)	-	5(2)
Carex trisperma	65(1)	43(3)	47(2)	50(6)	90(2)	-	-
Forbs:							
Introduced							
Taraxacum officinale	18(1)	60(5)	48(2)	75(6)	77(2)	-	96(1)
Cirsium arvense	13(1)	3(1)	-	40(2)	7(1)	-	93(1)
Achillea millefolium	-	57(4)	54(2)	64(5)	65(2)	-	27(1)
Native							
Artemesia biennis	-	30(1)	-	17(1)	-	-	40(1)
Fragaria vesca	50(1)	59(4)	27(1)	38(8)	43(2)	-	50(1)
Lathyrus venosus	-	33(2)	43(1)	40(1)	10(2)	-	-
Vicia americana	6(2)	36(5)	28(2)	29(5)	26(2)	-	17(2)
Stachys palustris	14(2)	36(3)	10(1)	20(1)	14(2)	-	-
Aster ciliolatus	7(1)	47(5)	30(2)	21(3)	33(2)	-	27(1)
Viola rugulosa	-	36(3)	17(1)	26(4)	7(2)	-	3(1)
Solidago canadensis	12(1)	61(3)	48(2)	18(2)	-	-	3(2)
Polygala senega	-	53(1)	-	10(1)	3(1)	-	-
Galium septentrionale	73(1)	50(4)	48(2)	52(4)	40(3)	-	17(2)
Anemone canadensis	40(1)	27(2)	20(1)	16(3)	15(4)	-	8(2)

Table 6 continued. Mean frequency (or density) of species in segments of the grazing gradient in 'cleared' sites. Only those species are included which occurred with a frequency of 40 percent or more in at least one stand. Each segment represents 100 units of grazing gradient (-300 to +400).

Species	Mean frequency (or density) values						
	Segment I -299 to -200	Segment II -199 to -100	Segment III -99 to 0	Segment IV +1 to +100	Segment V +101 to +200	Segment VI +201 to +300	Segment VII +301 to
<u>Shrubs</u>:							
Rosa acicularis	<u>90</u>(1)	50(3)	37(1)	57(3)	30(1)	-	-
R. woodsii	27(2)	<u>70</u>(2)	17(1)	45(2)	33(1)	-	-
Symphoricarpus occidentalis	22(2)	<u>48</u>(3)	14(2)	44(3)	22(3)	-	3(1)
<u>Tree seedlings</u>:							
Populus tremuloides	<u>45</u>(1)	32(4)	27(1)	18(6)	17(2)	-	10(1)
Number of stands	2	5	2	6	5		2

1/Number in parentheses denote the number of stands of occurrence.

2/Values underlined are maximum mean frequency values for the species along the grazing gradient.

Table 7 . Mean frequency (or density) of species in segments of the grazing gradient in 'seeded' sites. Only those species are included which occurred with a frequency of 40 percent or more in at least one stand. Each segment represents 100 units of the grazing gradient (-300 to +400).

Species	Mean frequency (or density) values						
	Segment I -299 to -200	Segment II -199 to -100	Segment III -99 to 0	Segment IV +1 to +100	Segment V +101 to +200	Segment VI +201 to +300	Segment VII +301 to +400
Grasses and Sedges:							
Seeded							
*Bromus inermis	81(3)[1]	54(3)	133(9)	135(15)	147(10)	75(5)	158(2)[2]
*Festuca rubra	46(1)	46(3)	133(3)	144(11)	150(3)	107(3)	-
Agropyron cristatum	70(1)	70(1)	73(6)	51(5)	29(8)	81(4)	100(1)
A. trachycaulum	30(2)	82(2)	70(3)	35(5)	59(3)	15(2)	-
Phleum pratense	-	30(2)	28(8)	20(11)	6(13)	19(3)	-
Native							
Poa compressa	-	-	20(2)	19(5)	43(2)	52(3)	93(1)
P. pratensis	5(3)	12(3)	28(6)	34(5)	52(7)	80(1)	25(1)
P. palustris	36(3)	44(4)	52(7)	48(6)	35(10)	24(5)	3(1)
Agrostis scabra	16(2)	5(2)	5(2)	13(5)	22(2)	-	3(2)
Festuca ovina	20(1)	3(1)	-	-	62(1)	-	-
Agropyron subsecundum	3(1)	13(2)	13(2)	25(2)	3(1)	-	-
Koeleria cristata	7(3)	7(1)	7(3)	20(1)	12(3)	-	3(1)
Carex trisperma	59(3)	62(3)	24(5)	22(4)	16(3)	20(2)	-
Elymus innovatus	55(3)	73(1)	15(2)	15(2)	-	-	-
Forbs:							
Introduced							
**Trifolium repens	-	-	46(2)	24(2)	17(2)	88(5)	17(1)
**Medicago sativa	30(1)	35(2)	32(4)	42(10)	47(5)	29(5)	15(2)
Taraxacum officinale	20(2)	7(4)	61(10)	74(8)	83(5)	75(6)	78(2)
Sonchus asper	5(1)	24(3)	34(6)	20(7)	28(2)	22(3)	-
Cirsium arvense	7(1)	20(2)	26(5)	19(6)	10(2)	10(2)	-
Native							
Axyris amaranthoides	-	-	-	17(1)	37(1)	-	-
Lathyrus venosus	-	10(1)	40(1)	11(4)	3(1)	10(1)	-
Polygala senega	15(2)	15(1)	17(4)	6(5)	-	3(1)	-
Galium septentrionale	44(3)	59(3)	38(9)	17(10)	24(5)	5(4)	7(1)
Vicia americana	45(2)	54(4)	32(11)	29(11)	14(4)	9(5)	7(1)
Solidago canadensis	26(3)	36(4)	20(11)	13(6)	6(3)	7(1)	3(1)
Viola rugulosa	33(3)	35(2)	8(5)	14(5)	6(2)	-	-
Anemone canadensis	-	35(3)	6(4)	12(4)	5(2)	3(1)	-

Table 7 continued. Mean frequency (or density) of species in segments of the grazing gradient in 'seeded' sites. Only those species are included which occurred with a frequency of 40 percent or more in at least one stand. Each segment represents 100 units of the grazing gradient (-300 to +400).

Species	Mean frequency (or density) values						
	Segment I -299 to -200	Segment II -199 to -100	Segment III -99 to 0	Segment IV +1 to +100	Segment V +101 to +200	Segment VI +201 to +300	Segment VII +301 to +400
Forbs:							
Native cont'd							
Achillea millefolium	72(1)	43(5)	35(6)	22(8)	28(7)	20(2)	10(1)
Fragaria vesca	63(1)	25(2)	20(3)	43(6)	40(1)	13(2)	3(1)
Aster ciliolatus	31(3)	21(4)	21(5)	14(6)	7(3)	3(1)	-
Thalictrum dasycarpum	30(2)	23(3)	25(5)	8(4)	5(2)	3(1)	-
Fragaria virginiana	30(1)	-	3(1)	10(1)	7(1)	6(2)	-
Lathyrus ochroleucus	32(3)	10(2)	8(2)	8(3)	-	-	-
Zizia aptera	32(2)	3(1)	-	-	-	-	-
Shrubs:							
Symphoricarpus occidentalis	48(2)	23(2)	25(6)	17(4)	26(2)	3(2)	-
Rosa woodsii	53(3)	50(1)	47(4)	27(3)	21(2)	-	10(1)
Tree seedlings:							
Populus tremuloides	26(3)	17(1)	16(6)	12(7)	7(1)	5(2)	-
Number of stands	3	5	13	18	13	8	2

1/Number in parentheses denote the number of stands of occurrence.
2/Values underlined are maximum mean frequency (or density) values for the species along the grazing gradient.
*Mean values are density values.
**Introduced species are seeded.

grazing gradient of cleared and seeded habitats, and light to segments IV + V, moderate to VI, heavy to VII, and very heavy to segment VIII in case of forest habitat. The segments are only referred to the range of gradient within which the stands occurred in each habitat type. There were no grazed stands included in the first three segments of the gradient which have been jointly referred to as the ungrazed portion of the gradient. The grazing intensity terms are exclusively arbitrary and do not pertain to the carrying capacity of the sites under study.

Grasses and sedges

Several native graminoids survive under grazing of forest and become important forage components of the pastures. After clearing, the grasses that were important under the forest are replaced by invading grasses like Poa species. Under seeded conditions all native grasses and sedges which were dominant under forest and cleared habitat disappear or become less important in seeded stands.

In the forest habitat native grasses namely, Agropyron trachycaulum and Schizachne purpurascens, were most abundant under moderate grazing (Fig. 16a). Calamagrostis canadensis, Agropyron subsecundum and Elymus innovatus either had very low frequency or disappeared under moderate to heavy grazing and showed their maxima under ungrazed conditions (Figs. 16a, 16b). Carex trisperma increased with increased intensity of grazing until it had its maximum under heavy grazing (Fig. 16a). It can not withstand very heavy grazing.

Native species of grasses, Poa pratensis, Poa palustris and Hordeum jubatum invaded the cleared areas and reached their maxima under very heavy intensity of grazing under cleared forest (Figs. 19a, 19b). Agropyron trachycaulum was most abundant under light to moderate grazing

(Fig. 19c). Calamagrostis canadensis, Schizachne purpurascens and Agropyron subsecundum did not withstand grazing at all. Their frequency gradually decreased with increased grazing intensity (Figs. 20b, 20c). Native grasses which occurred both under 'forest' and 'cleared' habitat, had higher frequencies in cleared sites under the ungrazed conditions. Calamagrostis canadensis, Schizachne purpurascens and Agropyron subsecundum exhibited such a behaviour.

Under the seeded habitat, native grass species, with the exception of Poa pratensis, P. palustris, Agrostis scabra and Festuca ovina, tended to be absent, under grazing (Figs. 23d, 24a to d). Poa spp. with the exception of Poa palustris had a maximum frequency under a heavy intensity of grazing (Fig. 23d) and Festuca ovina and Agrostis scabra were most abundant under moderate intensity (Fig. 24b). Among the seeded species, Bromus inermis, Festuca rubra (Figs. 23a, 23b) and Agropyron cristatum (Fig. 23c) were favoured under grazing and had maximum frequency (or density) under heavy intensity of grazing while Phleum pratense (Fig. 24a) and Agropyron trachycaulum (Fig. 23c) were not favoured under grazing. The greater abundance of increasing seeded species under high intensities of grazing does not mean that total productivity is increased under heavy grazing as vigour of grass might not be favoured under higher densities of shoots per unit area. But their behaviour does point out that these seeded species are adapted to grazing under seeded conditions.

