TAXONOMY AND ECOLOGY OF GRASSLAND SEDGES

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TAXONOMY and ECOLOGY of GRASSLAND SEDGES

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Part I - DIAGNOSTIC FEATURES

1. Introduction

In investigating the botanical composition of grasslands, it is often necessary to identify plants that are in the pre-flowering stage or in a closely grazed condition, and, therefore, without inflorescence. In such cases identification must be based on the vegetative characters of the plant.

Identification of grasses (Gramineae) by means of vegetative characters is shown to be practical through the work of various authors. Carrier (4), using vegetative characters of roots, stems, and various leaf parts, has developed a key and presented detailed descriptions of forty-eight grasses common to the eastern part of the United States. Nowosad, Swales and Dore (13) present a key for identification of thirty-nine grasses of pastures and meadows of eastern Canada. This key employs characters of the vegetative parts, especially those of the leaves, such as sheath, auricles, collar, ligule and blade. One-hundred and two native and naturalized grasses of the Prairie Provinces have been identified in a similar manner by Clarke, Campbell and Shevkenek (5).

In this thesis an attempt is made to utilize vegetative characters in a diagnosis of species of Carex, with a view to the production of a key for the identification of the

sedges of prairie grasslands.

The following sedges have been investigated.

Carex abbreviata Prescott = C. Torreyi Tuckerm.

Carex Eleocharis Bailey = C. stenophylla Wahl.

Carex filifolia Nutt.

Carex heliophila Mack.

Carex microptera Mack.

Carex obtusata Lilj.

Carex phaeocephala Piper.

Carex praticola Rydb.

Carex Raynoldsii Dewey.

Carex siccata Dewey.

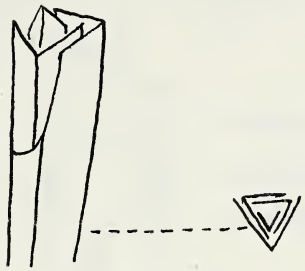
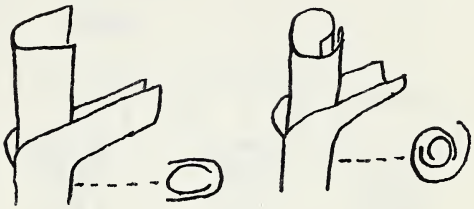
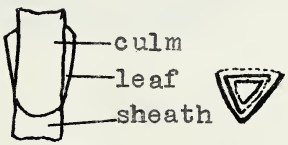
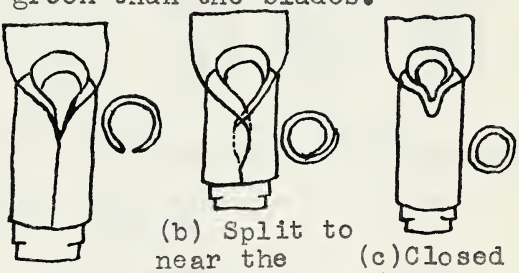
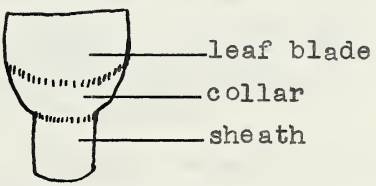
Carex umbellata Schkuhr.

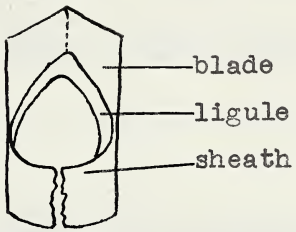
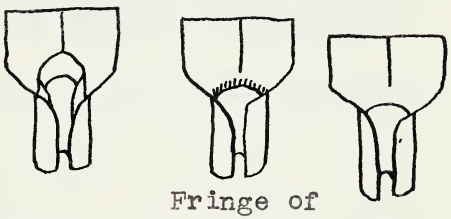
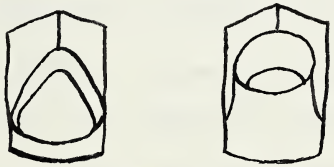
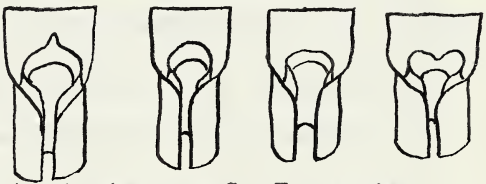
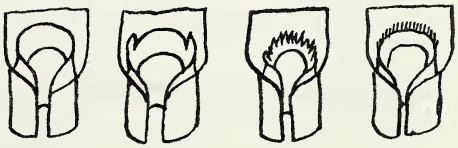
Carex xerantica Bailey.

2. Sedges and Grasses contrasted

Sedges or carices are often distinguishable with difficulty from grasses. This is especially true of those sedges occurring in pastures and meadows. The following table sets forth the contrasting vegetative characters of sedges and grasses.

SEDGES	GRASSES
A. The Bud Shoot - the arrangement of the leaves is tristichous with leaves	A. The Bud Shoot - the arrangement of the leaves is distichuus with leaves

SEDGES	GRASSES
folded. 	folded, *or rolled.* 
B. Sheath - the basal portion of the leaf enveloping the culm or young growing leaves. It is triangular in shape with two sides being extensions of the leaf blade and very similar in structure to the leaf while the third side is membranous and transparent and always closed as in (c) of grasses. 	B. Sheath - the tubular basal portion of the leaf enveloping the culm or young growing leaves. The color is generally a paler green than the blades.  (a) Split to near the base (b) Split to near the base with margins overlapping (c) Closed (rare amongst grasses).
C. Collar - is apparently absent. The leaf blade structure extends down the stem forming two sides of the sheath.	C. Collar - a meristematic band or growth zone marking the division point between the blade and the sheath. 

SEDGES	GRASSES
D. Ligule - an outgrowth at the junction of the blade and sheath clasping the culm or bud shoot.	D. Ligule - an outgrowth at the junction of the blade and sheath clasping the culm or bud shoot.
1. Types  Membranous	1. Types  Membranous Fringe of hairs Absent
2. Shapes  A. Ridge-like (common) B. Collar-like (rare)	2. Shapes  A. Acute C. Truncate B. Rounded D. Emarginate
3. Margins - nearly always entire.	3. Margins  A. Entire C. Lacerate B. Notched D. Ciliate
E. Blade - the free or non-clasping part of the leaf above the collar and the ligule. 1. Shapes - usually V-	E. Blade - the free or non-clasping part of the leaf above the collar and the ligule. 1. Shapes - usually is long

SEDGES	GRASSES
shaped near the base tending to flatten distally. In a few species the distal portion of the blade is involute.	linear and flat but sometimes it is tightly folded or rolled.
F. Nodes - indistinct.	F. Nodes - conspicuous.

3. Morphology of Carex Leaves

(a) Leaf ligule

This is a membranous tissue clasping the culm, or bud-shoot, inside the leaf, at the junction of the blade and sheath. In all the species studied it is opaque, and assumes the form of a fold of membranous tissue which extends up the culm for varying short distances (up to 1.5 mm.). In most of the sedges studied the ligule is ridge-like and clasps the culm on the two sides adjacent to the leaf-blade and gradually merges with the sheath on the third side. In Carex Eleocharis it clasps the culm on all three sides in a collar-like manner.

Thus the ligule of most sedges differs rather markedly from the typical grass ligule, in that it is a firm ridge-like structure rather than a delicate collar. Moreover, it is more persistent than the grass ligule which commonly becomes lacerated or otherwise broken down.

A possible function of these structures is to prevent

the intrusion of water and dust particles, and possibly fungal spores, between the culm and the leaf-sheath where they might have harmful effects.

(b) Leaf anatomy

A detailed examination of the internal structure of the leaves of the twelve sedge species was carried out, as a possible supplement to the use of larger vegetative characters for diagnostic purposes. Similar studies of grasses have been done by Burr and Turner (1) on "British Economic Grasses", and to a lesser extent by Nowosad, Swales and Dore (13) on grasses of pastures and meadows of Eastern Canada.

Transverse sections of typical leaves of each of the twelve sedges were cut at approximately one-third of the length of the leaf from the basal end. These were stained in safranin and mounted in a medium of sixty per cent glycerine, a method recommended by Johansen (9). Detailed drawings of these sections are shown, figs. 1 to 12. Though each section is drawn to scale, the same scale is not used throughout, but rather an attempt has been made to use a magnification suited to a representation of the structural details.

The cuticle is indicated by means of a heavy black line. Details of epidermal cells are shown, though not continued throughout the entire length of the drawing. Where cellular detail is not shown a fine black line marks

off the inner boundary of the epidermis. In all drawings detail of motor cells is shown. The mesophyll of these leaves consists of three distinct parts. The green coloured chlorenchyma which makes up the bulk of the mesophyll is shown white. The colorless, large-celled tissue, interpreted as water storage tissue, has complete cellular detail indicated. Very little cellular detail of the vascular tissue is indicated, (some 2 or 3 of the larger xylem cells being shown). The sclerotic tissue, some strands of which are without associated vascular tissue, is stippled with fine black dots.

On the following pages are drawings of leaf sections of twelve species of Carex. The approximate magnifications of these drawings are shown below.

Fig. 1.	Carex Raynoldsii	x 31
Fig. 2.	Carex microptera	x 42
Fig. 3.	Carex siccata	x 71
Fig. 4.	Carex phaeocephala	x 47
Fig. 5.	Carex obtusata	x 92
Fig. 6.	Carex filifolia	x 76
Fig. 7.	Carex praticola	x 68
Fig. 8.	Carex xerantica	x 72
Fig. 9.	Carex umbellata	x 75
Fig. 10.	Carex Eleocharis	x 80
Fig. 11.	Carex heliophila	x 76
Fig. 12.	Carex abbreviata	x 68

Figures 1 - 3 show a view of the leaf section in midrib and margin regions of the leaf. In each case a distinct break is left to indicate that an intervening portion is omitted.

A small insert in fig. 3 shows a detailed, highly magnified pair of asperities of the upper epidermis. Similar structures occur on the upper epidermis of several of these sedges. In fig. 12 is an insert showing cellular detail of the basal portion of one of the epidermal hairs of C. abbreviata.

A study of these leaf sections has led to the following observations and conclusions.

On the upper leaf surface of certain sedges there appear to be rounded, rib-like structures. These are not comparable with the ribs of grass leaves as described by Burr and Turner (1) but rather are protrusions of the mesophyll between girders of sclerotic tissue in the region of the bundles. Such structures appear in C. phaeocephala. When the tissues below the midrib are thickened and strengthened the blade is keeled in this region (fig. 4).

There are two types of epidermal cells. The more or less regular cells make up the bulk of the epidermis. The large thin-walled motor or bulliform cells are located on the upper surface in the region of the midrib. Outgrowths from the epidermis occur as trichomes, details of which are illustrated in fig. 12, or as short, stiff asperities,

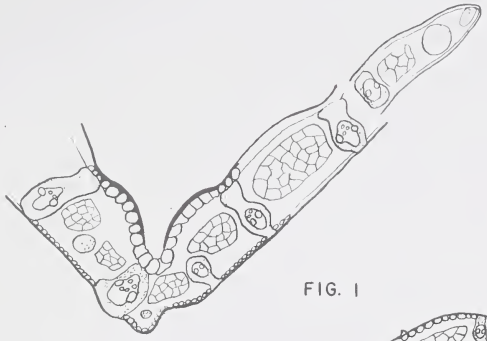


FIG. 1

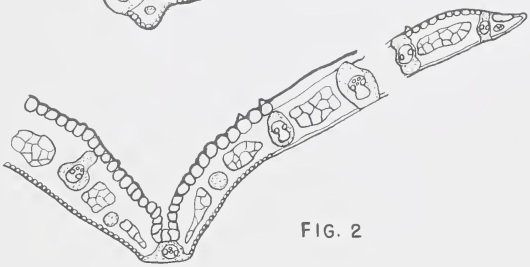


FIG. 2

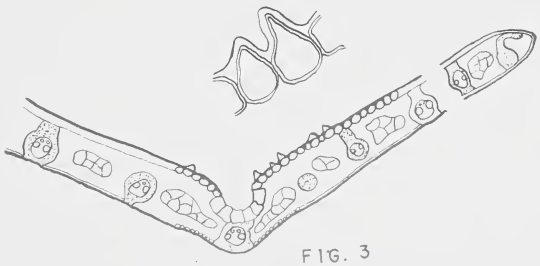


FIG. 3

FIG. 4

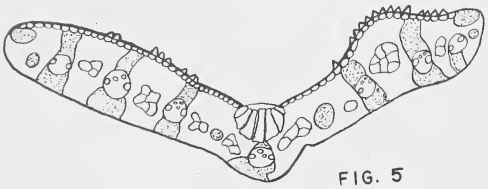


FIG. 5

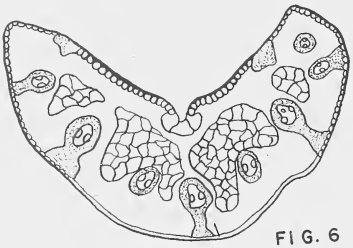


FIG. 6

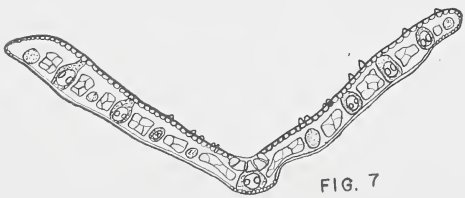


FIG. 7

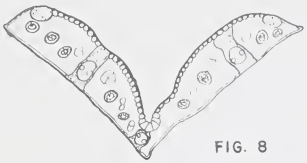


FIG. 8

FIG. 9

FIG. 10

FIG. 11

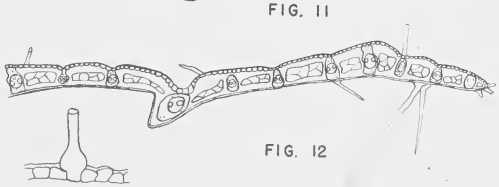


FIG. 12

details of which are illustrated in fig. 3.

