



Age distributions and some age relationships of key browse plants on big game ranges in Montana
by Terry N Lonner

A thesis submitted to the graduate faculty in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE in Fish and Wildlife Management

Montana State University

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Abstract:

This study determined the ages of 1,975 browse plants associated with 506 key utilization and condition trend transects on big game ranges throughout Montana. Data were obtained for 20 species, 11 of which were sufficiently represented to permit analyses of age distributions and general age relationships. Basic age distributions were as follows: 470 western serviceberry plants ranged from 2-85 years old with a mean age of $17.9 \pm \text{se } .56$; 321 big sagebrush plants ranged from 3-70 years old with a mean age of $23.9 \pm \text{se } .63$; 210 curl-leaf mountain mahogany plants ranged from 2-130 years old with a mean age of $37.3 \pm \text{se } 1.8$; 211 antelope bitterbrush plants ranged from 5-83 years old with a mean age of $30.4 \pm 1.06 \text{ se}$; 210 skunkbush sumac plants ranged from 4-160 years old with a mean age of $34.4 \pm \text{se } 1.4$; 59 Rocky Mountain maple plants ranged from 6-100 years old with a mean age of $35.0 \pm \text{se } 2.69$; 44 rubber rabbitbrush plants ranged from 4-45 years old with a mean age of $17.2 \pm \text{se } 1.43$; 139 common juniper plants ranged from 9-124 years old with a mean age of $43.4 \pm \text{se } 1.92$; 52 creeping juniper plants ranged from 20-140 years old with a mean age of $56.7 \pm \text{se } 3.71$; 115 common chokecherry plants ranged from 3-57 years old with a mean age of $14.3 \pm \text{se } 1.02$; and 34 silver sagebrush plants ranged from 6-56 years old with a mean age of $21.2 \pm \text{se } 1.98$. A paucity of plants in young age classes for all species, except common chokecherry and curl-leaf mountain mahogany, was attributed to both sampling bias toward older plants and lack of recruitment in recent years. Limited age-class determinations were presented for an incidental 45 plant collection from nine species. Age had little or no apparent influence on the intensity of browsing on individual plants of most species. Analysis of plant age relative to degrees of hedging (Form Classes) and decadency suggested these parameters of plant condition to be influenced somewhat by age as well as by browsing in previous years. Correlation coefficients for plant age-volume relationships ranged from .41 for antelope bitterbrush to .80 for curl-leaf mountain mahogany, although considerable variation was evident within and among the various species. This apparently reflected differences in browsing pressures and histories on the different ranges from which collections were made and differential effects of other environmental factors. Correlation coefficients for age and oldest cross-section area and age and oldest cross-section diameter relationships were highly significant ($P = .01$). Field age class measurements were indicated to be very crude indexes of plant age.

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KEY BROWSE PLANTS ON BIG GAME RANGES IN MONTANA

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TERRY N. LONNER

A thesis submitted to the graduate faculty in partial
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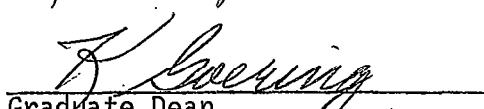
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ABSTRACT

This study determined the ages of 1,975 browse plants associated with 506 key utilization and condition trend transects on big game ranges throughout Montana. Data were obtained for 20 species, 11 of which were sufficiently represented to permit analyses of age distributions and general age relationships. Basic age distributions were as follows: 470 western serviceberry plants ranged from 2-85 years old with a mean age of $17.9 \pm \text{se } .56$; 321 big sagebrush plants ranged from 3-70 years old with a mean age of $23.9 \pm \text{se } .63$; 210 curl-leaf mountain mahogany plants ranged from 2-130 years old with a mean age of $37.3 \pm \text{se } 1.8$; 211 antelope bitterbrush plants ranged from 5-83 years old with a mean age of $30.4 \pm 1.06 \text{ se}$; 210 skunkbushsumac plants ranged from 4-160 years old with a mean age of $34.4 \pm \text{se } 1.4$; 59 Rocky Mountain maple plants ranged from 6-100 years old with a mean age of $35.0 \pm \text{se } 2.69$; 44 rubber rabbitbrush plants ranged from 4-45 years old with a mean age of $17.2 \pm \text{se } 1.43$; 139 common juniper plants ranged from 9-124 years old with a mean age of $43.4 \pm \text{se } 1.92$; 52 creeping juniper plants ranged from 20-140 years old with a mean age of $56.7 \pm \text{se } 3.71$; 115 common chokecherry plants ranged from 3-57 years old with a mean age of $14.3 \pm \text{se } 1.02$; and 34 silver sagebrush plants ranged from 6-56 years old with a mean age of $21.2 \pm \text{se } 1.98$. A paucity of plants in young age classes for all species, except common chokecherry and curl-leaf mountain mahogany, was attributed to both sampling bias toward older plants and lack of recruitment in recent years. Limited age-class determinations were presented for an incidental 45 plant collection from nine species. Age had little or no apparent influence on the intensity of browsing on individual plants of most species. Analysis of plant age relative to degrees of hedging (Form Classes) and decadency suggested these parameters of plant condition to be influenced somewhat by age as well as by browsing in previous years. Correlation coefficients for plant age-volume relationships ranged from .41 for antelope bitterbrush to .80 for curl-leaf mountain mahogany, although considerable variation was evident within and among the various species. This apparently reflected differences in browsing pressures and histories on the different ranges from which collections were made and differential effects of other environmental factors. Correlation coefficients for age and oldest cross-section area and age and oldest cross-section diameter relationships were highly significant ($P = .01$). Field age class measurements were indicated to be very crude indexes of plant age.

INTRODUCTION

Since 1958, big game management in Montana has been based primarily upon the condition and trend of winter ranges as reflected by annual measurements of condition and the degree of utilization of key forage plants on key range areas (Cole 1958). Interpretations of survey data and their application in evaluating the status and trends of forage plant populations on game ranges have been hampered by the paucity of basic ecological information on key plant species, especially browse plants. A lack of information on age distribution and basic age relationships of important plant species may be of particular importance. Age relationships to the growth and development, reproduction, senility, and death of individuals and natality and mortality in populations are widely applied by game managers and biologists in evaluating status and trends in animal populations and in establishing management measures. Although age relationships of plants have been less widely studied, they should have equal value and application in range research and management studies concerned with maintaining healthy productive forage plant populations on critical ranges.

At present, very few reliable data are available on the ages of browse plants on Montana rangelands. "Age-class" criteria applied in present range surveys may reflect past browsing histories rather than age, precluding their use for meaningful analyses of the status and trends in browse forage supplies. The only known effort to obtain definitive age data for management purposes was a limited study by

Trueblood (1968) who collected and counted growth rings of big sagebrush (*Artemisia tridentata* Nutt.) from six areas on which browse survey transects were located in northeastern Montana.

Age distributions and/or relationships of several browse species occurring on Montana rangelands have been studied in other areas. In Colorado, Cameron (1957) determined age distributions and relationships for big sagebrush, rabbitbrush (*Chrysothamnus* spp.); true mountain mahogany (*Cercocarpus montanus* Nutt.); and antelope bitterbrush (*Purshia tridentata* [Pursh.] DC.) on the Cache LaPoudre Winter Deer Range and Baker (1958) used age composition in an attempt to predict the fate of big sagebrush populations. Ferguson (1964) evaluated the rate of annual lateral growth of the stems of big sagebrush along the southern limits of its distribution on the basis of growth ring counts. McConnell and Smith (1963) related various stem and crown dimensions of antelope bitterbrush to plant age in Washington while Nord (1965) considered age in relation to the autecology of this species in California. Sanford (1970) presented age histograms and discussed some age relationships for skunkbush sumac (*Rhus trilobata* Nutt.) in western North Dakota. Findings from these studies, however, appear to have limited or only general application in Montana.

This study was established during the spring of 1971 to determine ages of key browse plants and browse plant communities associated with browse survey transects on big game winter ranges throughout Montana.

Data were obtained for 20 species of which 11 -- Rocky Mountain maple (*Acer glabrum* Torr.); western serviceberry (*Amelanchier alnifolia* Nutt.); silver sagebrush (*Artemisia cana* Nutt.); big sagebrush; rubber rabbitbrush (*Chrysothamnus nauseosus* [Pall.] Britt.); curl-leaf mountain mahogany (*Cercocarpus ledifolius* Nutt.); common juniper (*Juniperus communis* L.); creeping juniper (*Juniperus horizontalis* Moench.); common chokecherry (*Prunus virginiana* L.); antelope bitterbrush; and skunk-bush sumac -- were sufficiently represented to permit analyses of age distribution. Correlation of assigned ages with certain other plant parameters and measurements including plant crown volume, crown area, percent of crown dead, root/stem cross-sectional area and diameter, utilization of current leader growth, form class, and age class provided opportunity to extend the study to analysis of basic age relationships.

METHODS AND MATERIALS

Main root-stem samples were obtained from 1,975 plants of 20 different browse species associated with 506 browse utilization and condition trend transects (Table 1). The seven Fish and Game administrative districts (Figures 1 and 2) were used to describe regional difference in occurrence and age distribution of each species. The basic collection of 1,548 plant samples was made by State game management and cooperating Federal agency personnel during the course of range condition surveys in April, May, and June, 1971. In these collections, one to six plants (average three) were selected to represent the general size and/or age structure of plants of the key browse species on each transect. Usually plants representing the "youngest" (other than seedlings) "average," and "oldest" portion of each transect browse population were collected. Three special collections provided larger, 10 to 40 plant, systematically collected samples from 21 of the transects. These included 180 samples (6 of 25 plants each and 1 of 30 plants) of big sagebrush from Trueblood's (1968) collection from seven transects in northeastern Montana; 187 samples collected from 12 browse transect locations in the western half of the State between June and October, 1971 (included were five 10-plant samples of bitterbrush, one 10-plant and two 40-plant samples of serviceberry, one 20-plant and one 17-plant sample of curl-leaf mountain mahogany, and two 10-plant samples of skunkbush sumac); and 60 samples (30 bitterbrush and 30 big sagebrush) collected from two transects in southwestern Montana during December, 1971-

TABLE 1. NUMBER OF TRANSECTS SAMPLED AND SAMPLE QUANTITY FOR EACH BROWSE SPECIES SEPARATELY AND WITHIN ALL FISH AND GAME ADMINISTRATIVE DISTRICTS.