Forbs

There is greater variation among the species behaviour under the three habitat types. Under the forest habitat all native forbs tend to be favoured under grazing but most of these decrease under cleared forbs which occurred in forest, cleared as well as seeded, areas tended to be least abundant in seeded areas.

Shrubs

There were four common species of shrubs occurring under the three habitats. These were *Amelanchier alnifolia*, *Rosa acicularis*, *R. woodsii* and *Symphoricarpus occidentalis*. Under protection, the abundance of the shrubs is maximum in cleared areas. Under forest *Rosa acicularis* and *Amelanchier* decreased under grazing (Figs. 18a, 18c) and *Symphoricarpus*, and *Rosa woodsii* increased under heavy grazing (Fig. 18b). Under cleared and seeded habitats, all four shrubs became less abundant under increased intensity of grazing (Figs. 22c, 22d, 27c).

Tree seedlings

The seedlings referred to are the plants (up to $1\frac{1}{2}$' in height and stem diameter up to 1 inch) as a result of regrowth from roots. The seedlings of two tree species occurred in all the three habitat types. *Populus tremuloides* was much more common as compared to *Populus balsamifera*. The seedling of *Populus tremuloides* were most common on protected cleared areas. Under all three conditions it had minus grazing resistibility numbers and decreased with increased intensity of grazing. Under heavy grazing it had very low frequencies (Figs. 18d, 22c, 27d) under all the three habitats.

Nature of the grazing gradient

The phyto-sociological gradient is not exclusively a grazing gradient because the ungrazed stands are distributed over a considerable portion of the gradient. This separation of ungrazed stands presumably reflects the effect of differences in site, local environmental variation among stands on the same site, density of seeding (in seeded stands) and

Figure 16. Behaviour of selected species (having a frequency of 40 percent at least in one stand) along the grazing gradient in forest habitat. Segment I refers to the least utilization and segment VIII refers to the most heavy utilization. Frequency values are mean frequency values for the stands in which the species occurred.

FOREST

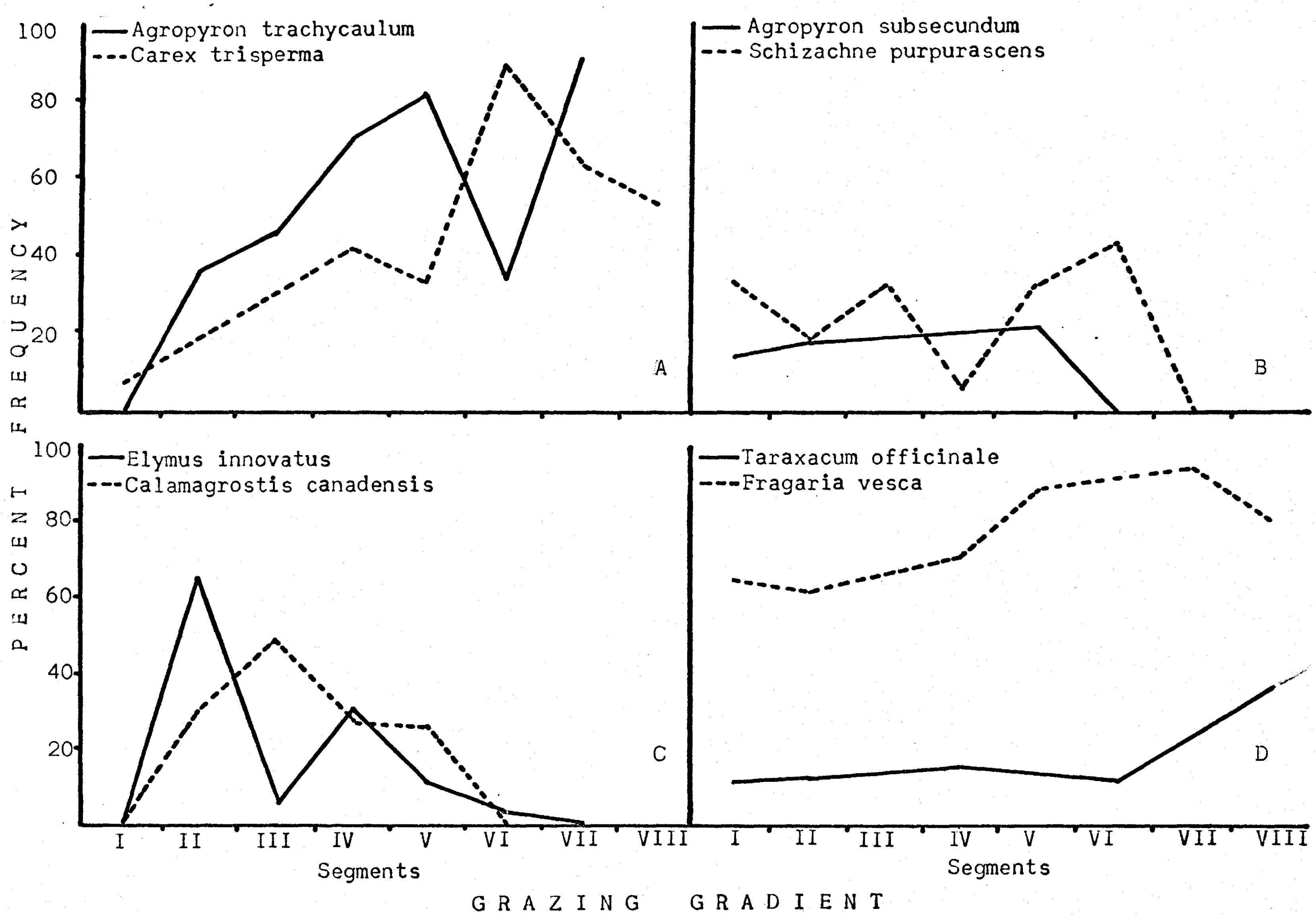
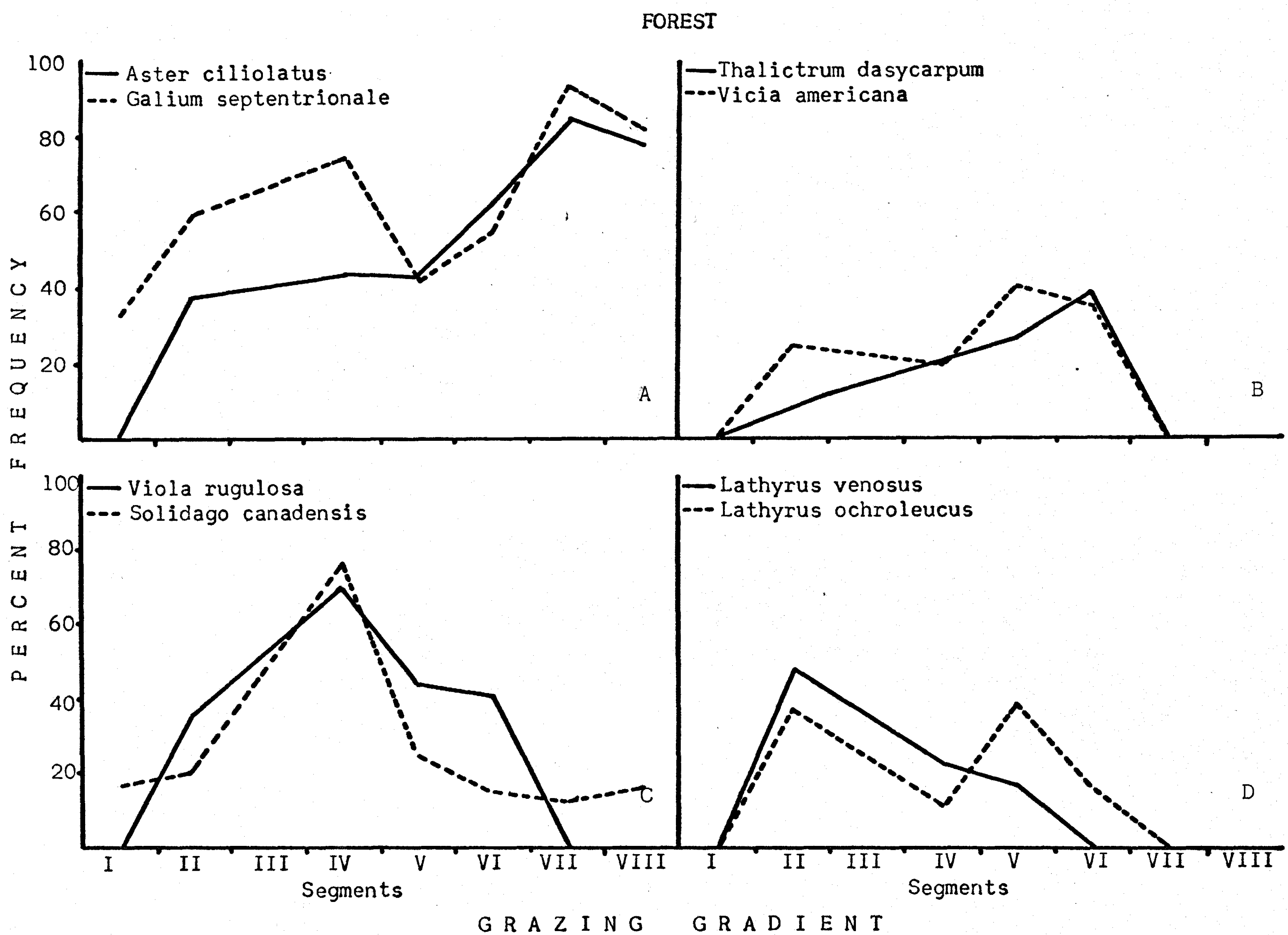

Agropyron trachycaulum
Carex trisperma
Agropyron subsecundum
Schizachne purpurascens
Elymus innovatus
Calamagrostis canadensis
Taraxacum officinale
Fragaria vesca
A
B
C
D
100
80
60
40
20
PERCENT FREQUENCY
I
II
III
IV
V
VI
VII
VIII
Segments
GRAZING GRADIENT

Figure 17. Behaviour of selected species (having a frequency of 40 percent at least in one stand) along the grazing gradient in forest habitat. Segment I refers to the least utilization and segment VIII refers to the most heavy utilization. Frequency values are mean frequency values for the stands in which the species occurred.



FOREST
Aster ciliolatus
Galium septentrionale
Thalictrum dasycarpum
Vicia americana
Viola rugulosa
Solidago canadensis
Lathyrus venosus
Lathyrus ochroleucus
A
B
C
D
100
80
60
40
20
PERCENT FREQUENCY
I
II
III
IV
V
VI
VII
VIII
Segments
GRAZING GRADIENT

Figure 18. Behaviour of selected species (having a frequency of 40 percent at least in one stand) along the grazing gradient in forest habitat. Segment I refers to the least utilization and segment VIII refers to the most heavy utilization. Frequency values are mean frequency values for the stands in which the species occurred.