The vascular bundles lie in parallel lines running from the base to the apex of the leaf. In section they appear as a row of isolated units extending from margin to margin of the blade. They vary in size and can be classified in three orders - midrib, principal and secondary. The midrib is not always larger than the principal bundles and in most sedges, apart from its central position, cannot be distinguished from them. Each bundle is surrounded by a well-marked sclerotic sheath, and the xylem vessels are well developed in the midrib and principal bundles.

Sclerotic tissue appears in groups or patches. It is present near the epidermis of some leaves and in varying amounts at the keel. It also subtends the vascular bundles in isolated patches or links the sclerotic sheath to the upper or lower surfaces, thus forming girders which stretch partially or entirely across the blade. Whilst girdering is more common in the principal bundles it is not confined to them. The sclerotic tissue below the bundles may spread laterally, as illustrated in fig. 6.

The mesophyll varies in amount according to the relative thickness of the blade. Certain portions of this mesophyll, usually between the bundles and in the central regions of the blade are devoid of chlorophyll. It is suggested that this may be water storage tissue.

Great similarity is exhibited in the general appearance of these sections. Differences do appear between certain of the species. The presence of epidermal hairs on C. abbreviata is unique for the twelve species. Asperities are quite common on the upper epidermis of several of these sedges. The leaf outlines of C. filifolia and C. Eleocharis differ from the others. But in all cases these differences are easily perceived, especially with the aid of a hand lens. It appears therefore that the information obtainable through the time-consuming preparation of leaf sections is of relatively little value for diagnostic purposes, and not sufficient to warrant the use of this procedure in species determination.

4. Detailed Descriptions of Twelve Carex Species

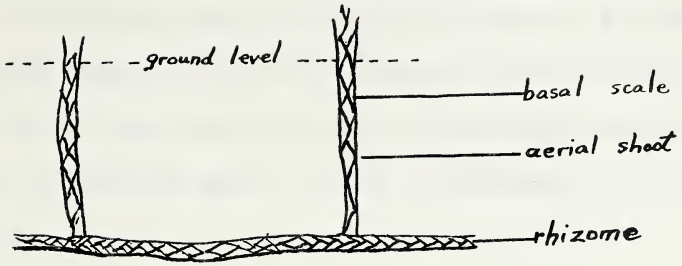
I. Carex obtusata Lilj.

A short, slender plant found on nearly all the drier grasslands, rarely found on lower, wetter areas. Usual height from 6 to 12 cm. Leaf blades 1 to 1.5 mm. wide, with prominent, entire, ridge-like ligules.

Has a long, slender, lustrous, purple rhizome covered with numerous fine bracts. Depth of rhizome varies with soil conditions. Often found growing in close association with C. heliophila which has a deeper rhizome.

The aerial shoots arise from the nodes of the rhizome as single shoots 1 to 2 cm. apart. These aerial shoots

have a series of bracts, larger and coarser than those of the rhizome.



II. Carex siccata Dewey.

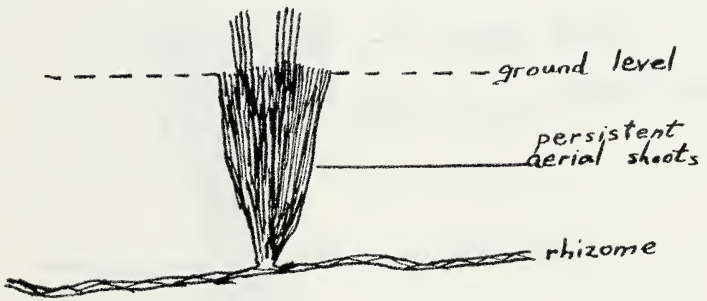
A relatively robust upland sedge. It exhibits considerable variation in habitat, but usually grows on the lower or wetter areas of the uplands, such as in shallow depressions, or north-facing slopes. Usual height is from 2 to 4 dm. The leaf-blades are from 2 to 3 mm. wide, with a narrow ridge-like ligule with very slightly lacerate margin.

Has a coarse well-developed rhizome, stramineous to light brown in colour. The depth of the rhizome varies with soil conditions. The bract scales of the rhizome and underground parts of the aerial shoots are large and well developed. The aerial shoots arise from the nodes of the rhizome as single shoots 1 to 6 cm. apart.

III. Carex Eleocharis Bailey.

A short, caespitose plant usually with some basal portions of previous seasons' growth persistent. Common in dry grasslands throughout southern Alberta. Usual height from 3 to 15 cm. Leaves 3 to 10 cm. long and up to 1.5 mm. wide, canaliculate, flattened basally, involute and roughened above, with a prominent, entire, collar-like ligule.

Has a long, slender, brown, rhizome with small bracts. Aerial shoots arise in bunches from nodes at intervals of from 3 to 6 cm.

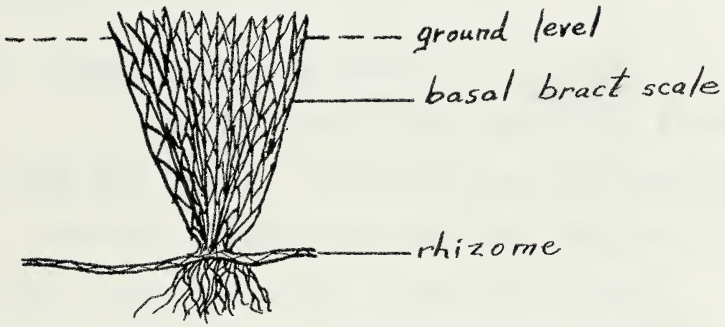


IV. Carex heliophila Mack.

A small, fine-leaved plant with several aerial shoots arising from each node to give a bunch-like growth. In older plants the base of the aerial tuft has a shredded or lacerate appearance and is reddish brown in colour. It grows on nearly all of the drier

grasslands throughout the region. Its usual height is from 1 to 2 dm. Leaf blade is from 1 to 2 mm. wide, and has a narrow entire ridge-like ligule.

Has a slender rhizome extending from 4 to 6 cm. between each bunch of aerial shoots. Depth of rhizome varies with soil conditions, but always grows deeper than the rhizomes of C. obtusata. The underground parts are reddish brown. The rhizome is covered with very fine bract scales and the underground parts of the aerial shoots are covered with longer and heavier bract scales.



V. Carex filifolia Nutt.

A short, densely caespitose plant, with portions of the previous seasons' growth persistent. Found on dry plains and ridges of southern Alberta. Usual height is 6 to 8 cm. Leaf blade is 3 to 8 cm. long and up to 0.25 mm. wide, acicular, roughened and involute with a wide, entire, ridge-like ligule.

Has a very short, black rhizome, and underground

parts of the aerial shoots are dark brown to stramineous in colour.

VI. Carex umbellata Schkuhr.

A densely caespitose plant with leaves becoming shredded or lacerated with age. Found in dry fields and woodland margins of southern Alberta. Usual height 1 dm. with leaf blades up to 2.5 dm. long. Leaves up to 2.5 mm. wide, flattened and somewhat scabrous, with a very narrow, entire, ridge-like ligule.

Has a short, stout rhizome. Basal portions of the aerial shoots are purple.

VII. Carex Raynoldsii Dewey.

A weakly caespitose plant with coarse light green culms and leaves. Occurs in mountain meadows. Usual height 2 to 3 dm. Leaves up to 20 cm. long and up to 8 mm. wide, with a narrow, entire, ridge-like ligule.

The rhizome is short and stout with basal portions of the aerial shoots stramineous to reddish purple.

VIII. Carex abbreviata Prescott.

A fairly large plant with short, slow-growing rootstock. Found in dry grasslands of Alberta. Usual height 2 to 3 dm. with flowering shoot extending up to 4 dm. The leaf blade is from 1.5 to 3 mm. wide, slightly pubescent, with a wide, entire, ridge-like ligule.

The underground parts are reddish brown to purple in

colour. The rhizome is slow-growing with single aerial shoots arising at intervals of from 2 to 4 mm., imparting a weakly caespitose aspect. The bract scales on the rhizome are very short. On the underground parts of the aerial shoots, and extending above ground a short distance are large, coarse scales.

IX. Carex xerantica Bailey.

A large, coarse plant with a very slow-growing rootstock which gives the plant a bunch-like appearance. Found in lower, grassland areas, such as very shallow depressions. Usual height 2 to 3 dm. The flowering stem extends as a strong stiff growth up to 4 dm. The leaf blade is 2 to 3 mm. wide, with a prominent, entire, ridge-like ligule.

The underground parts are stramineous to reddish brown in colour. The plant produces several aerial shoots from a very short rhizome, which grows close to the surface of the ground and has a well developed root-system.

X. Carex praticola Rydb.

A tall, slender plant with a very slow-growing rootstock which gives the plant a bunch-like appearance. Found in lower, moister grassland areas, such as quite shallow depressions. It also occurs in open woods. Usual height 2 to 3 dm. The flowering stem extends up to 4 dm. The leaf blade is 2 to 3 mm. wide, with a narrow, entire, ridge-like ligule.

The underground parts are stramineous to dark brown in colour. The very short, stout rhizome produces many aerial shoots. It grows close to ground level and has a well developed root-system.

XI. Carex microptera Mack.

A tall, robust plant with a coarse triangular culm. Weakly caespitose, Usually found in high mountain areas. Culms commonly 2 to 8 dm. in height. Leaves light green in colour, 1 to 5 dm. long, and 2 to 6 mm. wide, with a wide, entire, ridge-like ligule.

Rhizome is very short and stout. Basal leaves of aerial shoots short, up to 2 cm. long, stramineous to dark brown in colour.

XII. Carex phaeocephala Piper.

A tall, fine-leaved, weakly caepitose plant. Found in high mountain areas. Usual height from 2 to 5 dm. Leaves 1 to 4 dm. long and up to 2 mm. wide, with a very wide, entire, ridge-like ligule.

Rhizome is short and black. The basal leaves of the aerial shoots are long, up to 5 cm., and stramineous to dark brown in colour.

5. Key for Identification of Twelve Grassland Carex Species

A. Rhizome long, with aerial parts arising at intervals of from one to six centimetres.

1. Aerial shoots arising singly from the rhizome.

A.1. (a) Basal scales purplish, small..C. obtusata I

(b) Basal scales stramineous to light brown, large .....C. siccata II

2. Aerial shoots caespitose.

(a) Leaves involute and roughened above, basal scales stramineous to light brown .....C. stenophylla III

(b) Leaves flat and finely textured, basal scales reddish brown to purple .....C. heliophila IV

B. Rhizome very short, with aerial parts assuming a caespitose growth.

1. Plants densely caespitose.

(a) Rhizome black with basal scales stramineous to dark brown .....C. filifolia V

(b) Rhizome stout with basal scales reddish brown to purple .....C. umbellata VI

2. Plants weakly caespitose.

(a) Basal scales reddish brown to purple.