Browse Species	DISTRICTS							EXCLOSURE-TRANSECT PAIRS		TOTALS			
	1	2	3	4	5	6	7	Exclosures	Transects	No. Dists. Where Collected	No. Trans. Where Collected	Mean No. Samples Per Transect	Total Sample Quantity
Rocky Mountain Maple ¹	14/42 ²	3/9	-/-	3/8	-/-	-/-	-/-	-/-	-/-	3	20	3.0	59
Western Serviceberry ¹	55/165	46/215	3/4	6/23	-/-	-/-	1/3	3/45	3/45	5	111	4.5	500
Silver Sagebrush ¹	-/-	-/-	1/3	-/-	-/-	5/10	9/22	-/-	-/-	3	15	2.3	35
Big Sagebrush ¹	-/-	2/6	11/65	4/16	12/36	13/197	3/9	-/-	-/-	6	45	7.3	329
Curly-leaf Mountain Mahogany ¹	-/-	2/6	55/163	1/3	4/12	-/-	-/-	2/17	2/10	4	62	3.4	211
Redstem Ceanothus	6/13	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	1	6	2.2	13
Snowbrush Ceanothus	-/-	-/-	-/-	1/3	-/-	-/-	-/-	-/-	-/-	1	1	3.0	3
Red Dogwood	-/-	-/-	-/-	-/-	-/-	-/-	1/2	-/-	-/-	1	1	2.0	2
Crataegus	-/-	-/-	-/-	1/3	-/-	-/-	-/-	-/-	-/-	1	1	3.0	3
Rubber Rabbitbrush ¹	-/-	-/-	4/12	7/21	-/-	2/6	3/6	-/-	-/-	4	15	3.0	45
Green Rabbitbrush	-/-	-/-	-/-	-/-	-/-	-/-	2/3	-/-	-/-	1	2	1.5	3
Common Juniper ¹	-/-	-/-	-/-	37/110	10/30	-/-	-/-	-/-	-/-	2	47	3.0	140
Creeping Juniper ¹	-/-	-/-	-/-	20/54	-/-	-/-	-/-	-/-	-/-	1	20	2.7	54
Common Chokecherry ¹	-/-	15/47	-/-	11/33	1/3	-/-	12/36	-/-	-/-	4	39	3.1	119
Antelope Bitterbrush ¹	7/21	20/60	12/60	7/26	-/-	-/-	-/-	5/25	5/25	4	46	4.7	217
Skunkbush Sumac ¹	-/-	-/-	1/3	21/65	9/27	10/28	26/78	2/10	2/10	5	67	3.3	221
Squaw Currant	-/-	-/-	-/-	1/3	-/-	-/-	-/-	-/-	-/-	1	1	3.0	3
Willow	-/-	3/8	-/-	1/3	-/-	-/-	-/-	-/-	-/-	2	4	2.8	11
Canadian Buffaloberry	-/-	-/-	-/-	2/6	-/-	-/-	-/-	-/-	-/-	1	2	3.0	6
Western Snowberry	-/-	-/-	-/-	-/-	-/-	-/-	1/1	-/-	-/-	1	1	1.0	1
Totals -- 20 Species	82/241	91/351	87/310	123/377	36/108	30/241	58/160	12/97	12/90	7	506	3.9	1,975

¹Species with sufficient data for analysis.²Number Transects Sampled/Sample Quantity.

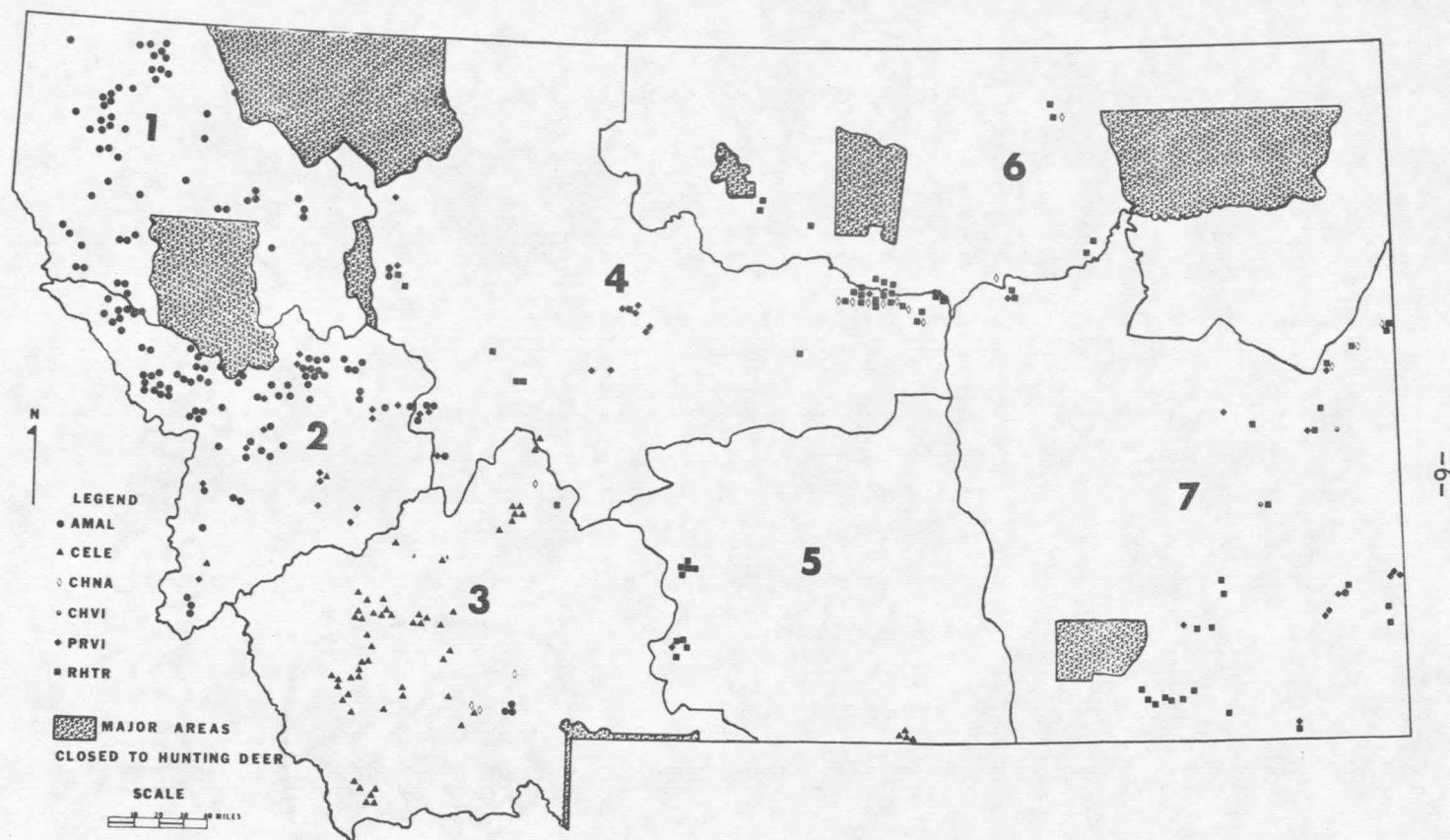


Figure 1. Collection points of western serviceberry (AMAL), curl-leaf mountain mahogany (CELE), rubber rabbitbrush (CHNA), green rabbitbrush (CHVI), common chokecherry (PRVI), and skunkbush sumac (RHTR). Numbers represent Montana Fish and Game administrative districts. Species abbreviations after Garrison *et al.* (1967).