FOREST

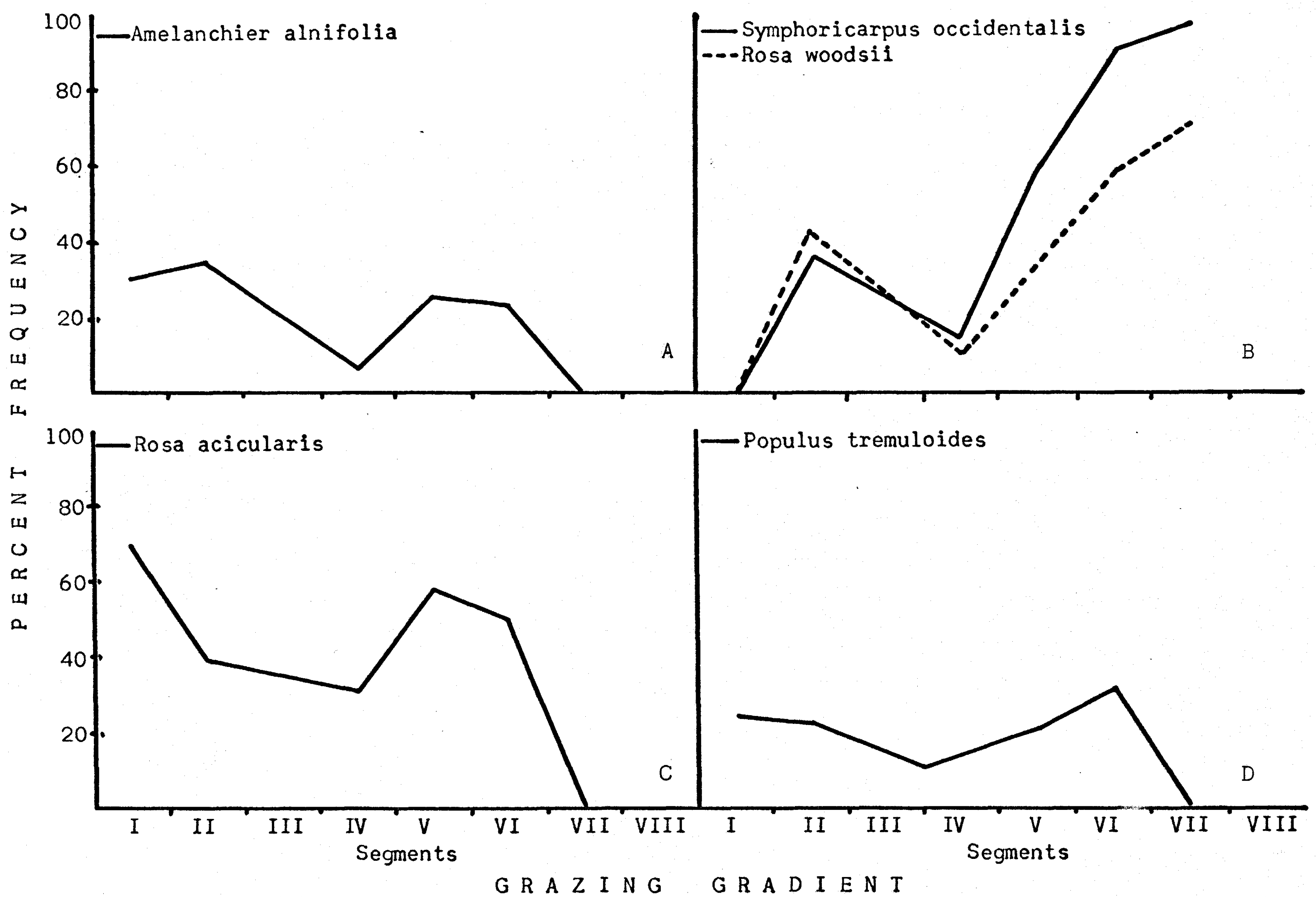

Amelanchier alnifolia
Symphoricarpus occidentalis
Rosa woodsii
Rosa acicularis
Populus tremuloides
PERCENT FREQUENCY
100
80
60
40
20
A
B
C
D
I II III IV V VI VII VIII
Segments
GRAZING GRADIENT

Figure 19. Behaviour of selected species (having a frequency of 40 percent at least in one stand) along the grazing gradient in cleared habitat. Segment I refers to the least utilization and segment VII refers to the maximum utilization. Frequency values are mean values for the stands in which the species occurred.

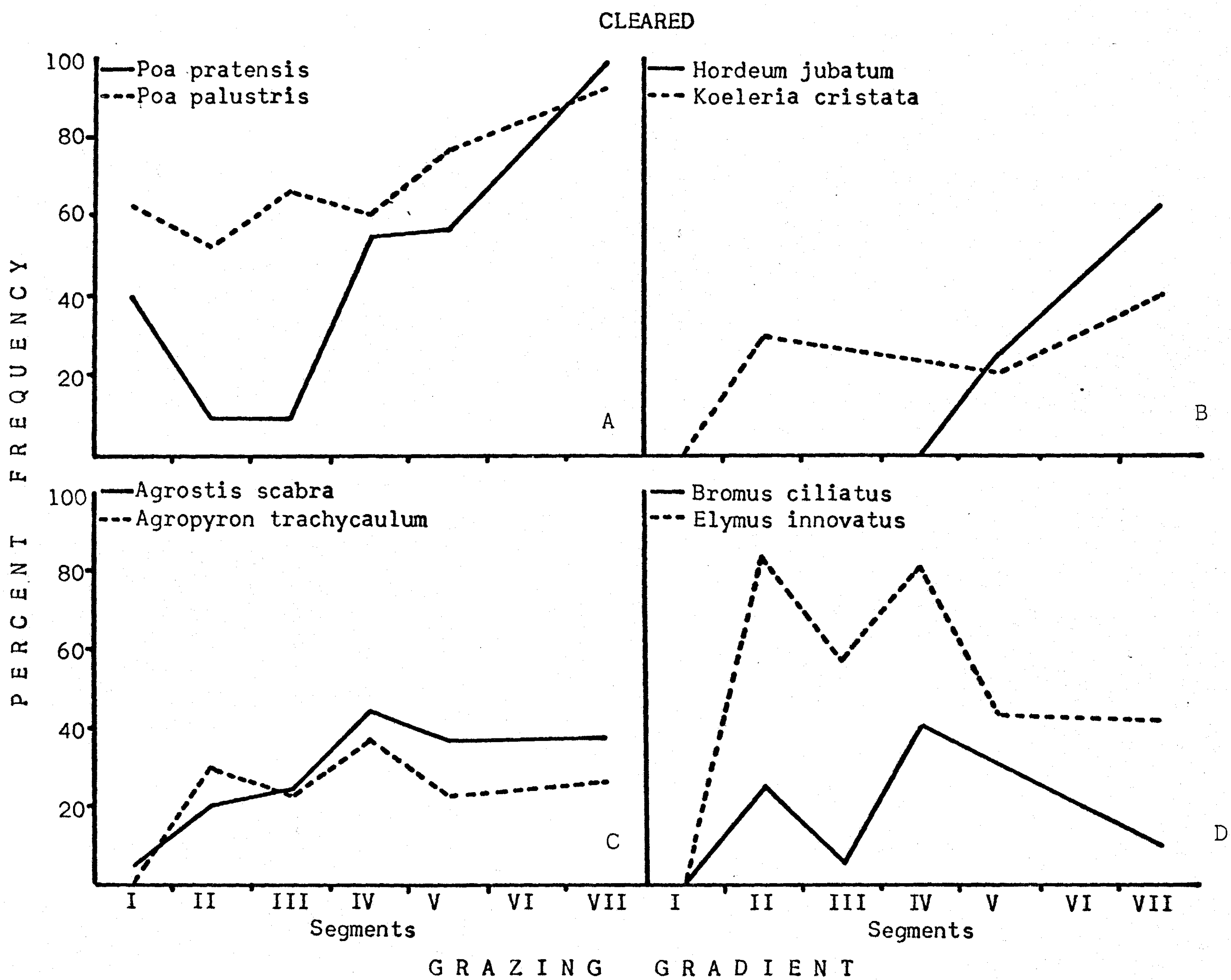

CLEARED
Poa pratensis
Poa palustris
Hordeum jubatum
Koeleria cristata
Agrostis scabra
Agropyron trachycaulum
Bromus ciliatus
Elymus innovatus
A
B
C
D
100
80
60
40
20
PERCENT FREQUENCY
I II III IV V VI VII
Segments
GRAZING GRADIENT

Figure 20. Behaviour of selected species (having a frequency of 40 percent at least in one stand) along the grazing gradient in cleared habitat. Segment I refers to the least utilization and segment VII refers to the maximum utilization. Frequency values are mean values for the stands in which the species occurred.

