



An ecological study of creeping juniper (*Juniperus horizontalis* Moench.) in Montana
by John Gage Miller

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE
in Fish and Wildlife Management
Montana State University
© Copyright by John Gage Miller (1978)

Abstract:

Various ecological characteristics and relationships for creeping juniper (*Juniperus horizontalis* Moench.) in Montana were determined through intensive studies in 30 widely separated juniper stands. Supplementary data were obtained from an additional 21 study sites. Creeping juniper was associated primarily with the mountain foothills of north-central, central and southcentral Montana, and the open prairies of eastern Montana. Ridges, rimrocks, escarpments and hilltops adjacent to a river or mountain range were typical areas of occurrence. Stands occurred more frequently on northerly exposures, slopes with gradients less than 40 percent, and at elevations below 1500 meters (4900 ft). Creeping juniper was the most important plant species in all stands, with mean canopy coverage of 32 percent. Graminoids were the most prominent plant associates, with Idaho fescue being the most common species. Trees typically were lacking. Eight creeping juniper "associations" were defined through simple ordination. Soils associated with creeping juniper stands appeared to be poorly developed with thin topsoils, large quantities of stone and exposed rock parent material, and some degree of surface erosion. They tended to be clay loam in texture, slightly basic ($\text{pH} = 7.2$), low to medium in organic matter content (4.6%), very low in phosphorus (18 ppm), medium to high in potassium (280 ppm) and low in salt hazard (.08 meq/100 gms soil). Creeping juniper plants averaged 6.4 cm in height, with 3.5 percent of the crown area dead. Most growth occurred horizontally on the peripheral branches or leaders. Annual twig growth commenced in early April, coincident with a crown color change from brown to green, and continued into September and possibly early October. The overall average terminal and lateral twig growth was 34.5 and 9.0 cm, respectively, during 1978. Longest twigs were produced in stands with northerly exposures and 13-14 inches of annual precipitation. Shortest twigs were produced in stands having a tree overstory. The "greening" of plants in early April coincided with staminate cone maturation. Once pistillate buds formed, berries generally formed and matured. Berry production peaked in mid summer (late June to early July). Ripening apparently requires 1-2 years after berries turn purple in late summer. Germination of seeds in the laboratory was very low (approximately 0.1%). Reproduction from seed also appeared to be a rare occurrence in the field where plants apparently are maintained vegetatively by rooting along branches. Plants producing the highest numbers of reproductive parts were associated with soils having relatively high phosphorus, moderate calcium and sodium levels and low salt hazard. Wildlife usage of creeping juniper included mule deer, small mammals and birds. Utilization by deer occurred mainly during the late winter and appeared to be influenced more by the distribution of deer, the relative availability and/or abundance of creeping juniper and the occurrence of other more preferred forage plants than by protein content. Data indicated that creeping juniper is subject to some damage and destruction by fire, though these effects may be less severe than reported for other species of juniper.

STATEMENT OF PERMISSION TO COPY

In presenting this thesis in partial fulfillment of the requirements for an advanced degree at Montana State University, I agree that the Library shall make it freely available for inspection. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by my major professor, or, in his absence, by the Director of Libraries. It is understood that any copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Signature

John D. Miller

Date

Feb 21, 1979

AN ECOLOGICAL STUDY OF CREEPING JUNIPER
(*Juniperus horizontalis* Moench.) IN MONTANA

by

JOHN GAGE MILLER

A thesis submitted in partial fulfillment
of the requirements for the degree

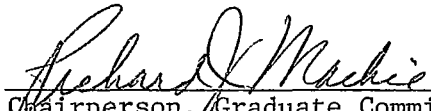
of

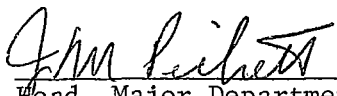
MASTER OF SCIENCE

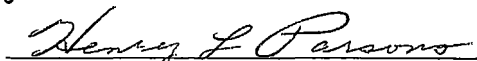
in

Fish and Wildlife Management

Approved:


Chairperson, Graduate Committee


Head, Major Department


Graduate Dean

MONTANA STATE UNIVERSITY
Bozeman, Montana

December, 1978

ACKNOWLEDGMENT

The author wishes to express his appreciation and gratitude to Dr. Richard J. Mackie, Montana State University, for his guidance and constructive criticism in the preparation of the manuscript; Dr. Theodore W. Weaver and Dr. Robert Eng, Montana State University, and Dr. Henry Jorgensen, Montana Department of Fish and Game, for critical reading of the manuscript and helpful suggestions for revisions; Dr. Richard Lund for assistance in preparation and interpretation of computer programs; Terry Lonner, Montana Department of Fish and Game, for assistance in setting up computer programs; Dr. John Rumely, Montana State University, for aid in identification of plant specimens; John McCarthy, Ken Hamlin and Bert Goodman, Montana Department of Fish and Game for assistance during the study; personnel of the Montana State University Seed Laboratory for aid during germination experiments; Forest Service personnel for assistance during distribution surveys; the private landowners who allowed me to establish study sites on their land; Mr. Larry Keown, Forest Service, for assistance during burn experiments; and to my wife, Connie, and mother, Edith, for assistance in typing and preparation of the manuscript. The study was supported by the Montana Department of Fish and Game under Federal Aid Projects W-120-R and W-130-R.

TABLE OF CONTENTS

	Page
VITA	ii
ACKNOWLEDGMENT	iii
LIST OF TABLES	v
LIST OF FIGURES	vii
ABSTRACT	x
INTRODUCTION	1
METHODS	4
RESULTS AND DISCUSSION	13
Distribution	13
Geographic	13
Physiographic	15
Phytosociological Characteristics	24
Community Associations	24
Environmental Attributes of the Eight Associations	35
Vegetational Composition of Creeping Juniper Associations	39
Edaphic Characteristics and Relationships	55
Growth Characteristics and Relationships	65
Growth Form	65
Annual Chronology and Twig Growth	70
Reproductive Characteristics and Relationships	81
Forage Characteristics and Utilization by Wildlife	89
Nutritional Characteristics	89
Available Forage Biomass	92
Utilization by Wildlife	93
Effects of Fire on Creeping Juniper	99
Stanford Burn	100
Sun River Burn	103
Discussion of Fire Effects	104
CONCLUSIONS AND RECOMMENDATIONS	107
LITERATURE CITED	110
APPENDIX	117

LIST OF TABLES

Table	Page
1. Distribution of 51 creeping juniper study sites among various exposures, slope gradients and elevations.	23
2. Constancy, canopy coverage and frequency of low growing taxa for the eight creeping juniper associations as determined by examination of 2 X 5 decimeter plots on each area	41
3. Constancy, canopy coverage and density of three trees on each of the eight creeping juniper associations	54
4. Edaphic characteristics of creeping juniper associations including pH, organic matter content, texture, salt hazard, soil depth, erosion and 5 important elements	56
5. Comparison of six soil factors from samples taken from under and between creeping juniper shrubs.	64
6. Height, decadence, biomass, and lateral and terminal growth of shrubs in eight creeping juniper associations, east of the Continental Divide	68
7. Reproductive characteristics of creeping juniper in Montana, and statistical comparisons among plants of eight juniper associations	85
8. Percentages of crude protein of creeping juniper plants for 12 study sites during one year, 1976 to 1977	89
9. Comparison of spring (April, May, June) precipitation at 12 creeping juniper sites between 1976 and 1977	90
10. Percent of creeping juniper twigs utilized by small mammals during the summer of 1977 on the 30 study sites.	95
11. Crown area and height of 21 creeping juniper plants within the Stanford experimental burn together with percent crown burned, post-fire fate of plants, temperatures of fire and fine fuel and soil moistures of the area	102

Table	Page
12. Comparison of the effects of fire on creeping juniper shrubs between the Sun River Game Range and Stanford experimental burns.	105
13. General and exact locations of the 51 creeping juniper study sites	118
14. Exposure, slope, elevation and drainage of 51 creeping juniper sites in Montana.	120
15. Scientific and common names of the 24 graminoids, 104 forbs, 18 shrubs and 3 trees in this study.	122
16. Percent canopy coverage and percent frequency among 2 x 5 plot frames for the 30 intensively studied creeping juniper sites	129
17. Edaphic characteristics of 51 creeping juniper sites including pH, organic matter content, texture, salt hazard, soil depth, erosion and 5 important elements. . .	153

LIST OF FIGURES

Figure	Page
1. Population trends of creeping juniper on 12 condition trend transects established by the Montana Department of Fish and Game along the east slope of the Continental Divide	2
2. Study areas showing the approximate locations of 51 study sites.	5
3. General distribution of creeping juniper in Montana. . . .	14
4. Site 1 on an alluvial plain near Barr Creek on the Sun River Game Range, Lewis and Clark County; <i>Juniperus-Festuca</i> important cover.	16
5. Site 3 near Haystack Butte southwest of Augusta, Lewis and Clark County; <i>Juniperus-Festuca</i> important cover. . . .	16
6. Site 14 near Sage Creek east of Denton, Fergus County; <i>Juniperus-Rhus-Stipa</i> important cover	17
7. Site 15 on edge of a <i>Pinus ponderosa</i> community south of Warhorse Reservoir, Petroleum County; <i>Juniperus-Calamovilfa</i> important cover.	17
8. Site 16 on an open prairie south of Warhorse Reservoir, Petroleum County, showing high degree of erosion; <i>Juniperus-Agropyron</i> important cover.	18
9. Site 19 in the foothills of the Big Snowy Mountains, Fergus County; <i>Juniperus-Potentilla-Festuca</i> important cover.	18
10. Site 21 in the foothills of the Little Belt Mountains, Wheatland County; near a <i>Pinus flexilis</i> — <i>Pinus ponderosa</i> community; <i>Juniperus-Festuca</i> important cover	19
11. Site 25 in an Absarokee mountain meadow near a community of <i>Pinus flexilis</i> and <i>Pseudotsuga menziesii</i> , Stillwater County, <i>Juniperus</i> and a variety of forbs important cover. .	19
12. Site 26 on an eastern Montana prairie, northwest of Terry, Prairie County; <i>Juniperus-Carex</i> important cover . .	20

Figure	Page
13. Site 27 on an eastern Montana prairie/foothill area northwest of Terry, Prairie County; <i>Juniperus-Andropogon</i> important cover.	20
14. Site 32 on the west side of the Continental Divide, east of Lincoln, Lewis and Clark County; under a stand of <i>Pinus contorta</i> and <i>Pseudotsuga menziesii</i> ; <i>Arctostaphylos-Agropyron-Juniperus</i> important understory cover.	21
15. Site 37 under a stand of <i>Pinus ponderosa</i> north of Ryegate in the Little Snowy Mountains, Golden Valley County; <i>Juniperus horizontalis</i> and <i>scopulorum</i> important understory cover.	21
16. Site 42 under a stand of <i>Pinus ponderosa</i> northwest of Broadus, Powder River County; <i>Juniperus-Stipa</i> important understory cover.	22
17. A simple ordination of 30 creeping juniper stands based on total vegetal composition, in two dimensions (X-Y axes)	29
18. The same ordination as Figure 17 only on a larger scale	30
19. A simple ordination of the 30 creeping juniper stands showing the X-Z (top) and Y-Z (bottom) axes	32
20. Soil depth (top) and percent frequency of stone (bottom) of soils in each of 30 creeping juniper stands plotted on the X-Y axes based upon the ordination in Figure 18.	37
21. Percent soil surface eroded (top) and percent bareground cover (bottom) of soils of 30 creeping juniper stands plotted on the X-Y axes based upon the ordination in Figure 18	38
22. Elevations in meters of 30 creeping juniper stands plotted on the X-Y axes based upon the ordination in Figure 18	40
23. Annual chronology of creeping juniper in stands east of the Continental Divide as determined by spring, summer and fall observations	71

Figure	Page
24. Growth curves of lateral (L) and terminal (T) twigs on creeping juniper shrubs in eight juniper associations as determined by the mean length of 15 terminal and 60 lateral twigs per site in 1977. a. <i>Juniperus-Potentilla-Festuca</i> association--sites 19, 20, 22, 25	73
24. Continued, b. <i>Juniperus-Agropyron</i> association--sites 2, 3, 5, 17.	74
24. Continued, c. <i>Pinus-Juniperus-Festuca</i> association--sites 6, 7, 8, 31	75
24. Continued, d. <i>Juniperus-Potentilla-Carex</i> association--sites 11, 12, 18.	76
24. Continued, e. <i>Juniperus-Calamovilfa</i> association--sites 15, 16, 26, 28, 29.	77
24. Continued, f. (top) <i>Juniperus-Rhus-Stipa</i> association--sites 13, 14 and 24g. (bottom) <i>Juniperus-Helictotrichon</i> association--sites 10, 30	78
24. Continued, h. <i>Juniperus-Andropogon-Festuca</i> association--sites 1, 9, 27.	79
24. Continued, i. Non-clustered sites--sites 4, 21, 23	80

ABSTRACT

Various ecological characteristics and relationships for creeping juniper (*Juniperus horizontalis* Moench.) in Montana were determined through intensive studies in 30 widely separated juniper stands. Supplementary data were obtained from an additional 21 study sites. Creeping juniper was associated primarily with the mountain foothills of north-central, central and southcentral Montana, and the open prairies of eastern Montana. Ridges, rimrocks, escarpments and hilltops adjacent to a river or mountain range were typical areas of occurrence. Stands occurred more frequently on northerly exposures, slopes with gradients less than 40 percent, and at elevations below 1500 meters (4900 ft). Creeping juniper was the most important plant species in all stands, with mean canopy coverage of 32 percent. Graminoids were the most prominent plant associates, with Idaho fescue being the most common species. Trees typically were lacking. Eight creeping juniper "associations" were defined through simple ordination. Soils associated with creeping juniper stands appeared to be poorly developed with thin topsoils, large quantities of stone and exposed rock parent material, and some degree of surface erosion. They tended to be clay loam in texture, slightly basic (pH=7.2), low to medium in organic matter content (4.6%), very low in phosphorus (18 ppm), medium to high in potassium (280 ppm) and low in salt hazard (.08 meq/100 gms soil). Creeping juniper plants averaged 6.4 cm in height, with 3.5 percent of the crown area dead. Most growth occurred horizontally on the peripheral branches or leaders. Annual twig growth commenced in early April, coincident with a crown color change from brown to green, and continued into September and possibly early October. The overall average terminal and lateral twig growth was 34.5 and 9.0 cm, respectively, during 1978. Longest twigs were produced in stands with northerly exposures and 13-14 inches of annual precipitation. Shortest twigs were produced in stands having a tree overstory. The "greening" of plants in early April coincided with staminate cone maturation. Once pistillate buds formed, berries generally formed and matured. Berry production peaked in mid summer (late June to early July). Ripening apparently requires 1-2 years after berries turn purple in late summer. Germination of seeds in the laboratory was very low (approximately 0.1%). Reproduction from seed also appeared to be a rare occurrence in the field where plants apparently are maintained vegetatively by rooting along branches. Plants producing the highest numbers of reproductive parts were associated with soils having relatively high phosphorus, moderate calcium and sodium levels and low salt hazard. Wildlife usage of creeping juniper included mule deer, small mammals and birds. Utilization by deer occurred mainly during the late winter and appeared to be influenced more by the distribution of deer, the relative availability and/or abundance of creeping juniper and the occurrence of other more preferred forage plants than by protein content. Data indicated that creeping juniper is subject to some damage and destruction by fire, though these effects may be less severe than reported for other species of juniper.

INTRODUCTION

Creeping juniper, *Juniperus horizontalis* Moench., occurs extensively on mountain foothill and prairie-plains habitat in Montana east of the Continental Divide. In many areas, it serves as an important source of forage for mule deer, especially during winter (Lovaas 1957, Kamps 1969, Eustace 1971, Dusek 1971, Hamlin 1976). Coverage measurements for creeping juniper on 12 condition-trend transects, established by the Montana Department of Fish and Game on foothill winter ranges along the eastern fringe of the Rocky Mountains, show a general decline in the occurrence of mature juniper during the past 20 years (Fig. 1).

Little is known as yet about the ecology of creeping juniper. Previous studies have been concerned mainly with diseases (Brener et al. 1974, Nemec 1968), chromosomal biology (Evans 1971, Evans and Rasmussen 1972, 1974), ornamental value (Lamphear 1966), chemistry (Couchman 1965), morphology (Bifoss 1947), associated insects (Bradley 1963, Nemec 1972), and hybridization (Fassett 1944a, 1944b, 1945a, 1945b, 1945c, Ross 1949). The lack of ecological information has hampered interpretation of possible interrelationships between the occurrence of creeping juniper and mule deer.

This study was established in the spring of 1975 to obtain basic ecological data for creeping juniper in Montana. Specific objectives include: (1) to determine the natural distribution and associated

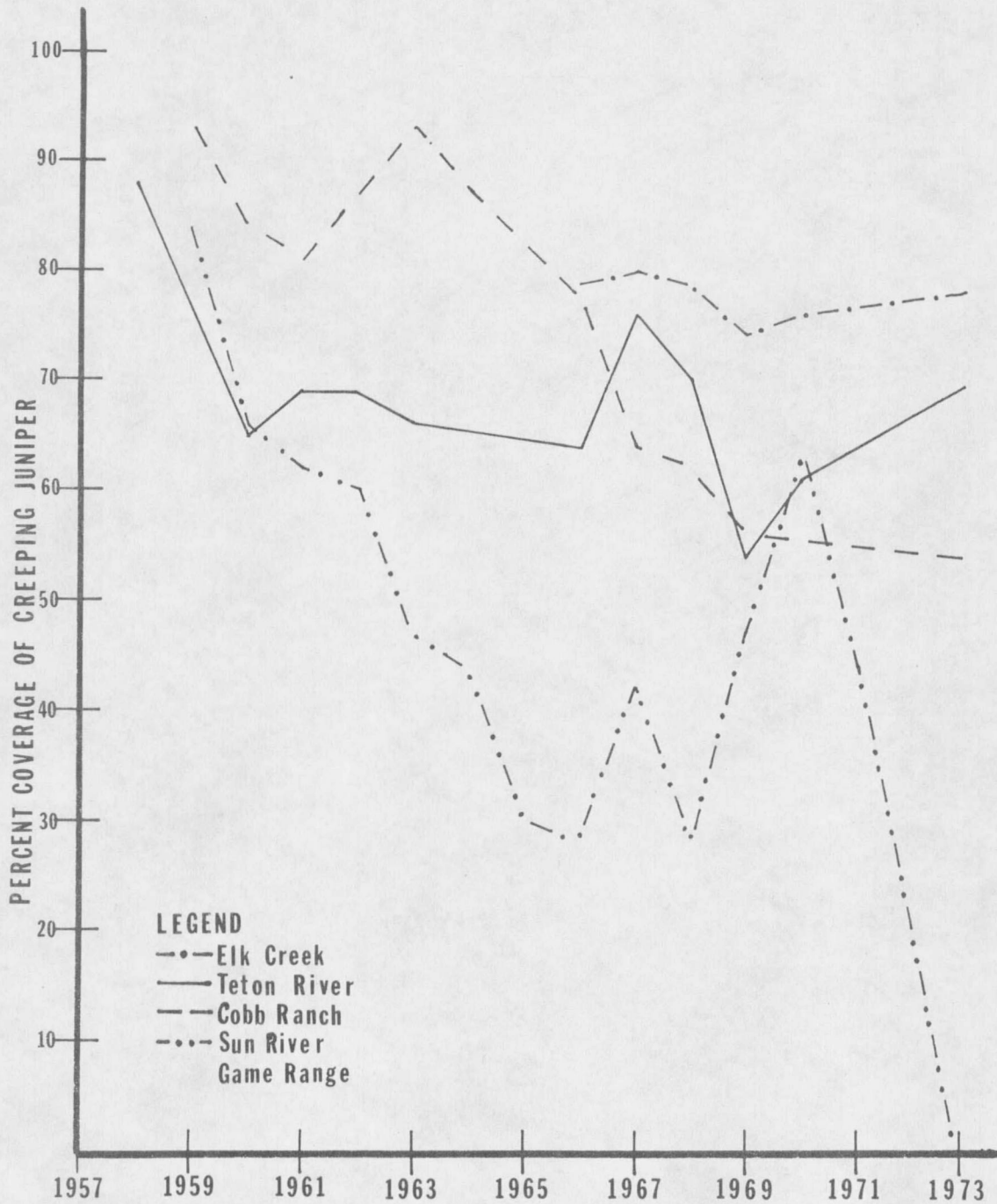


Figure 1. Population trends of creeping juniper on 12 condition trend transects established by the Montana Department of Fish and Game along the east slope of the Continental Divide.

edaphic and climatological characteristics; (2) to determine community relationships, phytosociology, and animal use relationships; and (3) to determine plant characteristics such as reproduction, growth and development, forage biomass, production indices, fire influences, and nutritional aspects and, to relate these to environmental conditions.

Field investigations were conducted primarily during the summers of 1975 and 1976 and in the spring and summer of 1977. Supplemental data were obtained in periodic field studies during the autumn and winter of 1976 and 1977.

METHODS

The natural distribution of creeping juniper in Montana was ascertained by ground reconnaissance throughout the State. Montana Department of Fish and Game range survey records and personal contacts with Department of Fish and Game and U. S. Forest Service personnel along with general publications as Little (1971) provided additional information.

Following the general distributional surveys, 30 sites representing an array of plant communities and physiographic situations (slopes, exposures, elevation, etc.) in which creeping juniper was observed to occur were selected for intensive investigation (Fig. 2). Additional basis for site selection were (1) a general and relative lack of major disturbance and (2) a history of importance for use by mule deer during winter. An additional 21 similarly selected sites were visited during the study to obtain supplementary data on edaphic and physiographic characteristics of creeping juniper stands. Locations of all sites are presented in Appendix Tables 13 and 14.

Generally, all study sites were located in northcentral, east-central and southcentral Montana. A majority (39 or 76 percent) were in areas currently grazed by domestic livestock. Two (4 percent) were situated in game exclosures on previously grazed sites. Two others were located in recreation areas and three (6 percent) were on big game winter range from which livestock grazing had been removed for at least

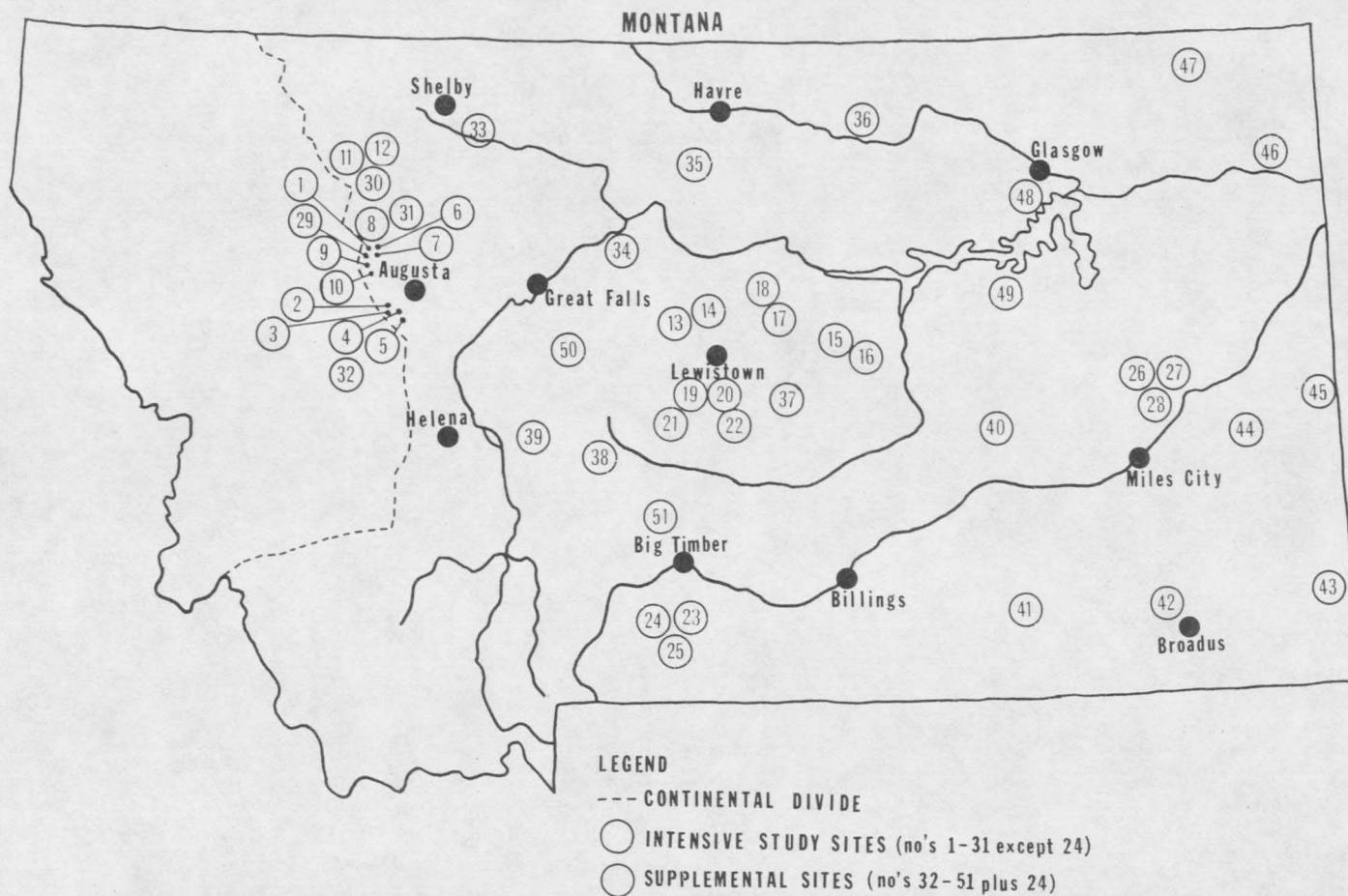


Figure 2. Study areas showing the approximate locations of 51 study sites.

twenty years. Five (10 percent) were within areas fenced for croplands which were ungrazed at the present time and may represent relict areas.

Slope, exposure, elevation and exact location were determined for each study site. Slope was estimated to the nearest five percent using a pocket transit. Exposure was recorded from compass readings along the fall-line of the slope. Elevation was determined using a simple pocket altimeter.

Within each of the 30 intensively studied stands, a 30.3 meters (100 ft) x 12.1 meters (40 ft) macro-plot was established. Sampling was conducted in the macro-plot along three permanent 30.3 meters (100 ft) transects spaced 6.1 meters (20 ft) apart along the contour of the slope. Canopy cover of low-growing vegetation was recorded following the method of Daubenmire (1959) within 2 x 5 dm plot frames spaced 3.1 meters (10 ft) apart along the three, 30.3 meters (100 ft) lines. The cover of each plant species as well as bare ground, rock and litter was recorded visually by class as follows: (1) 0 - 1 percent; (2) 1 - 5 percent; (3) 5 - 25 percent; (4) 25 - 50 percent; (5) 50 - 75 percent; (6) 75 - 95 percent; and (7) 95 - 100 percent. Measurements were made in early June. Common and scientific names of plants follow Booth and Wright (1958), Hahn (1973), and Hitchcock and Cronquist (1973). When creeping juniper was encountered in the frames, the sex of the plant and an estimate of the crown decadence within the plot were also recorded.

Where they occurred, trees and taller shrubs were sampled separately using a line intercept method. Three 30.3 meters (100 ft) lines were established: one located 24.2 meters (80 ft) upslope from the upper permanent transect line, one along the center transect line, and one 24.2 meters (80 ft) downslope from the lower transect line. Crown intercept was recorded to the nearest 0.3 meters (1.0 ft) along each line. On sites where few trees or tall shrubs occurred, all trees within a 60.6 meters (200 ft) x 60.6 meters (200 ft) plot at each site were measured as to species, crown diameter (mean of major and minor axes) to the nearest decimeter, percent of total crown dead, and percent live crown within an imaginary circle around the outer edge of the plant.

For data analyses, study sites were grouped on the basis of vegetational characteristics using a simple multidimensional ordination technique described by Bray and Curtis (1957) and modified by Beals (1960) and Orloci (1966). The ordination technique assumes that the compositional similarity between different stands can be used as comparative distances within a spatial model. The phytosociologic distances are based on a similarity index with 0 percent being completely dissimilar and 100 percent, theoretically, total similarity. The Spatz similarity index (Mueller-Dombois and Ellenberg 1974) was used to compare sites on the basis of (1) the number of plant species common to both sites and (2) the number of species present at each site. Data used in the

analyses were frequencies of occurrence of 84 low-growing species on study sites during June 1977. When indices were calculated for each two sites, the two most dissimilar sites became the reference points for the X-axis. A third site which was most distant from the X-axis (line A-B) became the third reference point for the X-Y plane. Finally a fourth site, chosen on its distance from (dissimilarity) the X-Y plane, became the fourth reference point for the X-Y-Z solid (third dimension). An X, Y, and Z coordinate was then calculated for each site using geometric formulae and the similarity indices. All sites were plotted first on X-axis, then on the X-Y plane, and finally on the X-Y-Z solid. Clusters of similar vegetation (associations) became apparent in this figure.

Two soil samples were obtained from each of the 30 intensive study sites. One of these was a composite of 10 subsamples from soil to a depth of 10 cm beneath creeping juniper plants; the other a similar composite of 10 subsamples from interspaces. One composite soil sample was taken within each of the 21 supplemental sites. Analyses were completed by the Montana State University Soils Testing Laboratory and included hand texture analysis, salt hazard, sodium, calcium, magnesium, potassium, phosphorus, and organic matter content, and pH. Depth to bedrock or parent material at each site was recorded as the mean of measurements with a sharply pointed (1.5 cm diameter) stake at 10 randomly located points at each site. An index of soil

surface erosion at both intensive and secondary study sites was obtained by visually estimating the overall percentage of surface eroded at each site by class as follows: Class 1 = less than 5 percent; Class 2 = 5-25 percent; Class 3 = 25-50 percent; Class 4 = 50-75 percent; and Class 5 = 75-100 percent. Wind and water erosion were not differentiated. Edaphic characteristics were compared statistically among the eight creeping juniper associations identified by ordination. In addition, the possible influences of each of the soil factors on frequencies of occurrence and canopy coverage values for each of 17 graminoids (grasses and grass-like plants), 39 forbs, 9 shrubs and 2 trees among study sites were evaluated by multiple regression.

Growth and reproductive characteristics of creeping juniper plants were measured during the spring and summer of 1977. Before the onset of growth, 15 major branches or "leaders" were tagged on each of 3 randomly selected plants at each study site. Leaders were marked with India ink on two year old or older growth, and the distances from the marks to the tips of leaders were measured to the nearest millimeter. Remeasurements were made at two-week intervals until growth ceased. Four lateral twigs were similarly marked and measured on each of the 15 leaders.

Standing crop of creeping juniper was estimated from the average air-dried weight of plant material, including needles, twigs

and new foliage growth clipped from ten, 2 x 5 dm frames per site.

Average plant heights to the nearest 0.5 cm was determined as the mean of 10 measurements at each site.

When growth had nearly ceased and "berries" were maturing, numbers of new pistillate (female) buds, old pistillate buds, new staminate cones, new "berries" and ripe "berries" were recorded at each site for each of 10 twigs on each marked leader for male and female plants respectively. Supplemental data were obtained by recording the same characteristics within 10 randomly placed 2 x 5 dm plot frames at each site.

General phenological data were recorded for each study site at approximately two-week intervals. These included brownness-greenness of foliage throughout the year, initiation and termination of growth, staminate cone formation, maturation and time of shedding, pistillate bud and berry formation, berry maturation and pollen shedding.

To evaluate reproductive potential from seeds, juniper berries were collected at 20 locations. Sufficient berries were collected to provide about 500 seeds per location (based on an average of 4 seeds per berry). Because juniper berries may not ripen for at least 1 - 2 years after they turn purple and drop (U. S. Dept. Agric. 1948), only berries found on the ground under plant crowns and which, by their pulpy exterior coat, were believed to be more than one year old were collected. Germination procedures followed those outlined for Rocky

Mountain juniper (U. S. Dept. Agric. 1948). Minor modifications included stratification of seeds for 125 days at 4° C and a germination period of six weeks at 12° C.

To determine nutritional value, samples of leaf-stem materials were collected at three month intervals from August 1976 through August 1977. Composite samples were clipped from a randomly selected plant at each of 12 study sites. In August 1977, samples from two additional plants per site were obtained. Samples were returned to the laboratory, air dried and ground using a Wiley Mill with 20 mesh screen. Ground samples were oven dried at 80° C for 48 hours and analyzed for protein content by the Montana State University Chemistry Station.

During the course of the study, incidental observations of twig use by small mammals and disease occurrence were made.

Observations on the effects of fire on creeping juniper were made at two locations during the spring and summer of 1977.

One area, located in the Blacktail Hills area of the Little Belt Mountains south of Stanford, Montana, had been subjected to controlled burning under experiments conducted by Mr. Larry Keown of the U. S. Forest Service, Stanford Ranger District. Here, three adjacent plots, each 100 m² were burned at different intensities (high, moderate and light) based upon temperature and rate of spread. Prior to the fire within each plot, seven juniper plants were randomly

selected, and major and minor axes, and height of each were recorded to the nearest 1.0 cm. Soil and fuel moisture samples were taken and pyrometers were positioned adjacent to each shrub. Following the burn the fate and regrowth characteristics of each plant were monitored visually during the summer of 1977. Information recorded included percent foliage burned and evidences of regrowth. Total air-dried weight of regrowth was recorded at the end of the growing season.

The second area, located on the Sun River Game Range west of Augusta, included a single 30.3 m^2 (100 ft^2) burn plot and a control plot of equal size.

Prior to burning, soil and fuel moisture samples were taken and pyrometers positioned at 6 locations within the burn-plot. Two 30.3 m^2 (100 ft^2) line transects were established, one in the burn-plot and one in the control. Occurrence of litter, live and/or dead grass, forb or shrub, or bare ground was recorded at 0.3 meters (1 ft) intervals along each transect.

RESULTS AND DISCUSSION

Distribution

Geographic

Juniperus horizontalis Moench. is one of about 60 species of evergreen shrubs and trees included in the genus *Juniperus*. Members of this genus occur in the middle and lower latitudes of the northern hemisphere in North America, the West Indies, Canary Islands, northern and eastern Africa and southeast Asia. Fifteen species are native to the United States. Of these 13 species are found in the western United States, and four are native to Montana. These include common juniper (*Juniperus communis*) and Utah juniper (*Juniperus osteosperma*), both shrubs occurring primarily in mountainous regions, Rocky Mountain juniper (*Juniperus scopulorum*), a tree-like form, occurring throughout the state, and creeping juniper, a very low shrub found primarily in mountain foothills and open prairies.

The center of distribution of creeping juniper in North America is in central Canada; the species occurs across the entire country in vast stands (Little 1971). In the northern United States it occurs from the east coast to the Rocky Mountains, primarily in scattered, local populations.