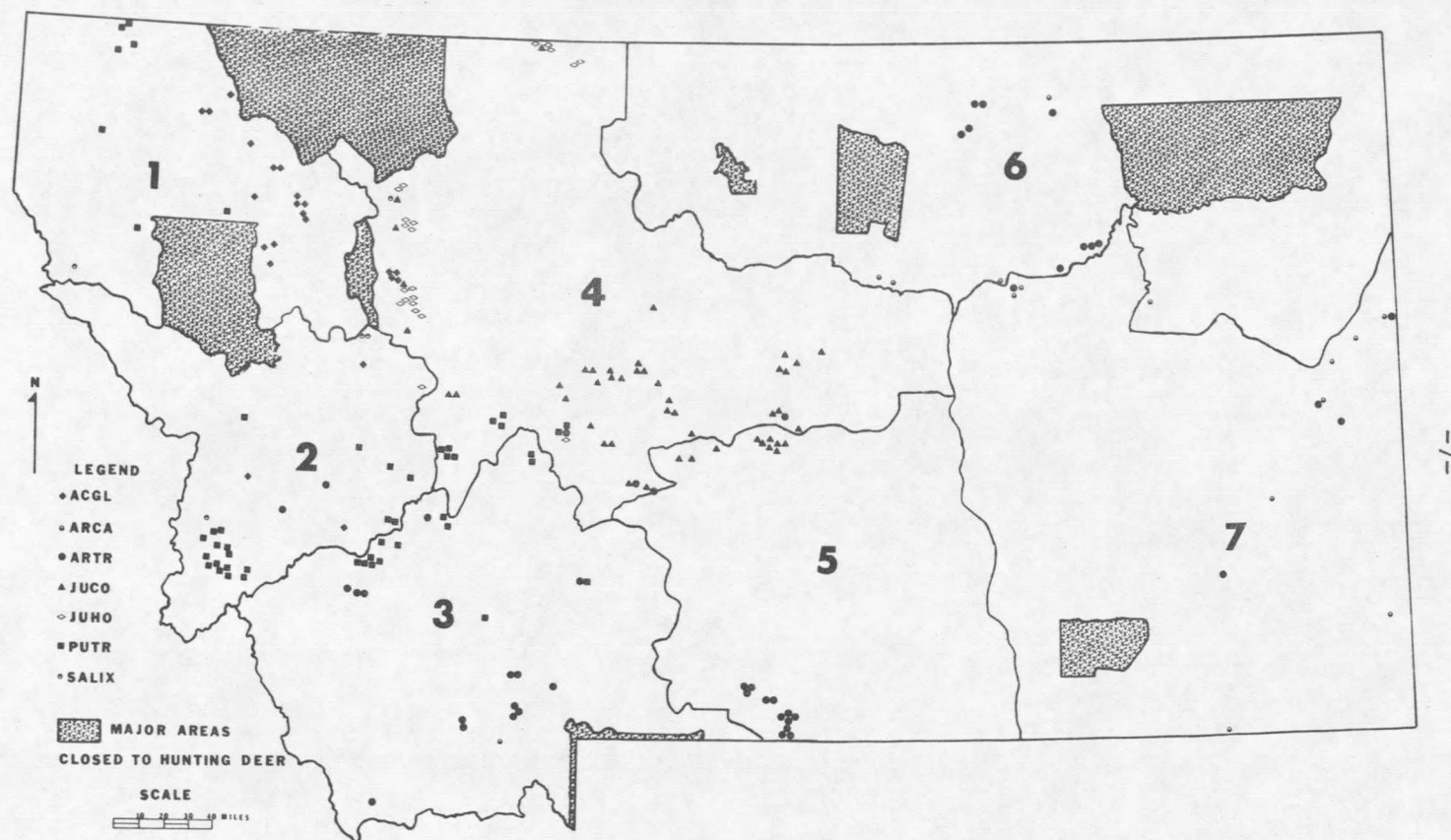


Figure 2. Collection points of Rocky Mountain maple (ACGL), silver sagebrush (ARCA), big sagebrush (ARTR), common juniper (JUCO), creeping juniper (JUHO), antelope bitterbrush (PUTR), and willow (SALIX). Numbers represent Montana Fish and Game administrative districts. Species abbreviations after Garrison *et al.* (1967).

January, 1972. The Trueblood collection sampled the nearest plants to regularly spaced points on straight line transects. Summer-fall, 1971 collections sampled nearest plants or nearest plants in each quarter to five points spaced equally as the five points on a die or spaced equidistant along a straight line the approximate length of the transect. Winter, 1971-1972 collections were made along imaginary line transects using the closest plant sampling technique (Cole 1958). Plant seedlings were not collected.

For each plant, except the Trueblood collection, the transect number, species, two diameter measurements (one the maximum diameter, the other at a right angle) across the canopy of the plant, plant height, crown height if different from total plant height, form class, age class, percent crown dead and percent of leaders used were recorded together with the exposure and degree of slope of the site. Only transect numbers and species were recorded for plants of Trueblood's collection. Plant crown measurements were recorded or converted to the nearest 0.5 dm. Form and age class assignments followed the method of Dasmann (1948, 1951) as modified by Cole (1958) for use in Montana. Form classes were: FC 1 -- all available, little or no hedging; FC 2 -- all available, moderately hedged; FC 3 -- all available, severely hedged; FC 4 -- partially available, little or no hedging; FC 5 -- partially available, moderately hedged; FC 6 -- partially available, severely hedged; FC 7 -- unavailable; FC 8 -- dead. Age

classes included: S -- seedling, stem base one-eighth inch or less in diameter; Y -- young, stem base one-eighth-one-fourth inch in diameter; M -- mature, stem base over one-fourth inch in diameter; D -- decadent, any living plant with 25 percent or more of its crown surface made of dead wood; R -- resprout. Leader use was estimated as the percentage of total available leaders (current annual growth twigs) showing use. The method of collection generally followed those of Baker (1958), McConnell and Smith (1963), Cameron (1957), Ferguson (1957), Roughton (1963), and others in that the main root-stem transition complex was obtained for plants of most species. In most cases collection of the major root system of multi-stemmed plants such as Rocky Mountain maple, western serviceberry, skunkbush sumac, and common chokecherry was collected to assure acquisition of the oldest portion of the plants. Comparisons of the ages of roots and stems from six multistemmed plants of serviceberry and four multistemmed plants of maple showed that the largest roots ranged from 10 to 36 years older than the largest stems.

Plant materials were cross-sectioned using equipment ranging from a razor blade to a 24-inch circular saw, depending on the shape and size of the specimen. Repeated cuttings (up to 75 per sample) at various angles and points along the main stem(s) and/or root(s) were made to obtain sections of maximum quality and ring clarity. Cross sections were surfaced by sequentially sanding with increasingly finer, 80 to 400 grit, papers on a belt sander. The number of prepared cross-section

surfaces ranged from 1 to 57 per plant. Various stains were applied to accentuate annual growth rings in some species. Number of samples collected and number of samples aged, mean number of cross-sections aged per plant sample, mean number of cross-section surfaces aged per sample, range of cross-section surfaces read per sample, percentage of samples with partial or complete core absence, stains used to aid in growth ring count, and reading quality characteristics for all browse species with data sufficient for analysis are presented in Appendix, Table 13.

Age determinations and age class assignments were made on the basis of growth ring counts. Roughton (1962) believed this method to be more accurate than age class estimations and bud-scar or branching node counts, but less reliable than the growth ring analysis or dendro-chronologic method. The latter requires more time and restricted sampling than possible within the scope of this study. In work involving some of the same species as my study, Roughton (1961, 1962) found mean discrepancies of 0 to 10 percent between known ages and ring count estimates, primarily due to omitted and/or false rings. Fewest discrepancies occurred in aging big sagebrush and antelope bitterbrush, while the greatest number occurred in true mountain mahogany. Growth rings on each cross section were counted two to three times with aid of a low power binocular microscope, or until the most accurate cross-section age was felt determined. Because of possible inaccuracies in

ring counts, final age assignments were based on 5- or 10-year age classes, depending on the overall difficulty incurred while "aging" each species. The 5-year age classes were designated by Roman Numerals as follows: I -- 0-5 years; II -- 6-10 years; ... XXI -- 101 years and older. The 10-year age classes were designated by Arabic Numerals as follows: 1 -- 0-10 years; 2 -- 11-20 years; ... 11 -- 101 years and older.

Following the growth ring count, two maximum diameter measurements, taken at right angles to each other across the oldest cross section surface, were recorded together with notations on growth rates and the reading quality of growth rings (Appendix, Tables 13 and 14).

Calculations of crown area, corrected crown area (crown area x estimated percent of crown alive), crown volume, plant volume, and oldest cross-section area were computed using the basic equations $(\pi/4D_1D_2)$ for area and $(\pi/4D_1D_2h)$ for volume after Lyon (1968). These computations and further statistical analysis of age distributions and age relationships were accomplished using a Monroe Programmable-Calculator, Model 1785W1.

RESULTS-DISCUSSION

Age Distribution

Ring sequences and reading qualities were consistently good or fair for all species except curl-leaf mountain mahogany and skunkbush sumac (Figures 3 to 8 and Appendix, Table 13). Thirty-four percent of the skunkbush samples had cores partially or completely absent, and 31 percent of the mahogany samples had poor ring sequences (Figure 7, Appendix, Table 13).

Age class frequencies for browse plants sampled in this study can not be interpreted directly to reflect the overall age structure of the various species populations throughout the State. In most cases they represent statewide, regional, or other accumulations of the general age structure of plants on individual browse transects as determined by aging the younger, average, and oldest plants associated with each. The most meaningful interpretations can be made by reference to both the collective age-class frequency distribution and the distribution of age-class frequencies within "age groups" for each species. The special, systematically collected samples provide more complete data for a few species and transects to aid in these interpretations.

Western Serviceberry. - This species occurs throughout Montana, but is of major importance as a browse plant in the northwestern and westcentral part of the State (Figure 1). It occurs on moist and rich soil as well as on dry, rocky and rather sterile soils; and can be found growing on all slopes, in canyons and gulches, and along streams,

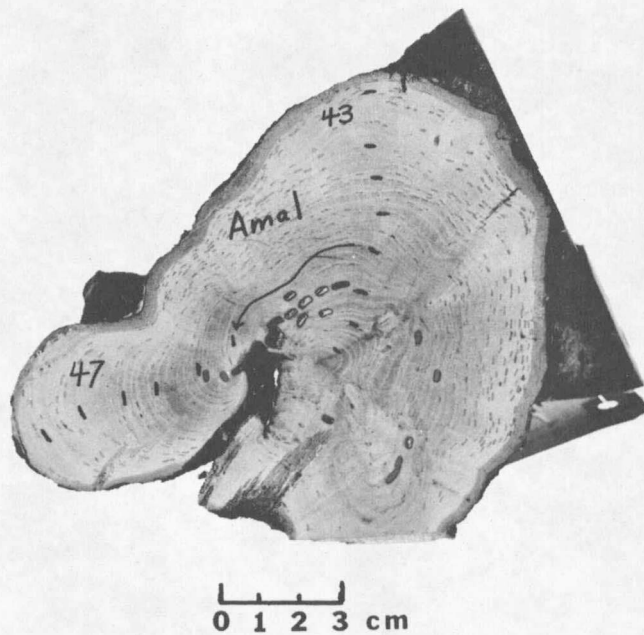
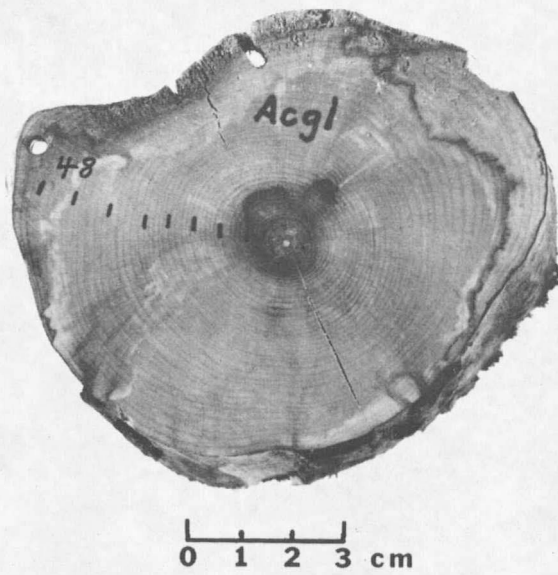
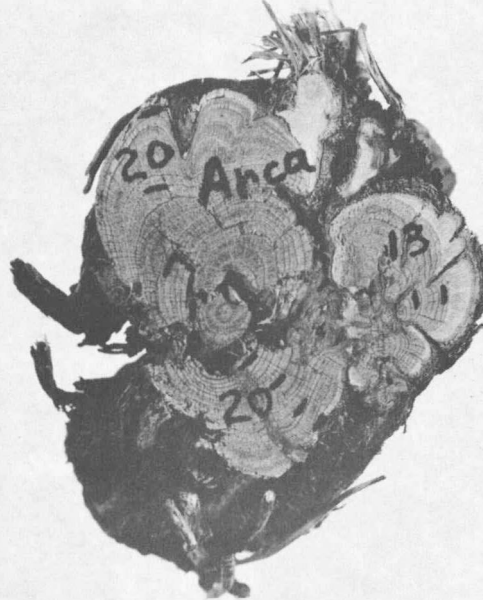
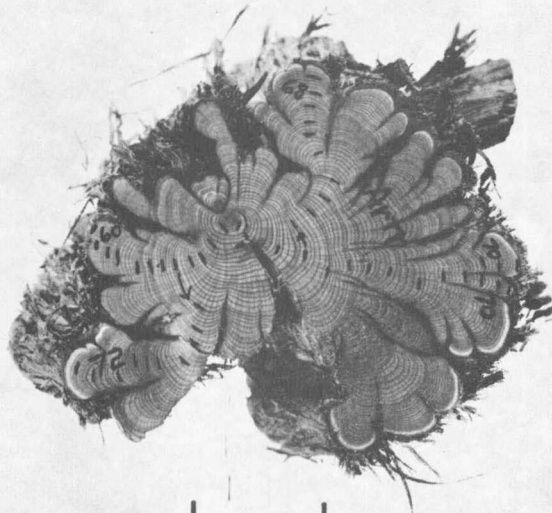