(c) Culm and leaves coarse.. C. Raynoldsii VII

(d) Culm and leaves fine ... C. abbreviata VIII

(b) Basal scales stramineous to dark brown.

(c) Plant with 2 to 4 leaves per culm situated near the base.

(e) Culm rigid, leaves coarse ..... C. xerantica IX

(f) Culm flexuous, leaves fine ..... C. praticola X

(d) Plant with 3 to 6 leaves per culm, spread over the lower third.

B.2. (e) Culm rigid, leaves coarse ..... C. microptera XI

(f) Culm flexuous, leaves fine ..... C. phaeocephala XII

Part II - ECOLOGICAL STUDIES

Introduction

Studies on the proportion of sedges in relation to grasses and other leading species of grassland associations were carried out in two widely separated regions of Alberta during the summer months of 1948 and 1949. The investigation of 1948 was in connection with general botanical field work in the Peace River region. The 1949 investigation was in connection with a range survey carried out by the Eastern Rockies Forest Conservation Board, in that part of the Rocky Mountain Forest Reserve known as the Crowsnest Forest.

Both investigations were accomplished by general reconnaissance, and by critical studies of localized areas, including quadrats. The 1948 survey of the Peace River region of Alberta was essentially a botanical survey. The 1949 survey of the Crowsnest Forest region of south-western Alberta was essentially an inventory of resources useful for range management purposes. Associated with these differences in general aim of the two surveys there were some differences in methods of sampling and recording.

A. Peace River Survey

1. Methods

The floristic composition of each area studied was recorded in the form of a species list of all the higher

plants and their prevalence as determined by detailed studies. The sampling method used was a modified form of the "Percentage Area Method of Pasture Analysis" as outlined by E. Wyllie Fenton (8) and by Tinney, Aamodt and Ahlgren (16). Quadrat samples were recorded for three grassland areas in the Grande Prairie section of the Peace River region. The first of these areas was a relict type located in a cemetery and a small adjacent area which had been relatively undisturbed and probably very close to the virgin condition. This area was some two miles south and three miles west of Sexsmith, on the old "Emerson Trail". Here thirty quadrats, three decimeters square (nine square dm. per quadrat), were recorded along a line transect of the area, the quadrats spaced nine meters apart. The coverage of each species was estimated to the nearest one per cent and recorded for each quadrat.

The second area was a very infrequently used horse pasture which approximated very closely the virgin condition. This area was some four miles north and eleven miles east of Grande Prairie. Thirty quadrats were laid out and recorded as for the first area. About half a mile west of this area a third area was investigated in a pasture that had been heavily grazed by both horses and cattle. Here fifteen quadrats were studied.

These three areas have very similar topography and were selected for more intensive study because they ap-

peared to best represent a relatively undisturbed native grassland and the effects of heavy grazing.

Formal citations of the species recorded for these areas are found in the Appendix.

2. Results and Analysis

The quadrat records of the three areas studied are shown in Tables I, II and III. In addition to the fifty species recorded for the first area and listed in Table I, fourteen others were observed within the area. While these fourteen species were of rather rare occurrence and seem to have little or no bearing on the analyses, they are listed below as part of the record.

Poa palustris	Juncus Vaseyi
Schizachne purpurascens	Potentilla gracilis ssp. Nuttallii
Artemisia frigida	Potentilla pulcherrima
" gnaphalodes	Zizia sp.
Castilleja rhexifolia	Rosa acicularis
Epilobium angustifolium	Salix Bebbiana
Gentiana sp.	" petiolaris

Table II records forty-eight species occurring within the quadrats of the second area. Nineteen additional species occurring within the area but outside the quadrats are listed below.

Avena Hookeri	Orthocarpus luteus
Calamagrostis montanensis	Potentilla pennsylvanica
Hierochloe odorata	Senecio cymbalarioides

TABLE I

Quadrat Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Agropyron trachycaulum	20						25		8	9	5	7		5	6	20	10		10	7			35	25		5		5	50	
Stipa spartea curtiseta	8		15	10		12		6	6		6	7				20	10	50	20		20	20	25		40	35	35	30		40
Avena Hookeri		6	10	10						4																				2
Koeleria cristata	8		5	5	8	20	10		15	7	8	20					5	5	10	15		20				10	3	2	3	1
Agropyron dasystachyum			5	5	2	10	6	6	10	3	8	10				20		8												
Poa pratensis				2																										
Danthonia intermedia		3		10	3	5			7	6	6			10			5	4	5	20		4	3	6	5		6	4	15	10
Poa interior							6																			2				
Stipa columbiana							5		7		6	5	4	5		8	4					2								
Stipa Richardsonii																15			15	35	45	20	2		15	8	35	20	20	25
Calamagrostis inexpansa													20		5															
Bromus ciliatus															5															
Festuca saximontana	5																		6				6	6	3					
Agrostis scabra	3						3																							
Carex praticola		5	4										6	5									3							2
Carex xerantica	7	5	3		10	13		10	5																					
Carex heliophila			2	5	5	4	5	6	3		18	8	8	2		5	12		3	2				4		5	1	2	2	3
Carex siccata	10	10	4		7					25			10	30	40		4													
Carex obtusata	7	10	15	15	10	4	5	2	5	15	2	5	6	8				2			2				2		2	2	2	1
Carex abbreviata													6	5																
Symphoricarpos occidentalis														9	10															
S. albus pauciflorus	12	15	18	20	20	4	20	35	10	4	15	25	5			6	30	9		5	20	8		5		5	6	8	2	6
Amelanchier alnifolia													20		15									25				10		
Rosa Woodsii		5								8																7				
Rosa arkansana					10		2	8				2	2	3	3				3											
Galium boreale	15	10	8	8	3	3	4	6	2	2	12	5	3	3	3	4	7	10	5	8	4	2	5	10	2	3	2	4	2	1
Erigeron glabellus			1	1	1	2		1	5	1	7							4	3	3	3	8	5	4	8	7	5	5	1	4
Aster laevis	1	8	2	2	10	5	1	10	6	7		2		10	2					2	4					2	2	1		2
Geum triflorum		8	6	7	7	6	2			2		2							5						2			1		
Thalictrum venulosum		1			2	5	1	7	3	2	3	2	1		2		3	1	2	1			1	2		2	1		2	1
Pulsatilla ludoviciana	2	2																3	8	2			1	4	10	8		1		
Hedysarum alpinum	2	4	1						4	2	2											8	2	4	4		1		1	
Campanula rotundifolia		2							2																					1
Antennaria spp.		5																					2							
Achillea Millefolium		1	1		2					1	1		1	1	1		2	1			2	1			2					
Fragaria glauca	2		2								1	1	1					1												
Heuchera Richardsonii	3													3																
Allium cernuum	2																												3	
Aster ericoides		3																							7					
Potentilla arguta		2													3		5							2						
Vicia americana			1	2															2					1		1				1
Agoseris glauca					2												2						2							
Erysimum parviflorum						1																								
Solidago lepida													5		3															
Solidago decumbens oreophila																			3				1	2				1		
Comandra pallida													1																	
Viola adunca															1														1	
Gaillardia aristata																2		2				7								
Stellaria spp.													1				1										1			
Hieracium scabriusculum																							7							

TABLE II

Quadrat Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Agropyron trachycaulum	15				8	10	45	15	25		10	18	5		5	25	5	30	20	15	30	15			15		15	15	30	10
Stipa spartea curtiseta	15		5		35	30	2	40	6	50	10	25	10	2	20	40	70		40	35	40	10	25	35	5	35		12	12	10
Agropyron dasystachyum							5	7	6														5			6	5			10
Koeleria cristata	5	12	10	5		2		3	5		5				2				5			5					2	7		
Danthonia intermedia	25	20	35	35	15	15	5		15	18	35	40	50	70	45	5	3	45		2		30	40	15	35	20			20	
Stipa Richardsonii			5		3			2								2								10	10		40	30		40
Poa pratensis		2			2			1						1	2							2						2	3	
Poa interior										1	1						1													
Festuca saximontana				12	3	10	5		2		2		5			4		2								3		2		
Agrostis scabra					2		2		1		1		1															1		
Calamagrostis neglecta							5																							
Carex siccata	4		3			2			6		2		2	4	3			2	4	20	10	15	8			3	5	10	4	
Carex heliophila		7	3	5		2	1			5	3	2		5	2	2	2		8	4				3	8	4				7
Carex obtusata	15	20	10	10	5	5	4	10	2	5	3	2	1	1	3	2	2	2	3	5	3	1	2	5	2	2	2		4	7
Juncus spp.	4	12	15	5		10		1			6			2			2													
Rosa Woodsii		8					2	5	3		2	2		5	5	2		2							3	3	2			
Helianthus subrhomboideus																			1											
Allium cernuum																									2					
Gentiana acuta																					2									
Vicia sparsifolia																				1										1
Solidago missouriensis																			2							3				
Solidago lepida																		5												
Potentilla arguta										2																		2		
Pulsatilla ludoviciana										2																				
Antennaria spp.	2							1	1			3	2		1	2		1	5		1						2			
Galium boreale	2	2	2	3	2		2	5	18	1	2		8	5	2	3	5	2	7	2	5	4	5	5	4	2	10		6	12
Thalictrum venulosum	3	2	1	5	2	1		1		1		1		1	1	1	1	1			1	1		1	2		1	2	8	1
Achillea Millefolium	1		1	2	1		1		1	1	1	1		1	1							2		1	1	1			1	
Aster laevis				1	1		3	4	3		2	1	3	1				4		5		2	2		8	8	7	7		
Cerastium arvense	1	1				1		1																	1		1			
Comandra pallida	2		1	2		1	4			2	1	1	6														2	1	1	
Solidago decumbens var. oreophila	2	5	1	1			1		1	1	2		2	1	2		2					2		4				2	3	
Agoseris glauca	2						1																							
Lilium philadelphicum var. andinum	1																													
Fragaria glauca		6					1		1																1				1	
Hedysarum alpinum		1						1						1																
Astragalus goniatus			1			1																								
Erigeron glabellus			2	10				1	2	1	2	1	3			8	3	2		1	5	6	8	25		4	4		2	
Stellaria longipes				1			1			1										1								1		
Hieracium scabriusculum					12																									
Geum triflorum					2	10				6	6				2															
Potentilla gracilis Nuttallii					1																									
Heuchera Richardsonii					1																									
Campanula rotundifolia					1		1															2					1		2	
Viola adunca					1		4		1	1	2		2		2	1	1			2		1				2				1
Vicia americana								1				1				1													1	1
Aster ericoides								1			2						2			2								2		
Mosses	1	2	5	3	3		5		2	2		2			2	2	1	2	5	5	1	4	1		3	2	1	4	2	

T A B L E I I I

Quadrat Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Agropyron trachycaulum	3	5		2	2	3	8			25	20	5			3
Agropyron dasystachyum	4	5	4	2			6								
Stipa spartea curtiseta	8		2	2	3	3	12			5	5				3
Koeleria cristata	6			3	3	3	5	5		5		6	5	10	15
Danthonia intermedia	30	35	12	4	5	15	30	50	65	20	25		20	8	6
Agrostis scabra						5		2			2				2
Festuca saximontana	8		5			2								1	5
Poa interior															2
Stipa Richardsonii					3			4						3	
Calamagrostis montanensis					2									1	
Poa pratensis														1	
Avena Hookeri				8	3	4						4			
Carex obtusata	6	5	4	5	10	8	12	5	5	8	12	10	10	12	20
Carex heliophila	18	30	20	10	35	16	8	8	6	10	16	20	25	25	8
Carex siccata			4			5		8				10	5		
Rosa Woodsii	5														
Galium boreale	2		5		1			3	2	6	2	2			
Erigeron glabellus	2	6	15		3	4		3	2	2	2		4	2	3
Achillea Millefolium	1	1		1	2					2	1	3	3	2	1
Solidago missouriensis oreophila	2	5	4	3	2	3	6	4	1	2	3	6			3
Orthocarpus luteus	1	1	1												
Comandra pallida		2	2			4	5	2	2		1	6	4	3	
Potentilla arguta		4								4					
Androsace puberulenta		1	2	2	1		1		1				1	1	
Geum triflorum				2			6				6			3	1
Cerastium arvense				1	3				1	1		2	2	1	
Gaillardia aristata					5										
Helianthus subrhomboideus					2										
Pulsatilla ludoviciana						2		2			2				
Viola adunca							1			2					
Aster laevis								4							6
Artemisia frigida										8		4			
Senecio cymbalarioides											3	2			
Antennaria spp.													1		3
Vicia sparsifolia														1	1
Stellaria longipes														1	1
Potentilla pennsylvanica															2
Mosses						8									
Bare ground	4		20	55	15	15			15			20	20	25	15

Carex praticola	Zizia aptera
" xerantica	Amelanchier alnifolia
Androsace puberulenta	Arctostaphylos uva-ursi
Anemone cylindrica	Juniperus communis var. montana
Artemisia frigida	Rosa acicularis
Erigeron caespitosus	Symphoricarpos occidentalis
Lychnis Drummondii	

Table III records thirty-eight species occurring within the quadrats of the third area. Eight additional species noted within this area but outside the quadrats are listed below. These seem to be of little or no significance in connection with the present analysis.