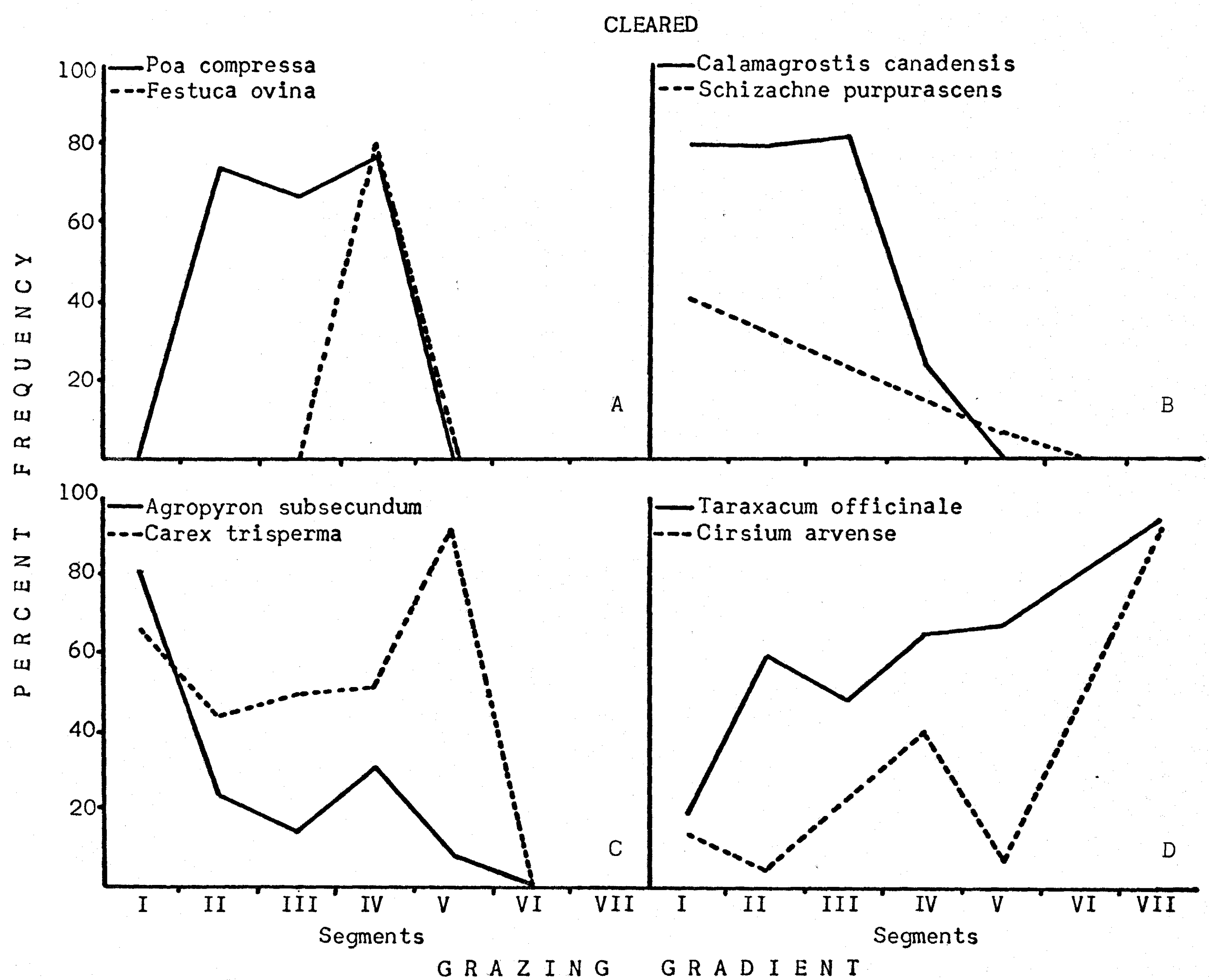

CLEARED
Poa compressa
Festuca ovina
Calamagrostis canadensis
Schizachne purpurascens
Agropyron subsecundum
Carex trisperma
Taraxacum officinale
Cirsium arvense
A
B
C
D
100
80
60
40
20
I II III IV V VI VII
Segments
PERCENT FREQUENCY
GRAZING GRADIENT

Figure 21. Behaviour of selected species (having a frequency of 40 percent at least in one stand) along the grazing gradient in cleared habitat. Segment I refers to the least utilization and segment VII refers to the maximum utilization. Frequency values are mean values for the stands in which the species occurred.

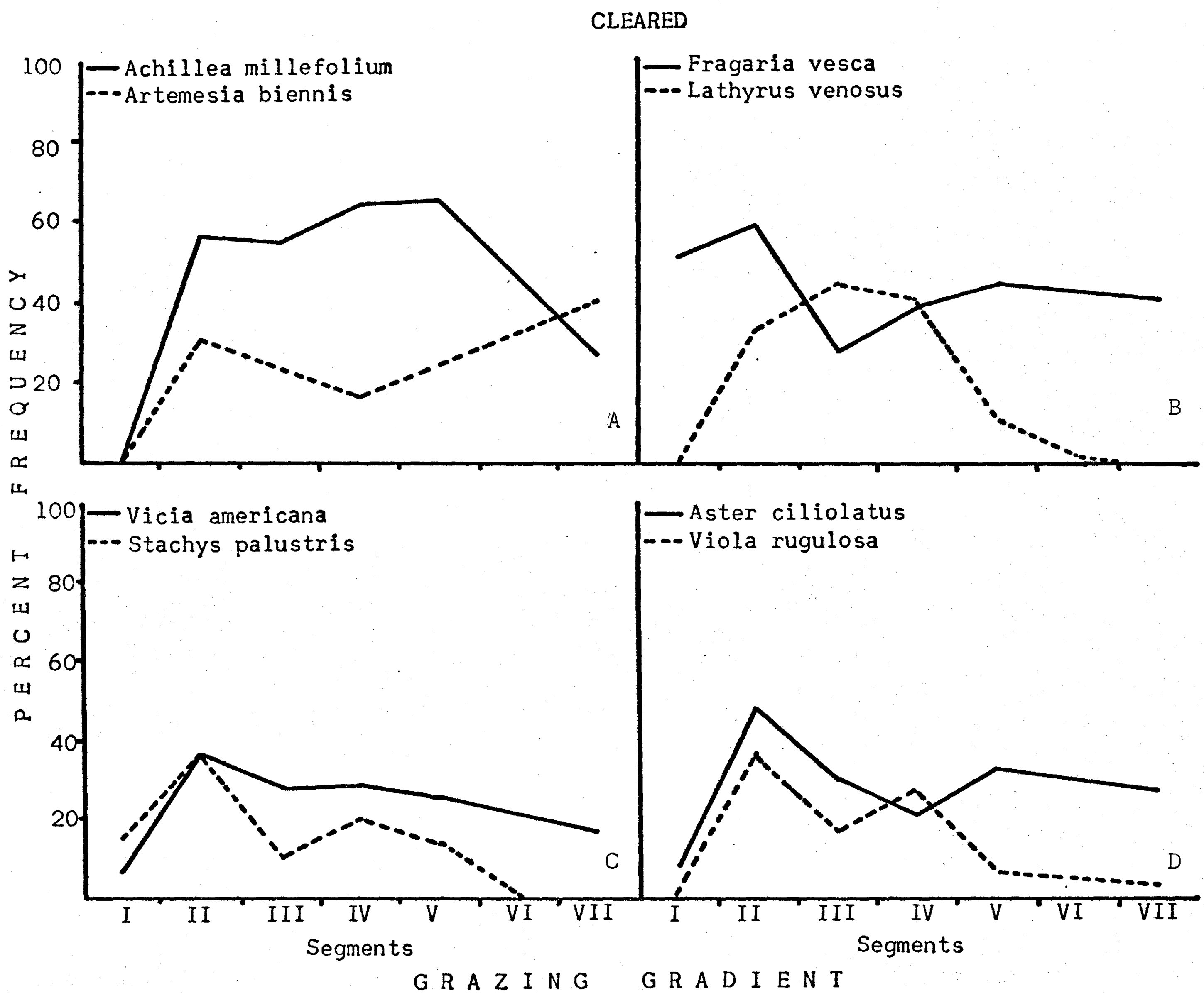

CLEARED
Achillea millefolium
Artemesia biennis
A
Fragaria vesca
Lathyrus venosus
B
Vicia americana
Stachys palustris
C
Aster ciliolatus
Viola rugulosa
D
PERCENT FREQUENCY
100
80
60
40
20
I
II
III
IV
V
VI
VII
Segments
GRAZING GRADIENT

Figure 22. Behaviour of selected species (having a frequency of 40 percent at least in one stand) along the grazing gradient in cleared habitat. Segment I refers to the least utilization and segment VII refers to the maximum utilization. Frequency values are mean values for the stands in which the species occurred.

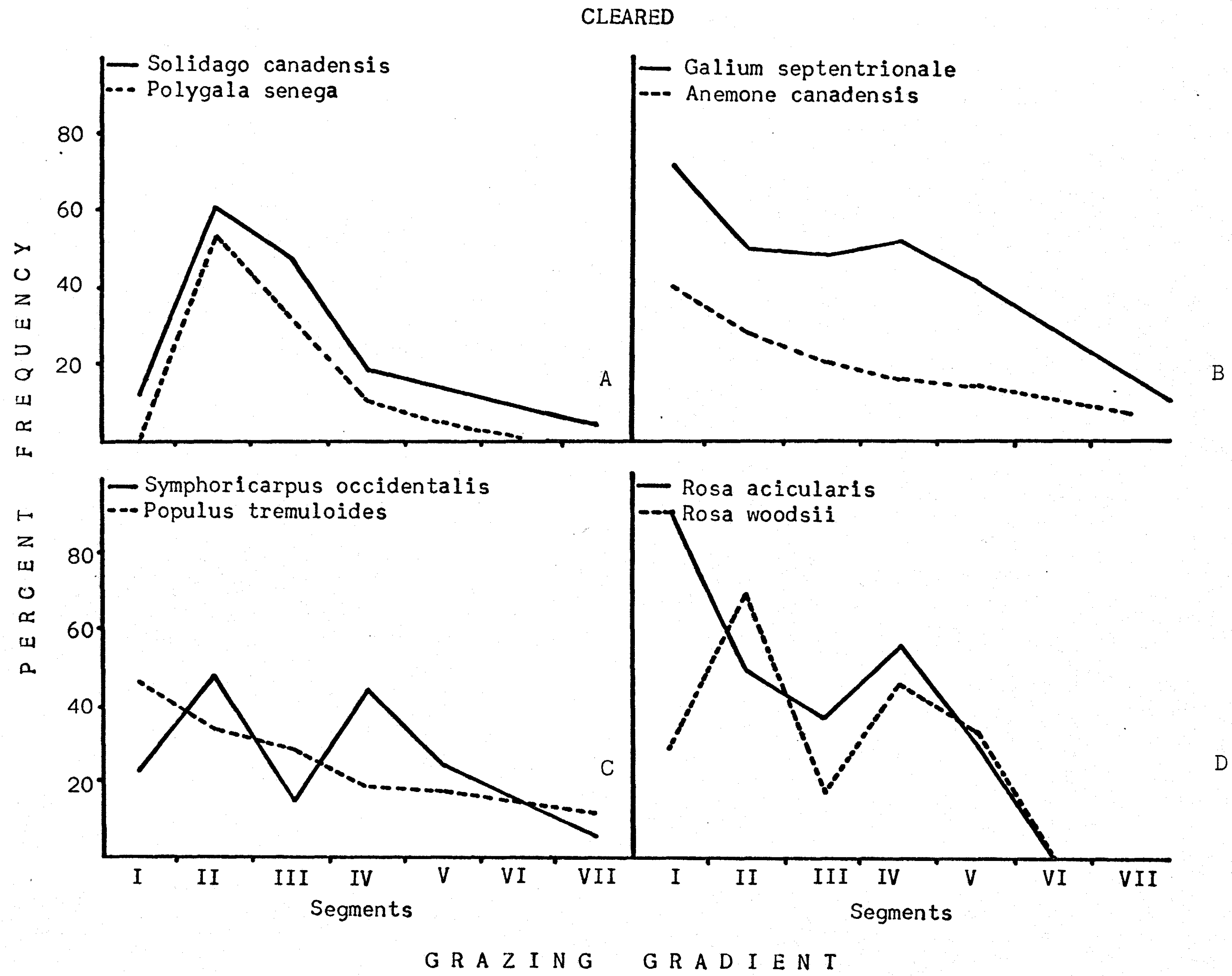

CLEARED
Solidago canadensis
Polygala senega
Galium septentrionale
Anemone canadensis
Symphoricarpus occidentalis
Populus tremuloides
Rosa acicularis
Rosa woodsii
A
B
C
D
80
60
40
20
FREQUENCY
PERCENT
I II III IV V VI VII
Segments
GRAZING GRADIENT

Figure 23. Behaviour of selected species (having a frequency of 40 percent at least in one stand) along the grazing gradient in seeded habitat. Segment I refers to the least utilization and segment VII refers to the most utilization. Frequency values are mean values for the stands in which the species occurred.