Within Montana, creeping juniper can be found in nearly every county east of the Continental Divide (Fig. 3). The most extensive stands occur along the Missouri River upstream to Fort Benton; along

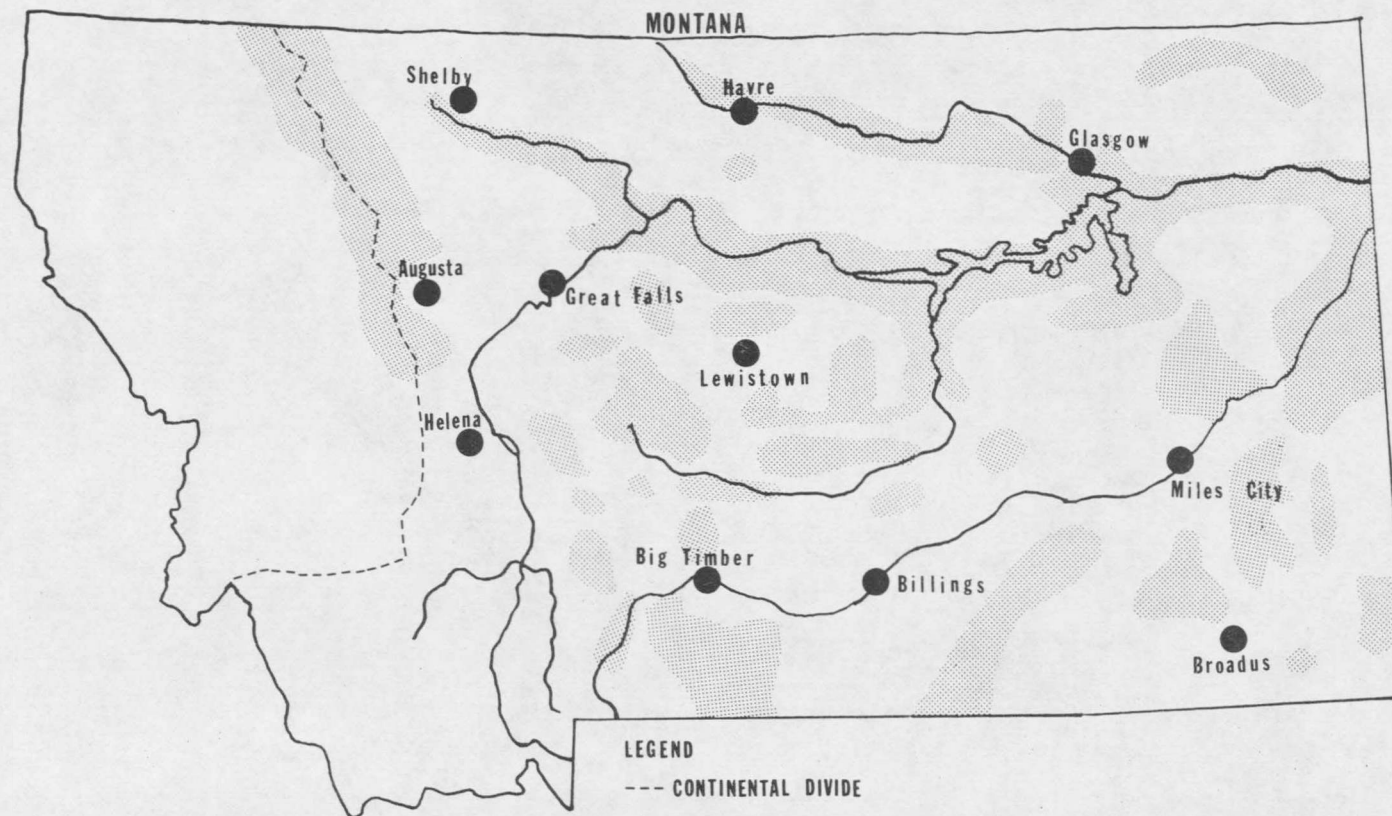


Figure 3. General distribution of creeping juniper in Montana.

the Milk River upstream to the Canadian border; in foothills along the east face of the Continental Divide from Glacier Park south to Wolf Creek; and throughout the foothills of the Snowy Mountains, Judith Mountains, and eastern portions of the Little Belt Mountains. Scattered local populations are found in far eastern Montana; and in the Beartooth-Absarokee Mountains south of Big Timber and west of Red Lodge.

Areas where creeping juniper was common were generally characterized by rough "breaks" and ridges adjacent to a river or mountain range. Ridges, rimrocks, hilltops and interstream divides were common landscapes supporting juniper communities; typically, however, juniper was restricted to the upper portions of these areas.

Physiographic

Creeping juniper is found in a wide variety of physiographic and physiognomic situations in Montana (Figs. 4 to 16). Study site elevations ranged from 2150 to 8200 feet; the average was 1326 ± 113 meters (4375 ± 373 feet). A majority of the sites (60 percent) were below 1500 meters (4900 feet) (Table 1). Slope gradients varied from 4.5 percent to 53.5 percent with a mean of 25.6 ± 4.0 percent; however, most of the sites were on slopes of less than 40 percent. All aspects or exposures were represented. Eight sites (15%) were ENE, 8 were SSE, 9 (18%) were NNE, 6 (12%) were WSW, 10 (20%) were NNW, 2 (4%) were WNW, 3 (6%) were SSW, 4 (8%) were ESE, and 1 (2%) faced south.



Figure 4. Site 1 on an alluvial plain near Barr Creek on the Sun River Game Range, Lewis and Clark County. *Juniperus-Festuca* dominant cover.



Figure 5. Site 3 near Haystack Butte southwest of Augusta, Lewis and Clark County. *Juniperus-Festuca* dominant cover.



Figure 6. Site 14 near Sage Creek east of Denton, Fergus County. *Juniperus-Rhus-Stipa* dominant cover.



Figure 7. Site 15 on edge of a *Pinus ponderosa* community south of Warhorse Reservoir, Petroleum County. *Juniperus-Calamovilfa* dominant cover.

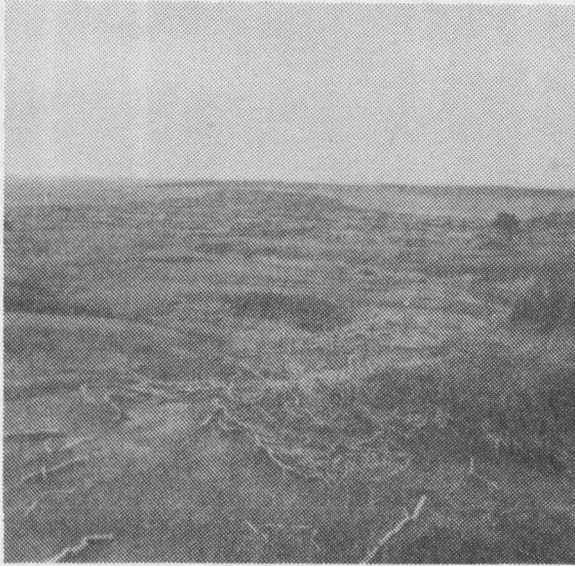


Figure 8. Site 16 on an open prairie south of Warhorse Reservoir, Petroleum County. *Juniperus-Agropyron* dominant cover.



Figure 9. Site 19 in foothills of the Big Snowy Mountains, Northside, Fergus County. *Potentilla-Festuca* dominant cover.

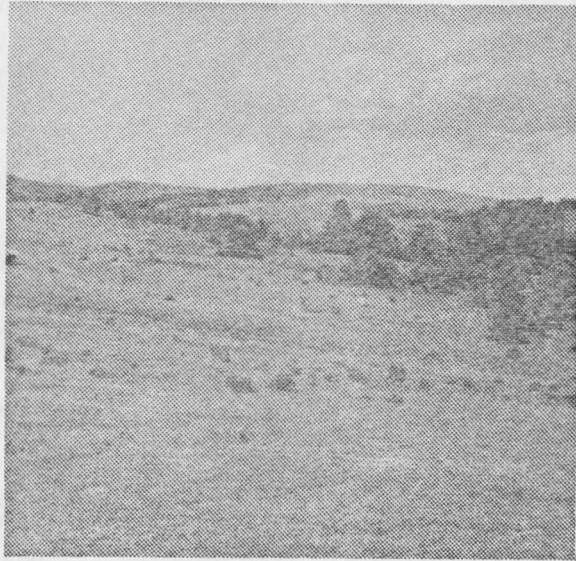


Figure 10. Site 21 in the foothills of the Little Belt Mountains, Southside, Wheatland County. Near a *Pinus flexilis* — *Pinus ponderosa* community; *Juniperus*-*Koeleria*-*Festuca* dominant cover.

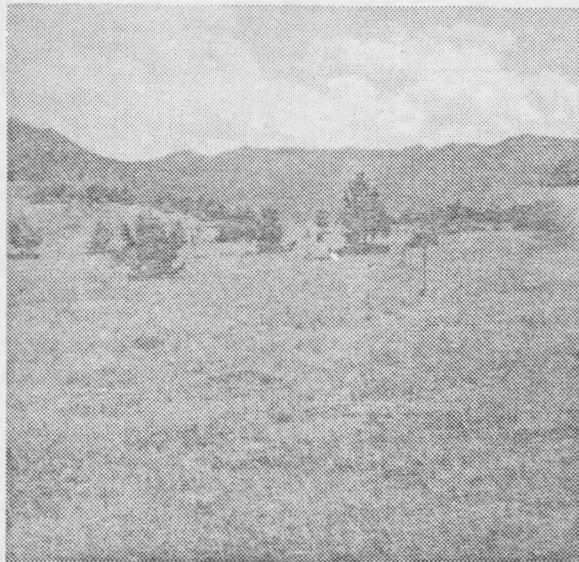


Figure 11. Site 25 in an Absarokee mountain meadow, Stillwater County. Near a community of *Pinus flexilis* and *Pseudotsuga menziesii*; *Juniperus*-variety of forbs such as *Zygodenus* and *Anemone* dominant cover.

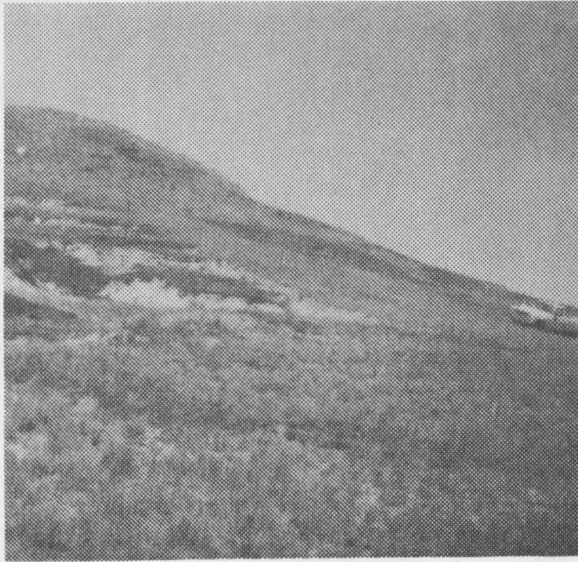


Figure 12. Site 26 on an eastern Montana prairie northwest of Terry, Prairie County. *Juniperus-Carex* dominant cover.

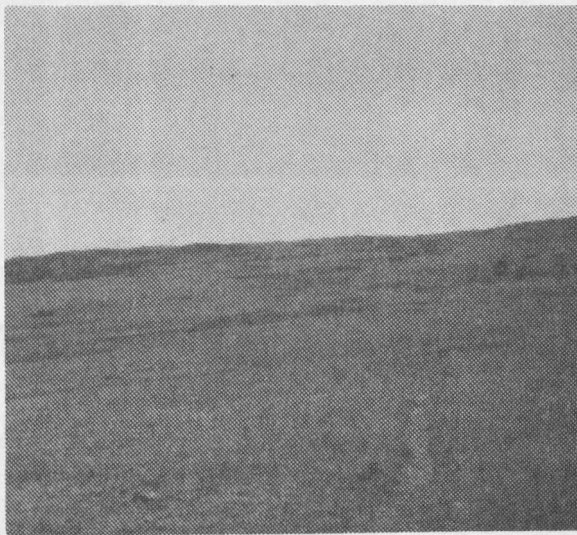


Figure 13. Site 27 on an eastern Montana prairie/foothill area northwest of Terry, Prairie County. *Juniperus-Andropogon* dominant cover.



Figure 14. Site 32 on the West side of the Continental Divide east of Lincoln, Lincoln County, under a stand of *Pinus contorta* and *Pseudotsuga menziesii*. *Arctostaphylos*-*Agropyron* dominant understory cover.



Figure 15. Site 37 under a stand of *Pinus ponderosa* north of Ryegate in the Little Snowy Mountains, Golden Valley County. *Juniperus horizontalis* and *scopulorum* dominant understory cover.

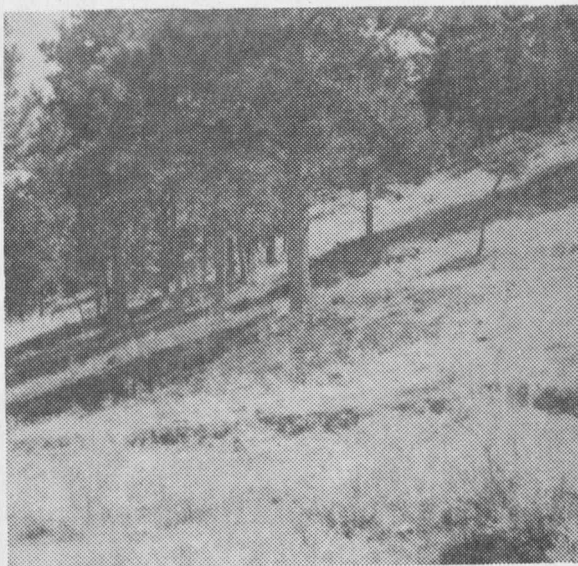


Figure 16. Site 42 under a stand of *Pinus ponderosa* northwest of Broadus, Powder River County. *Juniperus-Stipa* dominant understory cover.

Slope gradient, exposure, and elevation of individual study sites are given in Appendix Table 14.

Table 1. Distribution of 51 creeping juniper study sites among various exposures, slope gradients and elevations.

Physiographic Categories	Number of Stands	Percent
<u>Exposure (Azimuth Degrees)</u>		
NE 1-90	16	31
NW 271-360	13	26
SE 91-180	15	29
SW 181-270	7	14
N 271-90	29	57
S 91-270	22	43
E 1-180	28	55
W 180-360	23	45
<u>Slope Gradient (percent)</u>		
Less than 40	42	82
More than 40	9	18
<u>Elevation (feet)</u>		
Less than 4900	30	60
4900-5500	11	22
More than 5500	9	18

Creeping juniper appeared to be largely absent from three major regions of the state. These included all of Montana west of the Continental Divide with the exception of three areas (one near Rogers Pass, one near Red Mountain north of Lincoln, and one near Marias Pass); southwestern Montana; and a region along the Yellowstone River between

Columbus and Miles City (Fig. 3). These areas were typified either by mountains, in western and southwestern Montana, with dense forests and high precipitation, or flat grazing and farm-lands with deep and/or gravelly soils.

Phytosociological Characteristics

Community Associations

Because of its wide geographic range, creeping juniper occurs in numerous vegetational communities or associations along with a diverse array of plant species. However, most vegetational studies involving creeping juniper have been conducted along the southern border of its range.

Breitung (1954) included creeping juniper as part of the shrub component of mixed-grass prairie vegetation (*Agropyron-Stipa* association) characteristic of the eastern edge of the Cypress Hills in southeastern Alberta and southwestern Saskatchewan. This vegetation type, which occurred at 900-1200 meters (3,000-4,000 ft) elevation, was dominated by mixed grass species characteristic of the Canadian prairie. He also noted creeping juniper occasionally occurring on dry exposed hillsides 1200-1500 meters (4,000 and 5,000 ft) elevation.

In Montana, creeping juniper is important in two of the 22 vegetational types delineated by the Montana Agricultural Experiment Station (1973). These include the Badlands Grassland in eastern Montana and the Northeastern Grassland of northeast Montana. It also

occurs in the Foothill Grassland type, the Lodgepole Pine-Douglas Fir Forest type west of the Continental Divide, the Ponderosa Pine Savannah, the Missouri Breaks Scrub-Pine, the Northern Grasslands, and locally in the Teton River - Judith Basin Grasslands. The minor occurrence of creeping juniper in the Lodgepole Pine-Douglas Fir Forest type near Lincoln and near the Marias pass was its only observed occurrence west of the Divide.

Ross and Hunter (1976) placed stands of creeping juniper in a single "riverbreaks" climax vegetation type characteristic of eastern and western sedimentary plants. Major overstory associates included ponderosa pine (*Pinus ponderosa*), Rocky Mountain juniper, and limber pine (*Pinus flexilis*). The most common grasses were bluebunch wheatgrass (*Agropyron spicatum*), green needlegrass (*Stipa viridula*), and prairie sandreed (*Calamovilfa longifolia*). I observed creeping juniper in this association mainly in eastern Montana, along the Marias, Milk and Missouri Rivers.

In the Sweetgrass Hills of northcentral Montana, Thompson and Kuizt (1976) found creeping juniper in what they described as a Montana Grassland community covering most dry, south-facing slopes and foothills between 1,500 meters (4,950 ft) and 2,000 meters (6,600 ft) as well as many non-forested areas of north-facing slopes. This community was dominated by rough fescue (*Festuca scabrella*), Idaho fescue (*Festuca idahoensis*) and shrubby cinquefoil (*Potentilla fruticosa*). My study

sites along the eastern foothills of the Rocky Mountain front and in central Montana seemed to represent similar situations.

Jorgensen (1976) described two tentative habitat types in eastern Montana which included creeping juniper, a Broom Snakeweed—Bluebunch Wheatgrass type, which occurred on very steep, unstable south-facing slopes, and a Creeping Juniper — Bluebunch Wheatgrass type occurring on north-facing slopes. The most abundant species in the former, which appeared to represent the vegetation of my study site number 26, were bluebunch wheatgrass, broom snakeweed and creeping juniper. Other plants of importance listed were rose, eriogonum, skunkbush sumac and prairie thermopsis. The latter type was dominated by creeping juniper with bluebunch wheatgrass, flowery anemone (*Anemone multifida*) and Kelsey phlox as common associates, and was characteristic of vegetation at study sites 27 and 28.

In reviewing the foregoing studies on creeping juniper and its associates it should be kept in mind that each researcher used his own method of classification giving the impression that creeping juniper occurs in a wider variety of vegetational types than it actually does. In principle then, the various types described may only represent one or two types described by different men.

Existing vegetational descriptions, together with my observations, suggest that several species are commonly associated with creeping juniper. Tree species, if present, include ponderosa pine, limber pine

and/or Douglas fir (*Pseudotsuga menziesii*). Principle shrubs include shrubby cinquefoil, common snowberry (*Symphoricarpos albus*), skunk-bush sumac (*Rhus trilobata*), prickly rose (*Rosa acicularis*) and prairie rose (*Rosa arkansana*). Major grasses include bluebunch wheatgrass, Idaho fescue, rough fescue, spike oat (*Helictotrichon hookeri*), little bluestem (*Andropogon scoparius*) and prairie junegrass (*Koeleria cristata*). Two sedges, inflated sedge (*Carex vesicaria*) and threadleaf sedge (*Carex filifolia*), may also be prominent; while a variety of forbs commonly occur. The plant associates of creeping juniper in Montana presumably vary in their occurrence and relative importance with variation in environmental factors such as topography, soils, climate, fire, grazing and time; and "associations" (i.e., distinctive combinations of creeping juniper and other plant species which persist on the same area or on areas of similar site and environmental characteristics) may not be readily apparent by examination of a few important plant species alone.

As indicated earlier, I employed ordination of vegetational data for the 30 intensively studied stands to identify "associations" as well as to illustrate the nature of variation in creeping juniper communities and the relationship of this variability to the environment. The raw vegetative data for each site is presented in Appendix Table 16. An ordination of vegetational data for individual stands generates a figure where stands with similar vegetational characteristics are

positioned adjacent to one another and dissimilar sites are widely separated (Fig. 17). When environmental attributes of each site are plotted into this figure, those which are correlated with and possibly causal of the variation in vegetation will vary in parallel with the phytosociological structure while those which are not will vary randomly (Figs. 20, 21, 22). Specific ordination techniques were outlined under methods. Briefly, to identify "associations": (1) the phytosociological "distances" between stands or sites were calculated; (2) the most dissimilar sites were selected as reference points for the X-axis (Site Nos. 13 and 15), the X-Y plane (Site Nos. 13, 15 and 25) and the X-Y-Z solid (Site Nos. 13, 15, 25 and 16); and (3) each stand or site was plotted graphically, first on the X-axis, then on the X-Y plane and finally in the X-Y-Z solid.

The principle associations in which creeping juniper occurs in Montana are illustrated in Figure 18, where total variability of sites is collapsed into one plane represented by the X and Y-axis (Figs. 17 and 18). Eight clusters, representing vegetational associations are recognizable. Individually, the associations were (1) *Juniperus-Potentilla-Festuca*, (2) *Juniperus-Agropyron*, (3) *Pinus-Juniperus-Festuca*, (4) *Juniperus-Potentilla-Carex*, (5) *Juniperus-Calamovilfa*, (6) *Juniperus-Helictotrichon*, (7) *Juniperus-Rhus-Stipa*, and (8) *Juniperus-Andropogon-Festuca*.

Some clusters (associations) are not clearly separated from the

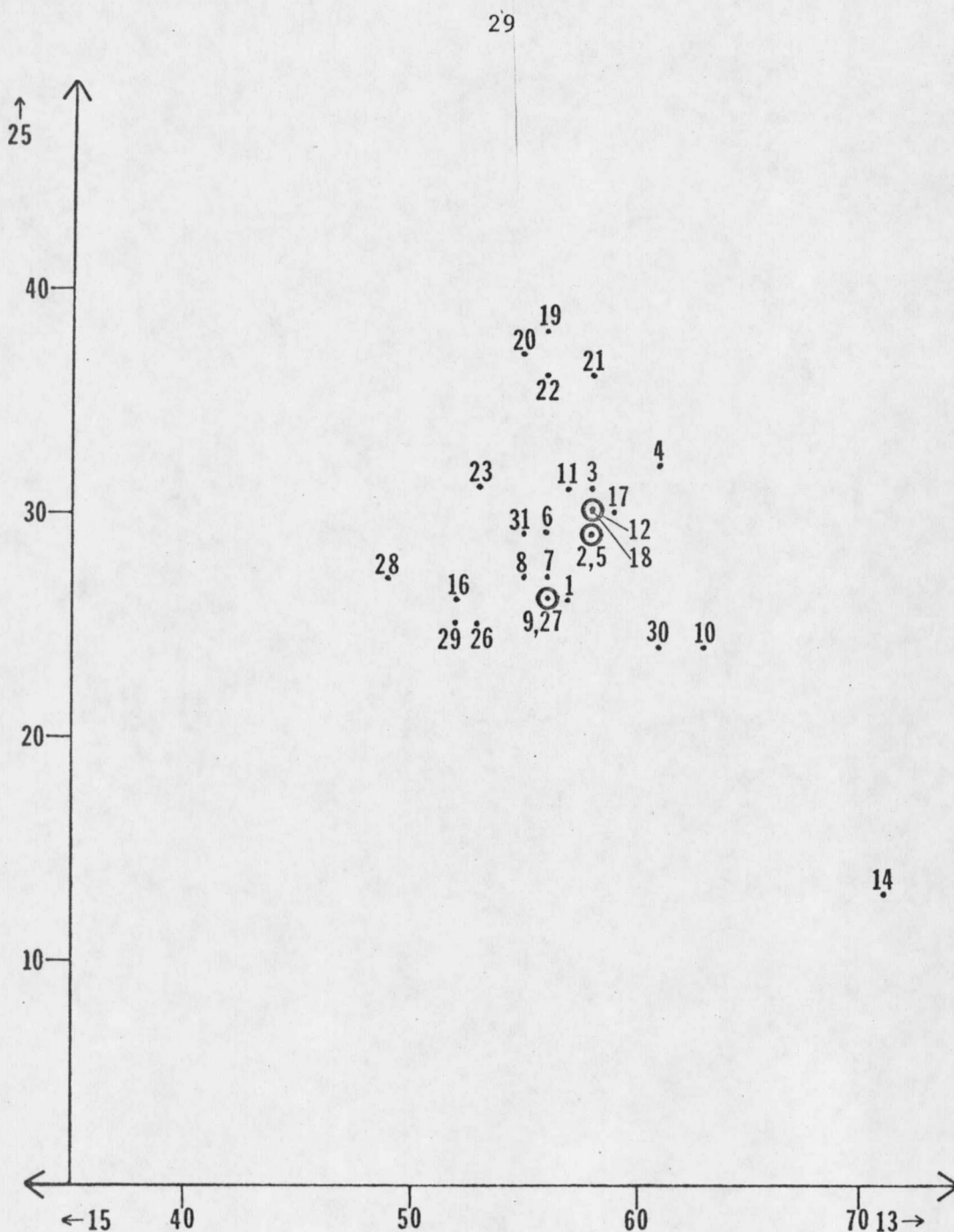


Figure 17. A simple ordination of 30 creeping juniper stands based on total vegetal composition, in two dimensions (X-Y axes). Axes represent compositional dissimilarity between stands.

others on the X-Y plane (Fig. 17). However, these clusters clearly separate when the third dimension (X-Z and Y-Z plots) of the ordination is examined. For example, sites 19, 20, 21, 22, and 25 appear to represent a single association on the X-Y graph. However, examination of the X-Z and Y-Z plane plots (Fig. 19) readily separates site 21 as possessing a different plant composition from the other sites.

Certain sites (4, 21 and 23) do not readily fit well into any of the associations listed. A larger number of samples would be required to understand their composition and environmental qualities. Since they appeared to be relatively unimportant, little further discussion will be devoted to them.

Juniperus-Potentilla-Festuca

This association occurs at elevations from about 1500 to 1800 meters (5000 - 6000 ft) in the foothill regions. It is typified by a high forb cover including death camas (*Zygadenus venosus*), Kelsey phlox (*Phlox kelseyi*), kitten-tail (*Besseyia wyomingensis*), white point-loco (*Oxytropis sericeus*), northern bedstraw (*Galium boreale*), and common yarrow (*Achillea millefolium*). Dominant graminoids include Idaho fescue, western wheatgrass (*Agropyron smithii*) and inflated sedge; while creeping juniper and shrubby cinquefoil were the major shrubs. This type is relatively open.

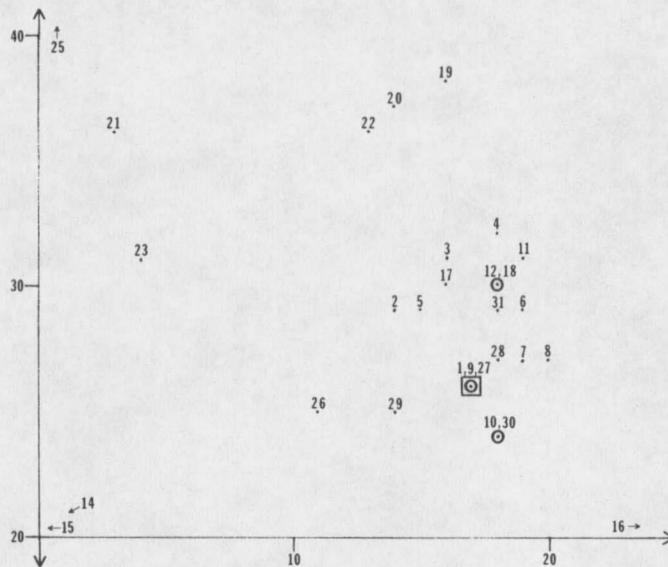
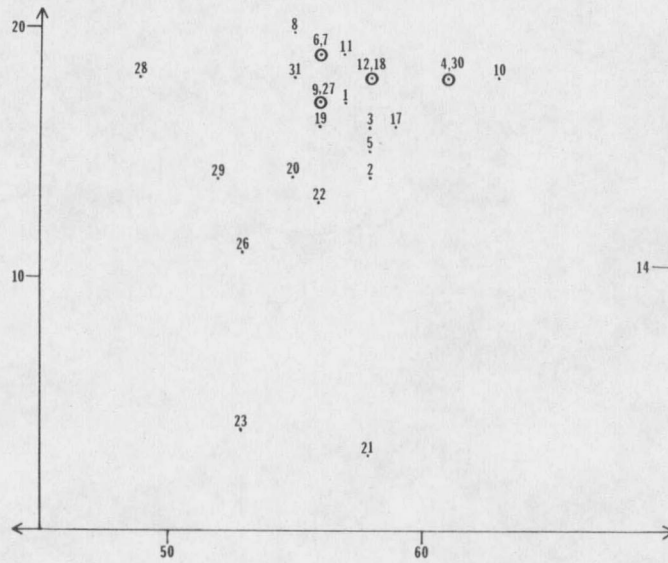


Figure 19. A simple ordination of the 30 creeping juniper stands showing the X-Z (top) and Y-Z (bottom) axes.

Juniperus-Agropyron

This association occurs between 1200 - 1500 meters (4000 - 5000 ft) in the prairie-foothill regions. It is characterized by rocky, shallow soils with very little overstory. The cover is made up primarily of graminoids including bluebunch wheatgrass, threadleaf sedge, Idaho fescue, and rough fescue. Common forbs are fringed sagewort (*Artemisia frigida*), northern bedstraw and alyssum-leaved phlox (*Phlox alyssifolia*). Creeping juniper and prickly rose make up the shrub complex.

Pinus-Juniperus-Festuca

This association is mainly found between 1500 - 1800 meters (5000 - 6000 ft). Rocky, shallow soils along with a limber pine overstory are characteristic. Bluebunch wheatgrass, threadleaf sedge, Idaho fescue and rough fescue are dominant graminoids. Prominent forbs are Kelsey phlox, fringed sagewort and Arizona hymenoxys (*Hymenoxys acaulis*). The only common shrub is creeping juniper.

Juniperus-Potentilla-Carex

Typically, this association occurs between 1200 and 1500 meters (4000 - 5000 ft) in the foothills. It commonly contains a high forb complement including such prominent species as common yarrow, Arizona hymenoxys, alyssum-leaved phlox, Kelsey phlox and ball anemone (*Anemone multifida*). The major graminoids are threadleaf sedge, inflated sedge,

single-spike sedge (*Carex scirpoidea*), spike oat, rough fescue and Idaho fescue. Shrubs present are creeping juniper and shrubby cinquefoil.

Juniperus-Calamovilfa

This association is characterized by a high amount of surface erosion and bareground. Also present is moderate tree cover mainly of ponderosa pine. It occurs at elevations between 900 - 1200 meters (3000 - 4000 ft). Dominant graminoids are prairie sandreed grass, threadleaf sedge, bluebunch wheatgrass and western wheatgrass. Forbs are pale bastard toad flax (*Comandra umbellata*), fringed sagewort and prairie thermopsis (*Thermopsis rhombifolia*). Common shrubs include creeping juniper, prairie rose, and big sagebrush (*Artemisia tridentata*).

Juniperus-Helictrotrichon

This association occurs at 1500 - 1800 meters (5000 - 6000 ft) in the foothills. Small trees, primarily limber pines, are common. Major graminoids are spike oat, bluebunch wheatgrass, threadleaf sedge, inflated sedge, Idaho fescue, rough fescue and prairie junegrass (*Koeleria cristata*). Common forbs are rose pussytoes (*Antennaria rosea*), buff fleabane (*Erigeron ochroleucus*) and Kelsey phlox. Dominant shrubs include creeping juniper, shrubby cinquefoil and prickly rose.

Juniperus-Rhus-Stipa

This association is found between 900 - 1200 meters (3000 - 4000 ft), and is typically dominated by shrubs. No trees occur in this association. Prominent shrubs are creeping juniper, skunkbush sumac and common snowberry. Common graminoids are threadleaf sedge and needle and thread (*Stipa comata*); narrowleaf poison vetch (*Astragalus pectinatus*), kittentail, prairie trefoil (*Lotus purshianus*) and Kelsey phlox were major forbs.

Juniperus-Andropogon-Festuca

This association occurs at elevations between 1200 - 1500 meters (4000 - 5000 ft) in the prairie regions. Prominent graminoids include bluebunch wheatgrass, Idaho fescue, rough fescue and threadleaf sedge, with prairie thermopsis and fringed sagewort as dominant forbs. Major shrubs are creeping juniper, shrubby cinquefoil and prickly rose.

Environmental Attributes of the Eight Associations

As noted above, environmental data from each site can be plotted into the X-Y ordination (Figs. 17 and 18). Factors apparently related to vegetational variation are plotted in Figures 20 to 22. Other environmental factors studied, but which were not correlated with variation in vegetational characteristics, and/or were not plotted, include frost-free season, average annual temperature and precipitation, percent organic matter, calcium, magnesium, sodium, potassium, or

phosphorus content, salt hazard, soil texture, pH, north, south, east, west exposure and slope gradient.

The *Pinus-Juniperus-Festuca* and *Juniperus-Agrophyron* associations near the center of Figure 20 had the rockiest and shallowest soils. The soils averaged near 10.0 cm. deep and had frequencies of 90-100 percent stone occurrence. Soils near the top of the graphs were moderately stony (frequency 50%) and relatively deep (14 cm.) while those at the lower edges were deepest and relatively free of stones averaging near 25 cm. deep and 30-50 percent frequency of stone occurrence.

Surface erosion increased toward the center and lower left corner of the graph (Fig. 21). The *Juniperus-Calamovilfa* association occurred on the most eroded sites and the *Juniperus-Potentilla-Festuca*, *Juniperus-Andropogon-Festuca* and *Juniperus-Potentilla* associations were on the least eroded, averaging approximately 50, 3, 3 and 3 percent of the surface eroded respectively. Erosion probably is more rapid where vegetal cover is low; i.e., where total bare ground cover is high.

Bare ground is well correlated with erosion estimates (Fig. 21). Associations, as the *Juniperus-Calamovilfa* and *Juniperus-Rhus-Stipa*, at the lower edge of the graph, averaged around 30 percent of the surface as bare ground. The associations toward the top, for example the two *Juniperus-Potentilla* associations (1 and 4), averaged much less

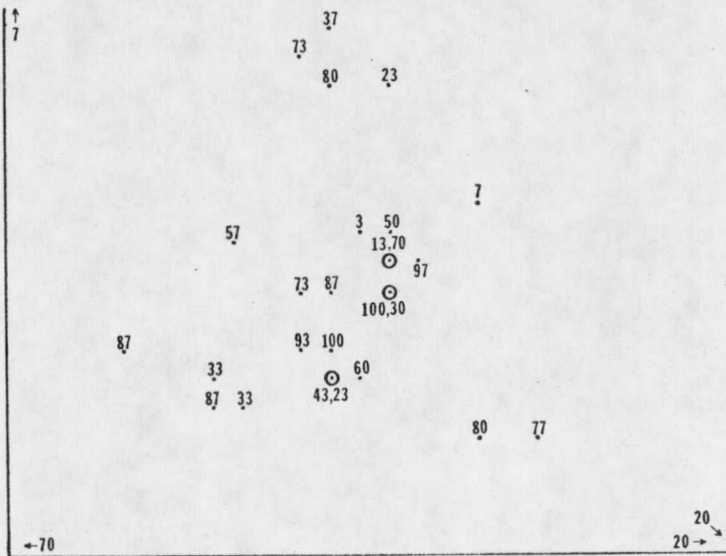
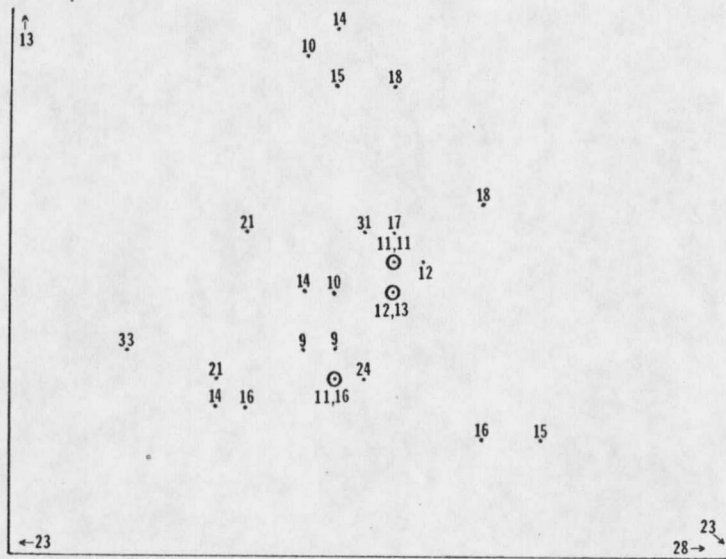


Figure 20. Soil depth in centimeters (top) and percent frequency of stone (bottom) of soils in each of 30 creeping juniper stands plotted at the locations of the respective sites within the ordination presented in Figure 18.