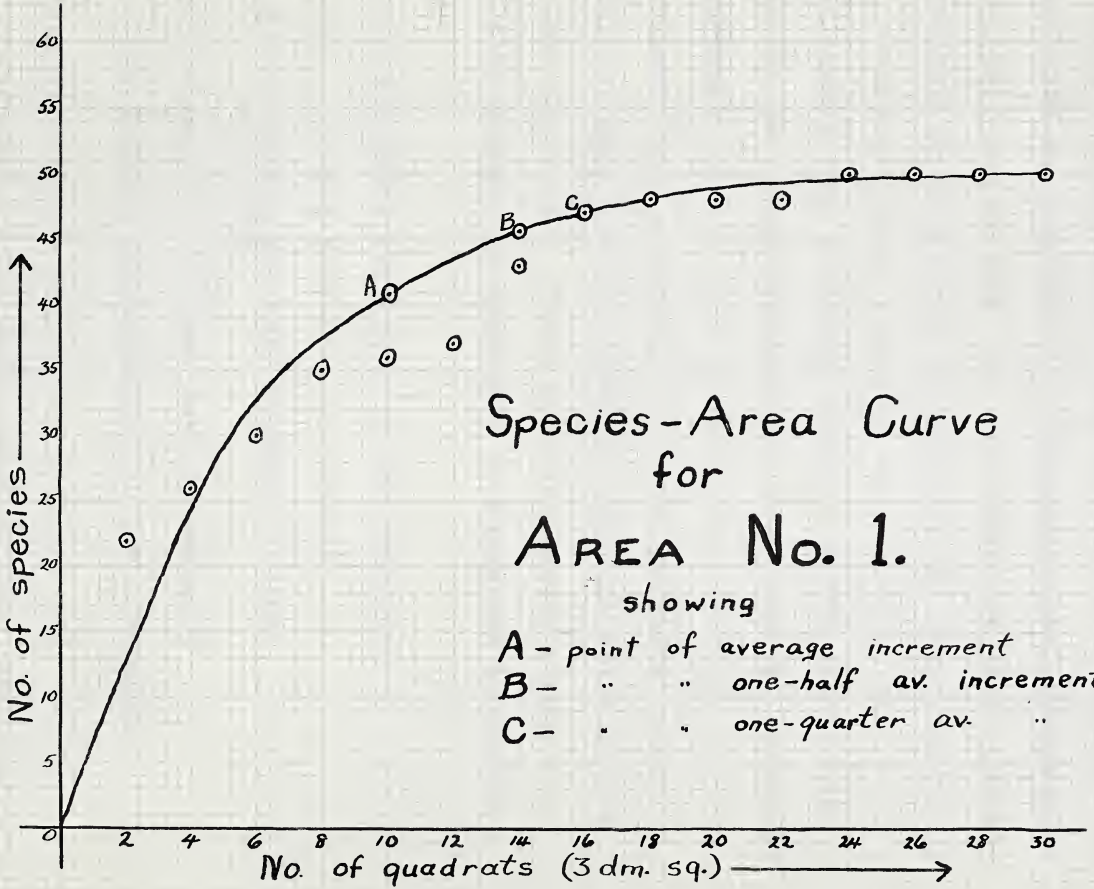
Carex xerantica	Lychnis Drummondii
Fragaria glauca	Potentilla gracilis
Gentiana acuta	Amelanchier alnifolia
Hedysarum alpinum	Symphoricarpos occidentalis

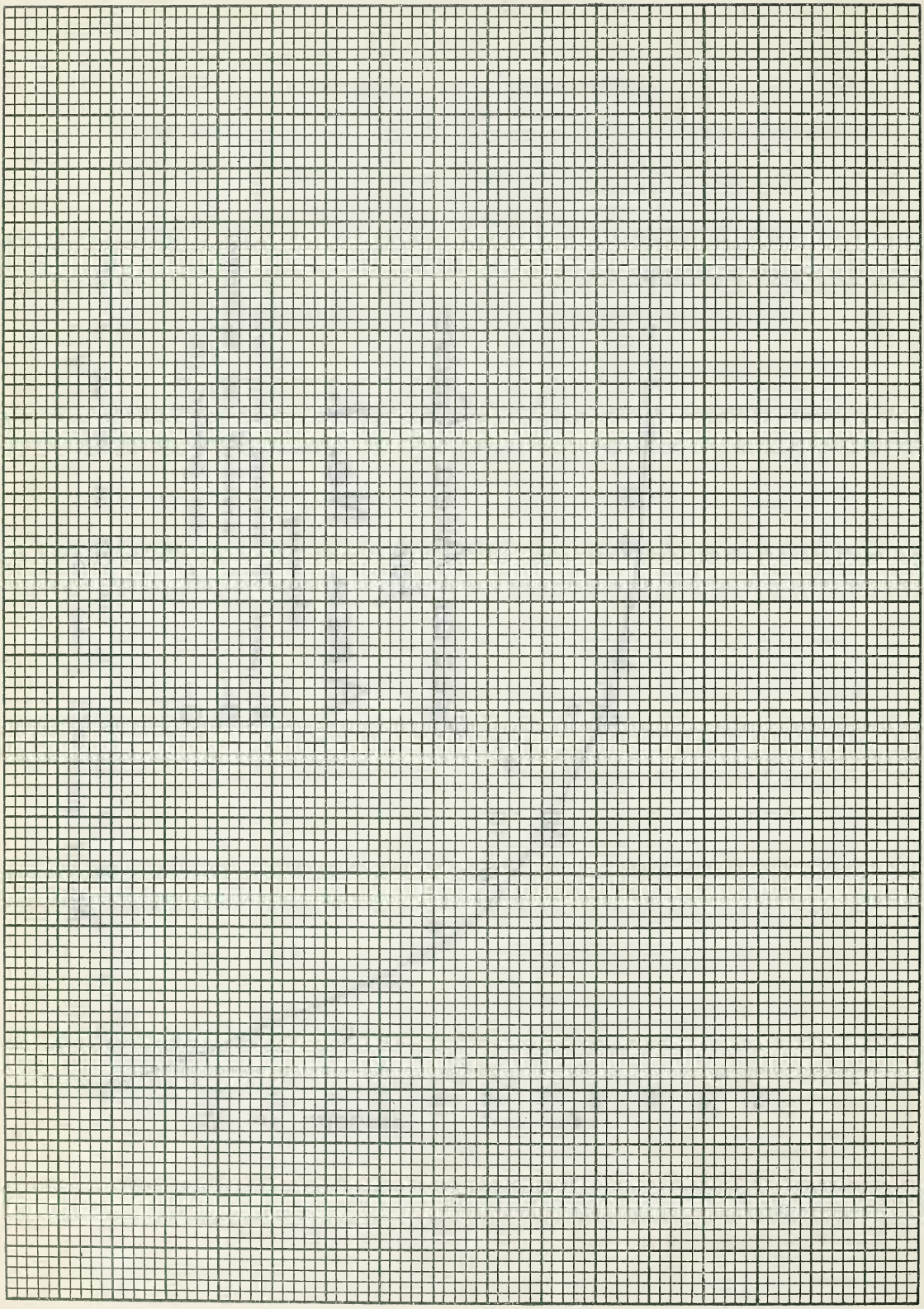
The number of quadrats required to give an adequate sample is determined by use of a species-area curve. This is a characteristic curve which results from plotting the number of species found against the quadrats sampled (14). The accumulated number of species recorded for the quadrats is expressed as an absolute number and plotted on the y axis and the corresponding quadrat numbers are arranged on the x axis. The curve formed by the joined points rises abruptly with the earlier increases in total sample area, but soon levels off, and tends to rise only slightly there-

after with increases of sampling area. For any type of vegetation the sampling is assumed to be adequate when the size of the sample somewhat exceeds the number of quadrats corresponding to the point at which the curve flattens strongly.

If the total number of species obtained in the sampling is divided by the total number of sample units (quadrats), the average increment of new species per additional sample unit is obtained. In Table 1 the average increment is fifty divided by thirty or 1.67 new species per quadrat. On the species-area curve, point A locates the position where addition of a unit sample produces an increment of 1.67 species (the average increment). Beyond this point addition of samples will yield progressively less than the average. In the region of point B a sample yields only one-half the information, i.e. an increment of 0.83 species per additional sample. In the region of point C a sample yields one-quarter of the information, i.e. 0.41 species per additional sample. In the accompanying species - area graph, point A occurs at 10, point B at 14 and point C at 16 quadrats.

A similar analysis for Table II has shown the sampling for the corresponding area is also more than adequate. The fifteen quadrats taken in the third area and shown in Table III are also adequate for average increments of species (point A) and for half the average increments of species (point B) but not adequate for one-quarter of the


60
55
50
45
40
35
30
25
20
15
10
5
0
No. of species
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
No. of quadrats (3 dm. sq.)
A
B
C
Species-Area Curve
for
AREA No. 1.
showing
A - point of average increment
B - " " one-half av. increment
C - " " one-quarter av. "



average increments of species (point C). It is, however, quite a suitable sample of the grassland for the purpose of the present study.

Analyses of these three areas are further presented in accordance with the procedure of Braun-Blanquet, summarized by Oosting (14) and by Cain (2). Involved are three quantitative analytical concepts pertaining to the organization of a plant community. These concepts are concerned with the number of plants, the coverage, and the uniformity of distribution and are known respectively as abundance, dominance and frequency.

Abundance is an appreciation of the relative number of individuals of each species entering into the constitution of the plant population of the territory under study. A scale of five degrees of abundance is suggested by Braun-Blanquet.

A 1 - species very rare in the community

A 2 - species rare in the community

A 3 - species not very abundant in the community

A 4 - species abundant in the community

A 5 - species very abundant in the community

Dominance concerns the extent (surface and volume) covered or occupied by the individuals of each species. A scale of five degrees of dominance is used here.

Do 1 - species covering 1 to 5% of the surface

Do 2 - species covering 6 to 25% of the surface

Do 3 - species covering 26 to 50% of the surface

Do 4 - species covering 51 to 75% of the surface

Do 5 - species covering 76 to 100% of the surface

Frequency is concerned with the uniformity with which the plants of a species are distributed throughout a plant community. The frequency of a species is expressed by the relation in per cent between the number of sample areas which contained it and the total number of such areas employed in the analysis. Frequency is usually expressed on a basis of five classes.

F 1 - species in 1 to 20% of the quadrats

F 2 - species in 21 to 40% of the quadrats

F 3 - species in 41 to 60% of the quadrats

F 4 - species in 61 to 80% of the quadrats

F 5 - species in 81 to 100% of the quadrats

The percentage is called the "frequency-index" of the species.

It is important to recognize the essential distinctness of the three concepts: number (abundance), area of coverage (dominance), and homogeneity (frequency). Accordingly a summary in terms of quantitative concepts relating to the species composing the three grassland communities of the Peace River for which data is available has been drawn up and is presented here.