Figure 3. Representative prepared cross-sections of Rocky Mountain maple (top) and western serviceberry (bottom).



0 1 2 3 cm



0 1 2 3 cm

Figure 4. Representative prepared cross-sections of silver sagebrush (top) and big sagebrush (bottom).

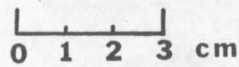
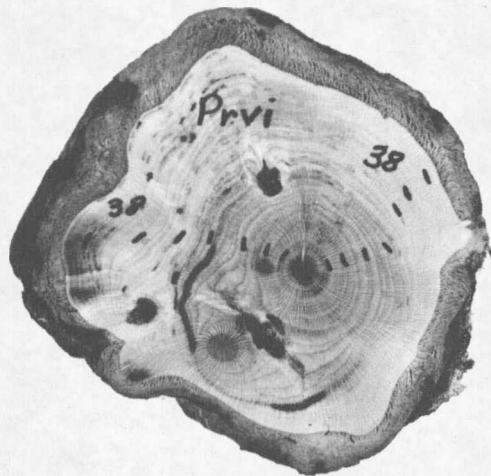
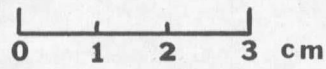
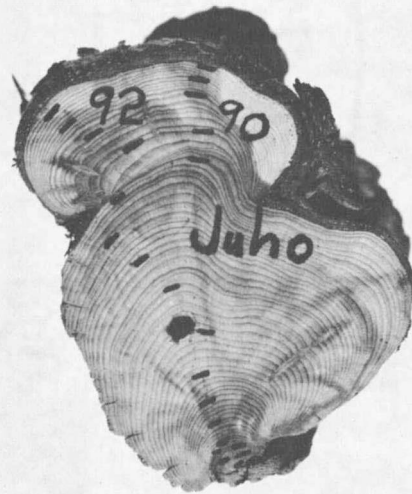
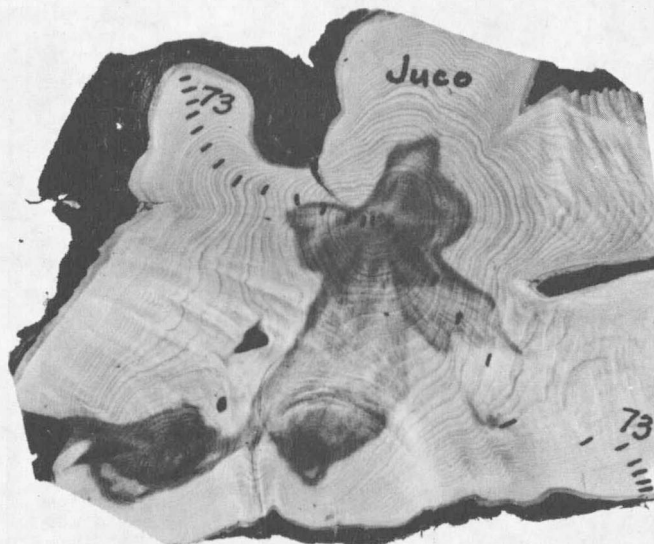
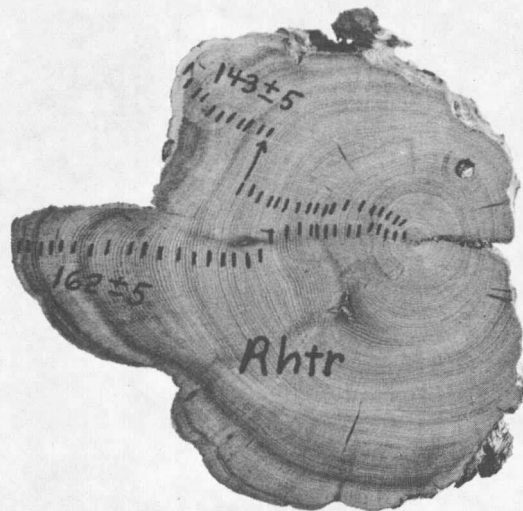


Figure 5. Representative prepared cross-sections of creeping juniper (top) and common chokecherry (bottom).

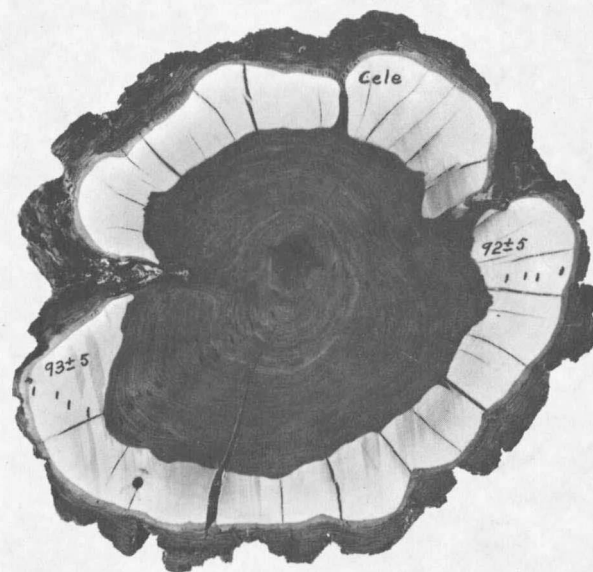


0 1 2 3 cm

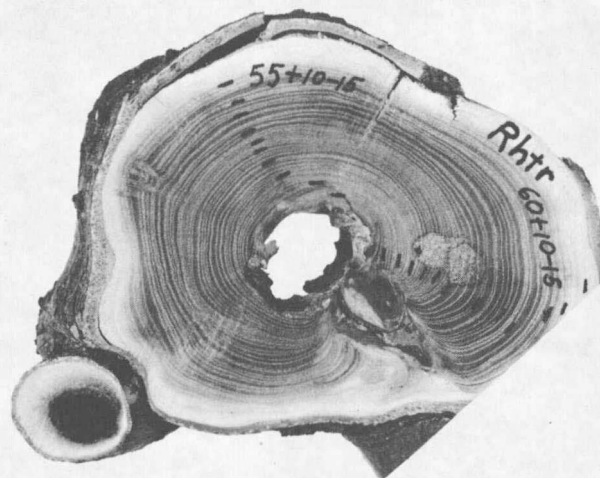


0 1 2 3 cm

Figure 6. Representative prepared cross-section of common juniper (top) and cross-section of oldest plant aged, skunkbush sumac (bottom).



0 1 2 3 cm



0 1 2 3 cm

Figure 7. Prepared cross-sections of curl-leaf mountain mahogany (top) showing lack of differentiation between "growth rings" and skunkbush sumac (bottom) showing core absence.

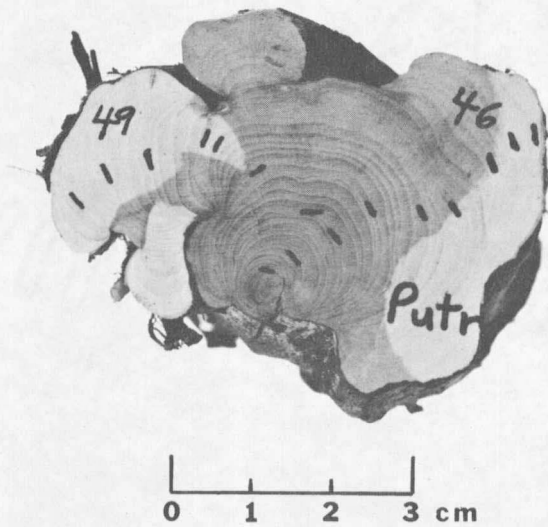


Figure 8. Representative prepared cross-section of antelope bitterbrush.

mountain sides, and ridge tops (Booth and Wright 1966, Dayton 1931). Plants range from 1 to 4 m tall. Samples collected in this study were from plants of two rather distinct growth forms -- low-growing plants, less than 1.5 m tall, which occur individually as sprouts from underground stems, and taller, multistemmed, clumped plants.

Age determinations were made for 470 serviceberry plants from 111 transect locations. Individual plants ranged from 2 to 85 years old. The mean age for the collection was 17.9 years $\pm$ se .56. The collective age-class frequency distribution was urn-shaped (Figure 9), showing a relatively small percentage of plants less than 5 years old, a predominance (61 percent) in age classes II-IV, and a gradual diminution in percentages for older classes.