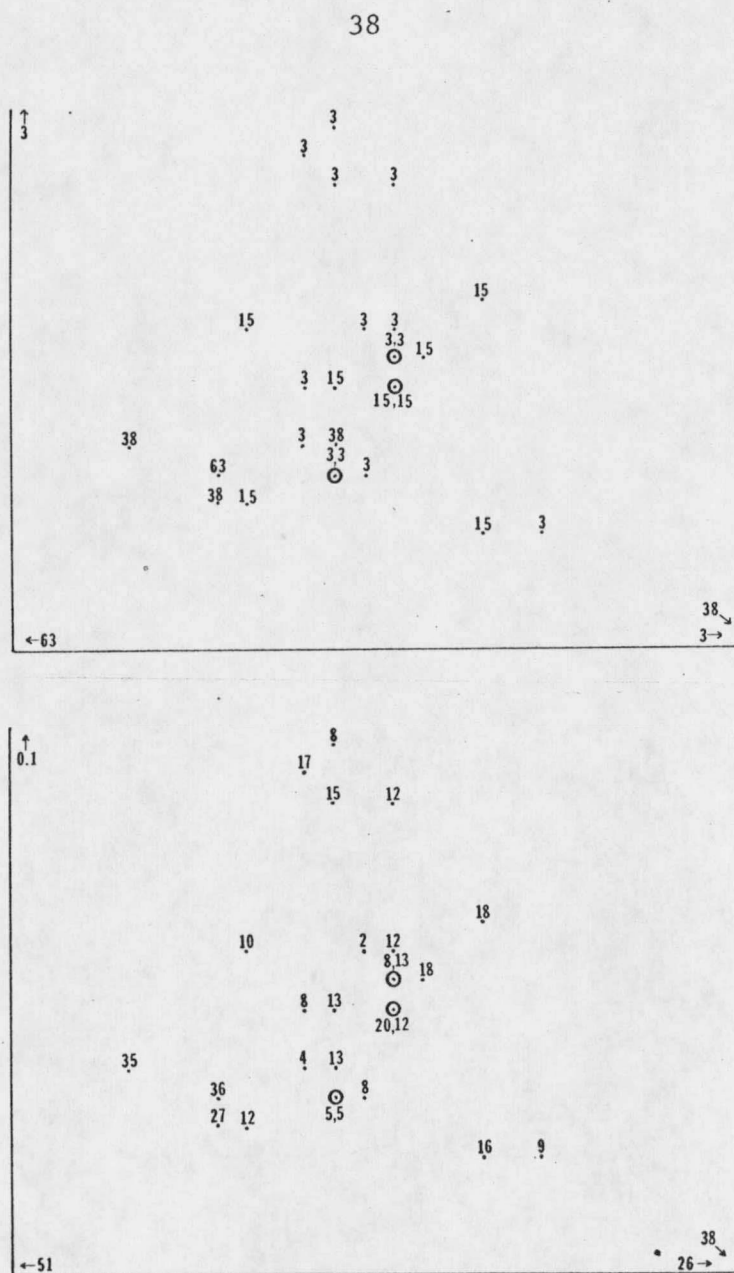


Figure 21. Percent soil surface eroded (top) and percent bareground cover (bottom) of soils of 30 creeping juniper stands plotted at the locations of the respective sites within the ordination presented in Figure 18.

bare ground (approx. 5-10 percent).

The association occurring at highest elevation, *Juniperus-Potentilla-Festuca*, was near the top of the graph (Fig. 22). Elevation appears to decrease toward the lower edge of the figure. Values ranged from near 1500 meters (5500 ft) in the *Juniperus-Potentilla-Festuca*, *Juniperus-Helictotrichon* and *Pinus-Juniperus-Festuca* associations to less than 1200 meters (4000 ft) for *Juniperus-Rhus-Stipa* and *Juniperus-Calamovilfa* associations.

Vegetational Composition of Creeping Juniper Associations

Plant species associated with creeping juniper are listed in Table 2 together with their average constancy, percent canopy coverage, and frequency of occurrence among 2 x 5 dm plot frames in each of the eight vegetation associations (Fig. 18). A total of 150 plant species was identified including 24 graminoids, 104 forbs, 18 shrubs and 3 trees. Common and scientific names are presented in Appendix Table 15.

The general vegetal composition of juniper stands may be obtained by averaging across all associations. Creeping juniper typically dominated the sites studied accounting for an overall average canopy coverage of 32 percent of the total area sampled. Although some sites have high (60-70 percent) canopy coverage of vegetation, considerable bare ground and exposed surface stone were common, and together accounted for 30 percent of the total canopy coverage. Deciduous and

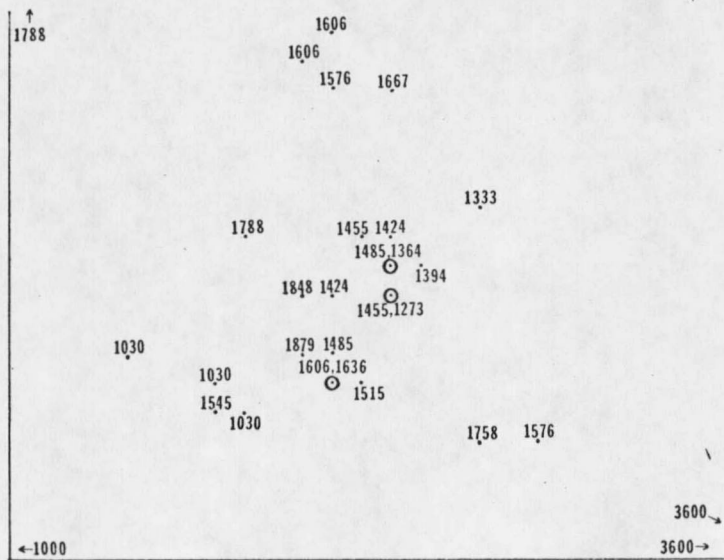


Figure 22. Elevations in meters of 30 creeping juniper stands plotted at the locations of the respective sites within the ordination presented in Figure 18.

Table 2. Constancy, canopy coverage and frequency of low growing taxa for the eight creeping juniper associations as determined by examination of 2 X 5 decimeter plots on each area.

Taxa	ASSOCIATIONS								Totals
	<i>Juniperus-Potentilla-Festuca</i>	<i>Juniperus-Agropyron</i>	<i>Pinus-Juniperus-Festuca</i>	<i>Juniperus-Potentilla-Carex</i>	<i>Juniperus-Calamovilfa</i>	<i>Juniperus-Helictotrichon</i>	<i>Juniperus-Rhus-Stipa</i>	<i>Juniperus-Andropogon-Festuca</i>	
Graminoids:									
<i>Agropyron smithii</i> *	100/ 6/45 ¹	- - -	- - -	- - -	40/ 4/22	- - -	- - -	33/ 2/ 7	25/ 1/ 9
<i>Agropyron spicatum</i> *	25/ 1/ 9	100/ 8/54	100/ 8/53	33/ 1/12	60/ 4/26	100/ 3/14	- - -	66/ 4/28	63/ 3/28
<i>Andropogon scoparius</i>	- - -	- - -	- - -	- - -	- - -	- - -	- - -	33/ 2/14	4/tr/ 2
<i>Aristida longiseta</i>	- - -	- - -	- - -	- - -	20/tr/ 1	- - -	- - -	- - -	4/tr/tr
<i>Bouteloua gracilis</i> **	- - -	- - -	- - -	- - -	- - -	- - -	50/ 1/ 6	- - -	8/tr/tr
<i>Bromus inermis</i> **	- - -	- - -	- - -	66/ 1/ 9	- - -	- - -	- - -	- - -	8/tr/ 2
<i>Bromus japonicus</i> *	- - -	- - -	- - -	- - -	- - -	- - -	- - -	33/tr/ 2	4/tr/tr
<i>Calamovilfa longifolia</i> *	- - -	- - -	- - -	- - -	60/ 5/33	- - -	- - -	- - -	11/ 1/ 5
<i>Calamovilfa purpescens</i> *	- - -	- - -	- - -	33/tr/ 3	- - -	- - -	- - -	- - -	4/tr/tr
<i>Carex elynoides</i> *	25/tr/ 9 ²	- - -	- - -	- - -	20/tr/ 1	- - -	- - -	- - -	8/tr/ 1
<i>Carex filifolia</i> *	25/tr/ 1	100/ 5/31	75/ 5/27	66/ 1/12	60/ 3/22	100/ 6/30	100/ 4/24	100/ 5/28	74/ 4/22
<i>Carex heliophila</i>	- - -	- - -	- - -	- - -	20/ 1/10	- - -	- - -	- - -	4/tr/ 1
<i>Carex scirpoides</i> *	- - -	- - -	- - -	33/ 3/16	- - -	- - -	- - -	- - -	4/tr/ 2
<i>Carex vesicaria</i> *	75/ 4/38	100/ 3/18	75/ 2/12	66/ 2/22	40/ 2/10	100/ 6/36	50/ 1/ 4	100/ 2/12	74/ 2/19
<i>Canthionia intermedia</i>	- - -	- - -	- - -	- - -	- - -	- - -	- - -	33/ 1/ 2	4/tr/tr
<i>Festuca idahoensis</i> *	100/ 8/64	100/ 7/38	75/ 6/37	100/ 3/22	40/tr/ 2	50/ 4/28	- - -	66/ 8/31	74/ 5/30
<i>Festuca scabrella</i> *	- - -	75/ 4/17	75/ 6/32	66/ 4/22	- - -	50/ 2/24	- - -	66/ 2/ 8	44/ 3/14
<i>Helictotrichon hookeri</i> **	- - -	- - -	25/tr/ 2	100/ 5/24	- - -	100/ 8/44	- - -	66/ 3/ 8	33/ 2/ 8
<i>Juncus balticus</i>	- - -	- - -	- - -	33/tr/ 2	- - -	- - -	- - -	- - -	4/tr/tr
<i>Koeleria cristata</i> *	- - -	75/ 1/ 5	100/tr/12	33/tr/ 3	40/tr/ 5	50/ 4/22	- - -	66/ 2/16	47/ 1/ 6
<i>Poa pattersoni</i> *	- - -	- - -	- - -	- - -	20/tr/ 2	- - -	- - -	- - -	4/tr/tr
<i>Poa</i> spp.	- - -	25/tr/ 4	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/tr
<i>Stipa comata</i>	- - -	25/tr/ 2	- - -	- - -	- - -	- - -	100/18/88	- - -	11/ 2/11
<i>Stipa viridula</i>	- - -	25/ 1/ 6	- - -	- - -	20/tr/ 1	- - -	- - -	- - -	8/tr/ 1
Unknown Grass	- - -	- - -	- - -	33/tr/ 3	40/ 1/ 6	- - -	- - -	- - -	11/tr/ 1
Total Graminoids*	100/20/98	100/29/97	100/27/99	100/21/98	100/20/85 ⁺⁺	100/28/98	100/25/98	100/28/96	100/22/96

Table 2. (continued)

Taxa	ASSOCIATIONS								Totals
	Juniperus- Potentilla- Festuca	Juniperus- Agropyron	Pinus- Juniperus- Festuca	Juniperus- Potentilla- Carex	Juniperus- Calomovilla	Juniperus- Helictotrichon	Juniperus- Rhus- Stipa	Juniperus- Andropogon- Festuca	
Forbs:									
<i>Achillea millefolium</i> *	75/ 3/29	50/ 1/ 8	50/tr/ 2	66/ 2/ 4	20/tr/ 1	100/ 1/ 7	50/ 1/ 7	66/ 1/11	55/ 1/10
<i>Allium cernuum</i>	- - -	- - -	- - -	66/tr/ 7	- - -	50/tr/ 4	- - -	- - -	- - -
<i>Allium textile</i> *	25/tr/ 6	75/ 1/25	75/ 1/26	33/tr/ 2	20/tr/ 2	50/tr/15	- - -	33/tr/11	40/tr/11
<i>Anemone multifida</i> *	50/ 2/16	25/tr/ 1	- - -	100/ 3/18	20/ 1/ 5	- - -	- - -	33/ 2/18	29/tr/ 7
<i>Anemone patens</i> **	75/ 5/41	25/tr/ 2	25/tr/ 1	66/ 1/17	- - -	50/tr/ 2	- - -	66/ 2/ 9	37/ 1/ 9
<i>Antennaria rosea</i> *	50/tr/ 7	75/ 1/11	100/ 1/21	66/tr/ 2	- - -	100/ 3/23	50/tr/ 1	66/tr/ 5	59/ 1/ 8
<i>Arenaria congesta</i>	25/tr/ 7	25/tr/ 1	25/tr/ 7	66/ 1/10	- - -	- - -	- - -	33/tr/ 2	22/tr/ 3
<i>Arenaria hookeri</i>	- - -	25/tr/ 9	25/tr/ 7	33/tr/ 3	- - -	- - -	- - -	- - -	11/tr/ 2
<i>Artemisia cana</i>	- - -	- - -	- - -	- - -	20/tr/ 2	- - -	50/tr/ 2	- - -	8/tr/tr
<i>Artemisia frigida</i> *	- - -	100/ 2/20	100/ 4/33	100/ 2/25	60/ 1/ 7	100/ 1/11	100/ 1/10	100/ 4/28	78/ 2/15
<i>Astragalus bisulatus</i>	- - -	- - -	- - -	33/tr/ 2	- - -	- - -	- - -	- - -	4/tr/tr
<i>Astragalus eucoemus</i>	- - -	25/tr/ 1	50/ 1/ 4	- - -	40/ 1/ 6	- - -	- - -	33/tr/ 1	18/tr/ 2
<i>Astragalus gilviflorus</i>	- - -	50/tr/ 1	50/tr/ 4	- - -	- - -	50/ 1/12	- - -	33/tr/ 1	22/tr/ 2
<i>Astragalus pectinatus</i>	- - -	- - -	- - -	- - -	- - -	- - -	50/ 4/19	- - -	4/tr/ 2
<i>Astragalus tenellus</i>	- - -	- - -	- - -	33/tr/ 3	- - -	- - -	- - -	- - -	4/tr/tr
<i>Balsamorhiza sagittata</i> *	25/ 1/ 5	25/tr/ 2	25/tr/ 1	- - -	20/tr/ 2	- - -	- - -	33/ 1/ 4	18/tr/ 2
<i>Besseyia wyomingensis</i> *	75/ 4/27	25/tr/ 3	25/tr/ 1	66/tr/ 2	20/tr/ 3	50/tr/ 8	50/ 3/15	100/ 1/17	47/ 1/ 9
<i>Buplerum americanum</i> *	- - -	75/ 1/ 8	50/ 1/ 3	33/tr/ 1	- - -	100/tr/ 7	- - -	- - -	29/tr/ 3
<i>Campanula rotundifolia</i> *	- - -	- - -	- - -	33/tr/ 1	20/tr/ 1	- - -	- - -	33/tr/ 7	11/tr/tr
<i>Castilleja sessiliflora</i>	- - -	- - -	- - -	33/tr/ 2	- - -	50/tr/ 2	- - -	- - -	8/tr/tr
<i>Cerastium arvense</i> *	100/ 1/11	75/tr/11	100/ 1/21	100/tr/24	20/tr/ 3	50/tr/10	50/tr/ 1	66/tr/ 3	67/tr/ 3
<i>Chrysopsis villosa</i>	- - -	- - -	- - -	- - -	20/tr/ 2	- - -	- - -	- - -	4/tr/tr
<i>Cirsium undulatum</i>	- - -	- - -	- - -	- - -	20/tr/ 1	- - -	- - -	- - -	4/tr/tr
<i>Clematis pseudoalpina</i>	25/ 1/ 4	- - -	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/tr
<i>Comandra unbellata</i> *	75/ 2/16	50/tr/11	25/tr/ 3	33/tr/ 2	80/ 2/15	50/ 1/11	100/ 1/ 7	33/ 1/ 9	55/ 1/10

Table 2. (continued)

Taxa	ASSOCIATIONS								Totals
	Juniperus- Potentilla- Festuca	Juniperus- Agropyron	Pinus- Juniperus- Festuca	Juniperus- Potentilla- Carex	Juniperus- Calomovilfa	Juniperus- Helictotrichon	Juniperus- Rhus- Stipa	Juniperus- Andropogon- Festuca	
Forbs: (continued)									
<i>Crepis occidentalis</i>	- - -	- - -	- - -	- - -	20/tr/ 2	- - -	- - -	- - -	4/tr/tr
<i>Cryptantha interrupta</i>	- - -	- - -	25/tr/ 2	- - -	- - -	- - -	- - -	- - -	4/tr/tr
<i>Delphinium bicolor</i>	50/tr/ 5	- - -	- - -	- - -	- - -	- - -	- - -	- - -	8/tr/ 1
<i>Dodecatheon conjugens</i>	25/tr/ 3	- - -	- - -	33/tr/ 1	- - -	- - -	- - -	- - -	8/tr/tr
<i>Echinaceae pallida</i>	- - -	- - -	- - -	- - -	40/tr/ 2	- - -	- - -	- - -	8/tr/tr
<i>Erigeron caespitosus</i>	- - -	- - -	- - -	- - -	- - -	- - -	- - -	33/tr/ 4	4/tr/tr
<i>Erigeron ochroleucus*</i>	- - -	75/tr/ 5	- - -	33/tr/ 1	20/tr/ 1	50/ 3/ 5	100/tr/ 3	- - -	29/tr/ 2
<i>Erigeron subtrinervis**</i>	50/tr/10	75/ 1/11	100/ 1/20	66/tr/10	- - -	100/ 1/ 9	50/ 1/12	- - -	52/ 1/ 9
<i>Erigeron</i> spp.	25/tr/ 4	- - -	- - -	- - -	- - -	- - -	50/tr/ 2	- - -	11/tr/ 1
<i>Eriogonum flavum</i>	- - -	25/tr/ 3	25/tr/ 2	- - -	- - -	- - -	- - -	33/tr/ 1	11/tr/ 1
<i>Eriogonum umbellatum</i>	- - -	- - -	- - -	- - -	20/tr/ 6	- - -	- - -	- - -	4/tr/ 1
<i>Eriogonum</i> spp.	- - -	50/tr/ 4	25/tr/ 3	- - -	- - -	50/tr/ 2	50/ 1/ 7	33/tr/ 1	22/tr/ 2
<i>Eritichum howardii</i>	25/ 2/13	- - -	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/ 2
<i>Erysium asperum</i>	25/tr/ 1	- - -	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/tr
<i>Frasera speciosa*</i>	50/ 1/ 6	25/tr/ 1	- - -	33/ 1/ 9	- - -	- - -	- - -	33/tr/ 1	18/tr/ 2
<i>Fritileria pudica</i>	- - -	25/tr/ 1	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/tr
<i>Gaillardia aristata*</i>	50/ 1/12	25/tr/ 2	25/tr/ 1	100/ 1/12	20/tr/ 2	50/tr/ 5	- - -	- - -	33/tr/ 4
<i>Galium boreale*</i>	75/ 3/36	75/ 7/29	25/tr/ 2	66/ 1/13	- - -	100/tr/ 9	50/tr/ 2	100/tr/10	55/ 1/14
<i>Geum triflorum*</i>	25/ 1/ 4	25/ 1/ 6	- - -	33/tr/ 1	- - -	50/tr/ 4	50/ 1/ 5	66/tr/ 4	25/tr/ 3
<i>Grindelia squarrosa</i>	- - -	- - -	- - -	- - -	- - -	- - -	50/tr/ 2	- - -	5/tr/tr
<i>Guterrhiza sarothrae</i>	- - -	- - -	- - -	- - -	20/tr/ 3	- - -	- - -	- - -	4/tr/tr
<i>Haplopappus armeroides</i>	- - -	25/tr/ 1	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/tr
<i>Haplopappus nuttali</i>	- - -	25/tr/ 2	- - -	33/tr/15	- - -	- - -	- - -	- - -	8/tr/ 2
<i>Haplopappus spinulosus</i>	- - -	25/tr/ 2	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/tr
<i>Hedysarum boreale</i>	- - -	25/tr/ 1	- - -	- - -	- - -	50/tr/ 3	100/ 2/ 7	- - -	18/tr/ 4

Table 2. (continued)

Taxa	ASSOCIATIONS								Totals
	<i>Juniperus- Potentilla- Festuca</i>	<i>Juniperus- Agropyron</i>	<i>Pinus- Juniperus- Festuca</i>	<i>Juniperus- Potentilla- Carex</i>	<i>Juniperus- Calamovilfa</i>	<i>Juniperus- Helictotrichon</i>	<i>Juniperus- Rhus- Stipa</i>	<i>Juniperus- Andropogon- Festuca</i>	
Forbs: (continued)									
<i>Hedysarum sulfurescens</i> *	25/ 2/15	- - -	- - -	66/ 1/11	- - -	- - -	- - -	33/tr/ 3	8/tr/tr
<i>Hymenoxys acaulis</i> **	- - -	75/ 1/14	100/ 2/20	33/ 2/ 3	20/tr/ 1	50/ 1/18	- - -	- - -	37/tr/ 7
<i>Leucocrinum montanum</i>	- - -	- - -	- - -	33/tr/ 3	- - -	- - -	- - -	- - -	4/tr/tr
<i>Liatris punctata</i> **	- - -	- - -	- - -	66/tr/ 3	40/tr/ 1	- - -	- - -	- - -	11/tr/ 1
<i>Linum perenne</i> *	75/tr/ 2	75/tr/ 4	- - -	33/ 1/ 1	60/tr/ 2	50/tr/ 4	100/ 1/ 8	- - -	47/tr/ 4
<i>Lithospermum ruderales</i>	- - -	- - -	25/tr/ 1	33/tr/ 3	- - -	- - -	- - -	33/tr/ 1	11/tr/tr
<i>Lomatium cous</i> *	75/ 1/16	100/tr/12	75/tr/ 8	66/tr/ 7	20/tr/ 1	100/tr/ 5	100/tr/ 5	33/tr/ 2	67/tr/ 7
<i>Lomatium macrocarpum</i>	- - -	25/tr/ 1	25/tr/ 8	- - -	- - -	- - -	- - -	33/tr/ 1	11/tr/ 1
<i>Lotus purshianus</i>	- - -	- - -	- - -	- - -	- - -	- - -	100/ 3/25	- - -	8/tr/ 3
<i>Lupinus sericeus</i>	- - -	- - -	- - -	33/ 1/ 3	- - -	50/tr/ 2	- - -	33/tr/ 3	11/tr/ 1
<i>Lupinus wytheii</i>	- - -	75/tr/ 6	- - -	- - -	- - -	- - -	- - -	33/tr/ 2	15/tr/ 1
<i>Lupinus</i> spp.	- - -	25/tr/ 2	- - -	33/tr/ 1	- - -	- - -	- - -	- - -	8/tr/tr
<i>Mertensia viridis</i>	25/tr/ 1	- - -	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/tr
<i>Monarda fistulosa</i>	25/ 1/ 5	- - -	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/ 1
<i>Musineon divaricatum</i> *	- - -	50/ 1/10	75/tr/ 3	- - -	40/tr/ 3	- - -	50/tr/ 3	66/ 1/15	37/tr/ 5
<i>Myosotis sylvatica</i>	25/ 1/ 3	- - -	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/tr
<i>Opuntia polycantha</i>	- - -	- - -	- - -	- - -	- - -	- - -	50/tr/ 1	- - -	4/tr/tr
<i>Orthocarpus luteus</i>	25/tr/ 1	- - -	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/tr
<i>Orthocarpus tenuifolia</i>	- - -	25/tr/ 2	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/tr
<i>Oxytropis besseyi</i>	- - -	- - -	- - -	- - -	40/ 1/16	- - -	- - -	- - -	8/tr/ .2
<i>Oxytropis sericeus</i> *	50/ 3/49	50/ 1/13	50/tr/ 4	100/ 1/48	- - -	100/ 1/15	50/tr/ 3	33/tr/ 2	47/ 1/14
<i>Oxytropis viscidia</i>	- - -	25/tr/ 1	- - -	- - -	- - -	50/tr/ 4	- - -	- - -	8/tr/ 2
<i>Paronychia sessiflora</i>	25/tr/ 2	25/tr/ 4	- - -	33/tr/ 1	- - -	- - -	- - -	- - -	11/tr/ 1
<i>Penstemon attenuates</i>	25/ 1/ 7	- - -	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/ 1
<i>Penstemon erianthus</i>	- - -	50/tr/ 2	- - -	- - -	- - -	- - -	- - -	- - -	8/tr/tr
<i>Penstemon nitidus</i>	- - -	- - -	- - -	- - -	20/tr/ 1	- - -	- - -	- - -	4/tr/tr

Table 2. (continued)

	ASSOCIATIONS								
Taxa	Juniperus- Potentilla- Festuca	Juniperus- Agropyron	Pinus- Juniperus- Festuca	Juniperus- Potentilla- Carex	Juniperus- Calamovilfa	Juniperus- Helictotrichon	Juniperus Rhus- Stipa	Juniperus- Andropogon- Festuca	Totals
Forbs: (continued)									
<i>Petalostemon candidum</i>	- - -	- - -	- - -	- - -	- - -	50/ 1/14	- - -	33/tr/ 3	8/tr/ 2
<i>Petalostemon purpureus</i>	- - -	- - -	25/tr/ 2	- - -	- - -	- - -	- - -	- - -	4/tr/tr
<i>Phlox alyssifolia</i> *	- - -	100/ 4/26	- - -	100/ 5/32	20/tr/ 3	- - -	100/tr/ 5	33/tr/ 2	40/ 1/ 9
<i>Phlox hoodii</i> *	- - -	50/tr/ 4	- - -	33/tr/ 4	- - -	- - -	- - -	- - -	11/tr/ 1
<i>Phlox kelseyi</i> *	50/ 2/23	50/tr/ 6	100/ 3/26	33/ 6/26	40/tr/ 3	100/ 5/43	100/ 3/45	100/ 1/14	67/ 2/19
<i>Phlox multiflora</i> *	25/tr/ 1	75/ 1/14	75/ 1/ 9	33/tr/ 4	- - -	- - -	- - -	- - -	29/tr/ 4
<i>Polygala alba</i>	- - -	- - -	- - -	- - -	20/tr/ 1	- - -	- - -	- - -	4/tr/tr
<i>Polygonum bistortis</i>	50/ 1/14	- - -	- - -	- - -	- - -	- - -	- - -	- - -	8/tr/ 2
<i>Potentilla gracilis</i>	25/tr/ 1	- - -	- - -	- - -	- - -	100/ 2/20	50/tr/ 2	33/tr/ 1	33/tr/ 2
<i>Potentilla hippiana</i> **	- - -	25/tr/ 1	75/tr/ 3	33/tr/ 1	- - -	- - -	- - -	- - -	4/tr/tr
<i>Ranunculus glaberrimus</i>	- - -	- - -	- - -	- - -	20/tr/ 1	- - -	- - -	- - -	4/tr/tr
<i>Saxifraga rhomboidea</i>	25/tr/ 1	- - -	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/tr
<i>Sisyrinchium sarmentosum</i>	- - -	- - -	- - -	33/tr/ 2	- - -	- - -	- - -	- - -	4/tr/tr
<i>Sedum lanceolatum</i> *	75/ 1/ 8	25/tr/ 2	- - -	- - -	- - -	50/tr/10	- - -	- - -	18/tr/ 2
<i>Senecio canus</i> *	25/tr/ 2	25/tr/ 1	25/tr/ 2	33/tr/ 2	- - -	100/tr/ 2	- - -	- - -	22/tr/ 2
<i>Smilicia racemosa</i>	- - -	- - -	- - -	33/tr/ 8	- - -	- - -	- - -	- - -	4/tr/ 1
<i>Solidago missouriensis</i> **	- - -	25/tr/ 2	- - -	- - -	20/tr/ 1	100/tr/ 7	50/ 1/14	66/tr/ 3	25/tr/ 2
<i>Solidago occidentalis</i>	- - -	- - -	- - -	- - -	20/tr/ 1	- - -	50/tr/ 4	- - -	8/tr/ 1
<i>Taraxacum officinale</i> *	- - -	- - -	- - -	33/tr/ 4	- - -	- - -	- - -	- - -	4/tr/tr
<i>Thermopsis rhombifolia</i> **	25/tr/ 3	25/ 1/ 9	25/tr/ 1	33/tr/ 1	100/ 6/29	50/tr/ 2	50/ 2/11	66/ 7/58	47/ 2/13
<i>Tragopogon dubius</i>	- - -	25/tr/ 1	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/tr
<i>Vicia americana</i> *	50/tr/ 2	75/tr/ 3	25/tr/ 2	66/tr/ 2	40/tr/ 5	- - -	100/ 2/13	33/tr/ 1	47/tr/ 3
<i>Viola nuttalli</i>	- - -	- - -	- - -	- - -	- - -	- - -	50/ 1/ 5	33/tr/ 2	8/tr/ 1
<i>Yucca glauca</i> **	- - -	- - -	- - -	- - -	- - -	- - -	50/ 1/ 4	- - -	4/tr/tr
<i>Zygadenus elegans</i> **	100/ 7/47	- - -	- - -	100/ 1/13	- - -	- - -	- - -	33/tr/ 1	29/ 1/ 9
<i>Zygadenus venosus</i> *	- - -	50/tr/ 4	50/tr/ 6	100/ 1/20	20/tr/ 1	50/tr/ 2	100/ 1/ 5	66/ 1/15	47/tr/ 6
Total Forbs:	100/21/96	100/17/92	100/11/90	100/21/93	100/13/76	100/15/91	100/21/69	100/15/86	100/16/89

Table 2. (continued)

	ASSOCIATIONS									
Taxa	<i>Juniperus- Potentilla- Festuca</i>	<i>Juniperus- Agropyron</i>	<i>Pinus- Juniperus- Festuca</i>	<i>Juniperus- Potentilla- Carex</i>	<i>Juniperus- Calamovilfa</i>	<i>Juniperus- Heliototrichon</i>	<i>Juniperus- Rhus- Stipa</i>	<i>Juniperus- Andropogon- Festuca</i>	Totals	
Shrubs:										
<i>Apocynum cannabinum*</i>	- - -	25/ 1/ 8	- - -	- - -	20/tr/ 2	- - -	- - -	- - -	8/tr/ 2	
<i>Arctostaphylos uva-ursi*</i>	- - -	- - -	- - -	- - -	- - -	- - -	- - -	33/tr/ 1	4/tr/tr	
<i>Artemisia longifolia</i>	- - -	- - -	- - -	- - -	20/tr/ 1	- - -	- - -	- - -	4/tr/tr	
<i>Artemisia tridentata</i>	- - -	- - -	- - -	- - -	20/ 1/ 5	- - -	- - -	- - -	4/tr/ 1	
<i>Atriplex canescens</i>	- - -	- - -	- - -	- - -	- - -	50/tr/ 3	- - -	- - -	4/tr/tr	
<i>Berberis repens</i>	25/tr/ 1	- - -	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/tr	
<i>Juniperus horizontalis*</i>	100/32/75	100/30/74	100/26/57	100/35/56	100/30/45	100/27/47	100/35/50	100/47/61	100/32/57	
<i>Potentilla fruticosa*</i>	75/ 7/27	- - -	- - -	66/ 2/17	- - -	100/ 4/28	- - -	66/ 1/ 7	29/ 2/ 9	
<i>Prunus virginiana</i>	25/tr/ 3	- - -	- - -	- - -	- - -	- - -	- - -	- - -	4/tr/tr	
<i>Rhus trilobata**</i>	- - -	- - -	- - -	- - -	20/tr/ 1	- - -	100/ 4/12	- - -	11/tr/ 1	
<i>Ribes</i> spp.	- - -	- - -	25/tr/ 3	- - -	- - -	- - -	- - -	- - -	4/tr/tr	
<i>Rosa acicularis*</i>	25/tr/ 2	25/ 1/ 7	- - -	66/tr/ 2	20/tr/ 3	100/ 2/ 8	100/ 2/20	33/ 2/13	37/ 1/ 6	
<i>Rosa arkansana*</i>	50/tr/ 2	- - -	- - -	- - -	40/ 1/ 7	- - -	- - -	- - -	15/tr/ 2	
<i>Symphoricarpos albus**</i>	50/ 1/ 8	- - -	- - -	- - -	- - -	- - -	50/ 7/37	- - -	8/ 1/ 4	
<i>Symphoricarpos occidentalis*</i>	- - -	- - -	- - -	- - -	- - -	- - -	- - -	33/tr/ 1	4/tr/tr	
TOTAL SHRUB	100/39/82	100/31/86	100/30/73	100/27/52	100/31/61	100/30/72	100/35/59	100/50/80	100/35/74	
TOTAL LICHEN	100/ 3/23	50/ 2/14	25/ 2/22	100/ 4/18	100/ 1/ 8	100/ 2/17	100/tr/ 2	100/tr/ 1	82/ 2/15	
TOTAL Sede ³	100/ 5/29	25/tr/ 1	75/11/29	66/ 6/26	100/tr/tr	100/ 7/25	100/tr/tr	100/ 4/11	82/ 4/15	
TOTAL BAREGROUND **	100/10/81	100/16/90	100/ 9/79	100/13/44	100/31/84 ⁺	100/13/83	100/34/81 ⁺	100/ 6/52	100/16/76	
TOTAL ROCK **	100/ 9/49	100/18/69	100/22/88 [#]	100/ 3/21	100/18/62	100/21/79	100/ 2/15	100/ 9/42	100/14/57	
TOTAL LITTER	100/13/95	100/26/98	100/18/96	100/29/97	100/17/94	100/24/97	100/21/99	100/26/96	100/21/96	

* = specie involved in statistical analysis.

** = statistical difference of canopy coverage and frequency between the 8 associations at P=.05.

+ = statistical difference of canopy coverage between the 8 associations at P=.01.

++ = statistical difference of canopy coverage and frequency between the 8 associations at P=.01.

= statistical difference of frequency between the 8 associations at P=.01.

¹ constancy (percent occurrence among sites)/canopy coverage (percent of area covered)/ frequency (percent occurrence among plots).²tr. = trace; canopy coverage less than 0.5 percent.³sede = seleginella densa.

coniferous litter together covered 21 percent of the area and except for grass cover, was the most frequently encountered ground cover.

Graminoids covered 67 percent as much surface area as juniper with a mean 22 percent canopy coverage. Forb cover was locally high but overall averaged only 16 percent. Aside from creeping juniper, total shrub cover accounted for 3 percent of the total canopy coverage. In addition to the other live plants, club moss (*Selaginella densa*) and lichen represented 6 percent of the surface cover. Although club moss had an overall cover value of 2 percent, in one association, *Pinus-Juniperus-Festuca*, the value was 11 percent as a result of a high canopy cover recorded at site 8. In this site, northwest of Choteau, club moss occurred in 93 percent of the plots and covered 42 percent of the area.

Cover classes and the frequency of occurrence of individual plant species varied within and between the eight associations (Table 2). As noted previously, bare ground and stone averaged 30 percent of the surface covered. Values ranged from 15 percent in the *Juniperus-Andropogon-Festuca* association to 49 percent in the *Juniperus-Calamovilfa* association. The low value in the former association was a result of the high shrub canopy cover, whereas the high value in the latter association may have been a result of the relatively high surface erosion. The bare ground cover was significantly higher ($P=.05$) in the *Juniperus-Calamovilfa* (31%) and the *Juniperus-Rhus-Stipa* (34%)

associations than in the other associations.

Litter cover ranged from 13 percent in the *Juniperus-Potentilla-Festuca* association to 29 percent in the *Juniperus-Potentilla-Carex* association with an average of 21 percent. No significant difference in the canopy coverage or the frequency of occurrence of litter between the eight associations was noted.