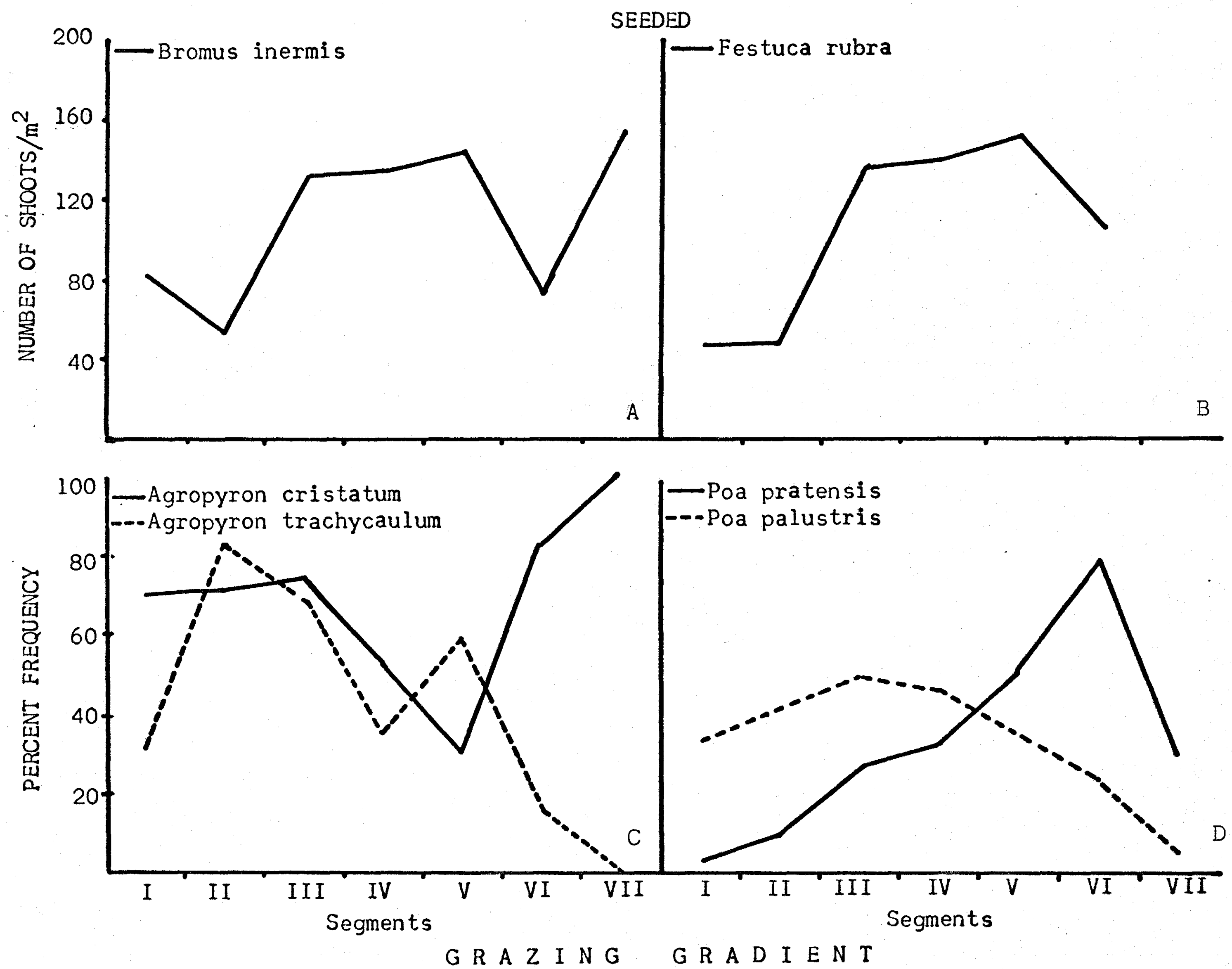

SEEDED
Bromus inermis
Festuca rubra
NUMBER OF SHOOTS/m2
200
160
120
80
40
A
B
Agropyron cristatum
Agropyron trachycaulum
Poa pratensis
Poa palustris
PERCENT FREQUENCY
100
80
60
40
20
C
D
I II III IV V VI VII
Segments
I II III IV V VI VII
Segments
G R A Z I N G   G R A D I E N T

Figure 24. Behaviour of selected species (having a frequency of 40 percent at least in one stand) along the grazing gradient in seeded habitat. Segment I refers to the least utilization and segment VII refers to the most utilization. Frequency values are mean values for the stands in which the species occurred.

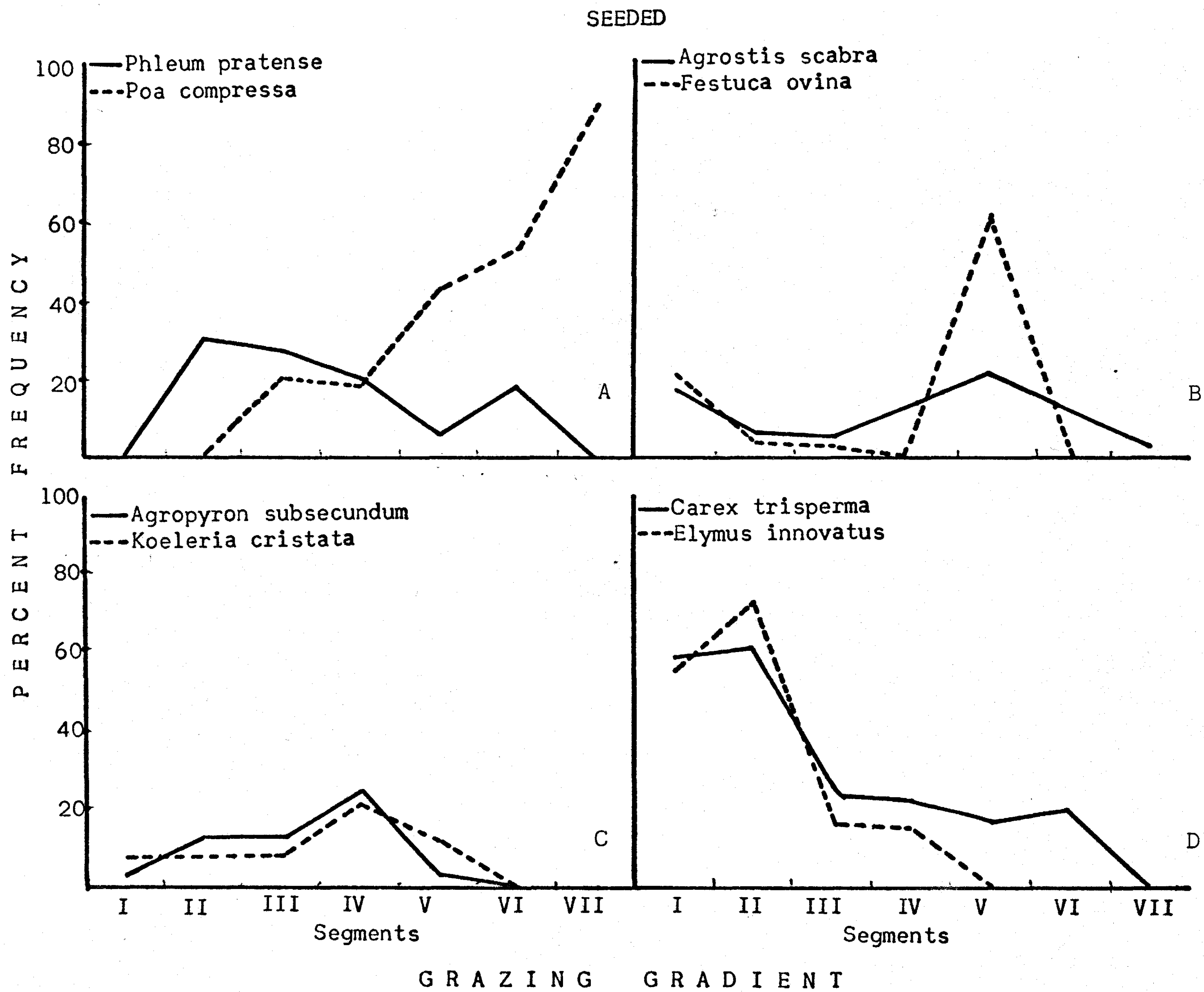

SEEDED
Phleum pratense
Poa compressa
A
Agrostis scabra
Festuca ovina
B
Agropyron subsecundum
Koeleria cristata
C
Carex trisperma
Elymus innovatus
D
100
80
60
40
20
PERCENT FREQUENCY
I
II
III
IV
V
VI
VII
Segments
GRAZING GRADIENT

Figure 25. Behaviour of selected species (having a frequency of 40 percent at least in one stand) along the grazing gradient in seeded habitat. Segment I refers to the least utilization and segment VII refers to the most utilization. Frequency values are mean values for the stands in which the species occurred.