Despite sampling limitations the data suggested that serviceberry stands associated with browse transects were characterized by a lack of reproduction and/or survival of "seedlings" in recent years and a predominance of relatively young plants. This conclusion was supported by the age distribution of plants from 98 transect sites where three samples were individually selected to represent the youngest, average, and oldest plants present (Figure 9). The younger plants occurring on nearly one-half (45 percent) of these sites were 11 years old or older, and plants less than 5 years old occurred on only 23 transects (23.5 percent). Plants in the average group, which in size and appearance represented most plants on a transect, were between 6

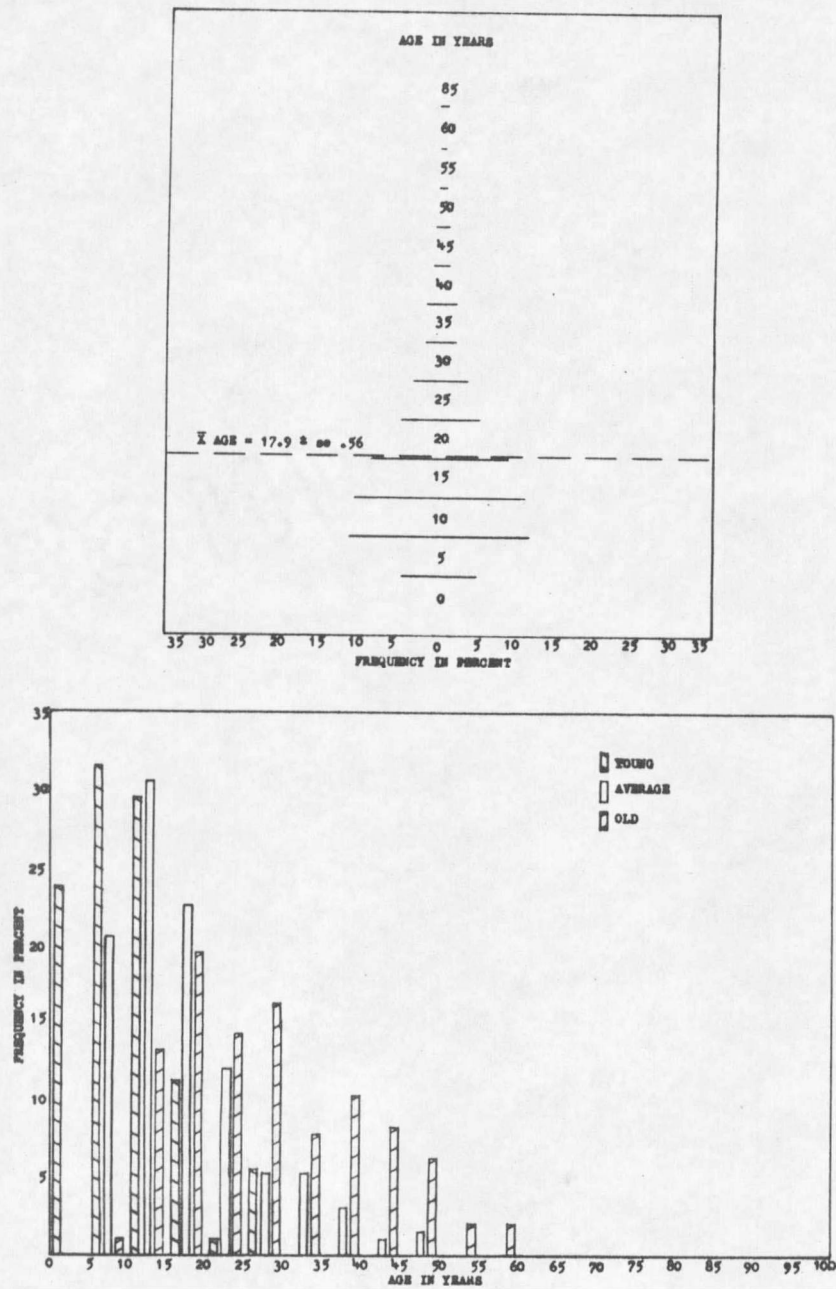


Figure 9. Age class frequency distributions of 470 western service-berry plants (top) and of plants representing young, average, and old groups from 98 transect locations (bottom).

and 20 years old on nearly three-fourths of the sites; and nearly half (48 percent) had oldest plants less than 25 years of age.

Age-class frequencies among two, 40-plant samples that were systematically collected from widely separated locations in northwestern Montana were similar. When these samples were combined, the mean age was significantly lower ($P = .05$) than that for the 159-plant basic collection from District 1 (Figure 10 A and B). Significant differences in the two age distributions were also shown by a chi-square test of homogeneity (Table 2). Some of the difference could be attributed to under-representation of the youngest age classes in the basic collection and gross analysis.

The collective age-frequency distribution (Figure 9) appeared to misrepresent age structural relationships of many serviceberry stands by inclusion of samples from the two, apparently quite different growth forms. The mean age of all tall, clumped plants in the collection (height >1.5 m, canopy area >25 dm²) was significantly greater ($P = .05$) than that for all plants of the dwarf, spreading form. Age-class frequency distributions also differed significantly (Figure 10 C and D). Age classes I-III comprised 72 percent of the dwarf plants, but only 22.7 percent of the taller, clumped plants. Longevity also differed in that only 11 percent of the former were 21 years old or older as compared to 59.4 percent of the latter. Virtually all plants older than 30 years were of the tall form.

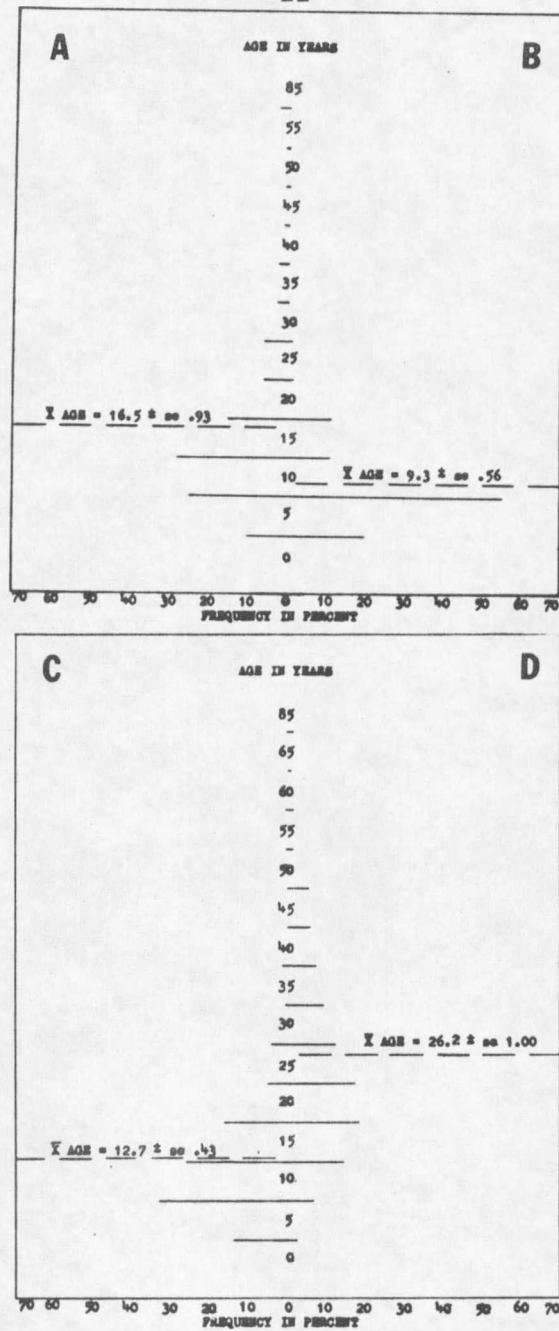


Figure 10. Age class frequency distributions of all western serviceberry plants visually selected (A) and systematically selected (B) in District 1. Age class frequency distributions of western serviceberry dwarf life-form (C), and tall life-form plants (D).

Regional (between districts) differences in age-class frequency distributions (Figure 11) apparently reflect differences in the spatial distribution and/or the occurrence of these two life forms on browse transects in western Montana. Sixty-five percent of the dwarf form plants were from transects in the northwestern area (District 1) and 64 percent of the tall plants were from transects in the westcentral area (District 2). A comparison of age-class frequencies for the gross collections from Districts 1 and 2 with those for gross collections of dwarf and tall plants, respectively (Figure 12), show significant similarity confirmed by chi-square tests for homogeneity (Table 2). Thus, stands of serviceberry associated with browse transects in District 1 tended to show more reproduction, due probably to the sprouting habit of the predominant dwarf plants, and to be comprised of relatively young but short-lived plants. Stands associated with transects in District 2 were comprised of older, relatively long-lived plants that perpetuated themselves by resprouting from stems and/or the root-crown of the clump, with relatively few entirely new plants being produced. Characteristics of serviceberry stands in other areas were similar to those of stands in District 1 or District 2 in accordance with the growth form present. The calculated longevity index of .077 (Table 3) indicates that the life expectancy of all serviceberry plants sampled was slightly below average as compared with other browse plants sampled.

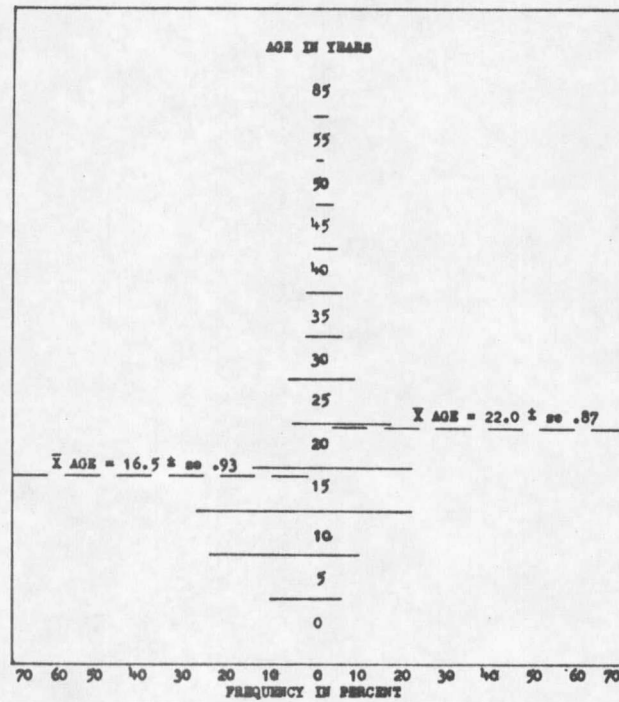


Figure 11. Age class frequency distributions of all western service-berry plants visually selected in Districts 1 (left) and 2 (right).