Of the 24 species of graminoids encountered, 8 had an overall canopy coverage of more than 1 percent (Table 2). The most important grass was Idaho fescue occurring in 74 percent of the sites; canopy coverage (C) 5 percent, frequency (F) 30 percent. Its importance ranged from its low in the *Juniperus-Calamovilfa* association (C < 0.5%, F = 28%) to its highest values in the *Juniperus-Potentilla-Festuca* association (C = 8%, F = 64%). Threadleaf sedge was second in overall importance (C = 4%, F = 22%), occurring at 74 percent of the sites. Its importance ranged from low values in the *Juniperus-Potentilla-Carex* association (C < 0.5%, F = 1%) to highest in the *Juniperus-Helictotrichon* (C = 6%, F = 30%) and *Juniperus-Agropyron* (C = 5%, F = 31%) associations. Other graminoids of importance included blue-bunch wheatgrass, inflated sedge, rough fescue, spike oat, needle and thread grass and prairie junegrass.

Most associations contained several grasses in approximately equal proportions with no single species dominating the others. However, four exceptions were noted. Needle and thread grass was the most

important grass within the *Juniperus-Rhus-Stipa* association ($C = 18\%$, $F = 88\%$), with a significantly higher cover and more frequent occurrence than in any other association ($P=.05$). The occurrence of this species may be inversely related to that of Idaho fescue as these species did not occur in the same locations. Spike oat was significantly more frequent and had a higher canopy coverage in the *Juniperus-Helictotrichon* and *Juniperus-Potentilla-Carex* association than in the other six associations ($P=.05$). Blue grama (*Bouteloua gracilis*) and smooth brome (*Bromus inermis*) occurred more frequently with a higher canopy cover in the *Juniperus-Rhus-Stipa* and *Juniperus-Potentilla-Carex* associations respectively ($P=.05$).

Total grass occurrence and canopy coverage in the *Juniperus-Calamovilfa* association ($C = 20\%$, $F = 85\%$) was significantly less than the other associations ($P=.05$).

The three sites, which did not cluster in the ordination (4, 21, and 23), contained total grass cover similar to the eight associations with the exception of No. 23 ($C = 32\%$, $F = 100\%$). The higher grass cover may have been a result of no grazing by livestock for at least 20 years.

The number of forb species recorded per site varied from 1 to 34 (Table 2). Among forbs, Kelsey phlox, fringed sagewort and prairie thermopsis were most important, ($C = 2, 2, 2\%$, and $F = 19, 15, 13\%$ respectively). Fringed sagewort was the most widespread forb occurring.

in 78 percent of the sites. Other important forbs included common yarrow, pale bastard toad flax, three-veined fleabane (*Erigeron subtrinervis*), kittentail and alyssum-leaved phlox. Although contributing little to the total canopy cover, mountain lomatium (*Lomatium cous*) and field chick weed (*Cerastium arvense*) were widespread, occurring in 67 percent of the sites.

Forb cover appeared to be unevenly distributed within each association. Several dominant forbs provided most of the cover, while the remainder was comprised of around 30 species of low individual importance. Additionally, the importance of several species was variable between the associations. The cover and frequency of pasqueflower varied significantly ($P=.05$) among the eight associations; it occurred mainly in the *Juniperus-Potentilla-Festuca* ($C = 5\%$, $F = 41\%$) and *Juniperus-Andropogon-Festuca* ($C = 2\%$, $F = 90\%$) associations. Death camas and Arizona hymenoxys were most important in the *Juniperus-Potentilla-Festuca* ($C = 7\%$, $F = 47\%$) and *Pinus-Juniperus-Festuca* ($C = 2\%$, $F = 20\%$) associations respectively ($P=.05$). Prairie thermopsis, Missouri goldenrod (*Solidago missouriensis*), horse cinquefoil (*Potentilla hippiana*) and three-veined fleabane were other forbs whose importance varied statistically among the eight associations ($P=.05$). No difference in general forb cover between the eight associations and the three unclustered sites (4, 21 and 23) were noted. Site 21 had a relatively high forb complex similar to the *Juniperus-Potentilla-Festuca* association.

Total shrub importance ranged from a low in the *Juniperus-Potentilla-Carex* association (C = 27%, F = 50%) to a high in the *Pinus-Juniperus-Festuca* association (C = 50%, F = 80%). Overall shrub canopy coverage and frequency of occurrence did not vary significantly among the eight associations. However, three shrubs, common snowberry, shrubby cinquefoil and skunkbush sumac individually showed a variation between associations ($P=.05$). Both snowberry (C = 7%, F = 37%) and skunkbush sumac (C = 4%, F = 12%) were statistically more important in the *Juniperus-Rhus-Stipa* association than in the other seven associations ($P=.05$). Shrubby cinquefoil varied significantly between the eight associations occurring most abundantly in the *Juniperus-Potentilla-Festuca* (C = 7%, F = 27%), *Juniperus-Helictotrichon* (C = 4%, F = 28%) and *Juniperus-Potentilla-Carex* associations ($P=.05$).

Creeping juniper was by far the most important shrub as well as the most important species (C = 32%, F = 57%). Coverage estimates ranged from 26 percent in the *Pinus-Juniperus-Festuca* association to 47 percent in the *Juniperus-Andropogon-Festuca* association. At site 27 within the latter association, creeping juniper covered 83 percent of the area demonstrating the high degree of community dominance attainable by this shrub. A common associate and the second most important shrub was shrubby cinquefoil (C = 2%, F = 9%) occurring at 29 percent of the sites and 50 percent of the associations. Other

important shrubs included prickly rose (C = 1%, F = 6%) and common snowberry (C = 1%, F = 4%).

Shrubs encountered but not sampled were Rocky Mountain juniper, silver buffalo berry (*Shepherdia argentea*) and common juniper.

Of the three unclustered sites, No. 21 was the only one to show any peculiar shrub characteristics. The total shrub cover was near 64 percent, mainly as a result of creeping juniper (C = 63%, F = 80%).

Both canopy coverage and frequency of creeping juniper were negatively and highly correlated with the southern azimuths (C, $r = -.53$; F, $r = -.59$). Generally those associations with the most creeping juniper had a north to northwest exposure. The slope gradient had little direct effect on the presence of juniper. It occurred on slopes ranging from 5 to 42 percent, although 67 percent of the sites were on slopes greater than 20 percent. In areas where slope was apparently a major factor as to the establishment of vegetation and/or providing a mesic environment, it may have indirectly limited the occurrence of creeping juniper. Although possibly not a major influence, elevation was negatively correlated with canopy coverage of juniper ($r = -.37$). Maximum cover values were attained in areas between 1300 meters (4000 ft) and 1500 meters (5000 ft). In areas less than 1300 meters or greater than 1500 meters percent of ground covered was considerably less.

Typically, creeping juniper sites lacked a definite tree overstory.

Only limber pine, ponderosa pine and Douglas fir were identified as being associates of creeping juniper within the eight associations (Table 3). Although deciduous trees were encountered within several hundred meters of several study sites, they invariably were associated with a different community. At one supplemental location (Site 24) high in the mountains south of Big Timber, whitebark pine (*Pinus albicaulis*) and lodgepole pine (*Pinus contorta*) were also encountered.

Total tree densities ranged from zero in the *Juniperus-Rhus-Stipa* association to 159 plants/ha in the *Juniperus-Helictotrichon* association with canopy coverage estimates varying from less than 0.5 percent in the *Juniperus-Rhus-Stipa* and *Juniperus-Agrophyron* associations to 24 percent in the *Pinus-Juniperus-Festuca* association.

Limber pine, the major tree associate, occurred at 48% of the study sites with an overall mean canopy coverage of 4% and density of 43 plants/ha. This species was also the most important tree among the eight associations, ranging from less than 0.5% coverage in the *Juniperus-Agrophyron* and *Juniperus-Rhus-Stipa* associations to 18 percent in the *Pinus-Juniperus-Festuca* association and, from 0 to 158 plants/ha. Although the canopy coverage of trees was higher in the *Pinus-Juniperus-Festuca* association than in the *Juniperus-Helictotrichon* association, the tree density was about one half. This may indicate the difference in age structure of limber pines between these two associations. The other two tree species were ponderosa pine, which occurred only in the

Table 3. Constancy, canopy coverage, and density of three trees on each of the eight creeping juniper associations.

Associations	TAXA			Total Trees/ha	Total Tree Cover (percent)
	<i>Pinus flexilis</i>	<i>Pinus ponderosa</i>	<i>Pseudotsuga menziesii</i>		
<i>Juniperus- Potentilla- Festuca</i>	25/ 1/ 14 ¹	- - -	25/tr/ 1.	15	1
<i>Juniperus- Agropyron</i>	50/tr/ 9	- - -	- - -	9	tr ²
<i>Pinus Juniperus Festuca</i>	75/18/ 73	- - -	25/ 6/12	85	24
<i>Juniperus Potentilla Carex</i>	66/ 3/ 34	- - -	- - -	34	3
<i>Juniperus Calamovilfa</i>	20/ 1/ 41	20/20/32	- - -	71	21
<i>Juniperus Helicto- trichon</i>	100/ 4/158	- - -	50/tr/ 1	159	5
<i>Juniperus- Rhus- Stipa</i>	- - -	- - -	- - -	-	-
<i>Juniperus- Andropogon- Festuca</i>	66/ 1/ 13	- - -	33/tr/ 2	15	1
TOTAL	48/ 4/ 43	4/tr/ 4	15/ 1/ 2	49	5

¹Constancy (percent occurrence among sites)/percent canopy coverage/density per Ha.

²Tr. = canopy coverage less than 0.5%.

Juniperus-Calamovilfa association in central and eastern Montana, and Douglas fir, which occurred in several associations at low densities.

Edaphic Characteristics and Relationships

Soils associated with creeping juniper stands appeared to be poorly developed, and were often characterized by thin topsoils, large quantities of stone, and exposed rock parent material. Also, because of their moderately steep slopes, relative openness, and sparse vegetation, some degree of erosion was typical on most sites. Analyses of soil samples from study sites (Table 4, Appendix Table 17) further indicated that soils tended to be clay loam in texture, slightly basic, low to medium in organic matter content, very low in phosphorus, medium to high in potassium, and low in salt.

Average apparent soil depth (to parent material) was approximately 16 cm, with a range from 9 cm to 33 cm for 51 sites (Appendix Table 17). A majority (73%) of the sites had soil less than 20 cm deep. Soil depth differed significantly between the eight associations ($P=.05$). Deepest soils (ave. 25.3 cm) supported the *Juniperus-Rhus-Stipa* association. Among individual plant species tested, soil depth was positively correlated with frequency of occurrence and coverage of purple reedgrass (*Calamovilfa purpescens*) ($r = .52$ and $r = .52$, respectively) and Hood's phlox (*Phlox hoodii*) ($r = .54$ and $r = .53$) and the frequency of pasque flower (*Anemone patens*) ($r = .51$). A negative relationship between soil depth and coverage of limber pine ($r = -.54$) was noted.

Table 4. Edaphic characteristics of creeping juniper associations including pH, organic matter content, texture, salt hazard, soil depth, erosion, and five important elements.

Associations	pH	Organic Matter Percent	Tex- ture ¹	Phos- phorus ppm ²	Potas- sium ppm	Magne- sium meq ³	Sod- ium meq	Cal- cium meq	Salt Hazard mmhos ⁴	Soil Depth cm	Surface Erosion Percent
<i>Juniperus- Potentilla- Festuca</i>	7.3	6.5(H)	SiL	23(VL)	373(H)	2.5	0.05	30.0	0.95	12.9	3.0
<i>Juniperus- Agropyron</i>	7.4	4.2(M)	L	19(VL)	198(M)	1.7*	0.03	22.6	1.2	13.7	12.0
<i>Pinus- Juniperus- Festuca</i>	7.1	4.9(M)	CL	17(VL)	251(H)	1.8	0.05	24.6	0.83	10.8	12.0
<i>Juniperus- Potentilla- Carex</i>	7.4	6.2(H)	SiL	14(VL)	375(H)	3.6	0.13	29.6	1.4	17.4	3.0
<i>Juniperus- Calamovilfa</i>	6.8	2.7(L)	CL	23(VL)	230(M)	3.1	0.13	28.0	0.58	21.1	43.0 ⁺
<i>Juniperus- Helictotrichon</i>	7.0	4.1(M)	SCL	8(VL)	262(H)	4.4	0.10	22.2	0.45	15.6	9.0
<i>Juniperus- Rhus- Stipa</i>	7.5	2.8(L)	C	17(VL)	246(M)	2.4	0.10	70.0 ⁺	3.4**	25.3*	15.0

Table 4 (Continued).

Associations	pH	Organic Matter Percent	Tex- ture ¹	Phos- phorus ppm ²	Potas- sium ppm	Magne- sium meq	Sod- ium meq	Cal- cium meq	Salt Hazard mmhos ⁴	Soil Depth cm	Surface Erosion Percent
<i>Juniperus- Andropogon- Festuca</i>	7.5	5.2(M)	CL	12(VL)	344(H)	5.2	0.03	27.5	0.87	16.8	3.0
Average	7.2	4.6(M)	CL	18(VL)	280(H)	2.9	0.08	29.5	1.1	15.9	12.5
Site 4 ⁶	7.6	2.7(L)	LS	18(VL)	71(VL)	1.2	Tr. ⁵	11.2	0.7	17.9	15.0
Site 21	7.3	6.8(H)	L	21(VL)	399(H)	3.0	Tr.	34.0	1.7	17.5	3.0
Site 23	8.0	3.8(L)	CL	9(VL)	312(H)	1.9	Tr.	21.0	0.9	20.8	15.0

¹ SiL=Siltloam; L=Loam; CL=Clayloam; SCL=Sandyclay loam; C=Clay; LS=Loamy Sand.

² ppm=pounds/one million pounds of soil.

³ meq=Millequivalents/100 grams of soil.

⁴ mmhos=millimhos 1mho=1/Ohm.

⁵ Ratings from Montana Soils Testing Laboratory Report, ST-Form 2; VL=Very Low; L=Low; M=Medium; H=High. Tr.=Trace; value less than 0.1%.

⁶ Individual sites; not clustered.

* and + mean significant difference at P=.05 and .001, respectively.

**=Slightly salty.

The proportion of soil surface eroded averaged 15 percent, but varied from 3 percent to over 60 percent at five sites. Seven sites (14%) showed 38 percent surface erosion, while the remaining 39 were judged to be 15 percent or less eroded. The eight associations differed significantly in surface erosion ($P=.001$). The *Juniperus-Calimovilfa* association occurred on more heavily eroded sites (ave. 43%). The other associations averaged only eight percent erosion. The frequency and/or coverage of four plant species appeared to be negatively correlated with soil erosion. These included frequency and coverage of rough fescue ($r = -.54$ and $-.57$, respectively), field chickweed ($r = -.57$ and $r = -.66$) and flowery phlox ($r = -.64$ and $r = -.51$), and frequency of Idaho fescue ($r = -.49$). Creeping juniper with its ability to root along its branches and form large mats may be able to tolerate the high soil surface erosion.

Clay loams, loams, silt loams, clays, sandy clay loams, sandy loams, sandy clays, silt clays and loamy sands comprised 31, 18, 14, 12, 10, 8, 4, and 2 percent of the sites respectively. The average of all sites was a clay loam (35% silt, 34% clay and 35% sand). The finest textured of these soils may impose difficulty for some plants to become established (Russell 1973); creeping juniper with its shallow root system has apparently been able to cope with the soils.

Soil pH values ranged from strongly acid (4.4) to moderately alkaline (8.5) among the 51 sites. The overall average was 7.39 or a

slightly alkaline condition. A pH value such as this provides an environment in which most of the common elements are available. The eight associations were not significantly different, with all ranging near 7.2. The *Juniperus-Calamovilfa* association was an exception with a pH of 6.8. Positive correlations between soil pH and the frequency and coverage of western snowberry (*Symphoricarpos occidentalis*) ($r = .59$), frequency of flowery phlox ($r = .49$) and the coverage of field chickweed ($r = .51$) were noted. A single negative correlation between pH and the frequency and coverage of prairie rose ($r = -.62$ and $-.59$, respectively) was also noted.

The organic matter content of a soil influences such physical and chemical properties as cation-exchange capacity, soil stability and nutrient supply and availability (Buckman and Brady 1969). Twelve sites (24%) were considered very low, 15 (29%) low, 10 (20%) moderate and 14 (27%) high. Average overall organic matter content was 4.1 percent (high) with a range from 0.8 to 7.4 percent. The areas of highest organic matter content were those having a relatively large percent of the ground covered by forbs and grasses. The converse was true at sites with low soil organic matter. The organic matter content in the eight associations, which ranged from 2.7 percent (low) in the *Juniperus-Calamovilfa* association to 6.5 percent (high) in the *Juniperus-Potentilla-Festuca* association, did not differ significantly. Only two associations were rated low, the others were either medium (4) or

high (2). Plant species positively correlated with organic matter content included frequency and cover of Hood's phlox ($r = .59$ and $r = .74$, respectively), and cover of Idaho fescue ($r = .61$) and textile onion (*Allium textile*) ($r = .63$). Frequency of flowery phlox ($r = -.51$) and coverage of Arizona hymenoxys ($r = -.53$) were negatively correlated with organic matter.

Phosphorus is a critical element in the growth of plants influencing the processes of reproduction, development and the intake of the other important elements (Buckman and Brady 1969). Three sites (6%) were rated low (45.0, 49.0 and 43.0 ppm), 1 (2%) was high (103.0 ppm) and the rest, 47 (92%), were very low (less than 30.0 ppm) in this element. The site near Lincoln, west of the Continental Divide, was found to be very high in comparison to all others, with a value of 103.0 ppm. The mean value for all sites was 15.6 ppm (very low); excluding the site near Lincoln, it drops to 13.5 ppm. In either case, the Lincoln value was approximately seven times greater than the average for the other sites. A combination of precipitation, location under conifers and relatively low levels of calcium may have attributed to this condition (Buckman and Brady 1969). Significant differences were not detected between the eight associations where the average was 16.6 ppm and the range was from 8 ppm (very low) in the *Juniperus-Helictotrichon* association to 23 ppm (very low) in the *Juniperus-Calamovilfa* and *Juniperus-Potentilla-Festuca* associations. Positive

correlations between phosphorus and plant parameters included coverage of western wheatgrass ($r = .63$) and field chickweed ($r = .62$), frequency of flowery phlox ($r = .53$) and frequency and cover of arrowleaf balsamroot (*Balsamorhiza sagittata*) ($r = .64$ and $.66$, respectively).

Potassium is an element essential to the photosynthetic process and transportation of its products (Russell and Russell 1974). Additionally, it is important in the synthesis of amino acids and proteins. Twenty-one sites (41%) were found to have high levels, 24 (47%) medium, 4 (8%) low and 2 (4%) very low. The content of samples varied from 69.0 ppm (very low) to 580.0 ppm (high), with a mean of 260.1 ppm (high). The eight associations were not statistically different at the .05 level. Potassium content varied from 198 ppm (medium) in the *Juniperus-Agropyron* association to 375 ppm (high) in the *Juniperus-Potentilla-Festuca* association with a mean of 284.9 ppm (high). This element was positively correlated with more plant species than any other soil factor. Positive correlations between potassium and plant occurrence included frequency and cover of mountain lomatium ($r = .53$ and $.51$, respectively), Kelsey phlox ($r = .51$ and $.60$, respectively), pasque flower ($r = .50$ and $.51$), blue flax (*Linum perenne*) ($r = .57$ and $.55$), common yarrow ($r = .73$ and $.55$), common dandelion (*Taraxicum officinale*) ($r = .59$ and $.59$), and blanket flower (*Gaillardia aristata*) ($r = .55$ and $.49$), frequency of northern bedstraw ($r = .51$), and coverage of meadow death camas ($r = .55$) and spotted fraseria (*Frasera speciosa*) ($r = .67$). Frequency and

coverage of inflated sedge ($r = -.57$ and $-.58$) and three-veined fleabane ($r = -.51$ and $-.51$), and frequency of flowery phlox ($r = -.55$) were negatively correlated with this element.

Calcium is essential for growth of meristems and particularly for the proper growth and function of root tips (Russell and Russell 1974). Calcium contents of samples from the 51 sites varied between 9.6 and 98.0 meq/100 grams of soil with a mean of 29.3 meq/100 grams of soil. The eight associations ranged from 22.2 meq for the *Juniperus-Helictotrichon* association to 70.0 meq in the *Juniperus-Rhus-Stipa* association with an average of 31.9 meq. One association, *Juniperus-Rhus-Stipa*, differed significantly ($P=.001$) from the other seven. This association had a calcium level of approximately $2\frac{1}{2}$ times the others and may have accounted for the relatively high average height of creeping juniper (ave. = 9.6 cm). Positive correlations of plant performance with calcium levels included cover of inflated sedge ($r = .53$) and frequency of pale bastard toad flax ($r = .54$). Frequency and cover of flowery phlox ($r = -.66$ and $-.65$, respectively) and frequency of mountain lomatium ($r = -.53$) were negatively correlated with calcium content.

Magnesium is a necessary element as a constituent of chlorophyll (Russell and Russell 1974). Overall, the element ranged from 0.7 to 7.3 meq with a mean of 2.8 meq. Variation within the eight associations was from 1.7 meq in the *Juniperus-Agropyron* association to 5.2 meq in the *Juniperus-Andropogon-Festuca* association. The average content was 30.9 meq. The

Juniperus-Agropyron association soil possessed significantly lower levels of magnesium (1.7 meq) from the other seven associations. Plant species positively correlated with this element comprised frequency and cover of inflated sedge ($r = .49$ and $.54$, respectively), kinnikinnik (*Arctostaphylos uva-ursi*) ($r = .58$ and $.58$), Japanese brome (*Bromus japonicus*) ($r = .58$ and $.58$), pale bastard toadflax ($r = .61$ and $.54$), and frequency of leafy musineon (*Musineon divaricatum*) ($r = .49$). Negative correlations included frequency and cover of mountain lomatium ($r = -.77$ and $-.53$, respectively), flowery phlox ($r = -.56$ and $-.54$), and cover of Arizona hymenoxys ($r = -.54$).

Sodium levels at all sites were less than 0.40 meq with the average at less than 0.1 meq. Within the eight associations it ranged from 0.03 to 0.13 meq and an average of 0.08. No significant difference was noted. A majority of the correlations with plant species were negative. These included frequency and cover of common yarrow ($r = -.68$ and $-.54$, respectively), common dandelion ($r = -.51$ and $-.51$), cover of spotted fraseria ($r = -.63$), and frequency of blue flax ($r = -.49$). The only positive correlation was frequency of western wheatgrass ($r = .65$).

Generally the salt concentration at all sites was low enough to have little effect on vegetation. Only two sites (Nos. 14 and 32) gave any indication of saltiness. Only the *Juniperus-Rhus-Stipa* association showed signs of saltiness and this was due to site 14. Frequency and cover of blue grama ($r = .75$ and $r = .75$), soapwell (*Yucca glauca*)

($r = .75$ and $.75$), flowery phlox ($r = .65$ and $.68$) and cover of skunk-bush sumac ($r = .50$) were positively correlated with salt hazard. Negative relationships included frequency and cover of prairie rose ($r = -.53$ and $-.50$) and inflated sedge ($r = -.54$).

No significant difference was noted in comparing six soil factors of samples taken from under creeping juniper shrubs with those between shrubs (Table 5). This appears to indicate that creeping juniper shrubs do not modify the soil in their immediate vicinity. A slightly higher organic matter content was noted under the plants, but not enough to be of any importance.

Table 5. Comparison of six soil factors from samples taken under and between creeping juniper shrubs.

Location	pH	Phosphorus ppm	Potassium ppm	Salt Hazard mmhos	Sodium meq/100gm	Organic Matter percent
under	7.18	21.1	380.1	1.2	.09	5.8
between	7.20	19.1	351.3	1.1	.06	5.0
t-value ¹	.06	.43	.51	.64	.75	1.3

¹t-value from table in Dixon and Massey, 1969, is 2.1 for $P=.05$.

The three sites (4, 21 and 23) which did not "fit" into any association had soil characteristics generally comparable to those of the eight associations with the following exceptions; site 4 had lower levels of magnesium, calcium and potassium possibly contributing to

poor plant conditions; and site 21 had relatively high organic matter probably caused by high creeping juniper ground cover (63%).

Growth Characteristics and Relationships

Growth Form

Creeping juniper typically occurred as a very low shrub, in dense mats less than one dm tall, growing horizontally or "creeping" along the ground. Occasionally, taller or small, bush-shaped plants occurred where browsing on peripheral branches reduced spreading or where disease caused abnormal growth. In some areas or stands, with histories of heavy use by deer, mats were often broken up, and individual plants were impossible to differentiate.

Mats consisted of a central section and peripheral, spreading branches or leaders on which most of the plant growth occurs. Little if any net growth appeared to occur within the central mat. Excavations showed that this central portion has a major root system consisting of several major and numerous minor roots. As the shrub enlarges, roots sprout along the peripheral branches anchoring them to the ground. Rooting generally started 10-20 cm from the tips of leaders. Depths of major roots of excavated plants ranged from 13.0 to 35.0 cm, with a mean of 22.4 ± 1.3 cm.

On relatively flat sites, plants appeared to grow laterally in all directions; on steeper slopes, lateral enlargement occurred mainly on the downhill side of the plant. As a rule, growing leaders adhered to

the ground, only rarely extending their tips off the ground, such that the low plant profile was maintained.

Annual growth occurred both laterally and terminally on individual branches or leaders less than 4-5 years old; and most new twigs and leaves originated from one and two-year-old stems. However, some new leaves and twigs were also noted to occur on older portions of the plant. Current annual growth of creeping juniper is essentially impossible to differentiate from previous years' growth by visual examination; though close inspection of known-age materials showed several possible distinguishing features. Current year's growth on twigs was bright green, with short, awl-like leaves closely appressed to the stem, and with very short interaxial leaf spaces. Second year growth generally also had bright green leaves, but they were less appressed to the stem and interspaces were approximately 5-10 times longer than on new growth. After the first two years, the flaring of leaves and interspaces remained uniform and similar to the second year growth, though the leaves turned a reddish brown and appeared to be dying.

When annual growth was nearly complete, both staminate and pistillate "flowers" developed from the tips of lateral and terminal twigs located both within the plant and peripherally. The flowers occurred on both first and second year twigs.

The height of creeping juniper plants varied significantly ($P=.005$)

between sites occupied by the eight associations in which this species occurred (Table 6). Mean plant heights ranged from 4.8 cm in the *Juniperus-Potentilla-Festuca* association to 9.6 cm in the *Juniperus-Rhus-Stipa* association. The overall mean plant height was 6.4 cm for all associations. Plants were significantly taller ($P=.05$) in the *Juniperus Calamovilfa* (8.5 cm) and *Juniperus-Rhus-Stipa* associations than in other associations, while plants in the *Juniperus-Potentilla-Festuca* association were significantly shorter ($P=.05$) than in the others. The two associations having the tallest juniper plants occupied sites which were fairly dry, at relatively low elevation, and had relatively low grass and forb coverage; whereas the sites occupied by *Juniperus-Potentilla-Festuca* were quite mesic, at high elevations, and had high grass-forb coverage.

Heights of creeping juniper plants appeared to be highly influenced by weather or climatic factors, little influenced by topo-geographic factors, and not influenced by soil factors. Among weather factors, maximum and average annual temperatures for 1976, and mean annual precipitation were positively correlated with height ($r = .55, .74, .51$, respectively). Minimum 1976 temperatures and normal annual temperatures were negatively correlated ($r = -.57$ and $-.63$, respectively). Overall, weather factors were highly correlated ($r = .76$) with plant heights. Although the effects of individual weather factors were difficult to separate within this correlation, it generally appeared that

Table 6. Height, decadence, biomass, and lateral and terminal growth of shrubs in the eight creeping juniper associations east of the Continental Divide.

Associations	Height (cm)	Decadence (percent)	Biomass		Lateral Growth (mm) ³	Terminal Growth (mm)
			Mean Crown Area ¹ (lbs/ft ²)	Standing Crop ² (lbs/acre)		
<i>Juniperus- Potentilla- Festuca</i>	4.8*	3.3	.027	386.1	8.7	30.8
<i>Juniperus- Agropyron</i>	5.7	5.8	.032	416.0	7.2	30.7
<i>Pinus- Juniperus- Festuca</i>	5.9	3.3	.036	436.2	6.5	17.8
<i>Juniperus- Potentilla- Carex</i>	5.3	4.0	.026	417.9	12.4	69.6
<i>Juniperus- Calamovilfa</i>	8.5*	1.4	.032	376.7	11.7	46.0
<i>Juniperus- Helictotrichon</i>	5.4	1.5	.031	354.9	6.2	21.3
<i>Juniperus- Rhus- Stipa</i>	9.6*	5.0	.038	548.6	11.5	36.9
<i>Juniperus- Andropogon- Festuca</i>	6.2	8.3	.029	589.2	7.9	19.8
Total	6.5	3.1	.031	444.9	9.0	34.5
Site 23	6.6	2.0	.039	290.5	13.7	57.9
Site 21	9.9	4.0	.035	908.2	5.5	21.1
Site 4	4.3	3.0	.038	485.2	4.0	9.3

*=statistical difference between associations at P=.05

¹pounds of creeping juniper per foot² of creeping juniper crown area

²pounds of creeping juniper per acre of total vegetation

³growth during 1977 growing season

temperature and precipitation had greatest influence on the height of creeping juniper plants throughout its range in Montana, overshadowing the effects of other factors such as length of the growing season which showed no significant correlation with height. Elevation was the only topo-geographic factor which appeared to be correlated with plant height ($r = -.65$), with plants at lower elevations tending to have a higher mean stature. Among edaphic factors, neither the pH, organic matter content, various mineral contents, nor texture of soils at study sites were correlated with the height of juniper plants.

The proportion of dead crown was relatively low among creeping juniper plants on all study areas. The mean ranged from 1.4 percent in the *Juniperus-Calamovilfa* association to 8.3 percent in the *Juniperus-Andropogon-Festuca* association with no significant difference between any of the eight associations. The average decadency for all plants and sites was 3.5 percent. This was much lower than reported for two other browse species in Montana, including skunkbush sumac -29 percent (Martin 1971) and curl-leaf mountain mahogany -26 percent (Duncan 1975). Soil characteristics apparently had no significant influence on the occurrence of dead crown; and elevation and slope had little effect. However, aspect, the north-south exposure of a site, was significantly negatively correlated with decadency ($r = -.50$). Those associations generally having a northern exposure, as *Juniperus-Andropogon-Festuca*, contained highest levels of dead crown while those typically found on

southerly exposures, as *Juniperus-Calamovilfa* had the least amount of dead crown. The high proportion of dead crown may also be a reflection of high amounts of deer utilization as noted by Kamps (1968) and in this study.

Annual Chronology and Twig Growth

A chronology of phenological events in the annual cycle of creeping juniper, based on observations and measurements during 1977, is presented in Figure 23. The annual cycle usually began in early April when plants almost simultaneously began to "green-up" and initiate twig growth. Among individual sites, dates of "green-up" and initial twig growth ranged from early April to early May.

The "green-up" or change in leaf color from a reddish-brown to a deep green coincided with the breaking of dormancy near the beginning of April and was completed in all plants by the first of May.

Twig growth was first noticed about the second week in April on plants of sites in the vicinity of Lewistown and continued into September. Generally, growth of all terminal and lateral twigs was completed by early September; however, plants on several sites continued to show growth well into September. Observations at site 29, on the Sun River Game Range, west of Augusta, over a three-year period indicated that a small amount of growth occurred after mid-September and possibly into early October. The period of most rapid growth was usually from the first of June to the end of July, where plants at all sites put on

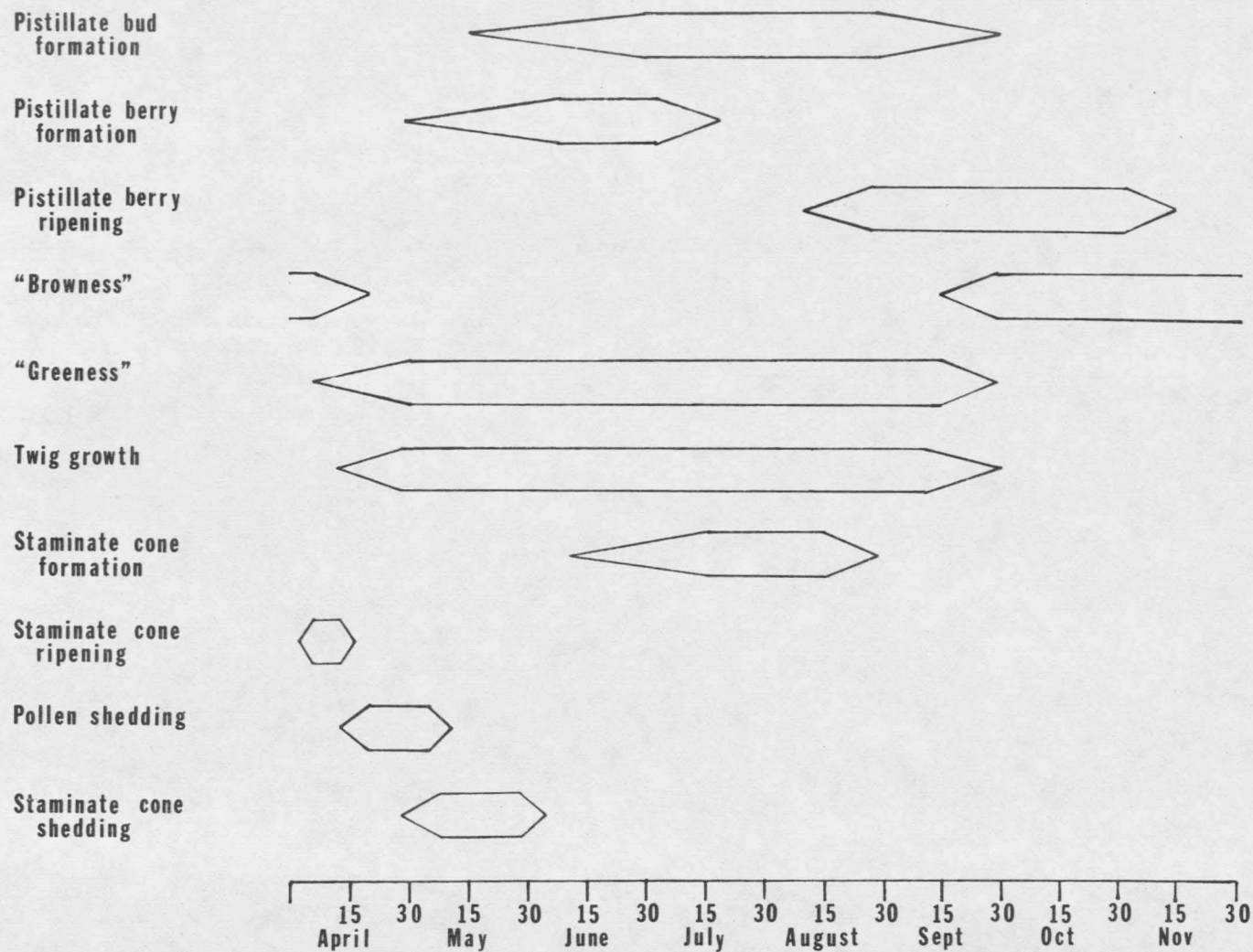


Figure 23. Annual chronology of creeping juniper in stands east of the Continental Divide as determined by spring, summer and fall observations.

between 10 and 100 mm growth.

Patterns of current annual growth of terminal and lateral twigs of creeping juniper plants in the eight associations plus the three stands which did not cluster are shown in Figures 24a through 24i. Seasonal growth, particularly of terminal twigs followed the "S"-shaped curve commonly found for most vegetative growth.

Lateral and terminal twig growth differed considerably, as might be expected. Lateral twig growth was slow but consistent whereas the terminal twigs put on a relatively greater proportion of their growth between June and July. Overall, the ratio of terminal to lateral growth was consistent within each association; that is, relatively long terminal growth on plants was accompanied by relatively long lateral growth and vice versa; however this ratio differed among plants in the different associations.