Phytosociological Summary for Table I

Species List	Abundance	Dominance	Frequency
Agropyron trachycaulum	4	2	3

Stipa spartea var. curtiseta	5	2	4
Avena Hookeri	2	1	2
Koeleria cristata	4	2	4
Agropyron dasystachyum	3	1	2
Poa pratensis	1	1	1
Danthonia intermedia	3	1	4
Poa interior	1	1	1
Stipa columbiana	2	1	2
Stipa Richardsonii	3	2	2
Calamagrostis inexpansa	1	1	1
Bromus ciliatus	1	1	1
Festuca saximontana	1	1	1
Agrostis scabra	1	1	1
Carex praticola	2	1	1
Carex xerantica	2	1	2
Carex heliophila	3	1	4
Carex siccata	3	1	4
Carex obtusata	3	1	4
Carex abbreviata	1	1	1
Symphoricarpos occidentalis	1	1	1
Symphoricarpos albus pauciflorus	5	2	5
Amelanchier alnifolia	1	1	1
Rosa Woodsii	1	1	1
Rosa arkansana	3	1	2
Galium boreale	5	1	5
Erigeron glabellus	4	1	4
Aster laevis	4	1	4

Geum triflorum	3	1	2
Thalictrum venulosum	3	1	4
Pulsatilla ludoviciana	2	1	2
Hedysarum alpinum	2	1	2
Campanula rotundifolia	1	1	1
Antennaria spp.	1	1	1
Achillea Millefolium	3	1	3
Fragaria glauca	1	1	1
Heuchera Richardsonii	1	1	1
Allium cernuum	1	1	1
Aster ericoides	1	1	1
Potentilla arguta	1	1	1
Vicia americana	1	1	1
Agoseris glauca	1	1	1
Erysimum parviflorum	1	1	1
Solidago lepida	1	1	1
Solidago decumbens oreophila	1	1	1
Comandra pallida	1	1	1
Viola adunca	1	1	1
Gaillardia aristata	1	1	1
Stellaria spp.	1	1	1
Hieracium scabriusculum	1	1	1

Phytosociological Summary for Table II

Species List	Abundance	Dominance	Frequency
Agropyron trachycaulum	5	2	4

Stipa spartea curtiseta	5	2	5
Agropyron dasystachyum	2	1	2
Keoleria cristata	3	1	3
Danthonia intermedia	4	2	4
Stipa Richardsonii	2	1	2
Poa pratensis	1	1	2
Poa interior	1	1	1
Festuca saximontana	2	1	2
Agrostis scabra	1	1	1
Calamagrostis neglecta	1	1	1
Carex siccata	3	1	3
Carex heliophila	3	1	3
Carex obtusata	4	1	5
Juncus spp.	2	1	2
Rosa Woodsii	2	1	3
Helianthus subrhomboideus	1	1	1
Allium cernuum	1	1	1
Gentiana acuta	1	1	1
Vicia sparsifolia	1	1	1
Solidago missouriensis	1	1	1
Solidago lepida	1	1	1
Potentilla arguta	1	1	1
Pulsatilla ludoviciana	1	1	1
Antennaria spp.	2	1	2
Galium boreale	5	1	5
Thalictrum venulosum	4	1	4

Achillea Millefolium	4	1	3
Aster laevis	4	1	3
Cerastium arvense	2	1	1
Comandra pallida	3	1	2
Solidago decumbens oreophila	3	1	3
Agoseris glauca	1	1	1
Lilium philadelphicum andinum	1	1	1
Fragaria glauca	1	1	1
Hedysarum alpinum	1	1	1
Astragalus goniatus	1	1	1
Erigeron glabellus	3	1	4
Stellaria longipes	1	1	1
Hieracium scabriusculum	1	1	1
Geum triflorum	1	1	1
Potentilla gracilis Nuttallii	1	1	1
Heuchera Richardsonii	1	1	1
Campanula rotundifolia	1	1	1
Viola adunca	2	1	3
Vicia americana	1	1	1
Aster ericoides	2	1	1
Mosses	5	1	5

Phytosociological Summary for Table III

Species List	Abundance	Dominance	Frequency
Agropyron trachycaulum	3	1	4
Agropyron dasystachyum	2	1	2

Stipa spartea curtiseta	3	1	3
Koeleria cristata	3	1	4
Danthonia intermedia	5	2	5
Agrostis scabra	2	1	2
Festuca saximontana	2	1	2
Poa interior	1	1	1
Stipa Richardsonii	1	1	1
Calamagrostis montanensis	1	1	1
Poa pratensis	1	1	1
Avena Hookeri	2	1	2
Carex obtusata	5	2	5
Carex heliophila	5	2	5
Carex siccata	2	1	2
Rosa Woodsii	1	1	1
Galium boreale	3	1	3
Erigeron glabellus	4	1	4
Achillea Millefolium	4	1	4
Solidago missouriensis oreophila	4	1	5
Orthocarpus luteus	1	1	1
Comandra pallida	2	1	4
Potentilla arguta	1	1	1
Androsace puberulenta	2	1	3
Geum triflorum	2	1	2
Cerastium arvense	2	1	3
Gaillardia aristata	1	1	1
Helianthus subrhomboideus	1	1	1

Pulsatilla ludoviciana	1	1	1
Viola adunca	1	1	1
Aster laevis	1	1	1
Artemisia frigida	1	1	1
Senecio cymbalarioides	1	1	1
Antennaria spp.	1	1	1
Vicia sparsifolia	1	1	1
Stellaria longipes	1	1	1
Potentilla pennsylvanica	1	1	1
Mosses	1	1	1

For purposes of comparison with results of the Crowsnest Forest survey, the records of Tables I, II and III are grouped into five main groups as shown below. These groups are: (1) Sedges, (2) Grasses, with 8 subgroups, (3) Forbs, including those regarded as indicators of retrogression, (4) Shrubs, (5) Bare ground.

Vegetational Coverage in Percentages

Species List	Table I	Table II	Table III
1. Sedges			
Carex heliophila	3.5	2.5	17.0
Carex obtusata	4.0	5.0	9.0
Carex siccata	4.5	3.5	2.0
Carex xerantica	2.0	nil	nil
Carex praticola	1.0	nil	nil
Carex abbreviata	nil	nil	nil

2. Grasses			
(a) Koeleria cristata	6.0	2.0	4.5
(b) Stipa spp.	24.0	25.5	3.5
(c) Festuca scabrella	nil	nil	nil
(d) Festuca idahoensis	nil	nil	nil
(e) Agropyron trachycaulum	8.5	13.0	5.0
(f) Agropyron spp.	3.0	1.5	1.5
(g) Danthonia spp.	4.5	21.0	20.5
(h) All others	3.0	3.0	3.0
3. Forbs			
(a) Artemisia frigida	nil	nil	1.0
(b) Artemisia spp.	nil	nil	nil
(c) Potentilla spp.	0.5	0.5	0.5
(d) Galium boreale	5.0	4.5	1.5
(e) Achillea Millefolium	0.5	0.5	1.0
(f) Solidago spp.	0.5	1.5	3.0
(g) Pulsatilla ludoviciana	1.5	nil	0.5
(h) Erigeron spp.	2.5	3.0	3.0
(i) Aster spp.	3.0	2.5	1.0
(j) Geum triflorum	1.5	1.0	1.0
(k) Geranium viscosissimum	nil	nil	nil
(l) Hedysarum spp.	1.0	nil	nil
(m) Senecio spp.	nil	nil	nil
(n) Lupinus spp.	nil	nil	nil
(o) Other forbs	4.0	6.5	6.5

4. Shrubs			
(a) Amelanchier alnifolia	2.0	nil	nil
(b) Symphoricarpos spp.	11.0	nil	nil
(c) Potentilla fruticosa	nil	nil	nil
(d) Rosa spp.	2.0	2.0	nil
(e) Arctostaphylos uva-ursi	nil	nil	nil
(f) Other shrubs	nil	nil	nil
5. Bare Ground	nil	nil	nil
Totals	99%	99%	99%

The final analysis of these areas consists of a breakdown of the total cover into three main classes. The first area (Table I) has the following coverage: grasses 49%, sedges 15% (a total of 64% coverage of graminoid species), shrubs 15%, and forbs 20%. The second area (Table II) has the following coverage: grasses 66%, sedges 11% (a total of 77% coverage of graminoid species), shrubs 2%, and forbs 20%. The third area (Table III) has the following coverage: grasses 38%, sedges 28% (a total of 66% coverage of graminoid species), shrubs less than 1%, forbs 19%, and bare ground 14%.

Summary of Total Coverage for the Three Areas

	Graminoids	Grasses	Sedges	Shrubs	Forbs	Bare
Table I	64%	49%	15%	15%	20%	nil
Table II	77%	66%	11%	2%	20%	nil
Table III	66%	38%	28%	nil	19%	14%

Observations of other areas in this region indicate that the 15% cover of shrubs in Table I is higher than that for most areas. The shrub cover in Tables II and III are probably somewhat too low for typical grassland of the region.

The effect of grazing in the third area (Table III) appears to be a marked reduction in grasses accompanied by an increase in sedges and bare ground. Similar proportions of forbs for the three areas indicate that grazing of the third area had not yet brought about an increase in these plants. It seems probable, from observations of other overgrazed areas in the region, and from results obtained elsewhere by other investigators, that some of the bare ground in the third area will be invaded eventually by forbs. The quadrat studies and general observations indicate that Antennaria spp., Pulsatilla ludoviciana, Solidago decumbens, Orthocarpus luteus, and Artemisia frigida are increasing. These will probably form the main cover of the bare ground, if present grazing pressure is maintained.

While the proportion of forbs in this heavily grazed area (Table III) is not increased, the grasses show a marked reduction over their occurrence in the slightly utilized areas, while the sedges exhibit a corresponding increase. This contrast points to the conclusion that species of Carex (in this instance, chiefly C. heliophila and C. obtusata) may serve as indicators of early stages in retrogression of native grassland, even in advance of such indicators as Artemisia frigida.

B. Crowsnest Forest Survey

1. Methods

This survey was more general in nature than that of the Peace River. The list indicating the floristic composition is thus not nearly so detailed, often only including generic names. The rugged topography of the Crowsnest forest area results in a great variation in vegetation types within very short distances. In a region with such a diversity of vegetation an area was "typed" according to the plants giving the appearance or physiognomy. This procedure resulted on the recognition of ten vegetation types.

1. Grassland - includes all grassland other than meadows.

2. Meadow - includes areas where moisture-loving sedges, rushes and grasses predominate. Two classes are recognized:

   (a) Wet Meadows characterized by sedges and rushes, and remaining wet throughout the year.

   (b) Dry Meadows as found in timber or along streams.

3. Perennial forbs - included untimbered areas where perennial weeds predominate.

4. Sagebrush - includes untimbered areas where sagebrush gives the aspect.

5. Browse - includes lands where shrubs predominate.

6. Conifers - all coniferous stands except juniper. There may be an understory of grass, weeds or browse.

7. Waste - includes all areas which have little or no forage value due to density of standing or down timber, sparseness of forage, or rough and inaccessible.

8. Barren - includes bed rock, shale, sand dunes or areas that normally bear no forage.

9. Broadleaf trees - includes deciduous timber, mainly cottonwood, aspen or birch.

10. Annuals - annual weeds or grasses. Bromus tectorum is the most common sub-type.

Each type was delimited by use of aerial photographs and inspection of the areas. After each type was delimited and classified it was sampled.

The sampling method employed in this survey is a modified version of a "reconnaissance" method based on a belt transection (transect) three feet wide and as long as the distance walked. This "reconnaissance" method is described in the Range Management Handbook for Region One of the U. S. Department of Agriculture Forest Service (10). The modified method is based on a series of plots located on a transect through the type. The number of plots varies according to the variations within the type, ten being taken as the base number, and the use of more or fewer being left to the judgment of the examiner. The transect is a meandering one with location left entirely to the judgment of the examiner. It should aim to include variations but the main part should cut through the average of the type. The sample plots are located at random along the transect, each being an area easily observed by the examiner and if feasible almost directly beneath him. Usually the plot is circular and approximately three feet in diameter. The field examiner endeavours to make an accurate estimate of the composition,

average density, and other features of the type. Records are made of plant species believed to be important because of abundance, palatability, poisonous or noxious properties or because of their value as indicators of range condition and trend. Species that form less than one per cent of the composition are not significant for range management and need not be listed. The density of the vegetation is estimated in tenths and represented as such. An area that has fifty per cent of the ground covered is a 0.50 density. Plant composition as used in range surveys is a percentage expression of the density of each of the three classes of forage (grass, weeds and browse) and also of the species within each class. The totals are one-hundred per cent in both cases. The total percentage composition of the grass species, for example, must therefore equal the percentage composition for grass cover.