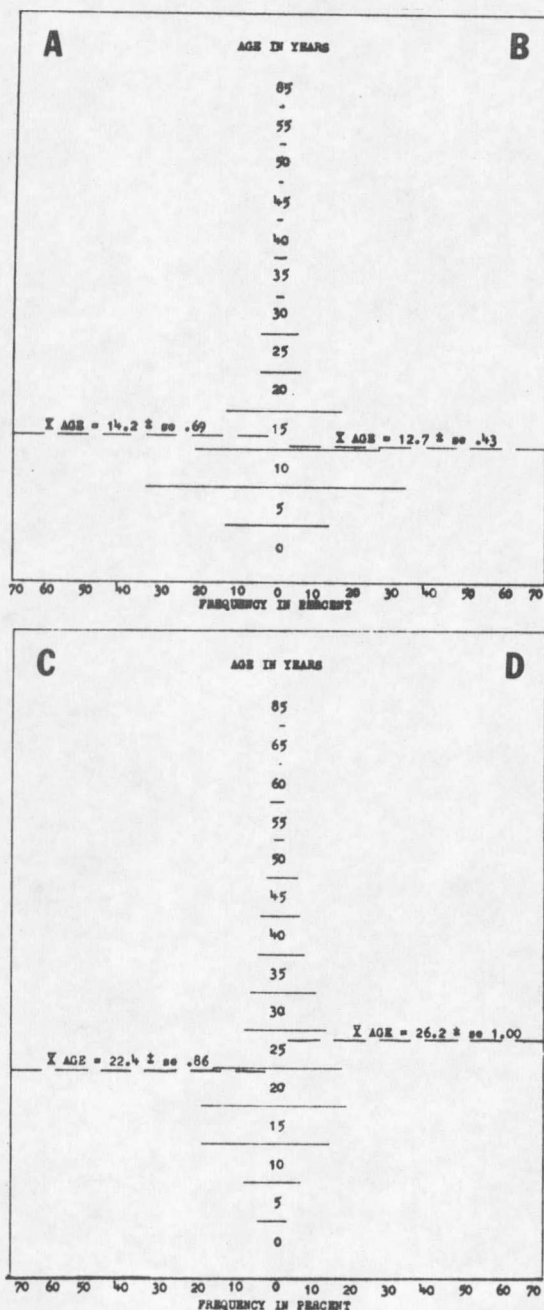


Figure 12. Age class frequency distributions of all western serviceberry plants collected in District 1 (A) and of all dwarf life-form plants (B). Age class frequency distributions of all western serviceberry plants collected in District 2 (C) and of all tall life-form plants (D).

TABLE 2. CHI-SQUARE TESTS FOR HOMOGENIETY AMONG BROWSE PLANT COLLECTIONS.

Species and Collection	CHI-SQUARE TEST FOR HOMOGENIETY			
	Test	Degrees of Freedom	χ^2	P
A Western Serviceberry D-1 Visually selected samples	A x B	12	40.6	<.005
B Western Serviceberry D-2 Visually selected samples	A x C	4	39.8	<.005
C Western Serviceberry D-1 Systematically selected samples	---	--	--	--
D Western Serviceberry "Dwarf" life-form samples	D x E	8	156.9	<.005
E Western Serviceberry "Tall" life-form samples	E x G	13	9.6	.8-.7
F Western Serviceberry D-1 All samples	F x D	8	8.5	.4-.3
G Western Serviceberry D-2 All samples	G x F	12	90.4	<.005
H Big Sagebrush 1971 Collection	H x I	11	48.5	<.005
I Big Sagebrush 1968 Collection	---	--	--	--
J Antelope Bitterbrush Visually selected samples	J x K	13	26.4	.025-.01
K Antelope Bitterbrush Systematically selected samples	---	--	--	--
L Skunkbush Sumac D-4 Samples	L x M L x O	8 11	16.9 18.4	.05-.025 .1-.05
M Skunkbush Sumac D-5 Samples	M x N	9	11.7	.3-.2
N Skunkbush Sumac D-6 Samples	N x O N x L	13 8	11.2 14.7	.3-.2 .1-.05
O Skunkbush Sumac D-7 Samples	O x M	9	11.7	.3-.2

TABLE 3. CALCULATED LONGEVITY INDEXES¹ AND RANKINGS FOR EACH OF 11 BROWSE SPECIES.

Browse Species	CELE ²	JUHO	RHTR	JUCO	ACGL	PUTR	ARTR	AMAL	ARCA	PRVI	CHNA
Longevity Index	.049	.051	.052	.056	.061	.066	.076	.077	.088	.108	.122
Ranking from Comparatively Long to Short Life-Span	1	2	3	4	5	6	7	8	9	10	11

¹Longevity Index = Average Percent Decrease of Plant Numbers Between Age Classes.

$$\frac{N - L}{N} / A$$

Where: N = Total Number of Plants in Sample
L = Total Number of Plants in Last or
Oldest Age Class
A = Total Number of Age Classes.

²CELE = Curl-leaf mountain mahogany; JUHO = Creeping juniper; RHTR = Skunkbush sumac;
JUCO = Common juniper; ACGL = Rocky Mountain maple; PUTR = Antelope bitterbrush;
ARTR = Big sagebrush; AMAL = Western serviceberry; ARCA = Silver sagebrush;
PRVI = Common chokecherry; CHNA = Rubber rabbitbrush.

Big Sagebrush. - This species occurs extensively in the southwestern, central, and eastern portions of the State (Booth and Wright 1966). Plants are stout, much-branched, and normally range from .5 to 4 m tall. They occur on all slopes and in a considerable variety of soils, attaining their optimum growth on deep, rich, moist alluvial loams (Dayton 1931).

A total of 329 big sagebrush plants was collected from 42 transect locations. Assigned ages ranged from 3 to 70 years with a mean of $23.9 \pm se .63$. Although 180 of the samples were collected in August, 1968, the error introduced by this 3-year time lapse was considered negligible and partially compensated for by the 5-year age-class divisions. The urn-shaped age-class frequency distribution for the entire collection (Figure 13) shows a relatively small percentage of plants less than 10 years old, a predominance (55.4 percent) in age classes IV-VI, and a gradual diminution in percentages for older classes. This apparent lack of plants in age classes I-III can be in part, attributed to sampling bias toward older and/or larger plants. Age-class frequency distributions among age groups for 90 plants collected from 30 transect locations (Figure 13) shows that 43.3 percent of the youngest plants were 5 years old or less, indicating recruitment of young individuals in nearly one-half of all the stands sampled. Plants in the average or representative age group were between 16 and 36 years old on 80 percent of the sites. Almost 75 percent (73.3) of

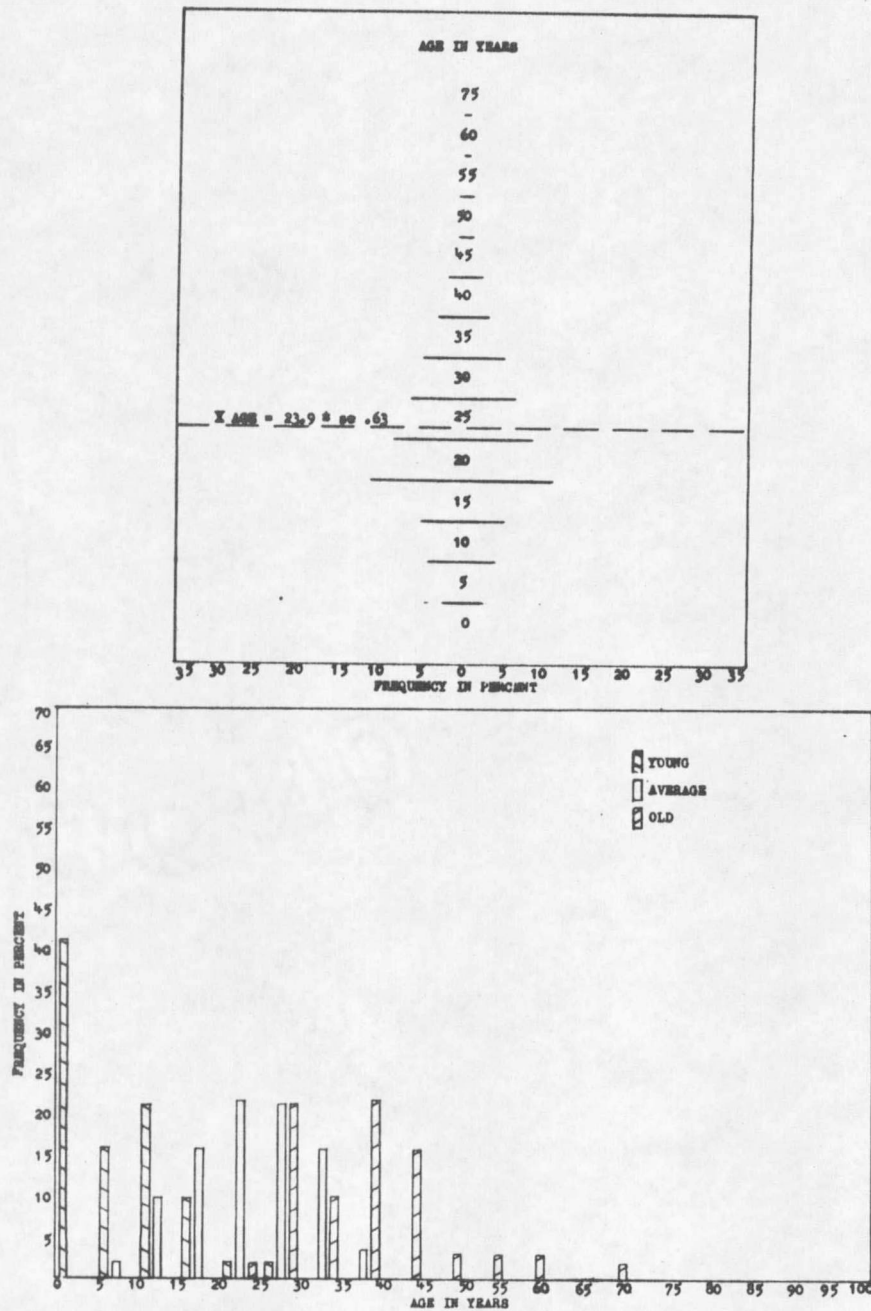


Figure 13. Age class frequency distributions of 321 big sagebrush plants (top) and of plants representing young, average, and old groups from 30 transect locations (bottom).

the oldest plant representation was between 26 and 45 years old.