Terminal and lateral twig growth varied between sites of the same association as well as among those of different associations, though differences were not statistically significant (Table 6, Figs. 24a to 24i). For example, a comparison of the growth of plants among sites of the *Juniperus-Potentilla-Carex* association (Fig. 24d) shows that annual growth on plants at site 18 was much longer, averaging more than 130 mm terminally and nearly 20 mm laterally, than that of plants at sites 11 and 12. Among sites of the *Juniperus-Calamovilfa* association (Fig. 24e), plants at site 26 produced longer terminal twigs (ave. 60 mm) than the

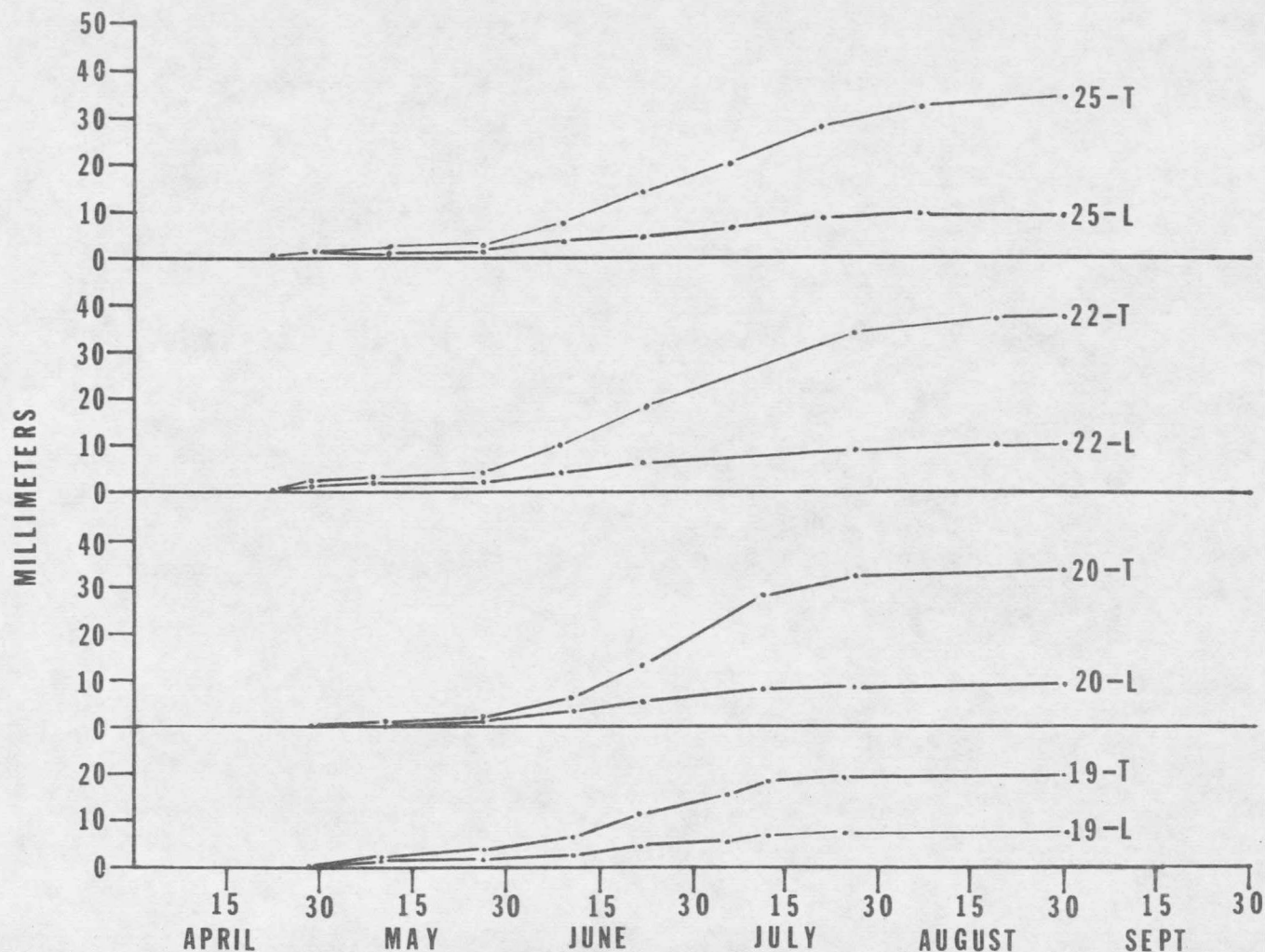


Figure 24. Growth curves of lateral (L) and terminal (T) twigs on creeping juniper shrubs in eight juniper associations as determined by the mean length of 15 terminal and 60 lateral twigs per site in 1977. a. *Juniperus-Potentilla-Festuca* association--sites 19, 20, 22, 25.

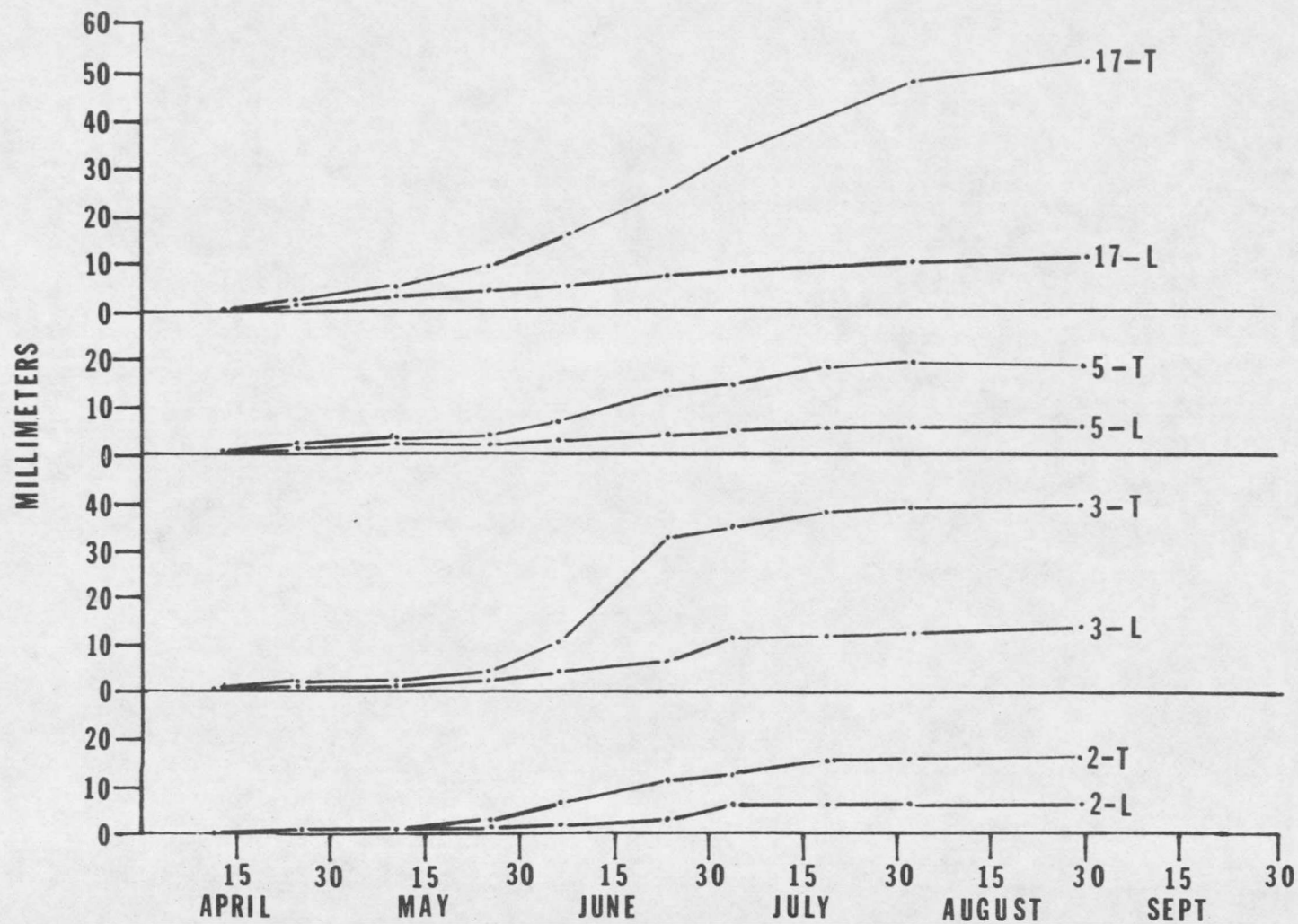


Figure 24. Continued, b. *Juniperus-Agrophyron* association--sites 2, 3, 4, 17.

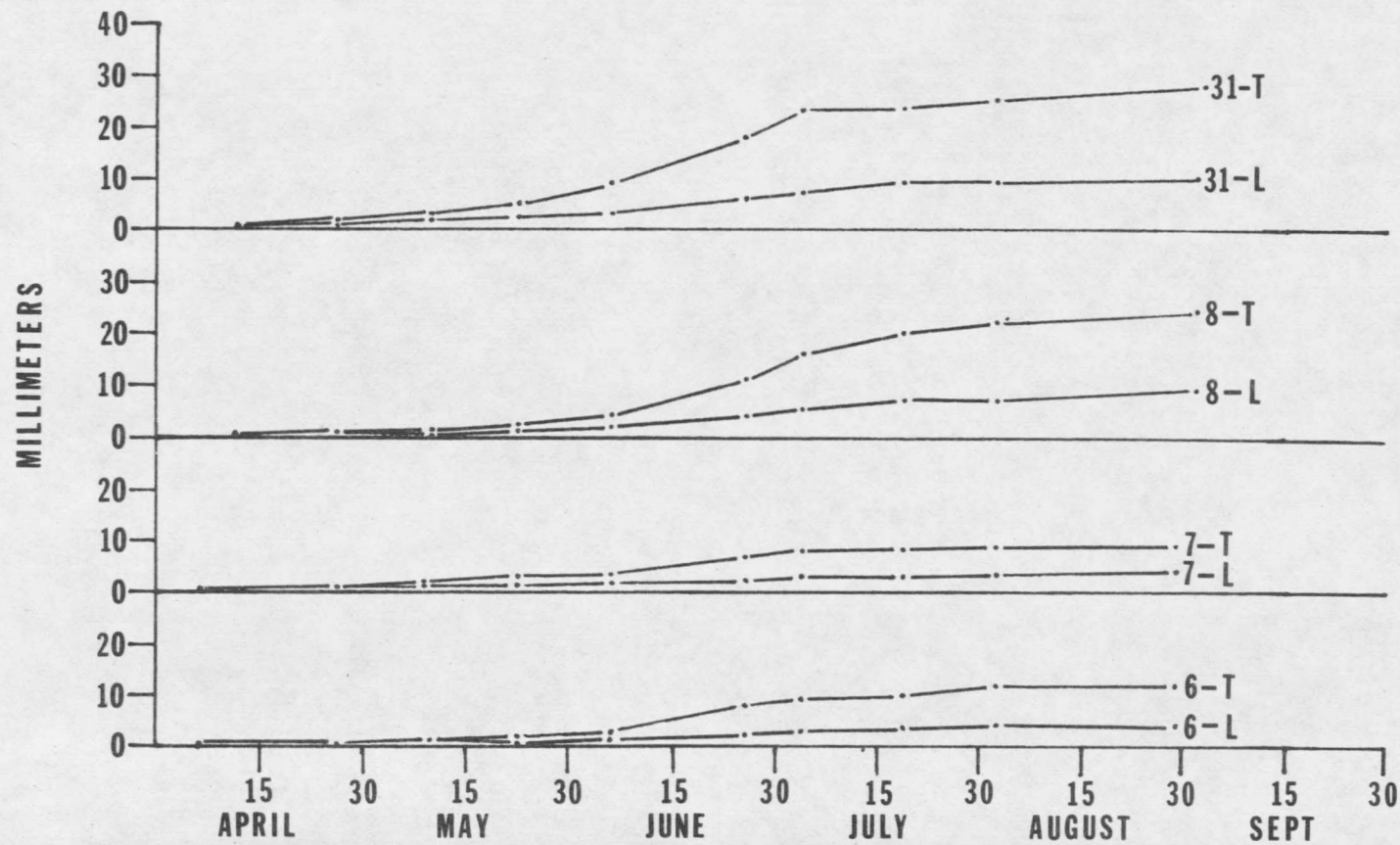


Figure 24. Continued, c. *Pinus-Juniperus-Festuca* association--sites 6, 7, 8, 31.

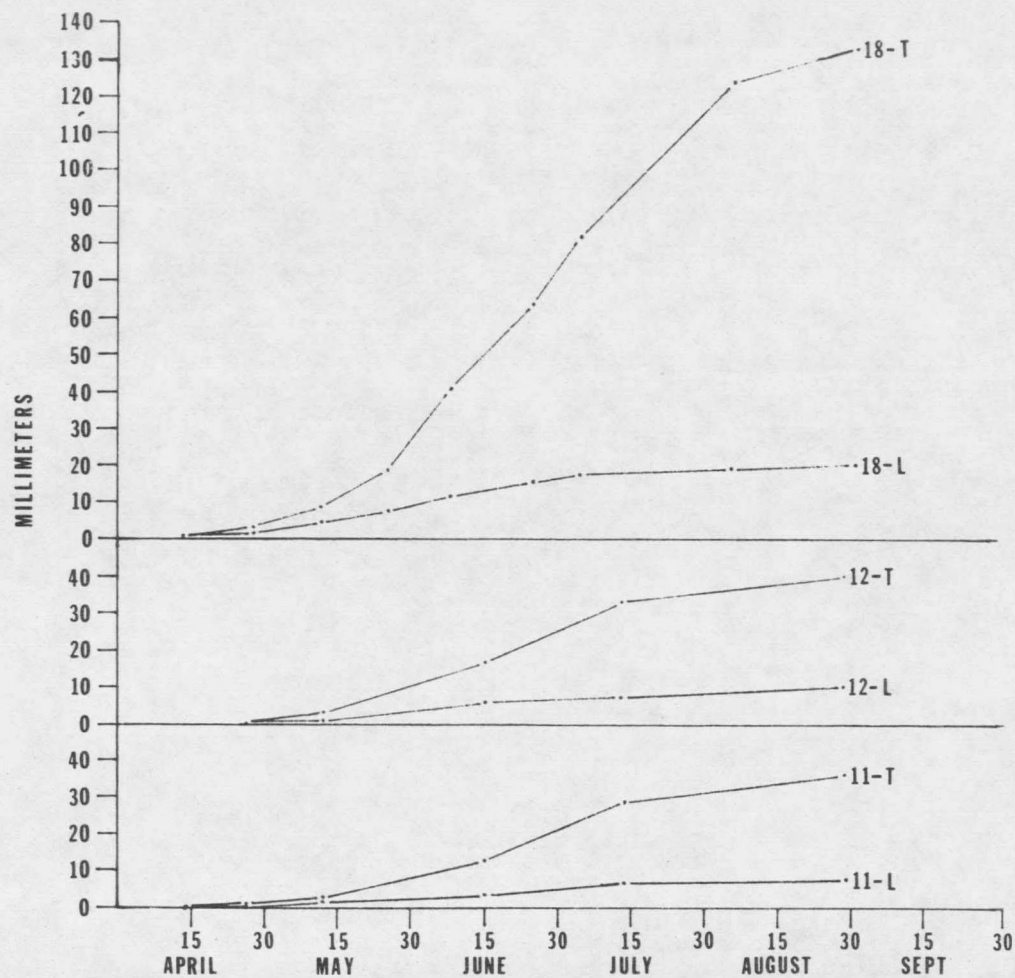


Figure 24. Continued, d. *Juniperus-Potentilla-Carex* association--sites 11, 12, 18.

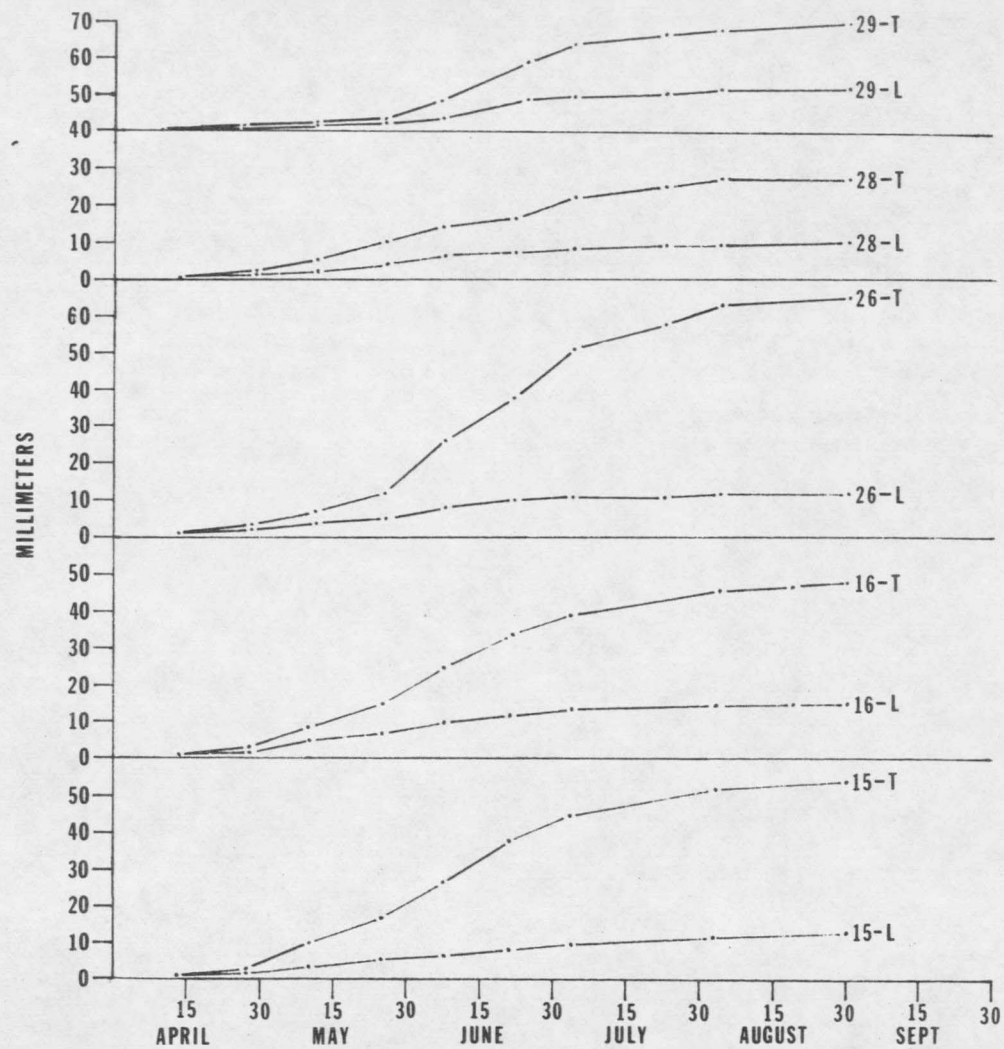


Figure 24. Continued, e. *Juniperus-Calamovilfa* association--sites 15, 16, 26, 28, 29.

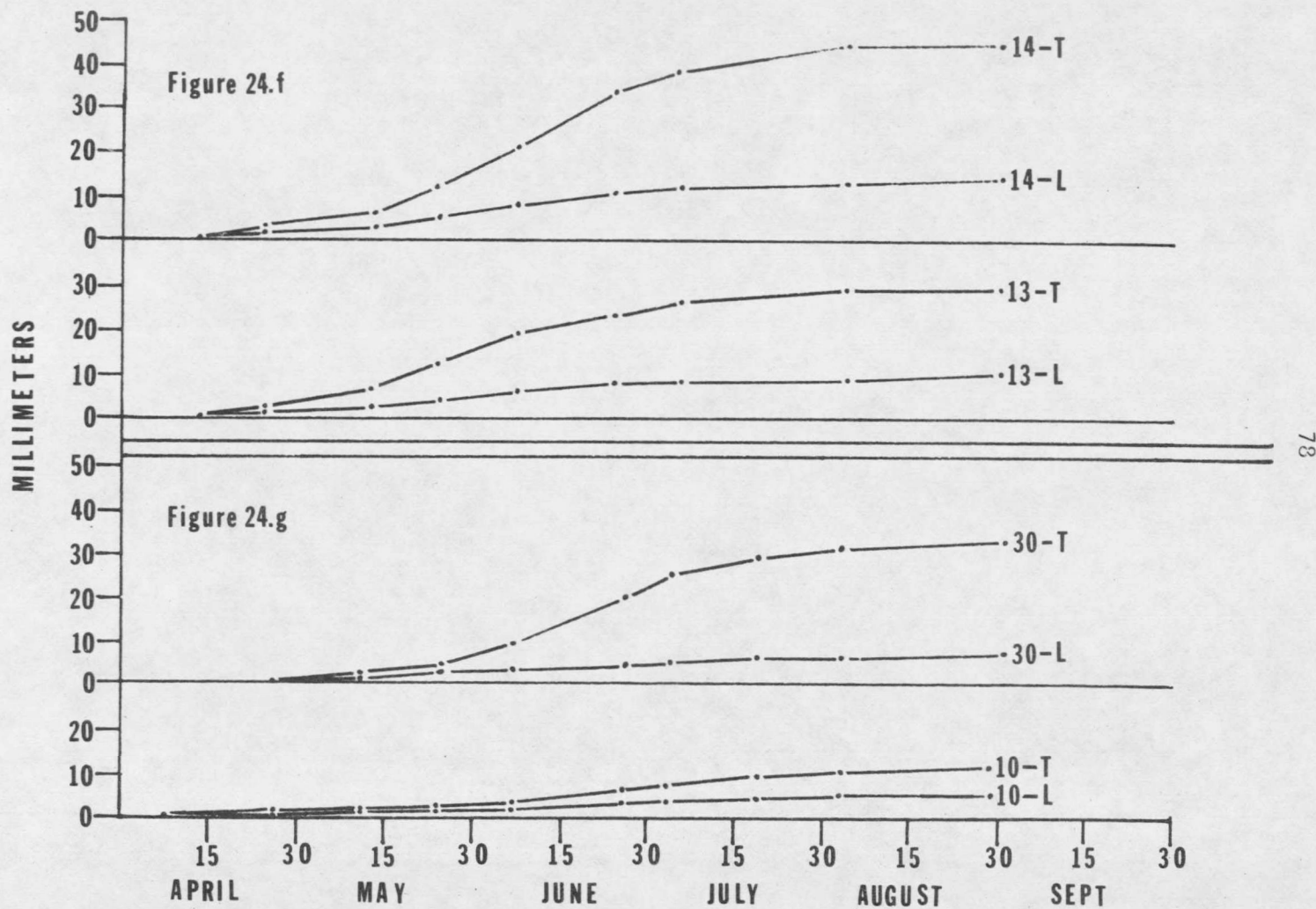


Figure 24. Continued, f. (top) *Juniperus-Rhus-Stipa* association--sites 13, 14 and 24 g. (bottom) *Juniperus-Helictotrichon* association--sites 10, 30.

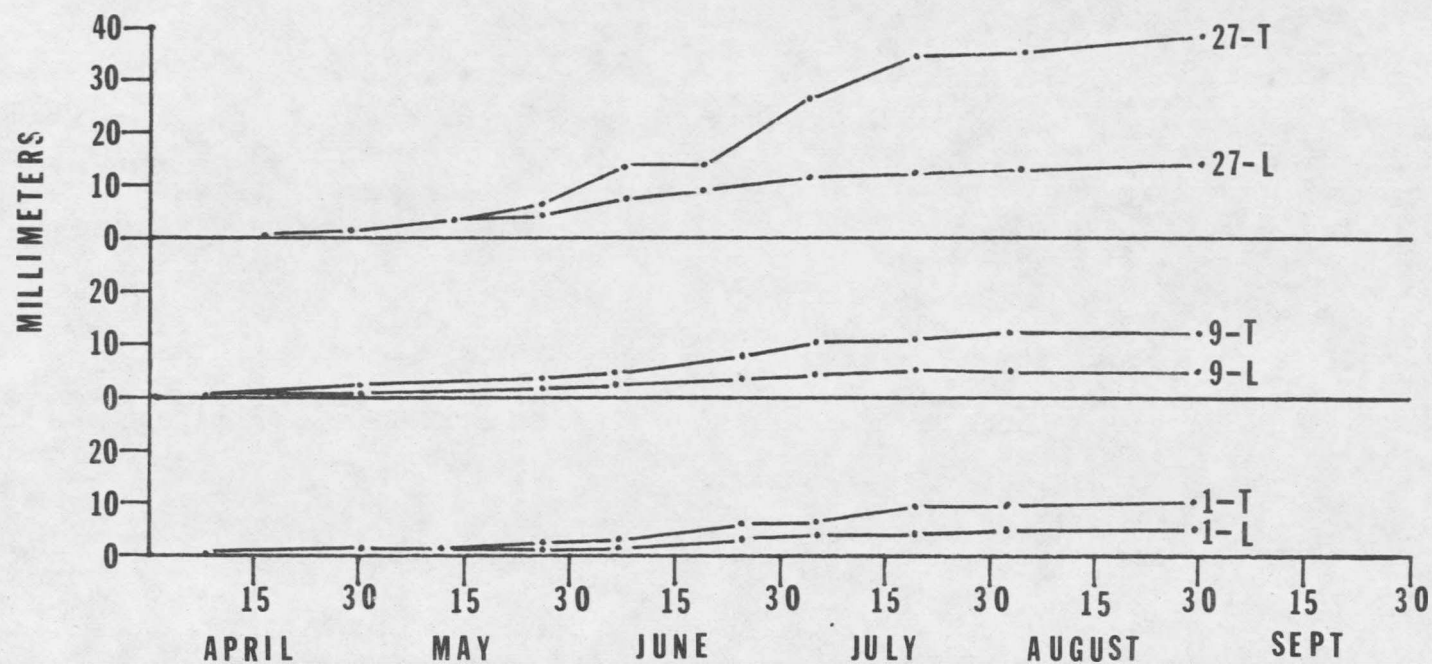


Figure 24. Continued, h. *Juniperus-Andropogon-Festuca* association--sites 1, 9, 27.

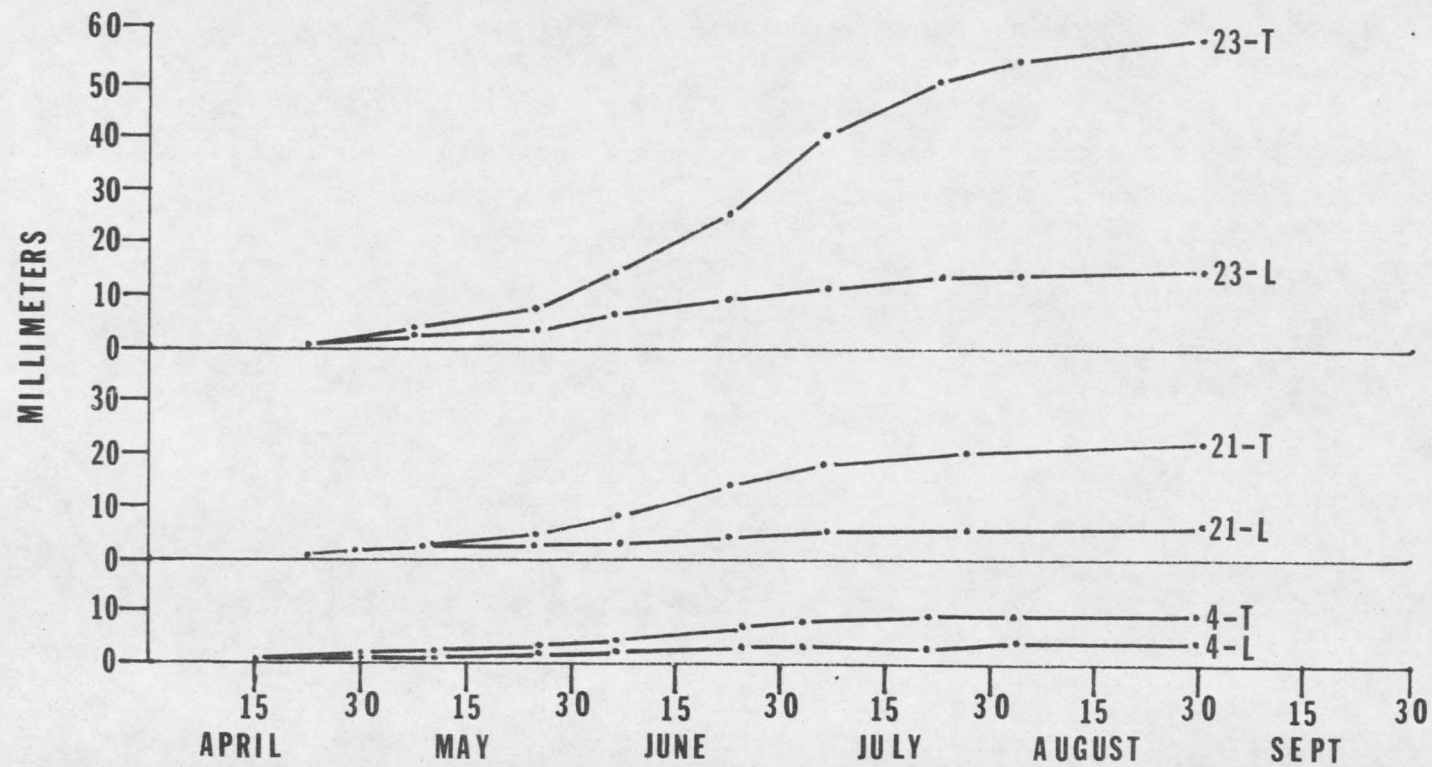


Figure 24. Continued, i. Non-clustered sites--sites 4, 21, 23.

other four sites, with site 15 a close second averaging 50 mm. Similarly, most other associations also included at least one site on which terminal twig growth was somewhat higher than at other sites. Overall, the longest twigs generally occurred in stands on open sites of northerly exposures and in areas of moderate precipitation (13-14 inches). However, there appeared to be little obvious correlation overall between twig growth and environmental factors.

Among associations, plants of the *Juniperus-Potentilla-Carex* association produced longer mean terminal and lateral twig growth than those of the other associations (Table 6). Stands of this association all occurred on northerly-facing slopes and in areas receiving relatively high amounts of precipitation continually throughout the growing season (18-19 inches annually). Plants of the *Pinus-Juniperus-Festuca* association produced the shortest mean terminal and lateral twig growth. This may reflect suppression of growth under an overstory.

The three sites (4, 21 and 23) which did not "fit" into any association possessed growth characteristics generally consistent with the eight associations (Fig. 24i).

Reproductive Characteristics and Relationships

Creeping juniper plants are dioecious, the unisexual flowers being borne on separate plants. In this study, the sex ratio was found to be 2:1 in favor of males. The staminate cones are cylindrical, pale brown, 4-5 mm long and 2 mm in diameter. They are composed

of scales occurring in rows of 4-5 each having 4 scales (Stephens 1973). Scales are approximately circular and 1-2 mm in diameter, each with 4 yellow pollen sacs attached near the base (Stephens 1973). At maturity, the scales spread and the pollen is shed. Pistillate buds consist of 2-6 oval ovules at the tip of a short, curved twig or branchlet (peduncle) approximately 2-3 mm long. The ovules are modified scales which fuse and enlarge to later form the berries. When first formed, "berries" or "fruits" are green, turning chalky purple when maturing. The peduncles of each are curved, leafy and about 3-5 mm long. The berries are nearly round, 8-10 mm across, and contain an average of 4 seeds (Fassett 1945). The exterior coat of each berry contains large resinous glands. The seeds are oval to rounded, acute, slightly grooved and ridged, 4-5 mm long, 2-3 mm wide, and red-brown with a hard, bony exterior and a large white scar on the base.

The "greening" of plants during the first two weeks of April coincided with initiation of maturation and opening of staminate cones. Pollen was shed two to three weeks later, with a peak during the last ten days of April and the first week of May. The staminate cones persisted for approximately two to three weeks after pollen was released before being shed. New staminate cones first appeared June 23 at site 2. Among individual plants, the new cones typically formed within about four weeks of the date on which old cones were shed. They

usually developed on twigs which had not formed cones during the previous year. Cone formation extended over a period of nearly three months after which cones became dormant until maturation the following spring.

Berries appeared about one to two weeks after the pollen was shed, in mid to late June, on the ends of twigs. Berry formation was first noted at site No. 3 on June 25. The light green berries continued to be produced for approximately two months, until mid-July. They remained green for about two more months before turning a chalky, purple color in the process of ripening. By mid-November, nearly all berries had become purple in color. These berries apparently remained on the plant, in the process of maturation, similar to Rocky Mountain Juniper (U. S. Dept. Agric. 1948), for one to two years before dropping to the ground. Germination experiments conducted during this study indicated that berries (seeds) do not ripen until at least the second year after formation. About one month after berries of the current year began to form, in mid to late June, the curved penunculate twigs characteristic of the new pistillate buds began to form.

Observations indicated that creeping juniper rarely reproduces by seed. Rather, plants and/or populations appear to be maintained primarily by vegetative means spreading horizontally and sprouting roots along branches or leaders. Observations indicate that new plants apparently are then formed by the break-up of old shrubs. Among the

study sites, only six plants were found which were believed to have been less than 10 years old and originated from seeds. Lonner (1971) found 52 creeping juniper plants from various sites in eastern Montana to range in age from 20 to 140 years. The mean age of 56.7 ± 3.7 years ranked creeping juniper second in longevity among 11 browse species studied. Only one of the 52 shrubs was 20 years old or less and only six were less than 30 years of age, which would also indicate a lack of recent reproduction from seed.

The low incidence of seedlings of any plant species may be attributed to a number of factors, including low seed production, maturation and/or germination, high seedling mortality, vegetative reproduction instead of seed reproduction, or species longevity. The following discussion of reproduction characteristics of creeping juniper seems to suggest that several of these factors are involved with the lack of creeping juniper seedlings.

Overall, the number of ripe berries per 100 twigs was 32.5 and the number per $.1 \text{ m}^2$ plant crown area was 68.8 berries (Table 7). The number of ripe berries ranged from 5.5 per 100 twigs examined in the *Pinus-Juniperus-Festuca* association to 101.4 per 100 twigs in the *Juniperus-Calamovilfa* association, and from 37.2/.1 m^2 of juniper crown area in the *Juniperus-Agropyron-Festuca* association to 107.4/.1 m^2 in the *Juniperus-Calamovilfa* association. These data are difficult to interpret in the absence of comparative studies for creeping juniper,

Table 7. Reproductive characteristics of creeping juniper in Montana, and statistical comparisons among plants of eight juniper associations.