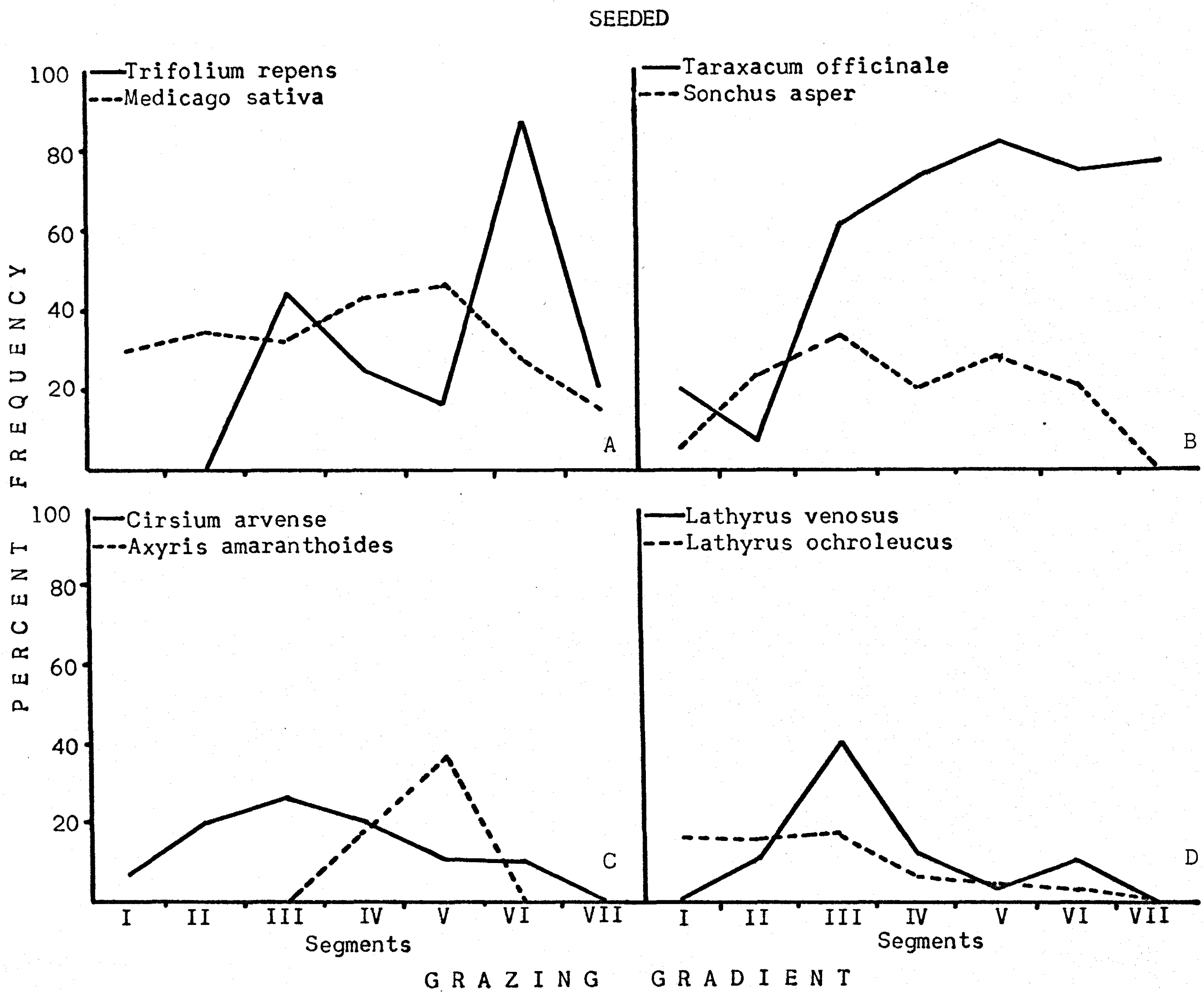

SEEDED
Trifolium repens
Medicago sativa
Taraxacum officinale
Sonchus asper
Cirsium arvense
Axyris amaranthoides
Lathyrus venosus
Lathyrus ochroleucus
100
80
60
40
20
A
B
C
D
PERCENT FREQUENCY
I
II
III
IV
V
VI
VII
Segments
GRAZING GRADIENT

Figure 26. Behaviour of selected species (having a frequency of 40 percent at least in one stand) along the grazing gradient in seeded habitat. Segment I refers to the least utilization and segment VII refers to the most utilization. Frequency values are mean values for the stands in which the species occurred.

SEEDED

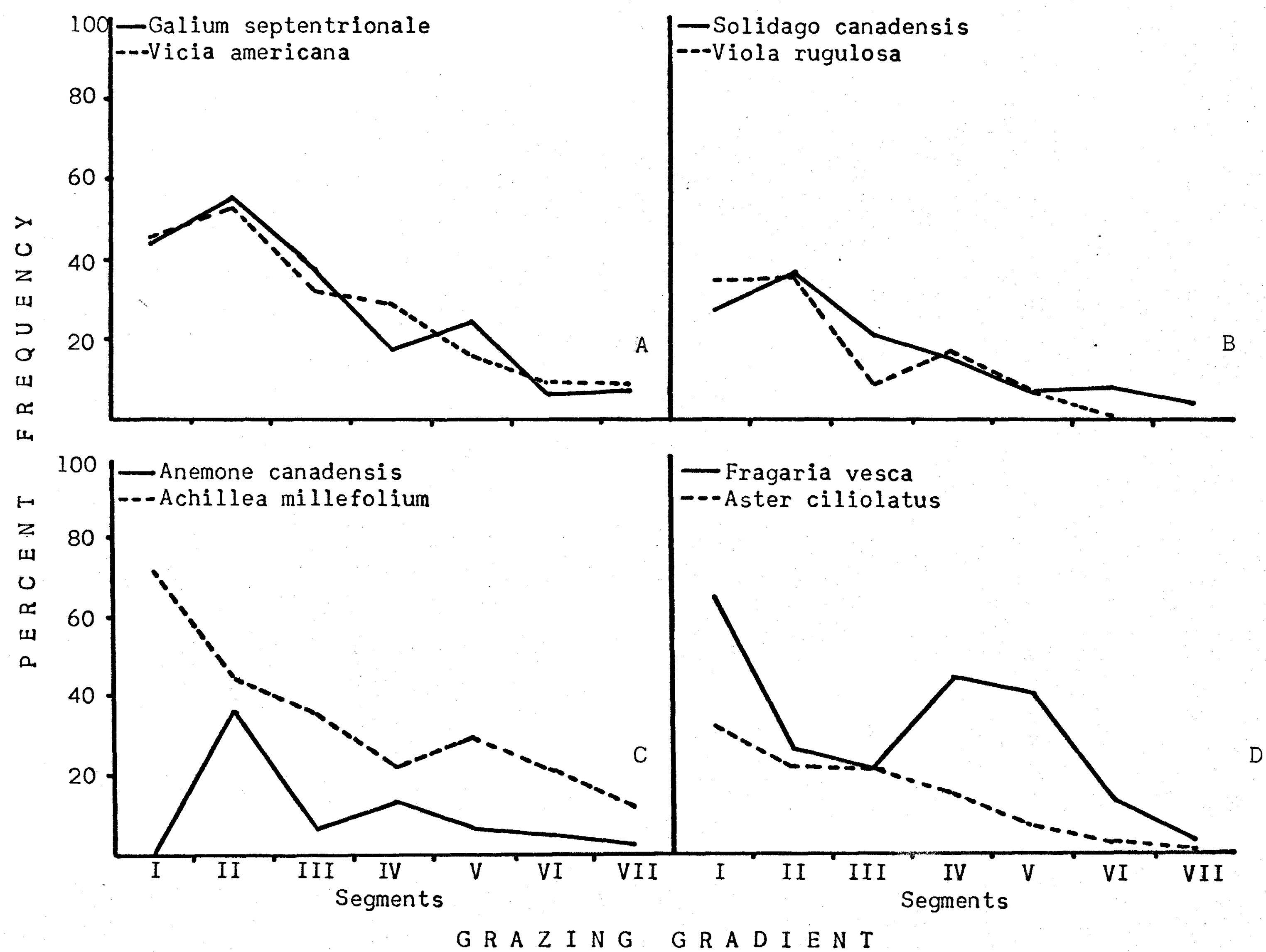
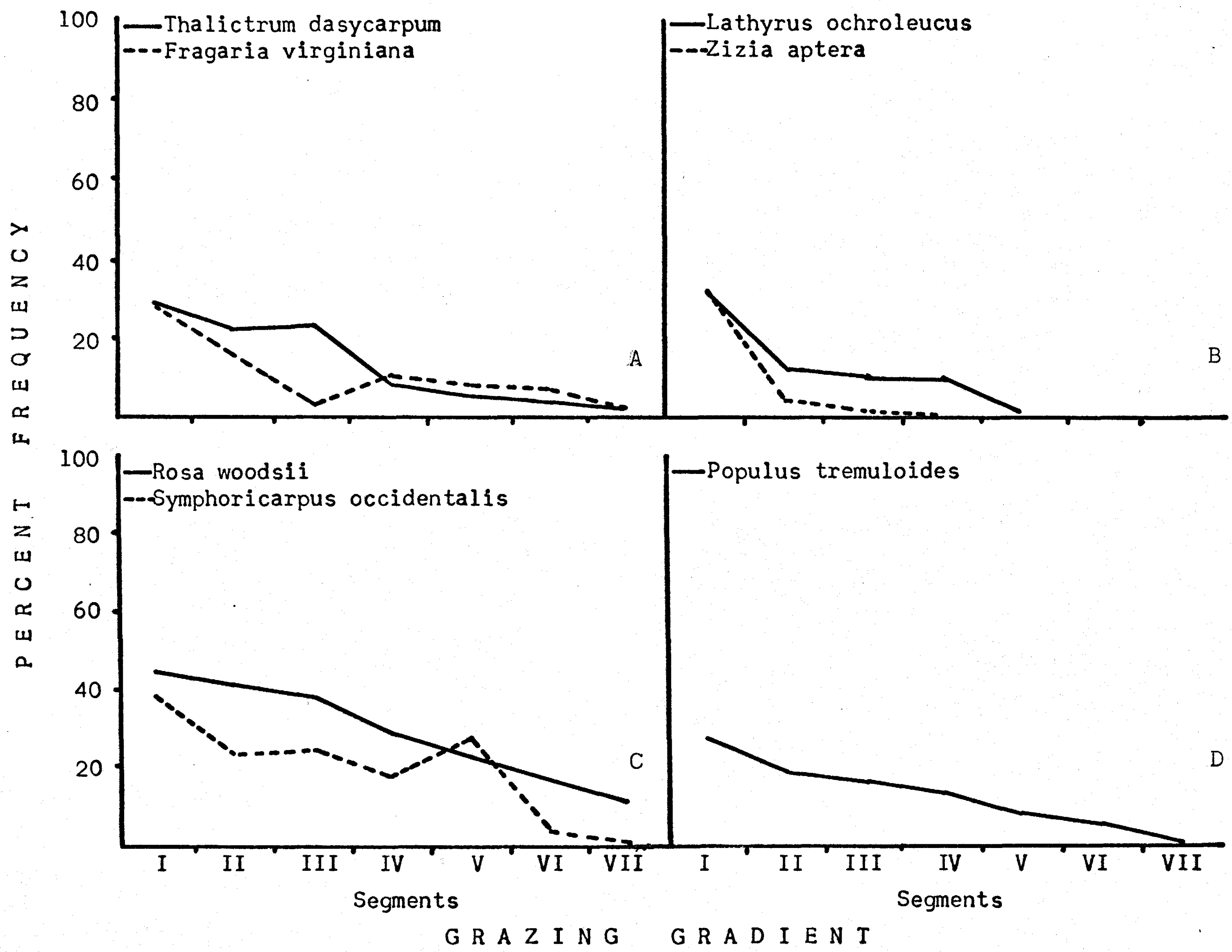

PERCENT FREQUENCY
Galium septentrionale
Vicia americana
A
Solidago canadensis
Viola rugulosa
B
Anemone canadensis
Achillea millefolium
C
Fragaria vesca
Aster ciliolatus
D
100
80
60
40
20
I II III IV V VI VII
Segments
GRAZING GRADIENT

Figure 27. Behaviour of selected species (having a frequency of 40 percent at least in one stand) along the grazing gradient in seeded habitat. Segment I refers to the least utilization and segment VII refers to the most utilization. Frequency values are mean values for the stands in which the species occurred.