Comparisons between the 1971 collection (141 plants) and the 1968 collection (180 plants) showed a significant difference ($P < .005$) between the age-class frequency distributions calculated for each (Figure 14 and Table 2). This may be attributed largely to the two different sampling procedures used. The 1968 collections were designed to systematically sample the overall age structures of sagebrush plants at seven different transect locations, while 80 percent of the 1971 collection was made by visual selection of representative young, average, and old-age plants. This latter approach would under-represent the predominant age-classes of sagebrush stands.

Big sagebrush was suggested to have an average life expectancy as compared to the other species calculated longevity index (Table 3).

Curl-leaf Mountain Mahogany. - This species is generally restricted to the southwestern and southcentral portion of the State (Booth and Wright 1966) (Figure 1). Mahogany stands occur primarily on warm, dry rocky ridges and southern or western slopes but occasionally they may occur on coarse soils on steep, north-facing slopes or among cliffs and ledges (Scheldt 1969). Collections for this study were made at elevations ranging from 4,000 to 7,000 feet. The plants ranged from .1 to 4 m tall.

The 210 mahogany plants collected from 62 transect locations ranged from 2 to 130 years in age. The mean was $37.3 \pm se 1.8$. A bell-shaped

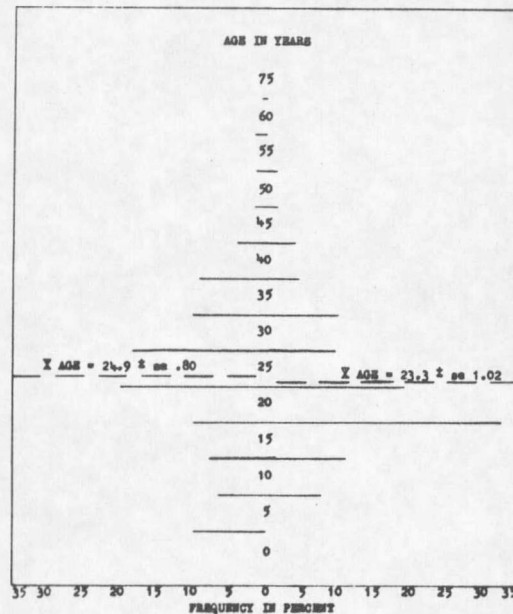


Figure 14. Age-class frequency distributions of 141 big sagebrush plants collected in 1971-1972 (left) and of 180 big sagebrush plants collected in August, 1968 (right).

polygon age-class frequency distribution for the collection (Figure 15) shows a gradual, somewhat erratic diminution in percentages of plants in successive 10-year age classes.

Despite larger age-class divisions (necessitated by the extreme difficulty encountered aging this species) and sampling bias, the data suggested that mahogany stands associated with browse transects were characterized by a preponderance of relatively young to middle-aged plants and relatively good recruitment to the younger age classes.

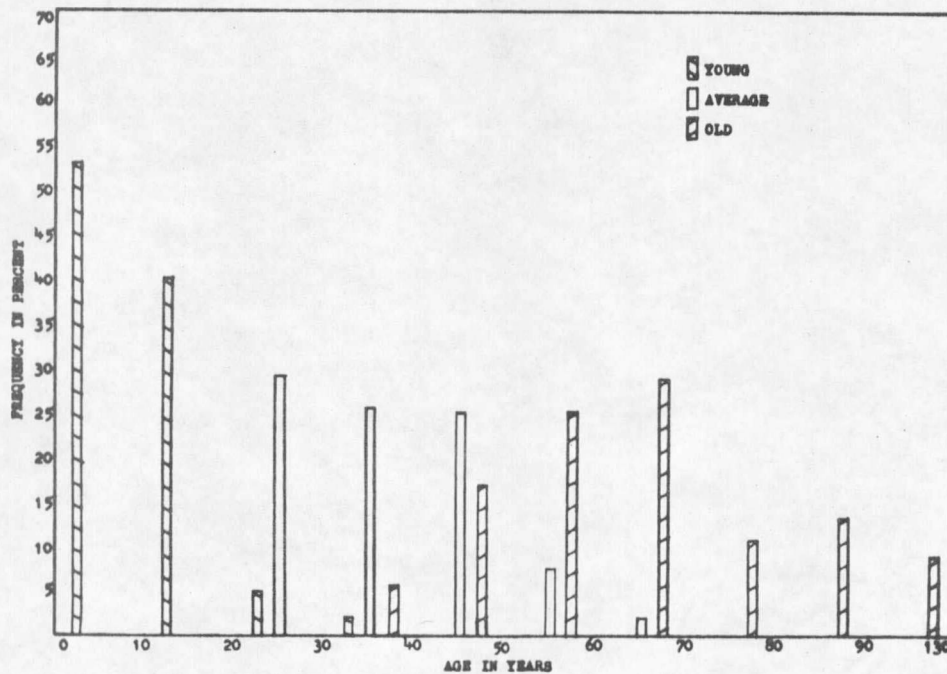
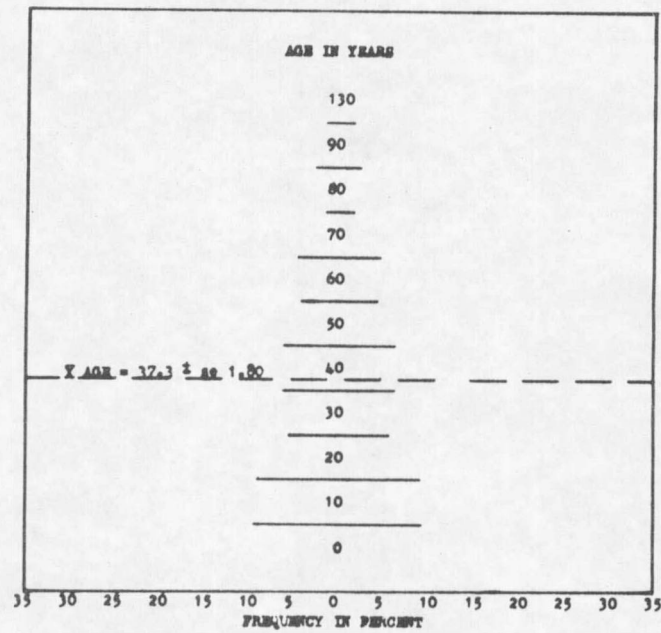


Figure 15. Age-class frequency distributions of 210 curl-leaf mountain mahogany plants (top) and of plants representing young, average, and old groups from 55 transect locations (bottom).

Thirty (53 percent) of 55 transects from which three samples were selected to typify the youngest, average, and oldest plants present (Figure 15) had the youngest plants 10 years old or less. Nearly all (93 percent) had the youngest plants 20 years old or less. Scheldt (1969) found that an average of 91 percent of seedlings surviving the first critical season lived to at least 15 years. Plants in the average group, representing the majority of the plants on all 55 transects, were virtually all between 20 and 50 years old. Over half of the oldest group (61.7 percent) was 61 years old or older.

The age-class frequency for systematically collected plants (26) showed over half (53.8 percent) of the plants to be 20 years old or less. This species ranked first in the plant longevity index rating, suggesting individual plants to have a comparatively long life span (Table 3).

Antelope Bitterbrush. - This species occurs generally in the western one-third of the State (Booth and Wright 1966) (Figure 2). The plants range from .2 to 2 m tall and occur on dry plains, hills, and mountain sides, mostly in well drained, gravelly, sandy, cindery, or rocky soils on south or southwestern exposures (Dayton 1931).

The 211 bitterbrush plants collected from 46 transect sites ranged from 5 to 83 years in age. The collection mean age was $30.4 \pm se 1.06$. The urn-shaped age-class frequency distribution for the collection (Figure 16) shows a relatively small number (17 percent) in the age