Characteristics	ASSOCIATIONS								Average
	<i>Juniperus-Potentilla-Festuca</i>	<i>Juniperus-Agropyron</i>	<i>Pinus-Juniperus-Festuca</i>	<i>Juniperus-Potentilla-Carex</i>	<i>Juniperus-Calamovilfa</i>	<i>Juniperus-Helictotrichon</i>	<i>Juniperus-Rhus-Stipa</i>	<i>Juniperus-Andropogon-Festuca</i>	
% twigs with:									
buds	15	9	7	16	32*	40*	15	7	18
berries	15	7	4	10	25	18	15	4	12
ripe berries	14	6	4	6	24	18	11	4	12
new buds	21	16	2*	36	36	56*	9	8	23
male cones	52	49	74	77	49	70	78	51	60
Number per 100 twigs:									
buds	51.3	22.3	16.5	33.0	132.8	99.5	39.5	9.0	52.8
berries	32.2	16.6	6.1	20.3	111.6	33.5	38.5	4.0	36.8
ripe berries	29.5	14.1	5.5	19.9	101.4	32.5	20.5	3.7	32.5
new buds	81.3	73.5	2.5*	193.3	250.0	230.0	28.5	66.7	115.0
male cones	810.0	490.0	870.0	1150.0	490.0	910.0	880.0	520.0	750.0
Number per .1 m ² crown area									
buds	93.1	177.7	170.8	93.3	179.9	129.8	153.6	78.1	138.8
berries	63.3	112.0	62.8	73.7	118.9	70.2	97.4	46.2	83.0
ripe berries	49.1	89.3	51.7	64.0	107.4	55.9	72.6	37.2	68.8
new buds	88.8	64.7	51.2	38.2	85.8	56.4	66.6	80.1	68.5
male cones	1018.0	726.6	432.8	888.0	1862.0	939.2	520.0	498.1	929.5
% Success:									
buds forming	68/62 ¹	63/74	37/37	78/61	66/84	54/34	63/97	60/44	60/70
berries									
buds forming	77/91	80/85	82/90	87/98	90/90	77/94	74/50	80/92	84/88
mature berries									
berries	53/57	50/63	30/34	68/60	60/76	42/32	47/50	48/41	49/62
maturing									
Sex Ratios	42/58 ²	28/72	41/59	63/37	20/80	29/71	31/69	51/49	36/64

¹ First number is success rate for "per m² crown area" data; second number is success rate for "per twig" data.

² First number is percent females; second number is percent male plants.

* = represents a significant difference between associations at P=.05.

however, they indicate that this level of berry (seed) production probably is sufficient to maintain the species under natural conditions.

The percentage of twigs bearing new pistillate buds was significantly higher ($P=.05$) in the *Juniperus-Helictotrichon* association and significantly lower ($P=.05$) in the *Pinus-Juniperus-Festuca* association than in the other associations. The percentage of twigs holding old buds was significantly higher in the *Juniperus-Helictotrichon* and *Juniperus-Calamovilfa* associations. Numbers of old buds, berries, ripe berries and new buds per 100 twigs all differed significantly ($P=.05$) between the eight associations, with the *Juniperus-Calamovilfa* associations being highest in all categories, while the *Juniperus-Andropogon-Festuca* association was lowest in the first three categories and the *Pinus-Juniperus-Festuca* association was lowest in the fourth. The number of reproductive parts per $.1 \text{ m}^2$ crown area was not significantly different between associations.

The dioecious nature of creeping juniper may also contribute to the low incidence of seedlings. Twice as many male plants as female plants were recorded during this study. Only one plant in this study was noted as not bearing either staminate or pistillate flowers.

Although the viability of seeds was not evaluated directly, only 9 of the approximately 9,500 new and two year old creeping juniper seeds tested in the laboratory germinated. None of the approximately 500 seeds of the current year germinated. Similar finds have been reported

for juniper species in general (Heit 1966, 1967).

Once pistillate buds form, berries also generally form and mature. Overall, 60 percent and 70 percent of the buds fruited (formed berries) in the interior (frame data) and along the periphery (twig data) of the shrubs, respectively (Table 7). About 84 and 88 percent of the buds fruited with the fruits continuing on to maturity within and at the edges of the plants, respectively; and 49 and 62 percent of the berries, once formed, matured within and at the edges, respectively. These data indicate generally higher success in fruiting and maturation along the edges of the plant, where a relatively greater amount of plant activity probably occurs, than within the interior of the plants.

In contrast to vegetative growth, the reproductive performance of creeping juniper varied in relation to soil characteristics of study sites with less influence from climatic and geographic factors.

Normally, numbers of reproductive parts per 100 twigs on plants were negatively correlated with salt hazard ($r = -.62$) and positively correlated with calcium ($r = .49$) and sodium content ($r = .78$) of the soil. Numbers per 0.1 m^2 crown area showed positive correlations with phosphorus ($r = .60$) and sodium ($r = .61$) content. Percentages of individual twigs bearing reproductive parts were negatively correlated with organic matter content ($r = -.68$), potassium content ($r = -.62$) and salt hazard ($r = -.63$), and positively correlated with sodium ($r = .57$) and calcium ($r = .50$) content of soils. Overall, salt hazard,

sodium, calcium and phosphorus levels in the soil appeared to be most influential with respect to numbers of reproductive parts on plants. Success rates within and at the periphery of plants were generally negatively correlated with pH of the soil.

The associations with highest production estimates generally were those such as *Juniperus-Calamovilfa* and *Juniperus-Helictotrichon* with soils higher in phosphorus than the other associations, but still very low, moderately high in calcium and sodium, and having a low salt hazard rating. Associations as *Pinus-Juniperus-Festuca* and *Juniperus-Andropogon-Festuca* with low seed production had opposite soil factor values. Additionally, associations with slightly acid or alkaline soils seemed to have higher reproductive success than either of those in more acid or alkaline soils.

Overall climatic factors examined by multiple regression appeared to obviously influence only the number of reproductive parts per $.1 \text{ m}^2$ crown area; but single factors were not well correlated. Positive correlations were noted among the combined influence of all weather factors (temperature, precipitation and frost-free periods) and number of buds per $.1 \text{ m}^2$ crown area ($r = .59$), numbers of berries per $.1 \text{ m}^2$ crown area ($r = .71$) and numbers of ripe berries ($r = .72$). Generally associations occurring on sites with higher annual maximum temperatures, and lower mean annual temperatures as the *Juniperus-Calamovilfa*, *Juniperus-Helictotrichon* and *Juniperus-Rhus-Stipa* association had plants with higher production.

Forage Characteristics and Utilization by Wildlife

Nutritional Characteristics

Average crude protein content of composite samples of creeping juniper leaves and twigs (Table 8), was 6.3 percent for summer (August 1976), 5.7 percent in autumn (November 1976), 5.7 percent in winter (February 1977), and 5.5 percent during spring (May 1977). Seasonal variations, from summer to autumn, autumn to winter and winter to spring, were not significant; while the difference between summer and spring was highly significant ($P=.01$).

Table 8. Percentages crude protein of creeping juniper plants for 12 study sites during one year, 1976 to 1977.

Site	August 1976	November 1976	February 1977	May 1977	(Ave.)	August 1977		
						Plant 1	Plant 2	Plant 3
4	6.5	5.2	4.9	5.3	(5.5)	6.5	4.8	5.2
7	5.5	5.0	5.2	4.7	(5.1)	5.1	5.8	4.4
11	7.6	7.4	6.7	5.9	(6.9)	5.9	5.9	6.1
13	7.2	6.6	6.1	6.2	(6.3)	6.0	6.5	5.7
15	5.8	4.4	5.1	4.7	(5.0)	5.1	4.3	4.6
17	7.4	5.5	---	5.6	(6.0)	6.0	4.9	6.0
19	5.7	5.6	6.1	6.1	(5.9)	5.2	6.1	5.7
21	5.3	5.5	5.5	4.8	(5.3)	5.3	5.7	5.9
22	6.8	5.4	5.8	6.3	(6.1)	5.2	5.1	5.9
23	4.8	4.7	5.7	5.6	(5.2)	5.3	5.8	5.7
27	5.5	6.1	5.3	5.6	(5.6)	6.0	5.7	6.1
31	7.0	7.4	6.3	6.0	(6.7)	6.3	6.5	6.1
Average	6.3	5.7	5.7	5.5	(5.8)	5.7	5.6	5.6

The average protein content of samples collected from one plant at each of 12 study sites during August 1976 (6.3%) was higher than that of the same plants in August 1977 (5.6%), though the difference was not significant. Comparison of precipitation at the 12 study sites during spring (April, May and June), between 1976 and 1977, indicated that these differences may be due to moisture differences (Table 9). At nearly every site the precipitation was higher in 1976 than in 1977 and the protein levels varied similarly.

Table 9. Comparison of spring (April, May, June) precipitation at 12 creeping juniper sites between 1976 and 1977.

Sites	Spring 1976 Precipitation (inches)	Spring 1977 Precipitation (inches)
4	5.8	3.1
7	6.3	3.9
11	4.3	2.7
13	8.0	5.7
15	8.3	4.2
17	5.5	5.3
19	7.1	5.3
21	6.9	3.5
22	6.9	3.5
23	7.9	3.6
27	6.0	5.1
31	3.8	3.3

Crude protein content of individual plants varied somewhat within sites (Table 8), but differences were not significant. Differences among plants within given sites ranged from about 0.2 percent between plants at site 11 to 1.7 percent between plants at site 4.

There were significant differences between the means for various sites ($P=.001$). For example, the annual (August 1976-May 1977) average protein content of plants at site 11 was 6.9 percent as compared with the low average of 5.0 percent among plants at site 15 and the overall average of 5.8 percent for all sites combined. Generally those sites with highest protein content were more mesic sites at elevations above 1400 meters (4500 ft).

Overall, the crude protein content of creeping juniper was lower than that reported for many other important deer browse plants in Montana (Eustace 1971, Duncan 1975, Morton 1976). The occurrence of maximum protein content in the late summer sample contrasts with other shrub species such as big sagebrush, silver sagebrush, skunkbush sumac, curl-leaf mountain mahogany, rabbitbrush, and chokecherry in which highest protein levels typically occur during early spring (Eustace 1971).

The nutritional value of creeping juniper, at least in terms of crude protein, appears to be relatively low throughout the year in relation to the minimal protein requirements of deer. Further, the time of maximum utilization, mid-to-late winter, corresponds with

minimum annual protein levels in the plants. This would further suggest that mule deer select and use creeping juniper on some basis other than its nutritional value or palatability, such as availability.

Available Forage Biomass

Creeping juniper plants are capable of supplying an abundance of forage throughout the year. Biomass availability measurements, obtained from clippings of old and new leaves, and twigs less than 5 mm diameter from plants in stands of the eight associations are presented in Table 6. Total average biomass of creeping juniper crown area in pounds per ft² ranged from .026 in the *Juniperus-Potentilla-Carex* association to .038 in the *Juniperus-Rhus-Stipa* association, with no significant differences between any of the associations. The overall mean biomass for all stands and associations was .031 pounds per ft². A figure of possibly greater value in evaluating availability of creeping juniper as a forage source is the mean pounds per acre or standing crop in relation to the total vegetation resource. This value ranged from 376.7 pounds in stands of the *Juniperus-Calamovilfa* association to 589.2 pounds in the *Juniperus-Andropogon-Festuca* association. The mean for all stands and associations was 432.0 pounds per acre with no difference noted between the associations. Overall the associations with higher standing crops of creeping juniper were those associated with northerly slopes, areas of moderate precipitation (13-15 inches annually), relatively higher annual temperatures (45° F) and occurring at lower elevations.

Utilization by Wildlife

Studies of the food habits of wild ungulates in Montana indicate that creeping juniper is utilized primarily by mule deer. Reports of important consumption by other species include pronghorn antelope (*Antilocapra americana*) during winter in northern Montana (Martinka 1967) and white-tailed deer (*Odocoileus virginiana*) during January in eastern Montana (Hamlin 1976). Martinka (1967) did not believe that creeping juniper was a suitable forage for pronghorns and attributed its usage to the scarcity of other forage during the severe 1964-65 winter when antelope experienced heavy mortality. Cole (1956) found minor use of this species by antelope during winter and spring in central Montana, while Dirchl (1963) reported minor antelope use of creeping juniper during fall and important usage during winter on one of his study areas in Saskatchewan, just north of the Montana border. Martinka (1968) reported light use of creeping juniper by white-tailed deer during winter in the Bear Paw Mountains of northcentral Montana. Minor utilization of the species by elk during the winter has been reported for the Sun River area by Casagrande and Janson (1957), Knight (1970) and Schallenberger (1965). Schallenberger (1965) also reported trace usage of creeping juniper by bighorn sheep and white-tailed deer in the Sun River Canyon during winter.

Creeping juniper is also apparently important to other mammals and birds in Montana. Yde (1977) recorded use of creeping juniper

berries and vegetation by juvenile and adult sharptailed grouse in Phillips County, Montana. Berries occurred in approximately 70 percent of the grouse crops collected in September 1976, comprising 40 percent of the total contents by volume. Vegetation and seeds occurred in about 20 percent of the crops and made up one percent of the volume. Nielsen (1977), working on the same area, recorded juniper berries in 46 percent of the sharptail crops comprising 25 percent of the total volume. Juniper was the second food item utilized.

During my study the incidence of small mammal use on 75 twigs examined on each of the intensive study sites throughout the summer of 1977 (Table 10) suggested that in some areas substantial small mammal use may occur. Percentage of twigs used ranged from 0 at several sites to 15 percent at site 20. The average for all study sites was 2.6 percent. At least some twigs were used at 80 percent of the sites. A species of *Marmota* was sighted several times in the vicinity of site 20 and the high use of twigs at that site might be attributed to that mammal. In addition to foliage use, gnawing of berries by small mammals was also noted.

The importance of creeping juniper in the diet of mule deer has been documented by several studies in central and eastern Montana (Cada 1971, Compton 1966, Dusek 1971, Eustace 1971, Hamlin 1975, Kamps 1969, Coop 1975, Lovass 1958, Martinka 1968, Schallenberger 1965, Stoneberg

Table 10. Percent of creeping juniper twigs utilized by small mammals during the summer of 1977 on the 30 study sites.

Site	Twigs Utilized by Small Mammals (percent)
1	4
2	-
3	-
4	1
5	4
6	1
7	-
8	1
9	3
10	1
11	3
12	-
13	4
14	1
15	-
16	3
17	-
18	7
19	1
20	15
21	-
22	4
23	4
25	12
26	3
27	-
28	4
29	1
30	1
31	-
Average	2.6

1975 and McCarthy et al. 1977) as well as western North Dakota (McKean 1954). However, utilization apparently is highly variable between areas on which creeping juniper occurs.

In areas of important usage, greatest consumption occurs during the winter months (January, February and March). Use generally begins in late December or early January and gradually increases to March. Thereafter, consumption generally has decreased dramatically, apparently due to the availability of other forages with spring green-up. Some exceptions to this pattern have been reported by Dusek (1971), who observed maximum usage during April, and Eustace (1971), who compared food habits of mule deer in Garfield and Rosebud Counties of eastern Montana. On the Garfield area, consumption of creeping juniper peaked between December and February, with moderate use occurring from September through November. In contrast, maximum use in Rosebud County occurred between March and May, with no apparent use during the fall months. In general, however, reports of utilization during spring and fall are rare. No summer usage has been reported.

Although I did not specifically attempt to quantify utilization patterns on the study sites, general observations of mule deer activity and utilization supported the conclusion that if creeping juniper is utilized, the majority of use occurs in late winter.

Spatial and seasonal variations in use of creeping juniper may be related to corresponding variations in the distribution of mule deer

and/or the relative availability of other, more desirable forage plants. This may be particularly important on mountain-foothill ranges where seasonal movements and use of cover types varies in relation to weather conditions. In the Snowy Mountains of central Montana, Kamps (1968) reported a progressive shift in mule deer use from cover types dominated by Douglas Fir and common juniper in late fall and early winter, to wind-blown ridges dominated by creeping juniper later in the winter when this species comprised 45 percent of the plant use at feeding sites. A similar shift in mule deer habitat usage leading to use of creeping juniper has since been observed in other areas (Coop, McCarthy pers. comm.). This shift may be dependent upon weather conditions, and the extent to which it occurs will vary between ranges and years.

In the Little Belt Mountains, Lovaas (1958) observed major differences between the food habits of mule deer wintering in Dry Pole Canyon and those using an adjacent prairie type. Common juniper was the most important forage plant on the former, a predominantly forested area, while creeping juniper was relatively unimportant in spite of moderate abundance. On the prairie area creeping juniper was the most important forage, while the rare common juniper was found only as a trace item in one rumen sample. Other plant species associated with creeping juniper on the prairie type were predominantly less desirable winter forages such as shrubby cinquefoil, rose, snowberry, fringed sagewort, and kinnikinnick.

Highly palatable browse plants such as antelope bitterbrush (*Purshia tridentata*), serviceberry (*Amelanchier alnifolia*), choke-cherry (*Prunus virginiana*) and curl-leaf mountain mahogany, were only rarely found in creeping juniper stands examined during this study. Thus, when deer used these areas, creeping juniper typically was the most abundant, available and, relatively, the most palatable browse species present, particularly during the winter. Coop (1975) felt variations in creeping juniper use was due to availability.

Measurements and general observations of plant height and cover suggested that moderate browsing had minimal effect on these parameters of creeping juniper. Heavy utilization, however, left plants either totally destroyed or with large sections of stripped and dead foliage. The latter was especially evident in stands in the foothills of the Snowy Mountains in central Montana and, in eastern and southcentral Montana.

The trend in live crown coverage of creeping juniper on transects established and measured by personnel of the Montana Department of Fish and Game in northcentral Montana (Fig. 1) was generally downward from the late 1950's, when measurements were first obtained, to 1973. This trend is similar to that found south of Big Timber in the Picket Pin Canyon and Horseman Flat areas. In the view of Montana Fish and Game and U. S. Forest Service personnel (pers. comm.) familiar with the area, the downward trend may have been the result of two major factors:

livestock grazing and/or high deer numbers. In the past, wintering deer numbers were reportedly high in areas, such as Picket Pin Canyon, where creeping juniper showed major declines. In other areas, such as that immediately south of the Sun River Game Range where livestock grazing was and is being controlled, the lack of grazing appears to have allowed the forb and grass complex to increase to such a level as to possibly be competitive with creeping juniper. Competition between grasses and other species, including one-seed juniper (Smith et al. 1975), may be sufficient to inhibit root growth and actually limit many junipers to certain topographies as escarpments and steep rocky ridges (Wells 1970).

Effects of Fire on Creeping Juniper

Fire or the lack of it has been considered one of the major factors influencing the distribution and abundance of junipers (Foster 1917, Johnson 1962, Leopold 1924), and considerable research has been directed to its effects on various species (Beuhring et al. 1971, Burkhardt 1976, Dalrymple 1969, Dwyer 1967, Foster 1917, Jameson 1962, Johnson et al. 1962, Leopold 1924, Martin et al. 1955, Parker 1945, Wink et al. 1973). Most of this work has focused on the use of burning to control juniper on rangeland. While none of these studies was concerned with the effects of fire on creeping juniper, findings for other species generally have indicated that burning results in nearly 100 percent mortality

of plants less than 0.3-0.45 meters (1-1.5 ft) in height. Mortality rates of taller plants vary by species, height of the shrubs or trees, and fuel and fire characteristics.

Observations in one stand of creeping juniper, burned by a lightning-caused wildfire, during the reconnaissance phase of this study suggested that burning may be less damaging to this species than reported for other junipers. Subsequently, observations and measurements of the response of creeping juniper to fire were made on two experimental burns. One of these was located in the Blacktail Hills, approximately 10 miles southwest of Stanford in central Montana; the other on the Sun River Game Range, 22 miles west of Augusta in westcentral Montana.

Stanford Burn - The three hectare burn site was in an area of slightly rolling topography, with a slope of 5 percent and a northerly exposure. The average elevation was 1785 meters (5890 ft). The vegetation was characterized by a dense stand of shrubby cinquefoil, a wide variety of grasses and forbs, and a sparse overstory of Douglas fir and lodgepole pine. Creeping juniper plants occurred exclusively beneath the shrubby cinquefoil plants at a density of 0.034 plants/m^2 . This area is heavily grazed by livestock which apparently avoid use of both the cinquefoil and juniper plants.

A total of 21 individual creeping juniper plants was tagged before the burn. Each was measured as to crown dimensions, amount burned and

killed and the amount of regrowth, if any (Table 11). Fire temperatures, fuel moisture and soil moisture at the time of burning were also recorded near each of these shrubs (Table 11). The plants were all relatively small, averaging 0.08 m^2 in crown area and 7.8 cm tall.

At the time of burning, the average soil moisture beneath these plants was 49.6 percent with a range of from 45 percent to 65 percent. Average fire fuel moisture content varied from 4.0 to 23.0 percent, with a mean of 15.0 percent. Although an effort was made to obtain three intensities of fire in separate 100 m^2 plots, burning actually resulted in a mosaic of varying intensities in each plot as evidenced by the wide range of temperatures at tagged plants: 78°C (109°F) to more than 406.9°C (700°F). The mean temperature was 205°C (337.6°F).

Post-burn measurements indicated that 53 percent of the plants were burned and died, 43 percent were burned to some extent but remained alive, and 4 percent (1 plant) were totally unharmed (Table 11). Approximately 48 percent of the total canopy coverage of creeping juniper on the plots were totally consumed, while 41 percent were burned to a lesser extent and 11 percent were unburned. The percentage of crown area burned on individual plants ranged from 0 (1 plant) to 100 percent (10 plants); the average was 85 percent. All plants with crowns totally consumed died. Only one of the plants was killed where less than 100 percent of the crown was burned. Plants not killed tolerated fire temperatures ranging from 78°C (109°F) to 267°C (450°F)

Table 11. Crown area and height of 21 creeping juniper plants within the Stanford experimental burn together with percent crown burned, post-fire fate of plant, temperature of fire, and fine fuel and soil moistures of the area.

Plant	Crown Area (m ²)	Height (cm)	Crown Area Burned ¹ (percent)	Regrowth (gms/plant)	Temperature (°C)	Fine Fuel Moisture (percent)	Soils Moisture (percent)
1	.08	11.0	100 ²	--	407	23 ³	45 ³
2	.09	7.5	37.5	--	43	23	45
3	.15	8.0	97.5	1.32	204	23	45
4	.01	6.5	100	--	343	23	45
5	.10	3.0	100	--	267	23	45
6	.06	12.0	62.5	1.35	78	23	45
7	.09	11.0	100	--	118	23	45
8	.11	5.0	100	--	343	23	45
9	.16	4.5	100	--	407	16	47
10	.13	8.0	100	--	204	8	51
11	.23	7.0	97.5	3.95	118	5	52
12	.05	8.5	85.0	2.10	78	5	46
13	.04	3.5	97.5	2.00	78	18	65
14	.02	4.0	85.0	0.21	78	8	65
15	.06	9.0	0.0	--	78	13	46
16	.05	6.0	100	--	343	5	58
17	.03	11.0	100	--	62	14	48
18	.10	9.0	100	--	204	4	57
19	.02	7.0	62.5	0.86	78	9	51
20	.04	8.0	62.5	0.37	118	4	45
21	.05	5.0	97.5	0.14	267	22	52
Average	.08	7.8	85.0	1.40	205	15	49.6

¹percent of plant burned and killed.

²100 percent = total consumption.

³samples 1 to 8 averaged and value shown is the average.

or an average of 134°C (209.2°F). However, the fact that several plants which experienced fire temperatures below 267°C (450°F) also died, indicated that under certain conditions, fires of even light intensity may be damaging to creeping juniper

Where plants were totally consumed and killed, fire damage usually extended into the root system, below ground level. Plants which remained alive or resprouted did not suffer this severe damage. These plants typically produced new leaf material and showed good growth during the first growing season; the regrowth averaging 1.4 grams per plant (0.14-3.95).

Sun River Burn - This site was located on a five percent slope of northeast exposure at an elevation of 1500 meters (4950 ft). The vegetation was characterized by a dominance of creeping juniper, grasses, including bluebunch wheat grass and rough fescue, and forbs, of which the major species were prairie thermopsis, silky lupine (*Lupinus sericeus*) and milkvetch (*Astragalus* spp.). The fire was of low intensity and moved slowly across the plot at a rate of about 0.61 meters (2 ft) per minute. Flames never exceeded one meter in height, moving at an angle of $60 - 90^{\circ}$ from the horizontal. The average fire temperature was 91°C (132.3°F). Average soil and fire fuel moisture were 11 percent and 32 percent, respectively. These temperatures averaged only about half as hot as those experienced by plants on the Stanford burn, while soils were drier and fuels contained more

moisture as compared with the Stanford site.

Effects of fire on individual plants were not measured as on the Stanford burn. Rather, only an estimate of effects on canopy coverage was obtained. Comparison of 2 x 5 plot frame data from the burn plot and the adjacent control plot suggest that approximately 31 percent of the total canopy coverage of creeping juniper were consumed, 29 percent were burned but not destroyed, and 40 percent were not burned (Table 12). This and supplemental data combined indicate that about 60 percent of the total crown area of creeping juniper were burned to some extent and 40 percent were unburned.

The terminal portions of all of the 10 major branches or leaders tagged prior to burning died. However, none of the plants was totally killed; and regrowth was detected on all tagged leaders during the first growing season (the summer of 1977).

Discussion of Fire Effects

The general effects of the two controlled burns on creeping juniper plants are summarized in Table 12. The results indicated that creeping juniper is subject to damage and destruction by fire, though these effects may vary by area and may be less severe than reported for other species of juniper. Several factors may account for these differences. The very low mat-like stature and extensive root system, together with the size of individual creeping juniper plants seem to be especially important. The low, dense mats may result both in poor

Table 12. Comparison of the effects of fire on creeping juniper between the Sun River Game Range and Stanford experimental burns.

Effect Characteristic	Sun River Game Range Burn	Blacktail Hills Burn - Stanford
Canopy Coverage Consumed (percent)	31	48
Canopy Coverage Burned and/or Killed (percent)	29	41
Total Canopy Coverage Burned (percent)	60	89
Canopy Coverage Unharmed (percent)	40	11
Plants Burned and Not Killed (percent)	N.M. ¹	43
Plants Burned and Killed (percent)	N.M.	53
Plants Unharmed (percent)	N.M.	4
Plants Consumed When Burned (percent)	N.M.	48
Plants Partially Defoliated (percent)	N.M.	48
Plants Unharmed (percent)	N.M.	4

¹N.M. = Not Measured.

air circulation around the plant and in low fire fuel supplies in and about the plant. Also, when the shrub occurs in larger, dense mats as on the Sun River burn area, fire may not carry completely over or across the plant because of low fuel and/or high moisture or relative air humidity in and around the crown area. With smaller, definitive plants as on the Stanford burn, greater amount of fuel may occur in, around and over the plants resulting in more complete burning and more destructive damage. Where more extensive, rooted mats occur, unburned portions of plants may survive.

CONCLUSIONS AND RECOMMENDATIONS

The results of this study provide baseline information concerning various biological and ecological attributes of creeping juniper in Montana. Generally, this information may be useful in evaluating wildlife usage and management needs and opportunities in rangeland habitats. In some cases, the results also serve to clarify existing knowledge and concepts about the plant, its use by wildlife, especially mule deer, and its importance in rangeland ecosystems. In many instances they point to the need for additional study.

The study clearly indicates that creeping juniper is an important component of rangeland vegetation. It occurs extensively on foothill and prairie ranges throughout most of Montana east of the Continental Divide, and was the dominant shrub or plant in at least eight different plant associations occurring on ridges, rimrocks, escarpments and hilltops. On these sites, which typically were very open and had only poorly developed soils, creeping juniper may be extremely important in both maintaining and building soils and also tends to be available for use by wildlife most of the time.

Creeping juniper appears to be capable of producing and providing large amounts of forage for wildlife, especially mule deer on sites where it occurs, although annual production varies between sites. Generally, sites with higher annual precipitation (13-15 inches) produced greater amounts of forage. Utilization by deer normally did not appear to adversely affect annual growth and forage production,

while light to moderate usage of twigs seemed to stimulate lateral growth of twigs. Concentrated utilization on local sites for long periods of time, however, may result in destruction of plant crowns. Domestic livestock grazing, which reduces competition from grasses and other plants, may be an important factor in maintaining viable stands of creeping juniper at least on some sites.

Management of creeping juniper stands should be directed to maintaining existing stands and plant productivity. Because of the two-dimensionality of plants, this species lends itself to measurement from aerial photographs to estimate trends in plant size and density, available biomass and reproduction. The apparent lack of natural reproduction from seed would appear to preclude attempts to stimulate increased plant densities by this means, however, additional seed germination experiments are important to fully understand this idea. Similarly, controlled burning appears to have little application in increasing plant densities and productivity, and may actually be detrimental to the species. Range fertilization appears to have little effect on productivity but may be a viable management tool when increased fruit success and production is desired.

Additional research would be desirable to determine factors associated with the distribution of creeping juniper in Montana, especially those responsible for its general absence from western and southwest Montana. Further definition and study of the plant

associations in which the species occurs and the age structure of creeping juniper stands with possible successional relations would be valuable. Further study into the digestibility for deer would be important in assessing the value as a forage species. Relationships between site factors and total nutritional characteristics require further study. Additional research into the effects of various site and environmental factors including grazing, burning, utilization by deer, climate, microclimate, and usage by wildlife other than deer on productivity, nutritional aspects and dominance of creeping juniper would also be useful.

LITERATURE CITED

- Beals, E. 1960. Forest bird communities in the Apostle Islands of Wisconsin. *Wilson Bull.* 72:156-181.
- Bifoss, C. G. 1947. The water conducting capacity and growth habits of *Juniperus horizontalis* Moench and *Juniperus virginiana* L. *Ecology* 28(3):281-289.
- Booth, W. E. and J. C. Wright. 1959. Flora of Montana, part II, Dicotyledons. *Mont. State Coll.*, Bozeman. 280 pp.
- Bradley, G. A. 1963. Two new species of *Cinara curtis* (Homoptera: Aphididae) from *Juniperus horizontalis* Moench. *Can. Entomol.* 95(3):287-291.
- Bray, J. R. and J. T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. *Ecol. Monogr.* 27(4):325-349.
- Breitung, A. J. 1954. A botanical survey of the Cypress Hills. *Can. Field Nat.* 68:55-92.
- Brener, W. D., E. C. Setliff and R. L. Norgren. 1974. *Sclerophoma phythiophila* associated with a tip dieback of Juniper in Wisconsin. *Plant Disease Reporter.* 58(7):653-657.
- Buehring, N., P. W. Santelmann and H. M. Elwell. 1971. Responses of eastern red cedar to control procedures. *J. Range. Manage.* 24:378-382.
- Buckman, H. O. and N. C. Brady. 1969. The Nature and Properties of Soils. 7th Ed. The MacMillan Co. 653 pp.
- Burkhardt, J. W. 1967. Ecology of Western Juniper in Idaho. M. S. thesis. Univ. of Idaho. 93 pp.
- Cada, J. O. 1971. South Little Belt Mountains deer investigations. Job Prog. Rept., Mont. Dept. Fish and Game, Fed. Aid Proj. W-130-R-1 and 2, Job I-5. 18 pp.
- Casagrande, L. and R. G. Janson. 1957. Wildlife investigations (Dist. 4): Big Game Surveys and Investigations. Job. Prog. Rept., Mont. Dept. Fish and Game, Fed. Aid Proj. W-74-R, Job A-1, Pt. 3. 19 pp.
- Cole, G. F. 1956. The pronghorn antelope, its range use and food habits in central Montana with special reference to alfalfa. *Mont. Agric. Exp. Sta. Tech. Bull.* 516. 63 pp.

- Compton, H. O. 1966. Wildlife investigations (Dist. 7): Big Game surveys and investigations. Mont. Dept. Fish and Game, Job Prog. Rept., Fed. Aid Proj. W-77-R-11, Job A-1. 42 pp.
- Coop, K. J. 1975. South Big Snowy Mountains mule deer studies. Mont. Dept. Fish and Game, Job Prog. Rept. Fed. Aid Proj. W-130-R-6, Job I-5. 30 pp.
- Couchman, F. M. and E. Von Rudloff. 1965. Gas-liquid chromatography of terpenes. Part III - The volatile oil of the leaves of *Juniperus horizontalis* Moench. Can. J. Chem. 43(5):1017-1021.
- Dalrymple, R. L. 1969. Cedar control in southern Oklahoma. S. Weed Conference. 22:272-273.
- Daubenmire, R. F. 1959. A canopy-coverage method of vegetational analysis. N.W. Sci. 33(1):43-64.
- Dirchl, H. J. 1963. Food habits of pronghorn in Saskatchewan. J. Wildl. Manage. 27(1):81-93.
- Dixon, W. J. and F. J. Massey, Jr. 1969. Introduction to Statistical Analysis. 3rd Ed. McGraw-Hill Inc. 638 pp.
- Duncan, E. A. 1975. Ecology of curl-leaf mountain mahogany (*Cercocarpus ledifolius* Nutt.) in southwestern Montana with special reference to utilization by mule deer. M.S. Thesis. Mont. State Univ., Bozeman. 85 pp.
- Dusek, G. L. 1971. Range relationships of mule deer in the prairie habitat, northcentral Montana. M. S. Thesis. Mont. State Univ. Bozeman. 63 pp.
- Dwyer, D. D. and R. D. Pieper. 1967. Fire effects on Blue grama-Pinyon-Juniper rangeland in New Mexico. J. Range Manage. 20:359-362.
- Eustace, C. D. 1971. Mule deer food habits and browse use study. Job Prog. Rept., Mont. Dept. Fish and Game, Fed. Aid Proj. W-130-R-1 and 2, Job 1-7.1. 25 pp.
- Evans, G. 1971. Chromosome counts in three cultivars of *Juniperus* L. Bot. Gazzette. 132(4):259-262.
- _____ and H. P. Rasmussen. 1972. Anatomical changes in developing graft unions of *Juniperus* L. J. Am. Soc. Hort. Sci. 97(2):228-232.

- _____ and _____. 1974. Serological determination of tissue contribution from the graft union of *Juniperus* L. grafts. Bot. Gazette. 135(3):163-169.
- Fassett, N. C. 1944a. *Juniperus virginiana*, *J. horizontalis* and *J. scopulorum* - I. The specific characters. Tor. Bot. Club. Bull. 71(4):410-418.
- _____. 1944b. *Juniperus virginiana*, *J. horizontalis* and *J. scopulorum* - II. Hybrids of *J. virginiana* and *J. scopulorum*. Tor. Bot. Club. Bull. 71(5):475-483.
- _____. 1945a. *Juniperus virginiana*, *J. horizontalis* and *J. scopulorum* - III. Possible hybridization of *J. horizontalis* and *J. scopulorum*. Tor. Bot. Club. Bull. 72(1):42-46.
- _____. 1945b. *Juniperus virginiana*, *J. horizontalis* and *J. scopulorum* - IV. Hybrids of *J. virginiana* and *J. horizontalis*. Tor. Bot. Club. Bull. 72(4):379-384.
- _____. 1945c. *Juniperus virginiana*, *J. horizontalis* and *J. scopulorum* - V. Taxonomic treatment. Tor. Bot. Club. Bull. 72(5):480-482.
- Foster, J. H. 1917. The spread of timbered areas in central Texas. J. For. 15:443-445.
- Hahn, B. E. 1973. Flora of Montana - Conifers and Monocots. Mont. State Univ. Bozeman. 124 pp.
- Hamlin, K. L. 1976. Population ecology and habitat relationships of mule deer and whitetail deer in prairie-agricultural habitats of eastern Montana. Job Prog. Rept., Mont. Dept. Fish and Game, Fed. Aid Proj. W-120-R-7:140-156.
- Heit, C. E. 1966. Part 3: Ten ways seed tests can help growers. Am. Nurseryman. Dec. 1966. 4 pp.
- _____. 1967. Part 9: Fall sowing of conifer seeds. Am. Nurseryman. Dec. 1967. 5 pp.
- Hitchcock, C. L. and A. Cronquist. 1973. Flora of the Pacific Northwest. Univ. of Wash. Press. Seattle. 730 pp.
- Jameson, D. A. 1962. Effects of burning on galleta-black grama range invaded by juniper. Ecology 43:760-763.