SEEDED



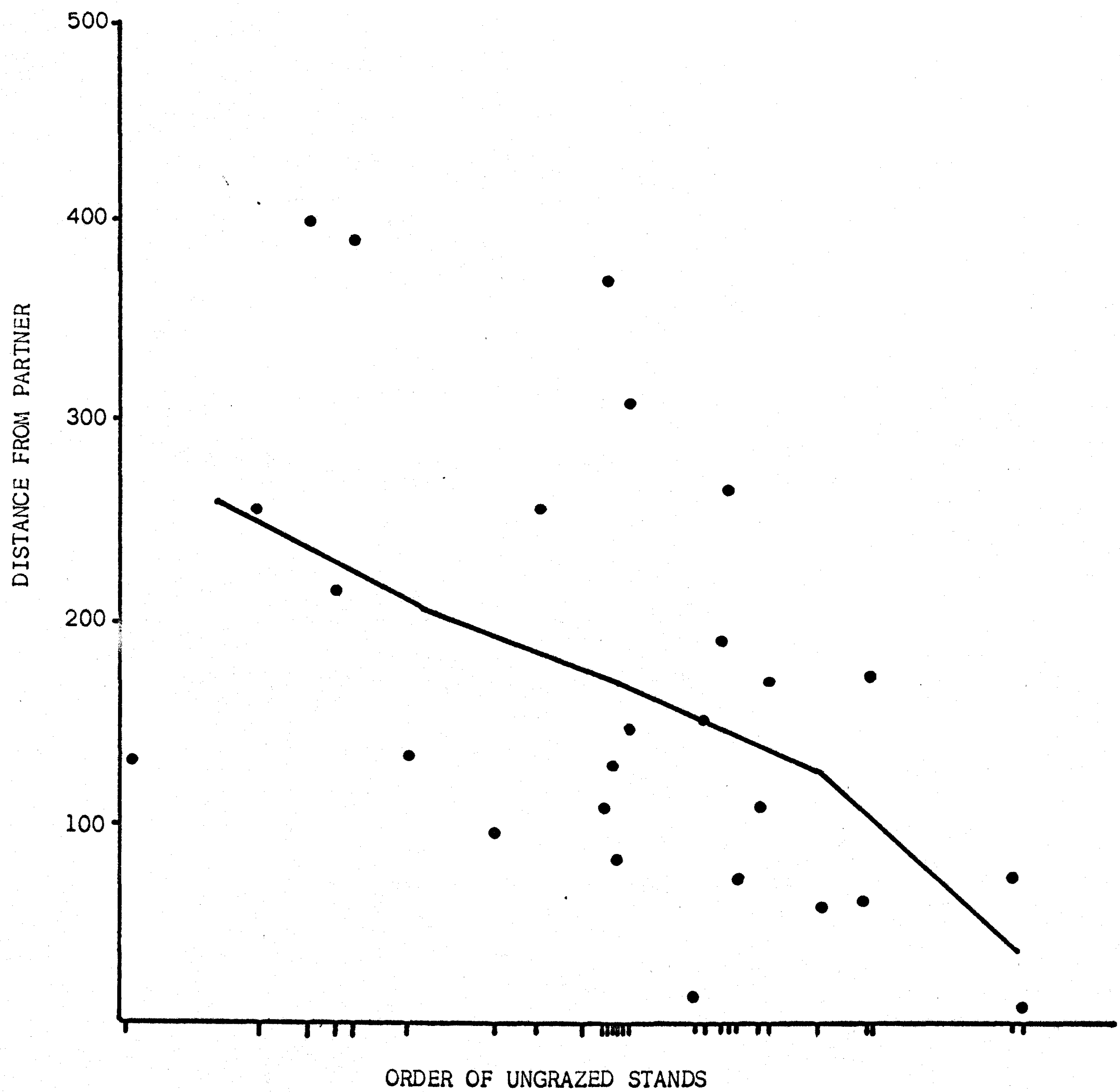
100
80
60
40
20
Thalictrum dasycarpum
Fragaria virginiana
A
Lathyrus ochroleucus
Zizia aptera
B
Rosa woodsii
Symphoricarpus occidentalis
C
Populus tremuloides
D
PERCENT FREQUENCY
I II III IV V VI VII
Segments
GRAZING GRADIENT

species pool of native species present. The separation of ungrazed stands, at least in the forest habitats, may be due to the varied disturbances prior to protection. At the same time the ungrazed partner is invariably positioned in the ordination on the left of the grazed partner of a stand pair. This is due to the difference in composition as a result of grazing and this justifies considering it as a grazing gradient.

Dix (1959) in his study on the effect of grazing on thin-soil prairies of Wisconsin and Cawley (1960) on Southern Wisconsin woodlands discussed the nature of grazing gradients over which the ungrazed stands were separated. They found this portion of the gradient to be a moisture gradient and also showed that the farther the ungrazed stand is to the right, the lesser is its distance from its grazed partner.

In the present study, when the distance between each ungrazed stand and its grazed partner was plotted against the position of the ungrazed stand on the part of the gradient for ungrazed stands (Fig. 28), a negative relationship was obtained, similar to that obtained by Dix (1959). This straight line correlation gives additional support to the concept that there is a factor other than grazing which affects the distribution of ungrazed stands along their portion of the gradient.

Figure 28. The phytosociological distance between the ungrazed stands and their grazed partners in seeded habitat. Marks below the base line indicate the position of the ungrazed stands as in Figure 15(C). The distance between partners decreases towards the right end of the gradient.



500
400
300
200
100
DISTANCE FROM PARTNER
ORDER OF UNGRAZED STANDS

DISCUSSION AND CONCLUSIONS

Several species do not respond the same to grazing under all habitat types. The allocation of species to the grazing categories reveals that the relative number of species in the five grazing categories is a function of the change in the behaviour of forest species, present in all three habitat types, while the difference in the total number of species among the habitats is related to different environmental conditions in each habitat type. The percentage of increasers is maximum in the uncleared forest habitat and at a minimum under the seeded habitat. Conversely, the percentage of decreasers and retreaters together is least in the forest habitat and greatest in the seeded habitat. There is an increase in the total number of species with the increased disturbance of the original forest vegetation.

The comparison of the numbers of invaders and retreaters point out that there is negligible or no net increase in the total number of species in cleared and seeded habitats as a result of grazing. However, the comparatively higher percentage of invaders under the forest habitat causes a net increase in the total number of species as a result of grazing. The greater number of species in cleared and seeded conditions as compared to that under forest habitat is attributed to a number of species that do not occur in forest. Several species come in after the clearing of the forest and ploughing of cleared areas. As a result of grazing of forest, the moisture and light regimes are changed at the forest floor due to thinning of the shrub layer so that the majority of the native and introduced herb species become more abundant. A further change in light and moisture conditions after clearing of forest results in the invasion of a number of new species.

Such species constitute two categories. The first category includes those species which come in after clearing and later behave as decreasers, increasers or retreaters in response to grazing. The other category is constituted by those species that invade the cleared area only as a result of grazing. The process of invasion is the same in seeded areas, but the species involved are other than those that invade cleared areas. By the comparison of percentage of invaders and retreaters and also analysis of species exclusive to one habitat type, it is inferred that there is hardly any gain in the total number of species in each habitat as a result of grazing. Increase in number of species under clearing and seeding is entirely a function of the changes in habitat conditions due to clearing and ploughing.

Species behave differently as a result of grazing under different habitat types. The comparison of species which constitute different grazing categories, has revealed that change in number of increasers and decreasers under different habitat types is primarily due to the change in behaviour of native grasses and forbs that become more abundant under grazing compared to their abundance under protected forest. About 80 percent of these species change their status from increasers to decreasers under seeded habitats in response to grazing. This change is less pronounced under the cleared habitat. It is thus concluded that increase in total number of species under different habitats is solely a function of change in habitat conditions and shift in percentage of increasers and decreasers among the three habitat types is due to the differential behaviour of forest species under three habitat types.

The principles and aims applied to grazing of grasslands and forest in North America are different. The effects of grazing on vegetation in the North American grassland zone are usually expressed in terms of the deterioration of the "climax" vegetation. The sequence of deterioration can be described in relation to phytosociological behaviour of the component species. The present situation is rather different because of additional factors of clearing and ploughing. Another consideration of major concern relates to the different aims of management in grassland and forest regions in North America. In arid and semi-arid range lands the management practices are aimed at effective use of ranges through light grazing in order to conserve the original vegetation. However, in the grazing of pastures in forest regions, the aim is not conservation of the original vegetation but its replacement by desirable forage species and heavy grazing. This is attained by a consideration of the behaviour of native and seeded species to grazing in general and to different intensities of grazing.

In the present study, the species that are common to more than one habitat respond differently to grazing under the three habitat types and also all species show varied behaviour within the same habitat.

The behaviour of species along the grazing gradient brings out the desirability of grazing the forest stands heavily because it results in increased abundance of forage species. Although it has been observed that all grasses and forbs are grazed, further study is needed to understand productivity, palatability and nutritive value. In the forest habitat a majority of the native grasses, and native and introduced forbs become more abundant under grazing with the exception of Calamagrostis canadensis, Elymus innovatus and Lathyrus spp. It is further interesting to note that the important grasses and forbs withstand moderate to heavy grazing. Behaviour of species in the forest habitat points out that although the original forest vegetation deteriorates from the point of view of "climax" vegetation, the increase in abundance of herbaceous species results in increased forage resources under grazing. The foliage and basal cover of grasses and forbs was observed to be poor as compared to their cover in cleared sites. This indicates that the use of forest areas without clearing for pastures is not profitable because of very low carrying capacity.