Density and composition estimates are made looking vertically at the ground. Care is required in estimating density of open clumps of grass, shrubs or spreading weeds to include only those parts that obscure the ground when viewed vertically and when spreading plants are bunched at an angle of thirty degrees from the vertical. Only the leafage and tips of trees and coarse shrubs clearly within reach of livestock enter into the estimate. The density of two-story vegetation, such as grass beneath shrubs, is estimated as for one-story vegetation with no allowance for overlap. These methods of judging reconnaissance den-

DENSITY CHART

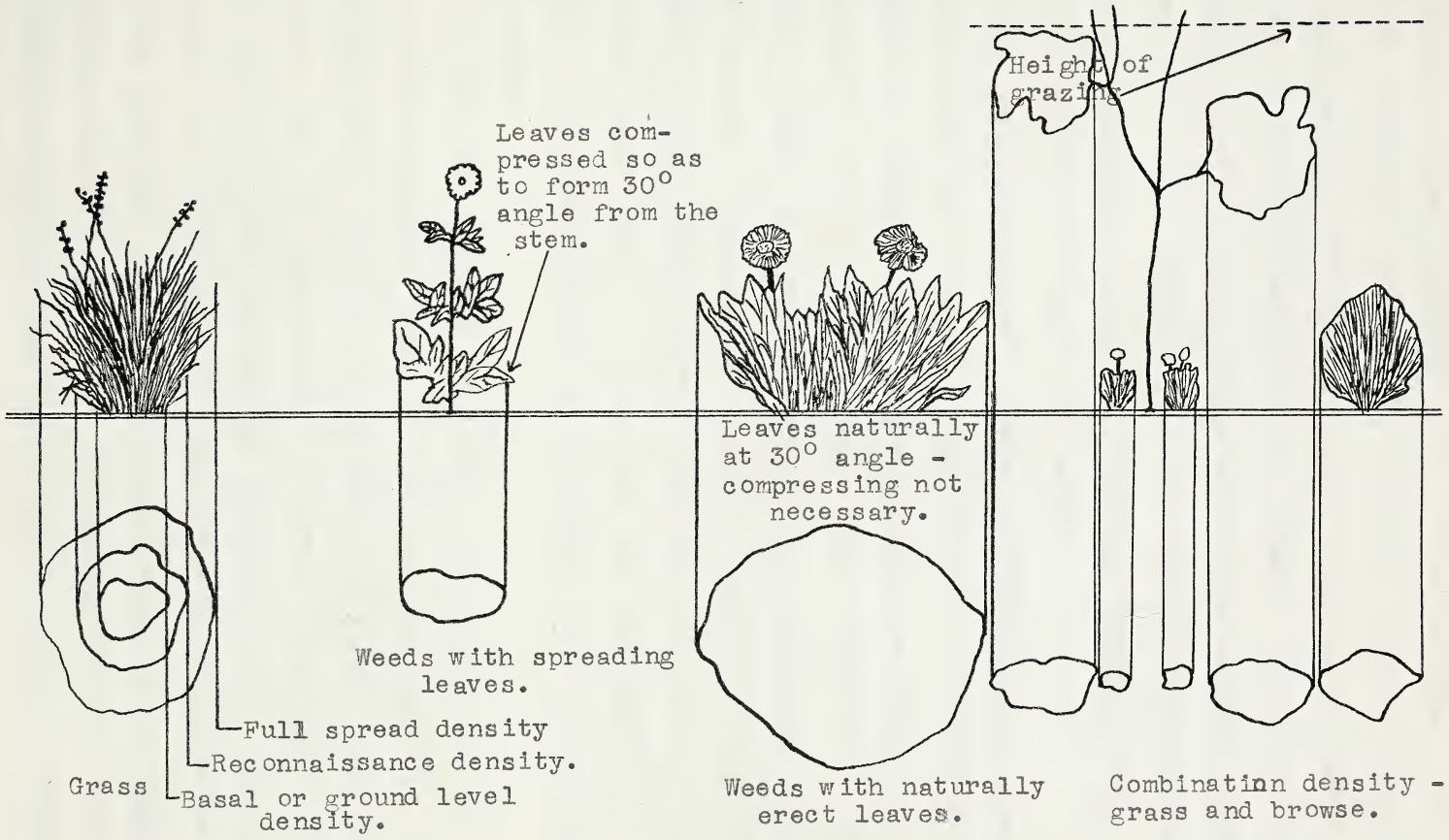


Illustration showing methods of judging reconnaissance densities for grasses, weeds and browse.

sities are further explained by the illustrations on the density chart shown on page 48. Heavily grazed vegetation is visualized in the unutilized condition and so estimated.

It is generally desirable to estimate composition by rating the species in accordance with their relative abundance in the type, starting with the most abundant species. It may be necessary to adjust individual initial ratings to make them total one-hundred per cent.

The foregoing method of range sampling depends almost entirely upon the judgment of the examiner. Accuracy in judgment and uniformity of judgment among the members of a field party is of first importance. Such uniformity is obtained by use of a training period at the beginning of the field season. Field examiners must demonstrate their ability to judge density uniformly with the chief of party before being permitted to work individually. This uniformity is essential if the data secured by the party are to be reliable and usable.

Of the many types of vegetation sampled during this survey only the record of one, the Festuca scabrella type, is presented here. This is a grassland with a number of sedge species. From the many records of areas belonging to this type seven have been selected as representative. These sample areas fall into two major categories which may be designated as A and B. Category A is represented by six Festuca scabrella areas that have been subjected to varying degrees or intensities of grazing. The recorded coverage of these

areas are set forth in Tables IV, V, VI, VII, VIII and IX. Category B is represented by one area, - a steep, south-facing hillside which has been severely overgrazed for many years. The virgin vegetation was probably a Festuca scabrella association, but the current aspect is that of Carex heliophila. During the previous summer a small plot of about two acres was enclosed by a three-strand barbed wire fence to exclude livestock. A sample taken from this exclosure is contrasted with one taken from outside. The records, together with more detailed descriptions of each, appear in Tables X and XI.

2. Results and Analyses

The records of the eight areas are presented in Tables IV to XI inclusive. They include the names of plants which occupy 1% or more of the total cover and some additional plants which occupy less than 1% of the total cover. These are listed as a trace (T). The total amount of plant cover is recorded as a density, the meaning of which has been given (page 47). The species comprising the plant cover are arranged in three groups, viz. graminoids, shrubs and forbs.

Tables IV to IX show the records of six "Festuca scabrella" grassland areas (Category A). The compositions of these areas are recorded in the tables as percentage of total cover.

Table IV

This is the record of a nearly virgin grassland covering

the floor and steep lower slopes of a mountain valley. The precipitous nature of the lower reaches of the valley render the region practically inaccessible to domestic stock. The valley floor has a very good covering of grass, almost entirely Festuca scabrella, its density being approximately 0.75. The cover thins out rapidly on the steeper slopes and this greatly reduces the over-all density of the area. The Carex population increases with steepness of slope and is mainly C. siccata and C. obtusata, with some C. heliophila. The vegetation density of this area is 0.40. Thus 60% of the ground surface is without cover. The plant cover of the remaining 40% consists of the following.

Graminoids

Festuca scabrella	60
" idahoensis	15
Elymus innovatus	T
Agropyron trachycaulum	T
Juncus spp.	T
Carex siccata	2
" obtusata	3
" heliophila	T

Shrubs

Potentilla fruticosa	3
Populus tremuloides	2
Arctostaphylos uva-ursi	T
Juniperus spp.	T

Rosa spp.	T
Rubus spp.	T

Forbs

Potentilla spp.	5
Geum triflorum	3
Aster spp.	5
Epilobium angustifolium	2
Campanula spp.	T
Frageria spp.	T
Eriogonum spp.	T
Solidago spp.	T
Lathyrus spp.	T
Achillea Millefolium	T

Table V

This is the record of a virgin grassland occupying a steep south-facing slope and the floor of a mountain valley. The lower valley is impassable to livestock. The steepness of the slope markedly reduces the average density of the cover. The valley floor is estimated to have a density of 0.80. The Carex population is mostly C. obtusata, with some C. siccata and C. heliophila. The vegetation density of the area is 0.35. Thus 65% of the ground surface is without cover. The plant cover of the remaining 35% consists of the following.

Graminoids

Festuca scabrella	25

Festuca idahoensis	15
Elymus innovatus	10
Poa spp.	5
Bromus carinatus var. marginatus	3
Koeleria cristata	T
Elymus canadensis	T
Phleum alpinum	T
Carex obtusata	2
" heliophila	T
" siccata	T

Shrubs

Arctostaphylos uva-ursi	10
Populus tremuloides	5
Juniperus spp.	2
Rosa spp.	2
Potentilla fruticosa	1
Spiraea spp.	T
Salix spp.	T
Pinus contorta var. latifolia	T
Amelanchier alnifolia	T

Forbs

Potentilla spp.	5
Hedysarum spp.	5
Senecio spp.	4
Solidago spp.	3

Galium boreale	2
Erigeron spp.	1
Antennaria spp.	T
Agoseris spp.	T
Achillea Millefolium	T
Vicia americana	T
Cirsium spp.	T
Epilobium angustifolium	T
Campanula spp.	T
Thalictrum spp.	T
Castilleja spp.	T
Aster spp.	T
Fragaria spp.	T
Oxytropis spp.	T
Gaillardia aristata	T

Table VI

This is the record of a relatively virgin grassland isolated by a road and a drift fence. The exposure is southeast and the elevation about 5,600 feet. The vegetation density of this grassland is 0.60, bare ground comprising 40%. The plant cover of the remaining 60% consists of the following.

Graminoids

Festuca scabrella	30
Festuca idahoensis	25
Bromus carinatus var. marginatus	5

Calamagrostis purpurascens	2
" rubescens	2
Agropyron trachycaulum	2
Poa spp.	2
Carex heliophila	2
" obtusata	T
" microptera	T
" Raynoldsii	T

Shrubs

Amelanchier alnifolia	3
Rosa spp.	2
Vaccinium caespitosum	2
Populus tremuloides	T
Potentilla fruticosa	T

Forbs

Geranium viscosissimum	5
Lupinus spp.	5
Aster spp.	5
Fragaria spp.	2
Galium boreale	1
Achillea Millefolium	1
Valeriana septentrionalis	1
Senecio spp.	1
Vicia americana	1
Potentilla spp.	1
Hedysarum spp.	T

Thalictrum spp.	T
Oxytropis spp.	T
Delphinium bicolor	T
Zygadenus spp.	T
Epilobium angustifolium	T
Eriogonum flavum	T

Table VII

This records a well used area showing little evidence of overgrazing. At the date of sampling the herbage was grazed off most of the area to the extent that the cattle had moved to the lower regions among the open poplar stands. The latter showed little evidence of use up to that time (July 16). The area is more or less isolated from the rest of the Reserve by mountain slopes and movement of livestock to and from the area is carried out by trailing them through the Reserve fence and down a creek valley. Due to these barriers drifting of livestock is at a minimum in the area and thus a definite number of animals can be (and is) maintained. This is one of the areas of the Reserve which was considered to be properly used. The vegetative density of the area is 0.25. Thus about 75% of the area is bare ground. The plant cover of the remaining 25% is as follows.

Graminoids

Festuca scabrella	15
" idahoensis	15
Danthonia spp.	10
Koeleria cristata	5

Agropyron spicatum	5
" trachycaulum	5
Bromus carinatus var. marginatus	3
Poa spp.	2
Carex heliophila	5
" obtusata	5
" siccata	T
" microptera	T
" xerantica	T

Shrubs

Amelanchier alnifolia	2
Rosa spp.	2
Spiraea alba	1
Potentilla fruticosa	T
Populus tremuloides	T

Forbs

Erigeron spp.	5
Geranium viscosissimum	5
Anemone spp.	5
Aster spp.	2
Solidago spp.	2
Hedysarum spp.	2
Lupinus spp.	1
Achillea Millefolium	1
Campanula rotundifolia	1

Epilobium angustifolium	1
Potentilla spp.	T
Pulsatilla spp.	T
Galium boreale	T
Fragaria spp.	T
Vicia americana	T
Castilleja spp.	T
Sedum stenopetalum	T
Oxytropis spp.	T
Astragalus spp.	T
Heuchera Richardsonii	T

Table VIII

This is a record of grasslands on the lower terraces of the Castle river. Due to presence of salting grounds, watering places, and surrounding steep hills, the cattle tend to overgraze these areas to the exclusion of the higher benches and hillsides. The area shows the effects of overgrazing. The bunches of Festuca scabrella are greatly reduced in size and number, and their place is being taken by Stipa spp. and Danthonia intermedia. Small bunches of Potentilla fruticosa are common over the entire area. At the date of the survey (June 28) the grasses had been grazed quite close to the ground, with the exception of Danthonia intermedia. This gave the appearance of a greater proportion of Danthonia than actually occurred. The vegetative density of this area is 0.45. Thus 55% of the area is bare ground. The

composition of the 45% plant cover is as follows.