- Johnson, T. N. 1962. One-seed juniper invasion of northern Arizona grasslands. Ecol. Monogr. 32(3):187-207.
- Jorgenson, H. E. 1976. Classification, description and ecology of the vegetation of eastern Montana, with special reference to the prairie region. Job Prog. Rept., Mont. Dept. Fish and Game, Fed. Aid Proj. W-120-R-7. 7 pp.
- Kamps, G. F. 1969. Whitetail and mule deer relationships in the Snowy Mountains of central Montana. M.S. Thesis. Mont. State Univ., Bozeman. 59 pp.
- Knight, R. R. 1970. The Sun River elk herd. Wildl. Monogr. No. 23. 66 pp.
- Lanphear, F. O. 1966. Influence of the stock plant environment of the rooting of *Juniperus horizontalis plumosa*. Proc. Am. Soc. Hort. Sci. 89:666-671.
- Leopold, A. 1924. Grass, brush, timber and fire in southern Arizona. J. For. 24(6):1-10.
- Little, E. L. 1971. Conifers and Important Hardwoods - Atlas of U.S. Trees. USDA For. Serv., Washington, D.C. 1:221-N, 221-E.
- Lonner, T. N. 1972. Age distributions and some relationships of key browse plants on big game ranges in Montana. M.S. Thesis, Mont. State Univ., Bozeman. 79 pp.
- Lovaas, A. L. 1958. Mule deer food habits and range use, Little Belt Mountains, Montana. J. Wildl. Manage. 22:275-282.
- Martin, P. R. 1973. An ecological study of skunkbush sumac (*Rhus trilobata*) in Montana east of the Continental Divide with special reference to utilization by mule deer. M.S. Thesis. Mont. State Univ., Bozeman. 97 pp.
- Martin, S. C. and J. S. Crosby. 1955. Burning and grazing on glade range in Missouri. USDA For. Serv., Cent. States For. Exp. Sta. Tech. Paper 147. 13 pp.
- Martinka, C. J. 1967. Mortality of northern Montana pronghorns in a severe winter. J. Wildl. Manage. 31(1):159-164.
- _____. 1968. Habitat relationships of whitetail and mule deer in northern Montana. J. Wildl. Manage. 32:558-565.

- McCarthy, J. J., R. A. Bucsis, C. R. Watts, F. G. Feist, G. L. Erickson. 1977. Big game survey and inventory (Dist. 4): Job Prog. Rept., Mont. Dept. Fish and Game, Fed. Aid Proj. W-130-R-8, Job I-4. 51 pp.
- McKean, W. T. 1954. Fall and winter foods of North Dakota deer. N. D. Agric. Exp. Sta. Bimon. Bull. 17(1):25-31.
- Montana Agricultural Experiment Station. 1973. Vegetative Rangeland Types in Montana. Bull. No. 671. 16 pp.
- Morton, M. A. 1975. Nutritional values of important mule deer winter forage plants in the Bridger Mountains, Montana. M.S. Thesis. Mont. State Univ., Bozeman. 104 pp.
- Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons. New York. 547 pp.
- Nemec, S. 1968. Response of certain woody ornamental plants to *Meloidogyne incognita*. Phytopathology. 58(12):1700-1703.
- _____. 1972. Histopathology of *Thuja orientalis* and *Juniperus horizontalis plumosa* infected with *Meloidogyne incognita*. J. Nematology. 4(1):72-74.
- Nielson, L. S. 1978. The effects of rest-rotation grazing on the distribution of sharptailed grouse. M.S. Thesis. Mont. State Univ., Bozeman. 52 pp.
- Orloci, L. 1966. Geometric Models in ecology: I. The theory and application of some ordination methods. J. Ecol. 54:193-215.
- Parker, K. W. 1945. Juniper comes to the grasslands. Am. Cattle. Producer. 27:12-14.
- Ross, J. G. and R. E. Duncan. 1949. Cytological evidences of hybridization between *Juniperus virginiana* and *J. horizontalis*. Tor. Bot. Club. Bull. 76(6):414-429.
- Ross, R. L. and H. E. Hunter. 1976. Climax Vegetation of Montana - Based on Soils and Climate. USDA Soil Conserv. Serv., Bozeman, Mont. 64 pp.
- Russell, E. J. and E. W. Russell. 1974. Soil Conditions and Plant Growth. Longmans Press. London. 10th Ed. 194 pp.

- Schallenger, A. D. 1965. Big game forage competition in Sun River Canyon. M.S. Thesis, Mont. State Univ., Bozeman. 43 pp.
- Smith, M. A., H. A. Wright and J. L. Schuster. 1975. Reproductive characteristics of Redberry juniper. J. Range Manage. 28(2): 126-128.
- Stephens, H. A. 1973. Woody plants of the Northcentral Plains. Regents Press. 516 pp.
- Stoneberg, R. P. 1975. Planning inventory, game, Beartooth-Absarokee Wildlife/Mining. Job Prog. Rept., Mont. Dept. Fish and Game, Fed. Aid Proj. FW-2-R-4, Job I-a. 53 pp.
- Thompson, L. S. and J. Kuizt. 1976. Montane and subalpine plants of the Sweetgrass Hills, Montana, and their relation to early post-glacial environment of the northern Great Plains. Can. Field Nat. 90(4):432-448.
- U. S. D. A. Forest Service. 1948. The Woody Plant Seed Manual. U. S. Govt. Printing Office. 416 pp.
- Wells, P. F. 1970. Post-glacial vegetational history of the Great Plains. Science 167:1574-1582.
- Wink, R. L. and H. A. Wright. 1973. Effects of fire on an Ashe Juniper community. J. Range Manage. 26:326-329.
- Yde, C. A. 1977. Distribution and movements of sharptailed grouse during spring and summer in relation to rest-rotation grazing. M.S. Thesis. Mont. State Univ., Bozeman. 70 pp.

APPENDIX

Table 13. General and exact locations of the 51 creeping juniper study sites.

Site	County	Nearest Post Office	Distance/ Direction from P. O.	Location
(kilometers)				
1	Lewis & Clark	Augusta	25 NW	T21N R 8W S16 SE $\frac{1}{4}$
2	Lewis & Clark	Augusta	17 SW	T19N R 7W S17 NE $\frac{1}{4}$
3	Lewis & Clark	Augusta	17 SW	T20N R 7W S16 NW $\frac{1}{4}$
4	Lewis & Clark	Augusta	17 SW	T19N R 7W S 9 SW $\frac{1}{4}$
5	Lewis & Clark	Augusta	17 SW	T19N R 7W S16 SE $\frac{1}{4}$
6	Lewis & Clark	Augusta	25 NW	T21N R 8W S 4 SW $\frac{1}{4}$
7	Lewis & Clark	Augusta	25 NW	T21N R 8W S22 SE $\frac{1}{4}$
8	Teton	Choteau	42 W	T25N R 8W S16 NW $\frac{1}{4}$
9	Lewis & Clark	Augusta	20 W	T20N R 8W S 8 SE $\frac{1}{4}$
10	Lewis & Clark	Augusta	20 W	T20N R 8W S 9 NW $\frac{1}{4}$
11	Pondera	Dupuyer	33 W	T28N R 8W S31 NW $\frac{1}{4}$
12	Pondera	Dupuyer	33 W	T28N R 9W S25 SE $\frac{1}{4}$
13	Fergus	Denton	8 E	T18N R15E S35 SE $\frac{1}{4}$
14	Fergus	Denton	8 E	T18N R15E S35 SE $\frac{1}{4}$
15	Petroleum	Teigan	8 N	T15N R25E S 6 SE $\frac{1}{4}$
16	Petroleum	Teigan	8 N	T15N R25E S 7 NW $\frac{1}{4}$
17	Fergus	Hilger	8 E	T19N R17E S16 NE $\frac{1}{4}$
18	Fergus	Hilger	8 E	T19N R17E S 9 SE $\frac{1}{4}$
19	Fergus	Moore	17 S	T13N R16E S35 NW $\frac{1}{4}$
20	Fergus	Moore	17 S	T13N R17E S30 SE $\frac{1}{4}$
21	Wheatland	Judith Gap	33 W	T11N R14E S23 SW $\frac{1}{4}$
22	Wheatland	Garneil	25 E	T11N R17E S16 SW $\frac{1}{4}$
23	Sweetgrass	Nye	17 NW	T 5S R14E S 1 NW $\frac{1}{4}$
25	Sweetgrass	Nye	25 W	T 5S R14E S 9 NW $\frac{1}{4}$
26	Prairie	Terry	42 NW	T15N R48E S19 NW $\frac{1}{4}$
27	Prairie	Terry	42 NW	T15N R48E S29 SE $\frac{1}{4}$
28	Prairie	Terry	42 NW	T15N R47E S36 NW $\frac{1}{4}$
29	Lewis & Clark	Augusta	25 NW	T21N R 8W S21 SE $\frac{1}{4}$
30	Pondera	Dupuyer	33 SW	T27N R 8W S17 NW $\frac{1}{4}$
31	Teton	Choteau	42 W	T25N R 8W S 9 NW $\frac{1}{4}$
32	Lewis & Clark	Lincoln	20 E	T15N R 7W S23 NW $\frac{1}{4}$
33	Toole	Shelby	20 SE	T31N R 1W S28 NW $\frac{1}{4}$
34	Choteau	Ft. Benton	8 E	T24N R 9E S19 SW $\frac{1}{4}$
35	Hill	Box Elder	12 E	T29N R14E S 2 NE $\frac{1}{4}$
36	Phillips	Dodson	7 E	T30N R27E S 1 SW $\frac{1}{4}$
37	Fergus	Ryegate	58 N	T12N R20E S27 SE $\frac{1}{4}$

Table 13. (continued)

Site	County	Nearest Post Office	Distance/ Direction from P. O.	Location		
(kilometers)						
38	Meagher	Checkerboard	25 S	T 9N	R 9E	S30 SW $\frac{1}{4}$
39	Meagher	White Sulfur	42 W	T11N	R 3E	S25 NW $\frac{1}{4}$
40	Rosebud	Ingomar	8 W	T10N	R34E	S20 SW $\frac{1}{4}$
41	Bighorn	Lame Deer	17 W	T 3N	R39E	S13 NW $\frac{1}{4}$
42	Powder River	Broadus	8 NW	T 4S	R50E	S. 2 NW $\frac{1}{4}$
43	Carter	Ekalaka	25 SE	T 2S	R60E	S24 NE $\frac{1}{4}$
44	Prairie	Ismay	5 N	T 9N	R55E	S 8. SW $\frac{1}{4}$
45	Wibaux	Wibaux	17 SE	T13N	R60E	S34 NW $\frac{1}{4}$
46	Roosevelt	Culbertson	5 N	T28N	R56E	S16 SW $\frac{1}{4}$
47	Daniels	Scobey	7 E	T35N	R49E	S 8 SW $\frac{1}{4}$
48	Valley	Ft. Peck	3 S	T26N	R40E	S20 NW $\frac{1}{4}$
49	Garfield	Jordan	25 N	T20N	R38E	S18 NW $\frac{1}{4}$
50	Cascade	Monarch	3 N	T16N	R 6E	S23 NW $\frac{1}{4}$
51	Sweetgrass	Melville	17 SW	T 3N	R13E	S13 SE $\frac{1}{4}$
24	Sweetgrass	Ney	42 NW	T 4S	R14E	S29 SW $\frac{1}{4}$

Table 14. Exposure, slope, elevation and drainage of 51 creeping juniper sites in Montana.

Site	Slope (percent)	Elevation (meters)	Exposure		Drainage
			Direction/Degrees		
1	5	1515	ENE	65	Picture Basin
2	14	1439	SSE	178	Elk Creek
3	33	1417	NNE	13	Elk Creek
4	5	1326	ENE	72	Elk Creek
5	14	1270	WSW	268	Elk Creek
6	36	1412	ENE	50	Dickinson Reservoir
7	41	1485	WSW	238	Barr Creek
8	28	1885	ENE	60	Chicken Coulee
9	26	1594	ENE	55	Cutrock Creek
10	21	1564	WSW	233	Cutrock Creek
11	27	1448	NNW	342	Dupuyer Creek
12	9	1479	WNW	280	Dupuyer Creek
13	38	1094	NNE	30	Sage Creek
14	35	1070	SSW	190	Sage Creek
15	5	1012	ENE	80	Warhorse Reservoir
16	11	1030	NNE	340	Warhorse Reservoir
17	40	1406	SSE	158	Deer Creek
18	15	1364	WNW	310	Deer Creek
19	19	1600	NNE	38	Rock Creek
20	24	1606	ESE	99	Rock Creek
21	12	1670	SSE	178	Roberts Gulch
22	40	1560	NNW	350	Dry Creek
23	30	1776	S	180	Picket Pin Creek
25	10	1794	NNE	25	Stillwater River
26	35	1040	ESE	123	Agate Creek
27	31	1048	NNE	10	Agate Creek
28	36	1030	SSW	195	Cherry Creek
29	42	1542	SSE	157	Rose Creek
30	19	1776	SSE	165	Dupuyer Creek
31	21	1845	SSE	165	Bynum Creek
32	34	1500	ESE	117	Blackfoot River
33	54	909	NNE	17	Marias River
34	38	848	NNW	347	Missouri River
35	40	936	NNW	330	Big Sandy Creek
36	24	758	WSW	240	Milk River
37	5	1621	ESE	117	North Willow Creek
38	7	2091	NNW	347	Musselshell River

Table 14. (continued)

Site	Slope (percent)	Elevation (meters)	Exposure		Drainage
			Direction/Degrees		
39	46	1561	NNW	353	Thomas Creek
40	42	939	NNW	357	Big Porcupine Cr.
41	50	1000	NNE	8	Rosebud Creek
42	33	969	NNW	317	Mizpah Creek
43	31	984	NNW	357	Spillman Creek
44	15	772	ENE	55	O'Fallon Creek
45	28	772	ENE	73	Beaver Creek
46	24	651	WSW	257	Missouri River
47	37	848	SSE	153	Poplar Creek
48	26	788	WSW	263	Missouri River
49	30	939	NNE	18	Hell Creek
50	5	1788	NNW	330	Belt Creek
51	19	--	SSE	175	Big Timber Creek
24	6	2485	SSW	200	Picket Pin Creek

Table 15. Scientific and common names of the 24 graminoids, 104 forbs, 18 shrubs and 3 trees in this study.

GRAMINOIDS

<i>Agropyron smithii</i>	Western wheatgrass
<i>Agropyron spicatum</i>	Bluebunch wheatgrass
<i>Andropogon scoparius</i>	Little bluestem
<i>Aristida longiseta</i>	Red threeawn
<i>Bouteloua gracilis</i>	Blue grama
<i>Bromus inermis</i>	Smooth brome
<i>Bromus japonicus</i>	Japanese brome
<i>Calamovilfa longifolia</i>	Prairie sandreed
<i>Calamovilfa purpescens</i>	Purple reedgrass
<i>Carex elynoides</i>	Kobresia-like sedge
<i>Carex filifolia</i>	Threadleaf sedge
<i>Carex heliophila</i>	Sun sedge
<i>Carex sciropoidea</i>	Single-spike sedge
<i>Carex vesicaria</i>	Inflated sedge
<i>Danthonia intermedia</i>	Timber danthonia
<i>Festuca idahoensis</i>	Idaho fescue
<i>Festuca scabrella</i>	Rough fescue
<i>Helictotrichon hookeri</i>	Spike oat
<i>Juncus balticus</i>	Wire rush
<i>Koeleria cristata</i>	Prairie junegrass
<i>Poa pattersoni</i>	Patterson's bluegrass
<i>Poa spp.</i>	Bluegrass species
<i>Stipa comata</i>	Needle and thread
<i>Stipa viridula</i>	Green needle grass

Table 15. (continued)

FORBS

<i>Achillea millefolium</i>	Western yarrow
<i>Allium cernuum</i>	Nodding onion
<i>Allium textile</i>	Textile onion
<i>Anemone multifida</i>	Ball anemone
<i>Anemone patens</i>	Pasque flower
<i>Antennaria rosea</i>	Rose pussytoes
<i>Arenaria congesta</i>	Ballhead sandwort
<i>Arenaria hookeri</i>	Hooker sandwort
<i>Artemisia cana</i>	Silver sagebrush
<i>Artemisia frigida</i>	Fringed sagewort
<i>Astragalus bisulatus</i>	Two-grooved milkvetch
<i>Astragalus eucosmus</i>	Elegant milkvetch
<i>Astragalus gilviflorus</i>	Three-leaved milkvetch
<i>Astragalus pectinatus</i>	Narrow leaf poisonvetch
<i>Astragalus tenellus</i>	Loose flower milkvetch
<i>Balsamorhiza saggitata</i>	Arrowleaf balsamroot
<i>Besseyia wyomingensis</i>	Kittentail
<i>Buplerum americanum</i>	American thorney
<i>Campanula rotundifolia</i>	Roundleaf harebell
<i>Castilleja sessiliflora</i>	Downy-painted cup
<i>Cerastium arvense</i>	Field chickweed
<i>Chrysopsis villosa</i>	Golden aster
<i>Cirsium undulatum</i>	Wavy leaf thistle
<i>Clematis pseudoalpina</i>	Climbing-purple clematis
<i>Comandra umbellata</i>	Pale bastard toad flax
<i>Crepis occidentalis</i>	Western hawksbeard
<i>Cryptantha interrupta</i>	Bristly cryptantha

Table 15. (continued)

Forbs

<i>Delphinium bicolor</i>	Low larkspur
<i>Dodecatheon conjugens</i>	Shooting star
<i>Echinacea pallida</i>	Purple coneflower
<i>Erigeron caespitosus</i>	Tufted fleabane
<i>Erigeron ochroleucus</i>	Buff erigeron
<i>Erigeron subtrinervis</i>	Three-veined fleabane
<i>Erigeron</i> spp.	Erigeron species
<i>Eriogonum flavum</i>	Yellow eriogonum
<i>Eriogonum umbellatum</i>	Sulfur eriogonum
<i>Eriogonum</i> spp.	Eriogonum species
<i>Eritichum howardii</i>	Howard's alpine forget me not
<i>Erysium asperum</i>	Plains wallflowers
<i>Frasera speciosa</i>	Spotted fraseria
<i>Fritillaria pudica</i>	Yellowbell
<i>Gaillardia aristata</i>	Blanket flower
<i>Galium boreale</i>	Northern bedstraw
<i>Geum triflorum</i>	Prairie smoke
<i>Grindelia squarrosa</i>	Curlicup gumweed
<i>Gutierrezia sarothrae</i>	Broom snakeweed
<i>Haplopappus armerioides</i>	Thrift goldenweed
<i>Haplopappus nattali</i>	Nuttall goldenweed
<i>Haplopappus spinulosus</i>	Spring goldenweed
<i>Hedysarum boreale</i>	Northern sweetvetch
<i>Hedysarum sulfurescens</i>	White sweetvetch
<i>Hymenoxys acaulis</i>	Arizona hymenoxys
<i>Leucrocrinum montanum</i>	Sand lily
<i>Liatris punctata</i>	Dotted blazingstar
<i>Linum perenne</i>	Blueflax

Table 15. (continued)

Forbs

<i>Lithoppermum ruderae</i>	Western gromwell
<i>Lomatium cous</i>	Mountain lomatium
<i>Lomatium macrocarpum</i>	Large-fruit lomatium
<i>Lotus purshianus</i>	Prairie trefoil
<i>Lupinus sericeus</i>	Silky lupine
<i>Lupinus wytheii</i>	Wyethe lupine
<i>Lupinus</i> spp.	Lupine species
<i>Mertensia viridis</i>	Greenleaf bluebell
<i>Monarda fistulosa</i>	Horse mint
<i>Musineon divaricatum</i>	Leaf musineon
<i>Myosotis sylvatica</i>	Alpine forget me not
<i>Opuntia polycantha</i>	Plains prickly pear
<i>Orthocarpus luteus</i>	Yellow owl clover
<i>Orthocarpus tenuifolia</i>	Thin-leaf orthocarpus
<i>Oxytropis besseyi</i>	Bessey pointvetch
<i>Oxytropis sericeus</i>	White pointloco
<i>Oxytropis viscidia</i>	Sticky pointloco
<i>Paroynchia sessiflora</i>	Stemless nailwort
<i>Penstemon attenuates</i>	Sulfur penstemon
<i>Penstemon erianthus</i>	Fuzzytongue penstemon
<i>Penstemon nitidus</i>	Waxleaf penstemon
<i>Petalostemon candidum</i>	White prairie clover
<i>Petalostemon purpescens</i>	Purple prairie clover
<i>Phlox alyssifolia</i>	Alyssum-leaved phlox
<i>Phlox hoodii</i>	Hoods phlox
<i>Phlox kelseyi</i>	Kelsey phlox
<i>Phlox multiflora</i>	Flowery phlox

Table 15. (continued)

Forbs

<i>Polygala alba</i>	White milkwort
<i>Polygonum bistortis</i>	Western bistort
<i>Potentilla gracilis</i>	Northwest cinquefoil
<i>Potentilla hippiana</i>	Horse cinquefoil
<i>Ranunculus glaberrimus</i>	Sagebrush buttercup
<i>Saxifraga rhomboidea</i>	Diamondleaf saxifrage
<i>Sisyrinchium sarmentosum</i>	Blue-eyed grass
<i>Sedum lanceolatum</i>	Lance-leaf stonecrop
<i>Senecio canus</i>	Wooly groundsel
<i>Smilicia racemosa</i>	False spikenard
<i>Solidago missourensis</i>	Missouri goldenrod
<i>Solidago occidentalis</i>	Western goldenrod
<i>Taraxicum officinale</i>	Common dandelion
<i>Thermopsis rhombifolia</i>	Prairie thermopsis
<i>Tragopogon dubius</i>	Common salsify
<i>Vicia americana</i>	American vetch
<i>Viola nuttalli</i>	Nuttall violet
<i>Yucca glauca</i>	Soapwell
<i>Zygodenus elegans</i>	Glaucos zygodenus
<i>Zygodenus venosus</i>	Meadow death camas

Table 15. (continued)

SHRUBS

<i>Apocynum cannabinum</i>	Hemp dogbane
<i>Arctostaphylos uva-ursi</i>	Kinnikinnick
<i>Artemisia longifolia</i>	Longleaf sagebrush
<i>Artemisia tridentata</i>	Big sagebrush
<i>Atriplex canescens</i>	Fourwing saltbrush
<i>Berberis repens</i>	Oregon grape
<i>Juniperus horizontalis</i>	Creeping juniper
<i>Potentilla fruticosa</i>	Shrubby cinquefoil
<i>Prunus virginiana</i>	Chokecherry
<i>Rhus trilobata</i>	Skunkbush sumac
<i>Ribes</i> spp.	Currant species
<i>Rosa acicularis</i>	Prickly rose
<i>Rosa arkansana</i>	Prairie rose
<i>Symphoricarpos albus</i>	Common snowberry
<i>Symphoricarpos occidentalis</i>	Western snowberry

Table 15. (continued)

TREES*Pinus flexilis*

Limber pine

Pinus ponderosa

Ponderosa pine

Pseudotsuga menziesii

Douglas fir

Table 16. Percent canopy coverage and percent frequency among 2x5 plot frames for the 30 intensively studied creeping juniper sites.

Taxa	Sites								
	1	2	3	4	5	6	7	8	9
GRAMINOIDS:									
<i>Agropyron smithii</i> (Agsm)	--	--	--	--	--	--	--	--	--
<i>Agropyron spicatum</i> (Agsp)	5/47 ¹	13/77	3/30	7/77	5/79	8/90	16/87	1/13	11/63
<i>Andropogon scoparius</i> (Ansc)	--	--	--	--	--	--	--	--	--
<i>Aristida longiseta</i> (Arlo)	--	--	--	--	--	--	--	--	--
<i>Bouteloua gracilis</i> (Bogr)	--	--	--	--	--	--	--	--	--
<i>Bromus inermis</i> (Brin)	--	--	--	--	--	--	--	--	--
<i>Bromus japonicus</i> (Brja)	--	--	--	--	--	--	--	--	1/ 7
<i>Calamovilfa longifolia</i> (Calo)	--	--	--	--	--	--	--	--	--
<i>Calamovilfa purpescens</i> (Capu)	--	--	--	--	--	--	--	--	--
<i>Carex elynoides</i> (Cael)	--	--	--	--	--	--	--	--	--
<i>Carex filifolia</i> (Cafi)	3/23	11/50	3/23	10/57	3/27	6/40	2/20	--	8/40
<i>Carex heliophila</i> (Cahe)	--	--	--	--	--	--	--	--	--
<i>Carex scirpoidea</i> (Casc)	--	--	--	--	--	--	--	--	--
<i>Carex vesicaria</i> (Cave)	1/13	1/10	1/10	--	1/ 7	4/27	1/ 7	1/13	tr/10
<i>Danthonia intermedia</i> (Dain)	--	--	--	--	--	--	--	--	--
<i>Festuca idahoensis</i> (Feid)	9/53	tr/ 3	10/60	4/47	17/77	8/47	--	11/70	22/73
<i>Festuca scabrella</i> (Fesc)	6/33	4/23	9/37	--	2/10	2/13	--	11/73	--

Table 16. (continued)

Taxa	Sites										
	10	11	12	13	14	15	16	17	18	19	20
GRAMINOIDS:											
(Agsm)	--	--	--	--	--	--	10/63	--	--	5/63	16/27
(Agsp)	1/ 7	3/47	--	--	--	1/ 3	--	2/30	--	--	--
(Ansc)	--	--	--	--	--	--	--	--	--	--	--
(Arlo)	--	--	--	--	--	--	--	--	--	--	--
(Borg)	--	--	--	--	2/13	--	--	--	--	--	--
(Brin)	--	2/20	2/17	--	--	--	--	--	--	tr/ 7	--
(Brja)	--	--	--	--	--	--	--	--	--	--	--
(Calo)	--	--	--	--	--	12/80	--	--	--	--	--
(Capu)	--	2/13	--	--	--	--	--	--	--	--	--
(Cael)	--	--	--	--	--	--	--	--	--	--	--
(Cafi)	4/20	3/23	3/23	2/17	6/30	--	--	2/23	--	--	1/ 3
(Cahe)	--	--	--	--	--	--	--	--	--	--	--
(Casc)	--	--	14/63	--	--	--	--	--	--	--	--
(Cave)	1/50	5/53	3/23	2/ 7	--	--	--	6/30	--	1/37	3/33
(Dain)	--	--	--	--	--	--	--	--	--	--	--
(Feid)	9/57	3/13	7/63	--	--	--	tr/ 3	tr/ 3	3/13	14/97	6/40
(Fesc)	--	15/67	2/20	--	--	--	--	--	--	--	--

Table 16.. (continued)

Taxa	Sites									
	21	22	23	25	26	27	28	29	30	31
GRAMINOIDS:										
(Agsm)	5/37	1/ 7	25/93	2/13	4/17	7/27	--	--	--	--
(Agsp)	--	--	1/ 7	2/37	3/33	--	--	12/67	1/20	8/80
(Ansc)	--	--	--	--	--	3/43	--	--	--	--
(Arlo)	--	--	--	--	1/ 3	--	--	--	--	--
(Borg)	--	--	--	--	--	--	--	--	--	--
(Brin)	--	--	--	--	--	--	--	--	--	--
(Brja)	--	--	--	--	--	--	--	--	--	--
(Calo)	--	--	--	--	2/23	--	4/27	--	--	--
(Capu)	--	--	--	--	--	--	--	--	--	--
(Cael)	--	--	--	1/37	tr/ 3	--	--	--	--	--
(Cafi)	--	--	--	--	8/40	7/47	5/40	1/10	7/40	12/50
(Cahe)	--	--	--	--	tr/ 3	--	--	--	--	--
(Casc)	--	--	--	--	--	--	--	--	--	--
(Cave)	1/20	10/83	--	--	6/23	3/27	1/10	--	3/23	--
(Dain)	--	--	--	--	--	--	--	--	--	--
(Feid)	3/33	5/63	--	8/57	--	--	--	1/ 3	--	1/30
(Fesc)	--	--	--	--	--	--	--	--	6/47	11/63

Table 16. (continued)

Taxa	Sites								
	1	2	3	4	5	6	7	8	9
GRAMINOIDS:									
<i>Helictotrichon hookeri</i> (Heho)	7/27	--	--	--	--	1/ 7	--	--	1/ 3
<i>Juncus balticus</i> (Juba)	--	--	--	--	--	--	--	--	--
<i>Koeleria cristata</i> (Kocr)	4/13	1/ 7	2/10	--	--	1/10	1/ 3	tr/10	--
<i>Poa pattersoni</i> (Popa)	--	--	--	--	--	--	--	--	--
<i>Poa</i> spp.	--	--	--	--	--	--	--	--	--
<i>Stipa comata</i> (Stco)	--	--	--	--	1/ 7	--	--	--	--
<i>Stipa viridula</i> (Stvi)	--	--	--	--	--	--	--	--	--
Unknown grasses									
FORBS:									
<i>Achillea millefolium</i> (Acmi)	--	--	2/27	1/17	--	tr/ 3	--	--	1/23
<i>Allium cernuum</i> (Alce)	--	--	--	--	--	--	--	--	--
<i>Allium textile</i> (Alte)	1/33	1/30	1/23	1/40	3/47	1/23	3/40	1/40	--
<i>Anemone multifida</i> (Anmu)	--	--	--	--	--	--	--	--	--
<i>Anemone patens</i> (Anpa)	2/10	--	1/10	--	--	--	tr/ 3	--	tr/ 3
<i>Antennaria rosea</i> (Anro)	tr/ 7	tr/ 3	1/13	tr/ 3	--	1/10	tr/ 7	5/60	1/ 7
<i>Arenaria congesta</i> (Arco)	1/ 7	--	1/ 3	--	--	--	--	1/23	--
<i>Arenaria hookeri</i> (Arho)	--	--	1/37	--	--	--	--	--	--
<i>Artemisia cana</i> (Arca)	--	--	--	--	--	--	--	--	--
<i>Artemisia frigida</i> (Arfr)	8/13	1/17	2/23	1/23	3/27	1/20	8/50	1/20	2/54

Table 16. (continued)

Taxa	Sites										
	10	11	12	13	14	15	16	17	18	19	20
GRAMINOIDS:											
(Heho)	13/60	tr/ 3	10/40	--	--	--	--	--	9/53	--	--
(Juba)	--	--	tr/ 6	--	--	--	--	--	--	--	--
(Kocr)	--	1/13	--	--	--	--	2/17	tr/ 3	--	--	--
(Popa)	--	--	--	--	--	--	--	--	--	--	1/ 7
<i>Poa</i> ssp.	--	--	--	--	--	--	--	1/10	--	--	--
(Stco)	--	--	--	13/87	22/90	--	--	--	--	--	--
(Stvi)	--	--	--	--	--	--	--	4/23	--	--	--
Unknown grasses								--	1/ 6	--	--
FORBS:											
(Acmi)	tr/10	--	tr/ 3	2/13	--	--	--	1/ 3	5/57	4/47	6/50
(Alce)	1/ 7	tr/10	tr/10	--	--	--	--	--	--	--	--
(Alte)	--	--	--	--	--	--	--	--	tr/ 7	--	1/23
(Anmu)	--	4/33	1/10	--	--	--	--	tr/ 3	2/13	--	--
(Anpa)	tr/ 3	4/47	--	--	--	--	--	--	tr/ 3	11/77	3/27
(Anro)	4/30	--	1/ 3	1/ 3	--	--	--	5/30	tr/ 3	--	--
(Arco)	--	2/17	tr/10	--	--	--	--	--	--	3/tr	--
(Arho)	--	1/10	--	--	--	--	--	--	--	--	--
(Arca)	--	--	--	--	--	--	--	--	--	--	--
(Arfr)	1/10	2/30	tr/ 3	1/10	1/10	--	1/10	1/13	3/13	--	--

Table 16. (continued)

Taxa	Sites									
	21	22	23	25	26	27	28	29	30	31
GRAMINOIDS:										
(Heho)	tr/ 3	--	--	--	--	--	--	--	--	--
(Juba)	--	--	--	--	--	--	--	--	--	--
(Kocr)	3/20	--	3/20	--	--	1/ 3	--	1/ 3	7/43	1/23
(Popa)	--	--	--	--	1/ 7	--	--	--	--	--
<i>Poa</i> ssp.	--	--	--	--	--	--	--	--	--	--
(Stco)	--	--	--	--	--	--	--	--	--	--
(Stvi)	--	--	--	2/ 3	--	--	--	--	--	--
Unknown grasses	--	--	--	3/17	--	2/13	--	--	--	--
FORBS:										
(Acmi)	1/10	--	1/ 7	tr/17	tr/ 3	1/10	--	--	1/ 3	tr/ 3
(Alce)	--	--	tr/ 3	--	--	--	--	--	--	--
(Alte)	--	--	--	--	--	--	--	tr/10	1/30	--
(Anmu)	--	2/23	--	4/40	--	5/53	3/23	--	--	--
(Anpa)	1/ 7	--	--	7/60	--	--	--	--	--	--
(Anro)	1/10	1/13	--	2/13	--	--	--	--	2/17	tr/ 7
(Arco)	--	--	--	--	--	--	--	--	--	--
(Arho)	--	--	--	--	--	--	--	--	--	1/20
(Arca)	--	--	--	--	1/10	--	--	--	--	--
(Arfr)	--	--	3/23	--	2/13	1/ 3	--	2/13	1/13	1/50

Table 16. (continued)

Taxa	Sites								
	1	2	3	4	5	6	7	8	9
FORBS:									
<i>Astragalus bisulatus</i> (Asbi)	--	--	--	--	--	--	--	--	--
<i>Astragalus eucosmus</i> (Aseu)	--	--	--	--	2/ 3	--	1/ 3	--	--
<i>Astragalus gilviflorus</i> (Asgi)		1/ 3					1/ 3		
<i>Astragalus pectinatus</i> (Aspe)	--		--	--	--	--	--	--	--
<i>Astragalus tenellus</i> (Aste)	--	--	--	--	--	--	--	--	--
<i>Balsamorhiza saggitata</i> (Basa)	--	--	--	--	tr/ 7	--	--	--	--
<i>Besseyia wyomingensis</i> (Bewy)	tr/ 3	--	2/13	--	--	--	--	--	--
<i>Buplerum americanum</i> (Buam)	--	1/ 7	2/20	--	1/ 3	3/23	--	--	--
<i>Campanula rotundifolia</i> (Caro)	--	--	--	--	--	--	--	--	--
<i>Castilleja sessiliflora</i> (Case)	--	--	--	--	--	--	--	--	--
<i>Cerastium arvense</i> (Cear)	1/27	tr/ 3	tr/23	tr/17	tr/17	1/23	tr/ 3	tr/20	1/13
<i>Chrysopsis villosa</i> (Chvi)	--	--	--	--	--	--	--	--	--
<i>Cirsium undulatum</i> (Ciun)	--	--	--	--	--	--	--	--	--
<i>Clematis pseudoalpina</i> (Clps)	--	--	--	--	--	--	--	--	--
<i>Comandra umbellata</i> (Coum)	--	1/17	--	1/17	1/27	tr/10	--	--	--
<i>Crepis occidentalis</i> (Croc)	--	--	--	--	--	--	--	--	--
<i>Cryptanthus interrupta</i> (Crin)	--	--	--	--	--	1/ 3	--	--	--
<i>Delphinium bicolor</i> (Debi)	--	--	--	--	--	--	--	--	--
<i>Dodecatheon conjugens</i> (Doco)	--	--	--	1/ 3	--	--	--	--	--
<i>Echinacea pallida</i> (Ecpa)	--	--	--	--	--	--	--	--	--

Table 16. (continued)

Taxa	Sites										
	10	11	12	13	14	15	16	17	18	19	20
FORBS:											
(Asbi)	--	--	--	--	--	--	--	--	tr/ 7	--	--
(Aseu)	--	--	--	--	--	--	--	--	--	--	--
(Asgi)	--	--	--	--	--	--	--	1/ 3	--	--	--
(Aspe)	--	--	--	--	7/37	--	--	--	--	--	--
(Aste)	--	--	1/10	--	--	--	--	--	--	--	--
(Basa)	--	--	--	--	--	--	--	--	--	--	4/20
(Bewy)	1/17	tr/ 3	--	5/30	--	--	3/17	--	tr/ 3	10/80	3/20
(Buam)	1/ 7	tr/ 3	--	--	--	--	--	--	--	--	--
(Caro)	--	--	tr/ 3	--	--	--	1/ 3	--	--	--	--
(Case)	--	--	1/ 7	--	--	--	--	--	--	--	--
(Cear)	tr/20	tr/37	tr/17	tr/ 3	--	--	--	--	tr/17	1/17	2/16
(Chvi)	--	--	--	--	--	--	--	--	--	--	--
(Ciun)	--	--	--	--	--	--	--	--	--	--	--
(Clps)	--	--	--	--	--	--	--	--	--	3/17	--
(Coum)	--	tr/ 7	--	1/ 3	1/10	--	5/40	--	--	2/13	tr/ 7
(Croc)	--	--	--	--	--	--	--	--	--	--	--
(Crin)	--	--	--	--	--	--	--	--	--	--	--
(Debi)	--	--	--	--	--	--	--	--	--	1/13	tr/ 7
(Doco)	--	1/ 7	--	--	--	--	--	--	--	1/13	--
(Ecpa)	--	--	--	--	--	--	--	--	--	--	--