It is evident that the cleared forest areas are better suited than the uncleared forest for grazing because of higher forage yields. There is high abundance of palatable grasses and herbs under heavy grazing. In ungrazed cleared areas, the frequency of grasses and forbs (Poa pratensis, Poa palustris, Elymus innovatus, Calamagrostis canadensis, Schizachne purpurascens, Taraxacum officinale, Achillea millefolium, Thalictrum dasycarpum) is higher than their frequencies in ungrazed forest. Only a few grasses, Poa spp., Hordeum jubatum and Koeleria cristata, are favoured under moderate to heavy grazing. Most of the native grasses are favoured only under light grazing. All introduced forbs withstand moderate to heavy grazing, while most native forbs are hampered by grazing. Thus the study of behaviour of grasses and forbs in cleared areas tends to show that cleared forest areas can be effectively used at heavy rate. This will result in the vegetation being dominated by Poa spp. and introduced herbs, such as Taraxacum officinale. How productive economically these cleared areas would be from the management point of view, is questionable. It is necessary to study animal production and to compare it with the production on seeded areas on a long term basis, before any final concepts of management are developed for the pastures of forest region.

The introduced grass species are well adapted to grazing. High productivity can be maintained in the seeded areas because of the high density of seeded species. Among seeded grasses, only Bromus inermis, Festuca rubra and Agropyron cristatum become more dense under grazing. The occurrence of Poa spp. with high frequencies in the seeded areas provides an opportunity for the species to replace the seeded species within a considerable period of time. This speculation is supported by the fact that in older seeded stands the frequency of Poa spp. was higher than their frequency in the younger seeded stands under grazing. The time period involved in the process may be so great during which tremendous yields can be produced in the seeded areas through introduced seeded species of grasses. The productivity (dry matter) has been found to be half for Poa pratensis as compared to Bromus inermis and other seeded species under experimental conditions at Melfort (Melfort Experimental Farm, Progress Report 1954-58) and Swift Current (Kilcher et al., 1956). Productivity of seeded species is observed to decline by 50 percent after four years from the time of seeding. This was true of conditions under the clipping experiments but the reaction of these grasses is not known for certain under additional factors of trampling and added fertility.

Taraxacum officinale is the only introduced forb which survives heavy grazing. Among the seeded introduced forbs Medicago sativa has its maximum under moderate grazing. Its frequency has been observed to be less than 50 percent in two to three year old stands, presumably when it was seeded with 100 percent frequency. In newly seeded stands, its frequency was 100 percent on both ungrazed and grazed stands, but its density tends to be lower under grazing. Trifolium repens was present in younger stands only and had much higher frequency on grazed stands under moderate to heavy grazing. From the information available from these pastures it is suggested that this species may be considered as a legume component for the seeding mixtures in the development of the wooded areas into seeded pastures. It seems plausible to clear the forest and seed the areas to Bromus inermis, Festuca rubra and a suitable legume.

Considering the productivity of forage species under the three habitats, the productivity of forest (for forage species) is lowest due to their low density as compared to the density under cleared and seeded habitats. Though cleared forest areas have much higher productivity than uncleared forest areas, the production is maximum in the seeded areas because of high density of seeded species. The high resistibility of Bromus inermis, Festuca rubra and their persistence for at least six to seven years at higher densities under grazed conditions suggest the suitability of these grasses for the pastures in the forest region. The basal cover and density of these grasses are much higher on grazed stands but it is not known, for how many years high productivity is maintained. However, it does bring out that introduced grass species are adapted to grazing under seeded conditions.

The behaviour of shrubs and regrowth of aspen towards grazing under the three habitat types is suggestive of the high intensity of grazing in the management of the wooded pastures. The frequency of shrubs and regrowth of aspen is extremely low under heavy grazing, especially under cleared and seeded conditions. The resistibility of desirable native and seeded species of grasses and forbs to heavy grazing supports the concept that control of wooded growth should be practised through heavy grazing.

SUMMARY

The study was designed primarily to consider the effect of grazing on herbaceous vegetation in pastures of the forest region of central Saskatchewan. This involved the study of stands under three habitat types: forest; forest, cleared; and forest, cleared, ploughed and seeded.

Quantitative data for herbs, shrubs and tree seedlings was collected for 49 pairs of stands; 7 pairs of forest stands, 11 pairs of cleared foest stands and 31 pairs of seeded stands. Frequency values for all herbs, shrubs and tree seedlings were collected for each stand on the basis of the occurrence of species in 30 0.5 m x 0.5 m quadrats. The point-centered quarter method was employed for measuring the densities for most abundant grass species. Densities of sod-formers was measured in terms of shoots/m^2 and that of bunch grasses in terms of basal area (cm^2/m^2). Measurements of density for each of the most abundant species was measured separately.

In order to determine the effect of grazing on each species, its frequency in quadrats or its measured density was compared in all pairs of stands in which it was present in one or both units. It was achieved by the use of scatter-diagrams, by calculating mean percent difference and grazing resistibility numbers. The species were categorized in five grazing categories based on their response to grazing under each habitat type separately; increasers, decreasers, neutrals, retreaters and invaders. The significance of mean percent difference was tested by using paired 't' test.

The behaviour of species under grazing pressure was also

determined by obtaining grazing resistibility numbers from the comparison of frequencies in measured densities on grazed and ungrazed stands. The grazing resistibility numbers objectively indicated the behaviour of species under grazing pressure. They are a measure of the ability of a species to withstand grazing. A high plus grazing resistibility number indicates that a species is favoured by grazing and a high minus number implies that a species is hampered by grazing. The species behaved differently under the three habitat types. Comparison of grazing resistibility numbers show that the sensitivity of such species which occurred under all the three habitats, tends to increase under cleared and seeded conditions.

The percentage of decreasers is maximum in seeded and least in forest habitats. In contrast, the percentage of increasers is highest in forest and lowest in seeded areas.

Two approaches were followed to study the effect of intensity of grazing on vegetation; firstly, by establishing grazing indices for each stand and secondly, by positioning the individual stands along a phytosociological grazing gradient. The first method was discarded because of certain shortcomings.

The grazing resistibility numbers were used to weight the relative frequency values as a means to position the stands on a grazing gradient. The weighted frequency values measured both degree of change in a species due to grazing as well as its relative abundance in a stand at a particular level of grazing. The sum of weighted figures for all species occurring in stand gave the stand index number which determined the relative position of the stand on the grazing gradient. The stand index number was negative when species with minus grazing resistibility numbers were abundant more than species with plus numbers and positive, when species with plus grazing resistibility were more abundant. The stand index is an estimation of change in a stand as a result of particular level of grazing.

As a means of finding the behaviour of individual species along the grazing gradient, the frequency or measured density of species were plotted along the gradient. A study of the behaviour of the species along the grazing gradient supports that species behave differently in each habitat type and independently in the same habitat type.

Several native graminoids, *Agropyron trachycaulum*, *Schizachne purpurascens*, *Carex trisperma* became important forage components of the pastures under moderate to heavy grazing. After clearing, the grasses that were important under grazing, are replaced by invading species of *Poa*. Under seeded conditions, all native species that were dominant under forest and cleared habitat disappear or become less important.

Most of the forbs, native as well as introduced, in forest increase as a result of grazing except *Lathyrus* spp. Conversely, most of the native forbs decrease under cleared and seeded habitats. Only introduced forbs survive under grazing in cleared and seeded conditions.

All shrubs and tree seedlings do not withstand grazing in the three habitats with the exception of *Rosa woodsii* and *Amelanchier alnifolia* that increase as a result of grazing in forest.

The relative number of species in five grazing categories is a result of differential behaviour of forest species to grazing under the three habitat types, while increase in number of species under clearing and seeding is entirely a function of changes in habitat conditions due to clearing and ploughing.

It is desirable to graze the forest, cleared and seeded areas heavily because of the reason that native desirable forage species increase under heavy grazing in forest and cleared areas and introduced seeded species can withstand heavy grazing for a number of years. The productivity is low in forest areas due to low density of forage species. Though clearing results in higher densities of native species, the productivity is maximum under seeded conditions due to high density of seeded species. *Bromus inermis*, *Festuca rubra*, *Agropyron cristatum* are suitable grasses for developing seeded pasture in forest areas.

The behaviour of shrubs and regrowth of aspen towards grazing is suggestive of the high rate of utilization in the management of the wooded pastures.

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$$\text{"Grazing Resistibility Number"} = \frac{(\text{Sum frequencies grazed}) - (\text{Sum frequencies ungrazed})}{\text{Sum frequencies grazed (when numerator is positive)} \text{ or } \text{Sum frequencies ungrazed (when numerator is negative)}} \times 10$$

The formula results in plus numerical figures for increasers and minus numerical figures for decreasers. This change also helped in having minus values on the left side and plus values on the right side of the grazing gradient. In context of the formula used in the study, higher the G.R.N., more a species can withstand grazing and lower the values of the G.R.N. for a species is, lesser the species is resistant to grazing. Thus the stands with high number of increasers will tend to lie on the right side of the gradient and the stands abundant in decreasers will tend to lie on the left side of the grazing gradient. This will mean, higher the intensity of grazing, higher the stand index number.

(2) Frequency data were used for species which showed difference in frequencies on grazed and ungrazed stands and density for species which did not show measurable difference in frequencies under the two conditions.

The grazing resistibility numbers derived using frequencies and calculated densities were similar. The percent frequencies were converted into densities using the well known mathematical relationship between frequency and density (Fracker and Britchle, 1944). The direct use of frequency in calculation of grazing resistibility numbers saved a considerable amount of time. The comparison of the numbers calculated using frequency and calculated density for some of the common species are presented in Table 1.

Table 1. Comparison of grazing resistibility numbers using frequencies and calculated densities.

Species	Grazing resistibility numbers Based on % F		Based on density	
Achillea millefolium	-0.6	(1)	-0.8	(1)
Agropyron trachycaulum	+4.1	(4)	+4.35	(4)
Agropyron cristatum	+3	(3)	+3	(3)
Amelanchier alnifolia	+6	(6)	+6.10	(6)
Artemesia biennis	+3.4	(3)	+3.45	(3)
Aster ciliolatus	-7.9	(8)	-8.2	(8)
Calamagrostis canadensis	-6	(6)	-5.9	(6)
Fragaria vesca	+3.49	(3)	-4.46	(4)
Galium septentrionale	-4	(4)	-3.95	(4)
Koeleria cristata	-0.91	(1)	-1.15	(1)
Poa compressa	+7.3	(7)	+7.7	(8)
Poa pratensis	+1.85	(2)	+1.65	(2)
Polygala senega	-5.4	(5)	-5.2	(5)
Taraxacum officinale	+1.7	(2)	+1.8	(2)
Vicia americana	+2.9	(3)	+3.12	(3)

The change in formula made it possible to use the frequency values directly and also gave positive grazing resistibility numbers for species which increase in response to grazing and negative numbers to species that decreased in response to grazing. The change also resulted in negative value at left side of the zero value of grazing gradient and plus value on the right side of the zero value, a normal mathematical sequence.