Graminoids

Festuca idahoensis	20
" scabrella	12
Stipa spp.	10
Danthonia intermedia	10
Agropyron trachycaulum	5
Bromus spp.	5
Koeleria cristata	3
Agropyron spicatum	T
Juncus spp.	T
Carex heliophila	5
" obtusata	5
" siccata	T

Shrubs

Potentilla fruticosa	2
Symphoricarpos spp.	1
Rosa spp.	1
Amelanchier alnifolia	1
Populus tremuloides	T
Shepherdia canadensis	T
Vaccinium caespitosum	T
Arctostaphylos urv-ursi	T
Salix spp.	T
Prunus demissa	T

Forbs

Geranium viscosissimum	5
Achillea Millefolium	3
Anemone spp.	2
Galium boreale	2
Potentilla spp.	2
Ranunculus spp.	2
Pulsatilla spp.	1
Lupinus spp.	1
Fragaria spp.	1
Solidago spp.	1
Geum triflorum	T
Heuchera Richardsonii	T
Gaillardia aristata	T
Sedum stenopetalum	T
Artemisia frigida	T

Table IX

This is a record of exposed south-facing river terraces with good grass coverage. Evidence that this area has been overgrazed for a number of years is shown by the reduction of Festuca scabrella and increase in Stipa spp. Moreover, the grass cover is being replaced by a cover of forbs. Carex heliophila is the principal sedge, with C. obtusata quite common. C. siccata and C. xerantica are also present in lower areas. The density here is 0.40. Thus 60% of the area is bare. The composition of the 40% plant cover is as follows.

Graminoids

Festuca idahoensis	15
Stipa spp.	15
Danthonia intermedia	10
Agropyron trachycaulum	7
Festuca scabrella	5
Koeleria cristata	3
Bromus carinatus var. marginatus	T
Juncus spp.	T
Carex heliophila	4
" obtusata	1
" siccata	T
" xerantica	T

Shrubs

Amelanchier alnifolia	3
Populus tremuloides	3
Rosa spp.	2
Symphoricarpos spp.	2
Juniperus spp.	T
Pinus contorta var. latifolia	T
Prunus demissa	T
Populus trichocarpa	T
Salix spp.	T
Ribes spp.	T
Arctostaphylos uva-ursi	T

Forbs

Geranium viscosissimum	5
Achillea Millefolium	5
Arnica Chamissonis	3
Heuchera Richardsonii	3
Geum triflorum	2
Galium boreale	2
Eriogonum flavum	2
Fragaria spp.	1
Epilobium angustifolium	1
Lithospermum ruderale	1
Pulsatilla spp.	1
Potentilla spp.	1
Lupinus spp.	1
Anemone spp.	1
Smilacina stellata	1
Zygadenus spp.	T
Lappula Redowskii	T
Solidago spp.	T
Sedum stenopetalum	T
Gaillardia aristata	T
Astragalus spp.	T
Artemisia frigida	T

Tables X and XI set forth the records of a Carex type of cover (Category B). This occurs on a fairly steep, south-facing hillside which has been severely

overgrazed for many years. Similar habitats in the region usually support a Festuca scabrella type. Moreover, small quantities of Festuca scabrella and Festuca idahoensis are present in the area, indicating that a Festuca scabrella association was present in pre-grazing times. A small part of this area was exclosed to domestic stock one year previous to the sampling. Table X presents records of a sample taken outside the exclosure and Table XI presents records from inside the exclosure.

Table X

The density of the area is 0.10. The composition of this 10% plant cover is as follows.

Graminoids

Agropyron spicatum	15
Stipa spp.	3
Bromus carinatus var. marginatus	3
Koeleria cristata	2
Danthonia Parryi	2
Festuca idahoensis	T
Calamagrostis montanensis	T
Carex heliophila	25
" obtusata	T

Shrubs

Symphoricarpos spp.	5
Rosa spp.	4
Prunus demissa	3

Arctostaphylos uva-ursi	2
Amelanchier alnifolia	1
Populus tremuloides	T

Forbs

Artemisia frigida	10
Potentilla spp.	6
Aster spp.	6
Geum triflorum	5
Lupinus spp.	3
Antennaria spp.	3
Galium boreale	2
Taraxacum officinale	T

Table XI

The density inside the exclosure is 0.25. Composition of this 25% plant cover is as follows.

Graminoids

Agropyron spicatum	10
Poa spp.	10
Bromus carinatus var. marginatus	5
Koeleria cristata	3
Stipa spp.	3
Danthonia Parryi	2
Agropyron trachycaulum	1
Festuca idahoensis	1
" scabrella	T

Elymus canadensis	T
Calamagrostis montanensis	T
Carex heliophila	15
" obtusata	T

Shrubs

Symphoricarpos spp.	7
Rosa spp.	5
Arctostaphylos uva-ursi	3
Amelanchier alnifolia	3
Prunus demissa	2

Forbs

Artemisia frigida	15
Aster spp.	5
Potentilla spp.	5
Geranium viscosissimum	2
Geum triflorum	2
Galium boreale	1
Heuchera Richardsonii	T

Carex heliophila is the principal sedge. Inside the exclosure the plants are about twice the size of those outside. In fact, this is true for all the graminoids. The ground cover of Carex increases by 50% on the inside of the exclosure. This is revealed when the percentage composition is multiplied by the density. Thus, 25% of C. heliophila at density of 0.10 gives a factor of .0250 for the outside,

while 15% of C. heliophila at density of 0.25 gives a factor of 0.375 for the inside. Though Artemisia frigida is very rare throughout the entire region, it comprises a considerable proportion of the shrub cover in this area.

Summary of Vegetative Coverage

Species List	Tables							
	IV	V	VI	VII	VIII	IX	X	XI
1. Sedges								
Carex heliophila	T	T	2	5	5	4	25	15
" obtusata	3	2	T	5	5	1	T	T
" siccata	2	T	nil	T	T	T	nil	nil
" xerantica	nil	nil	nil	T	nil	T	nil	nil
" praticola	nil	nil	nil	nil	nil	nil	nil	nil
" abbreviata	nil	nil	nil	nil	nil	nil	nil	nil
" microptera	nil	nil	T	T	nil	nil	nil	nil
" Raynoldsii	nil	nil	T	nil	nil	nil	nil	nil
2. Grasses								
(a) Koeleria cristata	nil	T	nil	5	3	3	2	3
(b) Stipa spp.	nil	nil	nil	nil	10	15	3	3
(c) Festuca scabrella	60	25	30	15	12	5	nil	T
(d) Festuca idahoensis	15	15	25	15	20	15	T	1
(e) Agropyron trachycaulum	T	nil	2	5	5	7	nil	1
(f) Agropyron spp.	nil	nil	nil	5	T	nil	15	10
(g) Danthonia spp.	nil	nil	nil	10	10	10	2	2
(h) All others	nil	18	11	5	5	T	3	15

3. Forbs								
(a) Artemisia frigida	nil	nil	nil	nil	T	T	10	15
(b) Artemisia spp.	nil	nil	nil	nil	nil	nil	nil	nil
(c) Potentilla spp.	5	5	1	T	2	1	6	5
(d) Galium boreale	nil	2	1	T	2	2	2	1
(e) Achillea Millefolium	T	T	1	1	3	5	nil	nil
(f) Solidago spp.	T	3	nil	2	1	T	nil	nil
(g) Pulsatilla ludoviciana	nil	nil	nil	T	1	1	nil	nil
(h) Erigeron spp.	nil	1	nil	5	nil	nil	nil	nil
(i) Aster spp.	5	T	5	2	nil	nil	6	5
(j) Geum triflorum	3	nil	nil	nil	T	2	5	2
(k) Geranium viscosissimum	nil	nil	5	5	5	5	nil	2
(l) Hedysarum spp.	nil	5	T	2	nil	nil	nil	nil
(m) Senecio spp.	nil	4	1	nil	nil	nil	nil	nil
(n) Lupinus spp.	nil	nil	5	1	1	1	3	nil
(o) Other forbs	2	T	4	7	5	13	3	T
4. Shrubs								
(a) Amelanchier alnifolia	nil	T	3	2	1	3	1	3
(b) Symphoricarpos spp.	nil	nil	nil	nil	1	2	5	7
(c) Potentilla fruticosa	3	1	T	T	2	nil	nil	nil
(d) Rosa spp.	T	2	2	2	1	2	4	5
(e) Arctostaphylos uva-ursi	T	10	nil	nil	T	T	2	3

(f) Other shrubs	2	7	2	1	T	3	3	2
Totals	100	100	100	100	100	100	100	100

The final analysis of these areas consists of a breakdown of the total coverage into three main classes. These are (1) graminoids, with further separation here into grass and sedge components, (2) shrubs, (3) forbs. This analysis is presented in the following table.

Summary of Total Cover

	Graminoids	Grasses	Sedges	Shrubs	Forbs
Table IV	80	75	5	5	15
" V	60	58	2	20	20
" VI	70	68	2	7	23
" VII	70	60	10	5	25
" VIII	75	65	10	5	20
" IX	60	55	5	10	30
" X	50	25	25	15	35
" XI	50	35	15	20	30

This summary sets forth the data for seven areas (Tables IV to X) in approximate order of grazing pressure and serves therefore to show the corresponding major changes in the vegetational cover. The graminoids decrease from 80% to 50% while the forbs and shrubs increase from20% to 50%. The grasses decrease from 75% to 25% and the sedges increase from 2% to 25%. These results indicate that proportions of sedges,

as well as proportions of forbs and of shrubs may serve to indicate varying degrees of grazing intensity in native grassland. An earlier summary (page 66) shows the sedges principally associated with overgrazing in the region are Carex heliophila and C. obtusata.

Discussion

The grassland sites described in this thesis have been selected to show the harmful effects of man's activities upon them. In both regions the native grassland has been so disturbed that little of it presents a virgin or nearly virgin aspect, except certain relict areas which for various reasons have escaped modifying influences. In the main these changes have come as an indirect result of man's activities, in the form of overgrazing by livestock. Other causal factors include fire and cultivation. The areas of virgin grassland studied have become relicts by reason of their isolation from grazing animals, either because of topographic barriers or through the use of exclosures.

The usual effect of overgrazing a grassland community is a progressive decrease in abundance and vigor of the more palatable species of grasses, associated with a corresponding increase in unpalatable species of weeds and, sometimes shrubs. Such results have been reported by Clarke, Tisdale, and Skoglund (6); Moss and Campbell (12); Moss (11); and Tisdale (17).

The earlier stages of destruction through overgrazing of grassland are detected by various methods. One of these methods is by the use of indicators. This method lends itself readily to observation and reconnaissance, and for this reason is popular. However, warnings against the indiscriminate use of this procedure have been given by several investigators. Clarke, Tisdale, and Skoglund (6) advise that considerable caution be used in interpreting abundance of unpalatable species as indicative of overgrazing because of the strong influence of climatic fluctuations. The grazing history of the areas described in this thesis is well known, and is such that evidence of retrogression in the areas may be attributed to the effects of overgrazing rather than to climate.

The principal grasses of the virgin grasslands in the Peace River are Stipa spp. and Agropyron trachycaulum. These become greatly reduced in quantity in heavily grazed areas. At the same time, a less palatable grass, Danthonia intermedia, becomes the leading grass species. The total coverage of grasses is reduced from 66% to 38% while the sedge cover increases from 11% to 28% (page 43).

In southwestern Alberta the virgin grasslands consist mainly of two species of fescue. The taller species, Festuca scabrella, usually grows in huge bunches up to one foot in diameter. Growing in the spaces between these large tussocks are found the smaller bunches of Festuca idahoensis. This condition exists only under very light grazing. Increase in

grazing intensity results in decrease in size of the F. scabrella bunches. This reduction in size progresses with increasing grazing pressure until small tufts of F. scabrella result. This reduction in size of clumps of F. scabrella increases the area of bare ground which is apparently then invaded by forbs and shrubs and some less palatable species of grasses. Further overgrazing results in reduction in numbers of both species of fescue as well as a reduction in size of the F. idahoensis. Finally the rough fescue (F. scabrella) disappears and only small remnants of F. idahoensis occur. By this time certain other grasses, notably Danthonia spp. and Agropyron spp. have increased considerably.