Table 16. (continued)

Taxa	Sites									
	21	22	23	25	26	27	28	29	30	31
FORBS:										
(Asbi)	--	--	--	--	--	--	--	--	--	--
(Aseu)	--	--	--	--	4/27	1/ 7	tr/ 3	--	--	2/13
(Asgi)	--	--	--	--	--	1/ 3	--	--	2/23	tr/ 3
(Aspe)	--	--	5/53	--	--	--	--	--	--	--
(Aste)	--	--	--	--	--	--	--	--	--	--
(Basa)	--	--	2/17	--	--	--	--	1/10	--	1/ 3
(Bewy)	--	--	--	--	--	1/13	--	--	--	1/ 3
(Buam)	--	--	--	--	--	--	--	--	tr/ 7	--
(Caro)	--	--	--	--	--	1/20	--	--	--	--
(Case)	--	--	--	--	--	--	--	--	1/ 3	--
(Cear)	1/23	tr/10	2/13	tr/ 3	--	--	--	1/13	--	2/37
(Chvi)	--	--	--	--	1/10	--	--	--	--	--
(Ciun)	--	--	--	--	tr/ 3	--	--	--	--	--
(Clps)	--	--	--	--	--	--	--	--	--	--
(Coum)	2/27	4/43	1/40	--	1/ 3	--	3/27	2/ 7	2/33	--
(Croc)	--	--	--	--	--	--	--	1/10	--	--
(Crin)	--	--	--	--	--	--	--	--	--	--
(Debi)	--	--	--	--	--	--	--	--	--	--
(Doco)	--	--	--	--	--	--	--	--	--	--
(Ecpa)	--	--	--	--	1/ 7	--	1/ 3	--	--	--

Table 16. (continued)

Taxa	Sites								
	1	2	3	4	5	6	7	8	9
FORBS:									
<i>Erigeron caespitosus</i> (Erca) - -	- -	- -	- -	- -	- -	- -	- -	- -	1/13
<i>Erigeron ochroleucus</i> (Eroc) - -	tr/10	tr/ 7	- -	1/ 3	- -	- -	- -	- -	- -
<i>Erigeron subtrinervis</i> (Ersu) - -	1/10	2/13	3/37	2/20	2/37	tr/ 3	2/37	- -	- -
<i>Erigeron</i> spp.	- -	- -	- -	- -	- -	- -	- -	- -	- -
<i>Erigeron falvum</i> (Erfl) - -	- -	- -	- -	1/ 3	- -	tr/ 3	- -	1/ 3	- -
<i>Eriogonum umbellatum</i> (Erum) - -	- -	- -	- -	- -	- -	- -	- -	- -	- -
<i>Eriogonum</i> spp.	- -	1/13	- -	tr/ 3	1/ 3	- -	- -	- -	- -
<i>Eritichum howardii</i> (Erhq) - -	- -	- -	- -	- -	- -	- -	- -	- -	- -
<i>Erysium asperum</i> (Eras) - -	- -	- -	- -	- -	- -	- -	- -	- -	- -
<i>Frasera speciosa</i> (Frsp) 1/ 3	- -	1/ 3	- -	- -	- -	- -	- -	- -	- -
<i>Fritileria pudica</i> (Frpu) - -	- -	- -	1/ 3	- -	- -	- -	- -	- -	- -
<i>Gaillardia aristata</i> (Gaar) - -	- -	- -	- -	1/ 7	- -	- -	1/ 3	- -	- -
<i>Galium boreale</i> (Gabo) tr/ 7	- -	1/10	tr/ 3	2/30	tr/10	- -	- -	1/20	- -
<i>Geum triflorum</i> (Getr) - -	2/23	- -	tr/ 7	- -	- -	- -	1/ 3	tr/ 7	- -
<i>Grindelia squarrosa</i> (Grsq) - -	- -	- -	- -	- -	- -	- -	- -	- -	- -
<i>Gutierrezia sarothrae</i> (Gusa) - -	- -	- -	- -	- -	- -	- -	- -	- -	- -
<i>Haplopappus armeroides</i> (Haar) - -	- -	- -	- -	- -	- -	- -	- -	- -	- -
<i>Haplopappus nuttali</i> (Hanu) - -	- -	- -	- -	- -	- -	- -	- -	- -	- -
<i>Haplopappus spinulosus</i> (Hasp) - -	- -	- -	- -	- -	- -	- -	- -	- -	- -
<i>Hedysarum boreale</i> (Hebo) - -	- -	- -	- -	- -	- -	1/ 3	- -	- -	- -

Table 16. (continued)

Taxa	Sites										
	10	11	12	13	14	15	16	17	18	19	20
FORBS:											
(Erca)	--	--	--	--	--	--	--	--	--	--	--
(Eroc)	--	--	tr/ 3	tr/ 3	1/ 3	--	1/ 7	--	--	--	--
(Ersu)	1/10	1/13	tr/17	--	--	--	--	--	--	--	--
<i>Erigeron</i> spp.	--	--	--	--	1/ 4	--	--	--	--	tr/13	--
(Erfl)	--	--	--	--	--	--	--	--	--	--	--
(Erum)	--	--	--	--	--	--	--	--	--	--	--
<i>Eriogonum</i> spp.	--	--	--	1/ 7	--	--	--	--	--	--	--
(Erho)	--	--	--	--	--	--	--	--	--	--	--
(Eras)	--	--	--	--	--	--	--	--	--	--	--
(Frsp)	--	--	--	--	--	--	--	--	4/27	2/17	1/ 7
(Frpu)	--	--	--	--	--	--	--	tr/ 3	--	--	--
(Gaar)	--	tr/ 7	1/17	--	--	--	--	--	2/13	--	2/10
(Gabo)	tr/ 7	--	1/33	1/ 3	--	--	--	9/83	1/ 7	4/67	3/27
(Getr)	tr/ 7	--	1/33	2/10	--	--	--	--	--	3/17	--
(Grsq)	--	--	--	--	1/ 3	--	--	--	--	--	--
(Gusa)	--	--	--	--	--	--	--	--	--	--	--
(Haar)	--	--	--	--	--	--	--	1/ 3	--	--	--
(Hanu)	--	--	--	--	--	--	--	1/ 7	6/47	--	--
(Hasp)	--	--	--	--	--	--	--	--	--	--	--
(Hebo)	--	--	--	--	--	--	--	--	--	--	--

Table 16. (continued)

Taxa	Sites									
	21	22	23	25	26	27	28	29	30	31
FORBS:										
(Erca)	--	--	--	--	--	--	--	--	--	--
(Eroc)	1/3	--	--	--	--	--	--	--	1/10	--
(Ersu)	--	1/27	--	tr/13	--	--	--	--	1/ 7	tr/ 3
<i>Erigeron</i> spp.	--	--	1/ 7	--	--	--	--	--	--	--
(Erfl)	--	--	--	--	--	--	--	--	--	1/31
(Erum)	--	--	--	--	--	--	2/33	--	--	--
<i>Eriogonum</i> spp.	--	--	1/ 7	--	--	--	--	--	tr/ 3	tr/ 7
(Erho)	--	8/53	--	--	--	--	--	--	--	--
(Eras)	--	--	--	tr/ 3	--	--	--	--	--	--
(Frsp)	--	--	--	--	--	--	--	--	--	--
(Frpu)	--	--	--	--	--	--	--	--	--	--
(Gaar)	tr/ 3	--	--	1/40	--	--	1/10	--	tr/10	--
(Gabo)	1/13	--	1/40	3/60	--	1/ 3	--	--	tr/10	--
(Getr)	--	--	--	--	--	tr/ 3	--	--	--	--
(Frsq)	--	--	--	--	--	--	--	--	--	--
(Gusa)	--	--	--	--	--	--	2/17	--	--	--
(Haar)	--	--	--	--	--	--	--	--	--	--
(Hanu)	--	--	--	--	--	--	--	--	--	--
(Hasp)	--	--	--	--	--	--	--	--	--	1/ 7
(Hebo)	--	--	--	--	--	--	--	--	--	--

Table 16. (continued)

Taxa	Sites								
	1	2	3	4	5	6	7	8	9
FORBS:									
<i>Hedysarum sulfurescens</i> (Hesu)	--	--	--	--	--	--	--	--	--
<i>Hymenoxys acaulis</i> (Hyac)	--	2/27	2/20	1/13	tr/7	1/3	2/17	2/27	--
<i>Leucrocrinum montanum</i> (Lemo)	--	--	--	--	--	--	--	--	--
<i>Liatris punctata</i> (Lipu)	--	--	--	--	--	--	--	--	--
<i>Linum perenne</i> (Lipe)	--	tr/3	--	tr/13	tr/10	--	--	--	--
<i>Lithopermuin ruderales</i> (Liru)	--	--	1/3	--	--	--	--	--	--
<i>Lomatium cous</i> (Loco)	tr/7	1/7	tr/20	tr/7	tr/7	--	tr/7	tr/17	--
<i>Lomatium macrocarpum</i> (Loma)	--	--	1/3	--	--	--	--	1/30	--
<i>Lotus purshianus</i> (Lopu)	--	--	--	--	--	--	--	--	--
<i>Lupinus sericeus</i> (Luse)	--	--	--	3/17	--	--	--	--	1/10
<i>Lupinus wytheii</i> (Luwy)	--	--	--	--	--	--	--	--	--
<i>Lupinus</i> spp.	--	--	--	--	--	1/7	--	--	--
<i>Mertensia viridis</i> (Mevi)	--	--	--	--	--	--	--	--	--
<i>Monarda fistulosa</i> (Mofi)	--	--	--	--	--	--	--	--	--
<i>Musineon divaricatum</i> (Mudi)	tr/3	1/17	--	--	--	tr/3	1/7	tr/3	3/43
<i>Myosotis sylvatica</i> (Mysy)	--	--	--	--	--	--	--	--	--
<i>Opuntia polycantha</i> (Oppo)	--	--	--	--	--	--	--	--	--
<i>Orthocarpus leuteus</i> (Orle)	--	--	--	--	--	--	--	--	--

Table 16. (continued)

Taxa	Sites										
	10	11	12	13	14	15	16	17	18	19	20
FORBS:											
(Hesu)	--	tr/7	3/27	1/7	3/7	--	--	--	--	7/60	--
(Hyac)	--	1/10	--	--	--	--	--	--	--	--	--
(Lemo)	--	1/7	--	--	--	--	--	--	--	--	--
(Lipu)	--	--	1/7	--	--	--	tr/3	--	1/3	--	--
(Lipe)	--	--	--	1/10	1/7	--	tr/3	1/3	3/53	--	tr/3
(Liru)	--	10/7	--	--	--	--	--	--	--	--	--
(Loco)	tr/17	tr/7	--	tr/7	tr/3	--	--	tr/13	1/13	2/23	2/17
(Loma)	--	--	--	--	--	--	--	--	--	--	--
(Lopu)	--	--	--	tr/3	7/47	--	--	--	--	--	--
(Luse)	--	2/10	--	--	--	--	--	--	--	--	--
(Luwy)	--	--	--	--	--	--	--	--	--	--	--
<i>Eupinus</i> spp.	--	--	1/3	--	--	--	--	--	--	--	--
(Mevi)	--	--	--	--	--	--	--	--	--	--	--
(Mofi)	--	--	--	--	--	--	--	--	--	--	6/20
(Mudi)	--	--	--	--	1/7	--	1/7	3/23	--	--	--
(Mysy)	--	--	--	--	--	--	--	--	--	--	--
(Oppo)	--	--	--	tr/3	--	--	--	--	--	--	--
(Orle)	--	--	--	--	--	--	--	--	--	--	--

Table 16. (continued)

Taxa	Sites									
	21	22	23	25	26	27	28	29	30	31
FORBS:										
(Hesu)	--	--	--	--	--	--	--	--	1/7	--
(Hyac)	--	--	--	--	--	--	--	tr/3	1/37	2/40
(Lemo)	--	--	--	--	--	--	--	--	--	--
(Lipu)	--	--	--	--	tr/3	--	--	--	--	--
(Lipe)	tr/3	tr/3	1/17	tr/3	tr/3	--	--	1/3	tr/7	--
(Liru)	--	--	tr/3	--	--	--	--	--	--	--
(Loco)	--	--	--	1/23	--	--	--	tr/7	tr/3	tr/10
(Loma)	--	--	--	--	--	--	--	--	--	--
(Lopu)	--	--	--	--	--	--	--	--	--	--
(Luse)	--	--	--	--	--	--	--	--	1/7	--
(Luwy)	--	--	--	--	--	--	--	--	--	tr/20
<i>Lupinus</i> spp.	--	--	--	--	--	--	--	--	--	--
(Mevi)	--	--	--	1/3	--	--	--	--	--	--
(Mofi)	--	--	--	--	--	--	--	--	--	--
(Mudi)	tr/17	--	1/10	--	--	--	--	1/10	--	--
(Mysy)	--	--	--	2/13	--	--	--	--	--	--
(Oppo)	--	--	--	--	--	--	--	--	--	--
(Orle)	--	--	--	--	--	--	--	--	--	--

Table 16. (continued)

Taxa	Sites								
	1	2	3	4	5	6	7	8	9
FORBS:									
<i>Orthocarpus tenuifolia</i> (Orte)	--	--	--	--	--	--	--	--	--
<i>Oxytropis besseyi</i> (Oxbe)	--	--	--	--	--	--	--	--	--
<i>Oxytropis sericeus</i> (Oxse)	tr/7	1/20	4/33	3/37	--	1/3	--	2/13	--
<i>Oxytropis viscida</i> (Oxvi)	--	--	--	--	--	--	1/3	--	--
<i>Paronychia sessiflora</i> (Pase)	--	--	--	--	--	--	--	--	--
<i>Penstemon attenuates</i> (Peat)	--	--	--	--	--	--	--	--	--
<i>Penstemon erianthus</i> (Peer)	--	tr/3	tr/3	--	--	--	--	--	--
<i>Penstemon nitidus</i> (Peni)	--	--	--	tr/10	--	--	--	--	--
<i>Petalostemon candidum</i> (Peca)	--	--	--	--	--	--	--	--	--
<i>Petalostemon purpureus</i> (Pepu)	--	--	--	--	--	--	--	--	--
<i>Phlox alyssifolia</i> (Phal)	--	8/33	1/10	1/13	3/30	--	--	--	1/7
<i>Phlox hoodii</i> (Phho)	--	--	1/7	--	1/10	--	--	--	--
<i>Phlox kelseyi</i> (Phke)	1/13	--	1/3	--	--	2/27	4/43	1/23	1/13
<i>Phlox multiflora</i> (Phmu)	--	tr/13	4/40	--	1/3	1/7	--	1/23	--
<i>Polygala alba</i> (Poal)	--	--	--	--	--	--	--	--	--
<i>Polygonum bistortidis</i> (Pobi)	--	--	--	--	--	--	--	--	--
<i>Potentilla gracilllis</i> (Pogr)	tr/3	--	--	--	--	--	--	--	--
<i>Potentilla hippiana</i> (Pohi)	--	--	--	--	--	tr/3	--	tr/3	--

Table 16. (continued)

Taxa	Sites										
	10	11	12	13	14	15	16	17	18	19	20
FORBS:											
(Orte)	--	--	--	--	--	--	--	--	--	--	--
(Oxbe)	--	--	--	--	--	--	--	--	--	--	--
(Oxse)	2/17	1/87	--	1/7	--	--	--	--	1/47	2/17	--
(Oxvi)	--	--	--	--	--	--	--	--	--	--	--
(Pase)	--	tr/3	--	--	--	--	--	1/17	--	--	1/7
(Peat)	--	--	--	--	--	--	--	--	--	--	--
(Peer)	--	--	--	--	--	--	--	--	--	--	--
(Peni)	--	--	--	--	--	--	1/3	--	--	--	--
(Peca)	--	--	--	--	--	--	--	--	--	--	--
(Pepu)	--	--	--	--	--	--	--	--	--	--	--
(Phal)	--	3/37	2/20	1/3	1/7	--	2/17	3/23	10/43	--	--
(Phho)	--	1/13	--	--	--	--	--	--	--	--	--
(Phke)	2/23	--	1/17	3/23	2/27	--	--	--	--	--	--
(Phmu)	--	1/13	--	--	--	--	--	--	--	--	1/3
(Poal)	--	--	--	--	--	--	--	--	--	--	--
(Pobi)	--	--	--	--	--	--	--	--	--	1/53	--
(Pogr)	1/17	--	--	1/3	--	--	--	--	--	--	tr/3
(Pohi)	--	1/3	--	--	--	--	--	1/3	--	--	--

Table 16. (continued)

Taxa	Sites									
	21	22	23	25	26	27	28	29	30	31
FORBS:										
(Orte)	--	--	--	--	--	--	--	--	--	1/7
(Oxbe)	--	--	--	--	--	--	4/43	3/33	--	--
(Oxse)	--	12/90	--	--	--	--	--	--	1/13	--
(Oxvi)	--	--	--	--	--	--	--	--	1/27	--
(Pase)	--	--	--	--	--	--	--	--	--	--
(Peat)	--	--	--	--	--	--	--	--	--	--
(Peer)	--	--	--	--	--	--	--	--	--	--
(Peni)	--	--	--	--	--	--	--	--	--	--
(Peca)	1/20	--	--	--	--	1/10	--	--	2/27	--
(Pepu)	--	--	--	--	--	--	--	--	--	1/10
(Phal)	3/37	--	4/43	--	--	--	--	--	--	--
(Phho)	--	--	--	--	--	--	--	--	--	--
(Phke)	--	--	--	--	1/3	1/17	--	1/13	7/63	2/10
(Phmu)	--	--	--	--	--	--	--	--	--	1/7
(Poal)	--	--	--	--	tr/3	--	--	--	--	--
(Pobi)	--	--	--	tr/3	--	--	--	--	--	--
(Pogr)	--	--	--	--	--	--	--	--	2/23	--
(Pohi)	1/3	--	--	--	--	--	--	--	--	tr/3

Table 16. (continued)

Taxa	Sites								
	1	2	3	4	5	6	7	8	9
FORBS:									
<i>Ranunculus glaberrimus</i> (Ragl)	--	--	--	--	--	--	--	--	--
<i>Saxifraga rhomboidea</i> (Sarh)	--	--	--	--	--	--	--	--	--
<i>Sisyrinchium sarmentosum</i> (Sisa)	--	--	--	--	--	--	--	--	--
<i>Sedum lanceolatum</i> (Sela)	--	--	tr/7	tr/3	--	--	--	--	--
<i>Senecio canus</i> (Seca)	--	tr/3	--	--	--	--	--	tr/7	--
<i>Smilicia racemosa</i> (Smra)	--	--	--	--	--	--	--	--	--
<i>Solidago missourensis</i> (Somi)	tr/17	--	--	--	tr/7	--	--	--	1/3
<i>Solidago occidentalis</i> (Sooc)	--	--	--	--	--	--	--	--	--
<i>Taraxacum officinale</i> (Taof)	--	--	--	tr/10	--	--	--	--	--
<i>Thermopsis rhombifolia</i> (Thrh)	3/47	--	--	--	3/37	1/3	--	--	11/70
<i>Tragopogon dubius</i> (Trdu)	--	tr/3	--	1/3	--	--	--	--	--
<i>Vicia americana</i> (Viam)	tr/3	--	tr/3	--	1/7	--	--	--	--
<i>Viola nuttalli</i> (Vinu)	--	--	--	--	--	--	--	--	--
<i>Yucca glauca</i> (Yugl)	--	--	--	--	--	--	--	--	--
<i>Zygadenus elegans</i> (Zyel)	tr/3	--	--	1/10	--	--	--	--	--
<i>Zygadenus venosus</i> (Zyve)	tr/3	--	tr/3	--	--	--	--	1/20	3/43

Table 16. (continued)

Taxa	Sites										
	10	11	12	13	14	15	16	17	18	19	20
FORBS:											
(Ragl)	--	--	--	--	--	--	--	--	--	--	--
(Sarh)	--	--	--	--	--	--	--	--	--	--	--
(Sisa)	--	--	--	--	--	--	--	--	1/7	--	--
(Sela)	tr/20	--	--	--	--	--	--	--	--	1/10	2/17
(Seca)	1/20	1/7	--	--	--	--	--	--	--	1/7	--
(Smra)	--	--	1/20	--	--	--	--	--	--	--	--
(Somi)	1/7	--	--	2/27	--	--	--	--	--	--	--
(Sooc)	--	--	--	--	1/7	--	tr/3	--	--	--	--
(Taof)	--	--	--	--	--	--	--	--	1/13	--	--
(Thrh)	1/10	--	--	--	3/23	18/57	5/30	--	1/3	--	--
(Trdu)	--	--	--	--	--	--	--	--	--	--	--
(Viam)	--	tr/3	--	3/23	1/3	--	2/20	1/3	1/3	--	--
(Vinu)	--	--	--	2/10	--	--	--	--	--	tr/7	tr/3
(Yugl)	--	--	--	--	2/7	--	--	--	--	--	--
(Zyel)	--	2/27	2/10	--	--	--	--	--	tr/3	7/57	1/7
(Zyve)	1/3	1/20	tr/3	1/7	1/3	--	--	1/13	3/37	--	--

Table 16. (continued)

Taxa	Sites									
	21	22	23	25	26	27	28	29	30	31
FORBS										
(Ragl)	--	--	--	--	1/3	--	--	--	--	--
(Sarh)	--	--	--	1/3	--	--	--	--	--	--
(Sisa)	--	--	--	--	--	--	--	--	--	--
(Sela)	--	--	--	tr/3	--	--	--	--	--	--
(Seca)	--	--	--	--	--	--	--	--	tr/3	--
(Smra)	--	--	--	--	--	--	--	--	--	--
(Somi)	--	--	--	--	tr/3	--	--	--	tr/7	--
(Sooc)	--	--	--	--	--	--	--	--	--	--
(Taof)	--	--	2/10	--	--	--	--	--	--	--
(Thrh)	--	1/10	--	--	1/3	--	1/3	4/57	--	--
(Trdu)	--	--	--	--	--	--	--	--	--	--
(Viam)	tr/10	--	3/53	--	--	--	--	tr/3	--	tr/10
(Vinu)	--	--	--	--	--	1/7	--	--	--	--
(Yugl)	--	--	--	--	--	--	--	--	--	--
(Zyel)	1/3	6/57	--	10/70	--	--	--	--	--	--
(Zyve)	1/7	--	--	--	--	--	--	1/3	--	tr/3

Table 16. (continued)

Taxa	1	2	3	4	Sites 5	6	7	8	9
SHRUBS									
<i>Apocynum cannabinum</i> (Apca)	-	-	-	-	-	-	-	-	-
<i>Arctostaphylos uva-ursi</i> (Aruv)	-	-	-	-	-	-	-	-	1/3
<i>Artemisia longifolia</i> (Artlo)	-	-	-	-	-	-	-	-	-
<i>Artemisia tridentata</i> (Artr)	-	-	-	-	-	-	-	-	-
<i>Atriplex canescens</i> (Atca)	-	-	-	-	-	-	-	-	-
<i>Berberis repens</i> (Bere)	-	-	-	-	-	-	-	-	-
<i>Juniperus horizontalis</i> (Juho)	43/60	19/67	33/73	31/77	35/83	36/83	34/67	16/43	16/23
<i>Potentilla fruticosa</i> (Pofr)	1/3	-	-	-	-	-	-	-	4/17
<i>Prunus virginiana</i> (Prvi)	-	-	-	-	-	-	-	-	-
<i>Rhus trilobata</i> (Rhtr)	-	-	-	-	-	-	-	-	-
<i>Ribes</i> spp.	-	-	-	-	-	1/13	-	-	-
<i>Rosa acicularis</i> (Roac)	-	-	-	-	-	-	-	-	1/40
<i>Rosa arkansana</i> (Roar)	-	-	-	-	-	-	-	-	-
<i>Symphoricarpos albus</i> (Syal)	-	-	-	-	-	-	-	-	-
<i>Symphoricarpos occidentalis</i> (Syoc)	-	-	-	-	-	-	-	-	-
TREES									
<i>Pinus flexilis</i> (Pifl)	1/20	1/15	-	-	1/22	22/91	48/188	1/13	2/21
<i>Pinus ponderosa</i> (Pipo)	-	-	-	-	-	23/47	-	-	tr/5
<i>Pseudotsuga menziesii</i> (Psme)	-	-	-	-	-	-	-	-	-

Table 16. (continued)

Taxa	Sites											
	10	11	12	13	14	15	16	17	18	19	20	
SHRUBS:												
(Apcu)	--	--	--	--	--	--	--	5/33	--	--	--	
(Aruv)	--	--	--	--	--	--	--	--	--	--	--	
(Artlo)	--	--	--	--	--	3/13	--	--	--	--	--	
(Artr)	--	--	--	--	--	--	5/23	--	--	--	--	
(Atca)	--	--	--	--	--	--	--	--	--	--	--	
(Bere)	--	--	--	--	--	--	--	--	--	--	tr/3	
(Juho)	27/53	47/77	30/47	53/73	16/27	17/33	35/50	32/73	28/43	40/73	9/37	
(Pofr)	4/20	3/20	4/30	--	--	--	--	--	--	13/50	9/30	
(Prvi)	--	--	--	--	--	--	--	--	--	--	1/13	
(Rhtr)	--	--	--	2/10	5/13	--	--	--	--	--	--	
<i>Ribes</i> spp.	--	--	--	--	--	--	--	--	--	--	--	
(Roac)	1/3	--	tr/3	1/13	2/27	--	--	4/27	tr/3	--	1/7	
(Roar)	--	--	--	--	--	3/23	1/13	--	--	1/3	--	
(Syal)	--	--	--	14/73	--	--	--	--	--	3/23	2/10	
(Syoc)	--	--	--	--	--	--	--	--	--	--	--	
TREES												
(Pifl)	2/93	1/93	1/7	--	--	--	--	--	--	--	--	
(Pipo)	tr/2	--	--	--	--	--	--	--	--	--	--	
(Psme)	--	--	--	--	--	4/160	--	--	--	--	--	

Table 16. (continued)

Taxa	Sites									
	21	22	23	25	26	27	28	29	30	31
FORBS:										
(Apcu)	--	--	--	--	--	--	--	2/10	--	--
(Aruv)	--	--	--	--	--	--	--	--	--	--
(Artlo)	--	--	--	--	--	--	--	--	--	--
(Artr)	--	--	--	--	--	--	--	--	--	--
(Atca)	--	--	--	--	--	--	--	--	1/10	--
(Bere)	--	--	--	--	--	--	--	--	--	--
(Juho)	63/80	26/63	11/60	57/90	56/63	83/100	25/53	10/27	27/40	20/33
(Pofr)	--	5/27	--	--	--	--	--	--	--	--
(Prvi)	--	--	--	--	--	--	--	--	--	--
(Rhtr)	--	--	--	--	--	--	--	1/3	--	--
<i>Ribes</i> spp.	--	--	--	--	--	--	--	--	--	--
(Roac)	--	--	--	--	--	--	2/13	--	2/13	--
(Roar)	--	1/3	--	--	--	--	--	--	--	--
(Syal)	--	--	--	--	--	--	--	--	--	--
(Syoc)	--	--	--	--	--	tr/3	--	--	--	--
TREES										
(Pifl)	10/70	--	4/48	5/58	--	--	--	3/200	5/220	--
(Pipo)	--	--	--	tr/2	--	--	--	--	--	--
(Psme)	1/23	--	--	--	--	--	--	--	--	--

Table 17. Edaphic characteristics of 51 creeping juniper sites including pH, organic matter content, texture, salt hazard, soil depth, erosion, and five important elements.

Sites	pH	Organic Matter Percent	Tex- ture ¹	Phos- phorus ppm ²	Potas- sium ppm	Magne- sium meq ³	Sod- ium meq	Cal- cium meq	Salt Hazard mmhos ⁴	Soil Depth cm	Surface Erosion Percent
1	7.8	4.5(M) ⁵	CL	2(VL)	199(M)	2.1	Tr. ⁶	36.0	0.6	23.6	3.0
2	7.7	3.2(L)	SL	17(VL)	162(M)	1.3	Tr.	28.4	1.0	12.2	15.0
3	7.0	3.9(L)	L	18(VL)	107(L)	1.5	Tr.	12.8	1.3	16.8	3.0
4	7.6	2.7(VL)	LS	18(VL)	71(VL)	1.2	Tr.	11.2	0.7	17.9	15.0
5	7.5	3.3(L)	L	16(VL)	171(M)	1.5	0.1	20.0	0.9	13.4	15.0
6	6.9	3.7(L)	CL	9(VL)	208(M)	3.6	Tr.	15.6	0.2	10.1	15.0
7	7.8	3.8(L)	CL	14(VL)	180(M)	0.7	Tr.	34.0	0.6	9.2	38.0
8	6.0	6.2(H)	L	26(VL)	199(M)	2.3	0.1	15.2	1.9	9.4	3.0
9	6.6	6.3(H)	L	28(VL)	539(H)	6.2	0.1	19.2	1.2	10.8	3.0
10	6.0	5.2(M)	CL	10(VL)	284(H)	4.1	0.2	12.8	0.5	14.7	3.0
11	7.6	6.0(H)	SiL	13(VL)	255(H)	5.0	0.2	28.0	1.0	30.7	3.0
12	7.3	6.2(H)	SiL	13(VL)	312(H)	3.6	0.2	24.4	1.2	10.6	3.0
13	7.5	3.9(L)	SiC	13(VL)	293(H)	4.0	0.1	42.0	0.6	27.8	3.0
14	7.5	1.6(VL)	C	20(VL)	199(M)	0.7	0.1	98.0	6.2	22.7	38.0
15	4.4	1.8(VL)	C	49(L)	236(M)	2.2	0.2	33.0	1.1	22.5	63.0
16	6.2	2.2(VL)	CL	45(L)	190(M)	3.3	Tr.	22.0	0.4	20.5	63.0
17	7.2	6.2(H)	SiL	23(VL)	351(H)	2.4	0.2	29.2	1.4	12.2	15.0
18	7.4	6.3(H)	L	17(VL)	519(H)	2.3	Tr.	36.4	2.0	11.0	3.0
19	7.2	7.4(H)	SiL	23(VL)	419(H)	2.5	0.1	32.0	1.4	13.8	3.0
20	7.6	6.8(H)	SiL	43(L)	439(H)	2.0	Tr.	37.6	0.8	10.3	3.0
21	7.3	6.8(H)	L	21(VL)	399(H)	3.0	Tr.	39.0	1.7	17.5	3.0
22	7.9	4.8(M)	L	6(VL)	144(M)	2.9	Tr.	34.0	0.8	14.8	3.0
23	8.0	3.8(L)	CL	9(VL)	312(H)	1.9	Tr.	21.0	0.9	20.8	15.0
25	6.4	6.8(H)	L	20(VL)	488(H)	2.4	0.1	16.4	0.5	12.8	3.0
26	7.9	3.9(L)	SiL	7(VL)	190(M)	3.9	0.1	30.4	0.6	15.5	15.0
27	8.0	4.8(M)	SC	7(VL)	295(H)	7.3	Tr.	27.2	0.7	16.1	3.0
28	8.5	1.0(VL)	CL	2(VL)	69(VL)	3.7	Tr.	23.2	0.4	32.6	38.0
29	7.1	4.5(M)	CL	14(VL)	463(H)	2.4	.33	24.0	0.4	14.3	38.0

Table 17. (continued)

Sites	pH	Organic Matter Percent	Tex- ture ¹	Phos- phorus ppm ²	Potas- sium ppm	Magne- sium meq ³	Sod- ium meq	Cal- cium meq	Salt Hazard mmhos ⁴	Soil Depth cm	Surface Erosion Percent
30	8.0	2.9(VL)	SCL	6(VL)	239(M)	4.6	Tr.	31.6	0.4	16.4	15.0
31	7.7	5.8(M)	CL	17(VL)	415(H)	0.7	0.1	33.6	0.6	14.4	3.0
32	6.7	3.8(L)	CL	103(H)	200(M)	1.3	Tr.	9.6	0.4	N.M. ⁷	3.0
33	7.5	1.5(VL)	C	11(VL)	184(M)	1.1	0.3	35.4	3.7	"	15.0
34	7.9	2.1(VL)	C	4(VL)	236(M)	3.4	0.3	37.1	0.4	"	3.0
35	7.5	5.9(M)	CL	6(VL)	333(H)	5.3	0.4	28.0	0.7	"	3.0
36	8.0	1.1(VL)	SCL	8(VL)	120(L)	3.3	Tr.	31.2	0.4	"	15.0
37	7.8	4.5(M)	CL	9(VL)	390(H)	2.6	Tr.	35.2	0.8	"	3.0
38	7.7	3.9(L)	C	7(VL)	290(M)	1.4	0.1	40.0	0.6	"	3.0
39	6.5	6.6(H)	SCL	14(VL)	333(H)	2.8	0.4	17.5	0.3	"	3.0
40	8.3	0.8(VL)	SL	7(VL)	110(L)	3.3	Tr.	25.2	0.4	"	15.0
41	8.2	0.8(VL)	CL	6(VL)	160(M)	3.2	0.1	31.6	0.7	"	38.0
42	6.9	3.5(L)	SCL	9(VL)	201(M)	2.5	0.3	10.0	0.2	"	3.0
43	7.4	4.8(M)	CL	2(VL)	342(H)	4.4	0.3	36.6	0.5	"	3.0
44	8.1	3.4(L)	C	4(VL)	229(M)	4.3	0.3	28.4	0.4	"	63.0
45	8.0	6.4(H)	SL	6(VL)	218(M)	3.0	0.3	28.0	0.6	"	3.0
46	8.1	2.9(L)	CL	6(VL)	210(M)	3.5	Tr.	37.2	0.5	"	38.0
47	8.0	5.9(M)	SCL	6(VL)	184(M)	3.7	0.3	37.1	0.6	"	38.0
48	8.1	2.7(L)	CL	6(VL)	218(M)	4.3	0.3	36.6	0.5	"	15.0
49	8.2	1.8(VL)	CL	15(VL)	110(L)	2.0	Tr.	24.4	0.4	"	63.0
50	7.0	6.3(H)	SiL	19(VL)	340(H)	1.9	Tr.	37.2	0.8	"	3.0
51	8.0	1.8(VL)	SC	6(VL)	218(M)	1.0	0.4	34.6	0.4	"	63.0
24	7.0	7.0(H)	L	28(VL)	580(H)	1.6	Tr.	32.4	1.5	11.2	3.0

¹SiL=Silt Loam; L=Loam; CL=Clay Loam; SCL=Sandyclay Loam; C=Clay; LS=Loamy Sand; SC=Sandy Clay; SiC=Silty Clay.

²ppm=pounds/one million pounds of soil.

³meq=Millequivalents/100 grams of soil.

⁴mmhos=millimhos 1mho=1/Ohm

⁵Ratings from Montana Soils Testing Laboratory Report, ST-Form 2; VL=Very Low; M=Medium; H=High.

⁶Tr.=Trace; less than 0.1 percent

⁷N.M.=not measured.

539 2494

MONTANA STATE UNIVERSITY LIBRARIES



3 1762 10014939 0


N378
M615
cop. 2