Results of studies on grassland areas, contained in the summary on page 68, have been arranged to show the effects of progressively increased grazing pressure, beginning with the study of a virgin grassland reported in Table IV and ending with the greatly modified grassland reported in Table X. The grass cover ranges from a high of 75% (composed largely of the two highly palatable fescue species), to a low of 25% (composed largely of Agropyron spp. and containing no fescues). The shrubs and forbs meanwhile increase from a low of 20% to a high of 50%.

Accompanying these great changes in vegetative cover are increase in numbers of certain species of plants (among many others) which have come to be regarded as indicators of retrogression. The more important of these are Danthonia spp.,

Potentilla fruticosa and Artemisia frigida.

Potentilla fruticosa has not been reported from the Peace River area. Artemisia frigida is not reported in our studies of the nearly virgin grasslands of that region, but occurs in the heavily grazed area in even greater quantities than is indicated by the quadrat studies. Quadrat results in the first area (Table I) report D. intermedia as making up 4.5% of the cover. Studies in the second area, which is nearly virgin though subject to some winter grazing by horses, reports D. intermedia covering 21% of the area. The intensely grazed pasture area reported in Table III shows D. intermedia occupying 20.5% of the area. Probably the factor of winter grazing has a marked effect upon the amount of D. intermedia, which may explain the increase of its cover on the second area.

Danthonia spp., Artemisia frigida, and Potentilla fruticosa are reported in the studies of grassland areas in the Crowsnest Forest region. The results (Tables IV-XI) show that P. fruticosa makes up less than 1% of the total cover. Observations of other overgrazed grasslands in the region indicate that this shrub increases with heavy grazing. Moss and J. A. Campbell (12), in a study of Festuca scabrella grasslands, state that P. fruticosa increases with grazing. J. B. Campbell (3), in a study of grasslands of the Crowsnest Forest region, shows a definite increase in P. fruticosa in overgrazed areas. It seems therefore that P. fruticosa

may be regarded as an indicator of overgrazed condition in grasslands of this region. In the present investigation Danthonia spp. are shown (Tables IV - XI) to increase from less than 1% in the virgin grasslands (Table IV) to 10% in the overgrazed area (Table IX). Artemisia frigida also shows an increase from less than 1% in the virgin grasslands (Table IV) to 15% in the heavily overgrazed area (Table XI). From these results it seems that Danthonia spp. and A. frigida may also be regarded as indicators of overgrazed condition in grasslands of this region. This is in accord with the conclusions of earlier investigators in the region (3, 11, 12).

Results of studies of Peace River grasslands show that sedges increase from 11% in the virgin grassland (Table II) to 28% in the heavily grazed grassland (Table III). Results of studies of Crowsnest Forest grasslands show that sedges increase from 2% in the virgin grassland (Table IV) to 25% in the heavily grazed grassland (Table X). This increase in sedge cover begins to show at a very early stage of overgrazing and continues until the sedges make up nearly all of the available forage in a heavily grazed area.

It seems probable, from observations of the area reported in Tables X and XI, and from observations of other overgrazed areas in the region, that the reduced vegetative cover resulting from overgrazing may lead to an increase in erosion sufficient to cause an unstable soil condition. Reduction of the vegetative cover through overgrazing repre-

sents a retrogression towards a more primitive condition. Ramaley (15), in a study of the role of sedges in some Colorado plant communities, states that sedges exist chiefly in primitive communities or unstable soil situations. The conditions are the direct results of overgrazing and provide a favourable habitat for extension of sedge cover.

This increase in sedge cover may be further explained in terms of the reproductive features of the plants themselves. The sedges involved are mainly C. heliophila and C. obtusata, both of which begin growth very early in the season, and produce flowering stalks and seed much earlier than the grasses. Observations in early June showed that these sedges had ripened seed before extensive spring grazing of the grassland had taken place. In addition to early maturation of seed these sedges have another means of reproduction, namely long, fast-growing rhizomes that enable these plants to invade denuded areas and to compete effectively with other species.

The most important conclusions of this study of Alberta grasslands are: (1) that certain sedges, C. obtusata and C. heliophila, increase appreciably even under moderate grazing; (2) that these species may be used as indicators of slight grazing intensity, whereas, such commonly recognized indicator species as Potentilla fruticosa and

Artemisia frigida become useful only in advanced stages of overgrazing.

SUMMARY

The first part of this thesis deals with diagnostic features of grassland species of Carex. A table showing contrasting vegetative characters of sedges and grasses is presented. The morphology of the sedge leaf is discussed with special reference to the ligule and the anatomy of the leaf blade. Descriptions of twelve species of Carex include information on growth characteristics, features of their subterranean parts and occurrence in Alberta. A key for the identification of these twelve sedge species is presented. This key, based on external features of the leaves, crowns and underground organs, should prove useful in rangeland studies involving records of the herbage cover.

The second part of the thesis is concerned with ecological studies of the sedges. Records of detailed studies in two widely separated rangelands of Alberta are tabulated and summarized. A consideration of the amount and importance of sedge cover in relation to grasses and other leading species of the rangeland is directed towards contrasting the virgin or nearly virgin parts of grasslands with those subjected to varying intensities of grazing. The use of certain plants as indicators of overgrazed conditions is discussed. The following conclusions are drawn:

1. Retrogression due to overgrazing is commonly evidenced by a reduction in size and numbers of the leading,

more palatable, species and by an increase of the unpalatable ones.

2. Certain of these unpalatable species can be used as indicators of retrogression, but usually they become apparent only after the grassland has become severely depleted. Some of the more important of these indicator plants are Danthonia spp., Potentilla fruticosa, and Artemisia frigida.

3. Certain species of Carex extend rapidly in numbers and coverage with increased grazing pressure. This study discloses that these species may be used as indicators of early retrogression, well in advance of serious depletion of the rangeland through heavy grazing.

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APPENDIX

Grasses

Agropyron dasystachyum (Hook.) Scribn.

" Griffithsii Scribn. and Smith.

" spicatum (Pursh.) Scribn. and Smith.

" trachycaulum (Link) Malte.

Avena Hookeri Scribn.

Bromus anomalus Rupr.

" ciliatus L.

" carinatus Hook. and Arn. var. marginatus (Nees) Hitchc.

Calamagrostis inexpansa A. Gray.

" neglecta (Ehrh.) Gaertn.

" montanensis Scribn.

" Rubescens Buckl.

Danthonia intermedia Vasey.

" Parryi Scribn.

Elymus canadensis L.

" innovatus Beal.

Festuca idahoensis Elmer.

" saximontana Rydb.

" scabrella Torr.

Hierochloe odorata (L.) Beauv.

Koeleria cristate (L.) Pers.

Phleum alpinum L.

" pratense L.

Poa compressa L.

" interior Rydb.

" palustris L.

" pratensis L.

" secunda Presl.

Schizachne purpurascens (Torr.) Swallen.

Stipa columbiana Macoun.

" Richardsonii Link.

" spartea Trin. var. curtiseta Hitchc.

" viridula Trin.

Sedges

Carex abbreviata Prescott = C. Torreyi Tuckerm.

" Eleocharis L. H. Bailey = C. stenophylla Wahl.

" filifolia Nutt.

" heliophila Mack.

" microptera Mack.

" obtusata Lilj.

" phaeocephala Piper.

" praticola Rydb.

" Raynoldsii Dewey.

" siccata Dewey.

" umbellata Schkuhr.

" xerantica Bailey.

Forbs

Achillea Millefolium L.

Agoseris glauca (Nutt.) Greene.

Allium cernuum Roth.

Androsace puberulenta Rydb.

Anemone cylindrica A. Gray.

Anemone globosa Nutt.

Antennaria aprica Greene.

" campestris Rydb.

" concinna E. Nels.

" nitida Greene.

" pulcherrima (Hook.) Greene.

" rosea (D. C. Eat.) Greene.

Arabis divaricarpa A. Nels.

" hirsuta (L.) Scop. var. pycnocarpa (Hopkins) Rollins.

" Nuttallii Robinson.

Arnica Chamissonis Less.

Artemisia frigida Willd.

" gnaphalodes Nutt.

Aster adsurgens Greene.

" commutatus (T. and G.) A. Gray.

" laevis L.

Astragalus Drummondii Dougl.

" flexuosus Dougl.

" goniatus Nutt.

" striatus Nutt.

Balsamorrhiza sagittata (Pursh.) Nutt.

Campanula rotundifolia L.

Castilleja lutea Heller.

" lutescens (Greenm.) Rydb.

" rhexifolia Rydb.

Cerastium arvense L.

Cirsium Flodmanii (Rydb.) Arth.

" undulatum (Nutt.) Spreng.

Comandra pallida A. DC.

Delphinium bicolor Nutt.

Erigeron caespitosus Nutt.

" conspicuus Rydb.

" glabellus Nutt.

Epilobium angustifolium L.

Eriogonum flavum Nutt.

Erysimum parviflorum Nutt.

Fragaria glauca (S. Wats.) Rydb.

Gaillardia aristata Pursh.

Galium boreale L.

Gentiana acuta Michx.

" affinis Griseb.

" amarella L.

Geranium viscosissimum Fisch. and Mey.

Geum triflorum Pursh.

Hedysarum alpinum L.

" sulphurescens Rydb.

Helianthus subrhomboideus Rydb. = H. rigidus (Cass.) Desf.

Heuchera Richardsonii R. Br.

Hieracium canadense Michx.

" scabriusculum Schwein.

Juncus balticus Willd. var. montanus Engelm.

" Vaseyi Engelm.

Lappula Redowskii (Hornem.) Greene var. occidentalis (Wats.) Rydb.

Lathyrus ochroleucus Hook.

Lilium philadelphicum L. var. andinum (Nutt.) Ker.

Lithospermum ruderale Lehm.

Lupinus argenteus Pursh.

" leucopsis Agardh.

Lychnis Drummondii S. Wats.

Monarda menthaefolia Benth.

Orthocarpus luteus Nutt.

Oxytropis Macounii (Greene) Rydb.

" gracilis (A. Nels.) Jones.

" splendens Dougl.

Penstemon confertus Dougl.

" nitidus Dougl.

" procerus Dougl.

Potentilla arguta Pursh.

" gracilis Dougl. ssp. Nuttallii (Lehm.) Keck.

" pennsylvanica L.

" pulcherrima Lehm.

Pulsatilla ludoviciana (Nutt.) Heller.

Ranunculus cardiophyllus Hook.

" ovalis Raf.

Sedum stenopetalum Pursh.

Senecio canus Hook.

" cymbalarioides Nutt.

Smilacina stellata (L.)Desf.

Solidago decumbens Greene var. oreophila (Rydb.) Fern.

" glaberrima Martens.

" lepida D.C.

" missouriensis Nutt.

Stellaria longipes Goldie.

Taraxacum officinale Weber.

Thalictrum venulosum Trelease.

Valeriana septentrionalis Rydb.

Vicia americana Muhl.

" sparsifolia Nutt.

Viola adunca J. E. Smith.

" vallicola A. Nels.

Zizia aptera (Gray) Fern.

Zygadenus elegans Pursh.

" gramineus Rydb.

Trees and Shrubs

Abies lasiocarpa (Hook.) Nutt.

Amelanchier alnifolia Nutt.

Arctostaphylos uva-ursi (L.) Spreng.

Betula glandulosa Michz.

Elaeagnus argentea Pursh.

Juniperus horizontalis (Moench.) Rydb.

Juniperus sibirica Burgsd.

Pinus contorta Loud. var. latifolia Engelm.

Populus tremuloides Michx.

" trichocarpa T. and G.

Potentilla fruticosa L. = Dasiphora fruticosa (L.) Rydb.

Prunus demissa (Nutt.) Walp.

Ribes oxyacanthoides L. Mill.

" setosum Lindl.

Rosa acicularis Lindl.

" arkansana Porter.

" Woodsii Lindl.

Rubus strigosus Michx.

Shepherdia argentea Nutt.

" canadensis (L.) Nutt.

Spiraea alba. DuRoi.

Symphoricarpos occidentalis Hook.

" albus (L.) Blake. var. pauciflorus (Robbins) Blake.

Vaccinium caespitosum Michx.