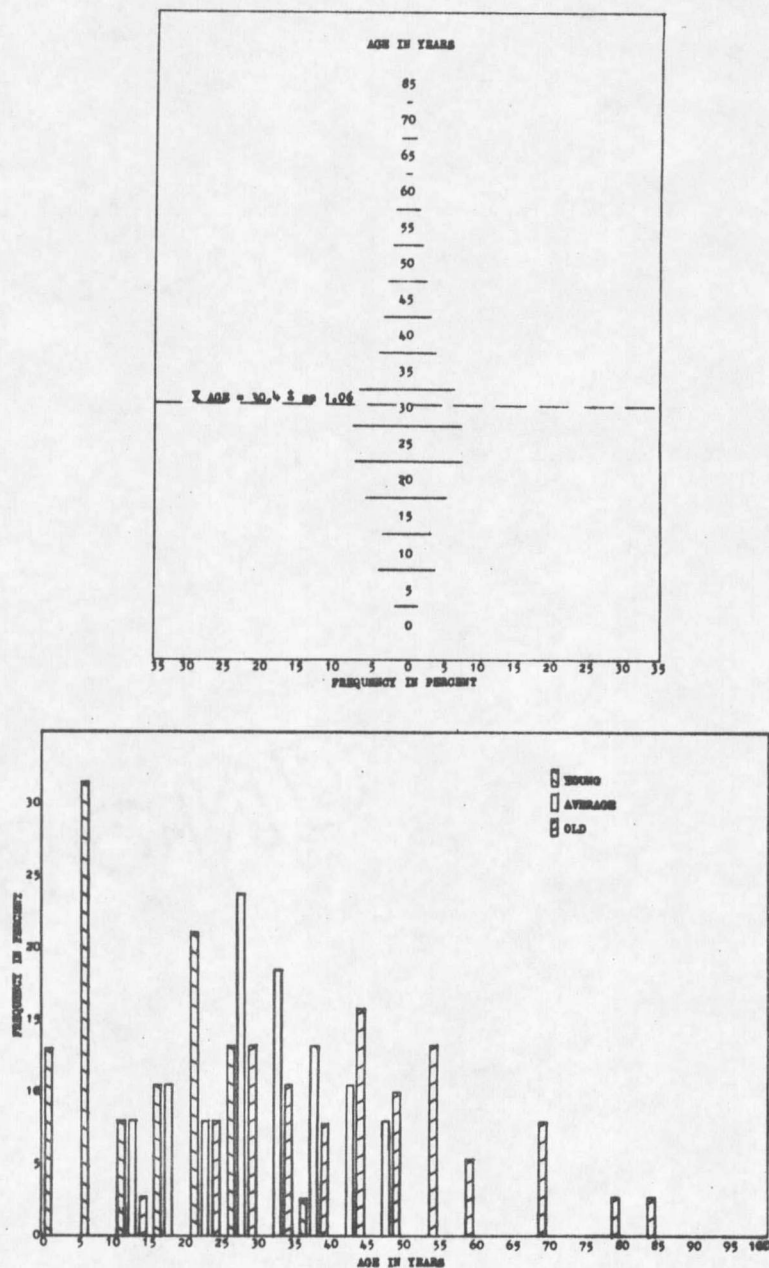


Figure 16. Age-class frequency distributions of 211 antelope bitterbrush plants (top) and plants representing young, average, and old groups from 38 transect locations (bottom).

classes I-III, a predominance (52.6 percent) in age classes IV-VII, and a more or less gradual diminution in percentages for older classes.

Although sampling may have been biased toward older and/or larger plants, the sparcity of plants in age classes I-III, and the predominance of comparatively middle-aged plants on bitterbrush transects indicated a lack of reproduction and/or survival of young plants in recent years. Age-class frequency distributions of plants representing the young, average, and old population segments from 38 transect locations (Figure 16) also supported this conclusion. Approximately half (47.3 percent) of the youngest plant group were over 15 years old and only 13.1 percent were 5 years old or less. The majority (66 percent) of plants representing the average group were between age classes VI-IX and the oldest plants from the various transect locations ranged from age classes III-XVII with the majority (57.9 percent) between age classes VII-XI. The large amount of overlap for the three population groups (Figure 16) suggests that age structures were quite dissimilar among bitterbrush stands associated with individual transects.

Chi-square tests of homogeneity between age-class frequency distributions for all systematically selected samples in Districts 1 and 2, the total 131-plant basic collection, and a systematically selected collection of 80 plants from six transects were similar (Figure 17 and Table 2).

The longevity index indicated plants of this species to have an

average life expectancy when compared to plants of other species (Table 3).

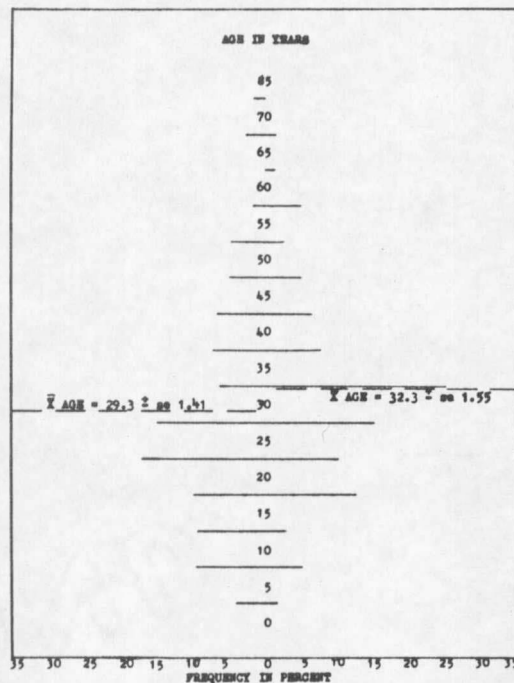


Figure 17. Age-class frequency distributions of antelope bitterbrush plants visually selected (left) and systematically selected (right).

Skunkbush Sumac. - Skunkbush occurs throughout Montana east of the Continental Divide (Figure 1), where it is variably important as a browse species. Skunkbush plants generally occur on dry, rocky hillsides of various exposures (Dayton 1931) and can manifest a great deal of plasticity in their growth form, ranging from 7 m to less than .3 m tall (Sanford 1969). Samples collected in this study

generally ranged from .3 to 1.5 m in height.

The 210 plants collected from 67 transect locations included the oldest plants of any species studied. Ages of individual plants ranged from 4 to 160 years old with a mean of $34.4 \pm \text{se } 1.4$. The urn-shaped age-class frequency distribution for the collection (Figure 18) shows a preponderance of plants in the middle-age classes and only a relatively small percentage of plants 15 years old or less. Seventy percent of all plants collected were 25 years old or older. Age-class distributions for the three representative population groups from 48 transect locations are shown in Figure 18. The age-class frequency distribution of the youngest plants at each location shows a predominance (60.5 percent) of plants over 15 years of age and only four plants (8.3 percent) in age class I. The mean age was $17.6 \pm \text{se } .8$. The paucity of plants in the younger age classes would seem to indicate low recruitment of young plants in most of the stands from which collections were made. The significance of this with respect to the survival of skunkbush populations is not clear. Sanford (1969) concluded that skunkbush seedlings have a very high mortality rate; and that the primary means of short-ranged dispersal was vegetative sprouting from the underground structure of existing plants. The latter, together with the characteristically heavy resprouting that occurs from root systems of older skunkbush plants could be sufficient to perpetuate most stands indefinitely. It is also likely that my samples were biased toward

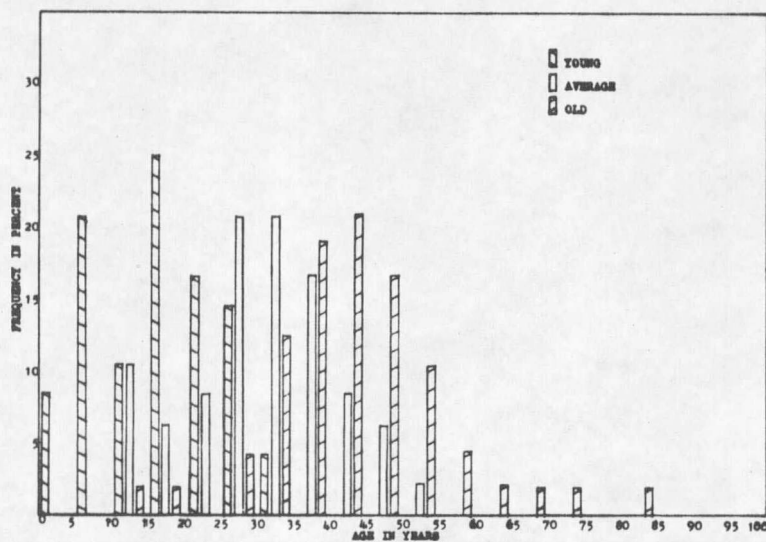
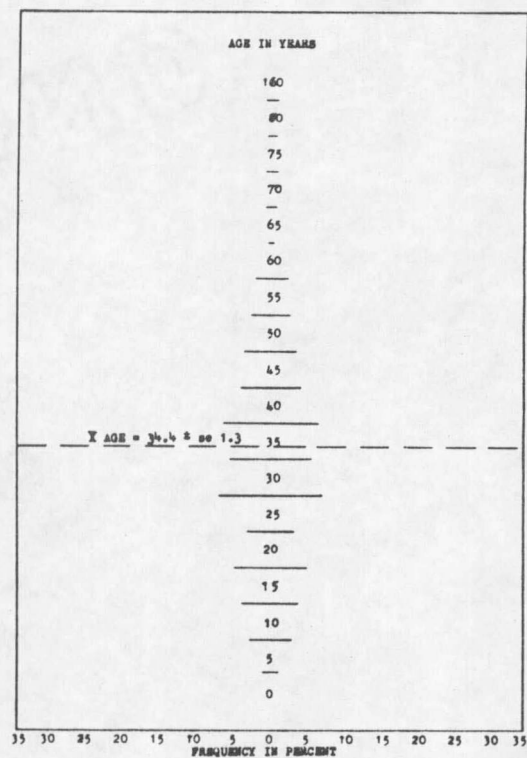


Figure 18. Age-class frequency distributions of 210 skunkbush sumac plants (top) and of plants representing young, average, and old groups from 48 transect locations (bottom).

older plants because of efforts to collect the central and oldest portions of root-stem complexes of clearly individual plants.

Plants in the average group were between 25 and 45 years old on over two-thirds of the sites. Nearly two-thirds (60.5 percent) of the transects had oldest plants over 40 years of age. The extensive overlap between three age groups (Figure 18) suggested that the age structure of skunkbush populations associated with individual transects varied considerably: i.e., from mostly young plants to mostly older plants.

Twenty skunkbush plants systematically collected as 10-plant samples from two transects showed older age plants to predominate in both locations. The youngest plant at either site was about 31 years and most were between 35 and 50 years old. Age-class frequency distributions for individual collections from Districts 4, 5, 6, and 7 were similar. These results reflect consistency of the visual selective sampling procedure and/or homogeneity between district age-class frequency distributions.

The longevity index rating indicated plants of this species to be relatively long-lived as compared to the other species studied.

Rocky Mountain Maple. - This species occurs as a shrub or small tree 20 to 30 feet tall along mountain streams and canyons in the western one-third of the State (Marks 1963). It is important as a browse plant primarily in District 1, the northern part of District

2, and the western portion of District 4 (Figure 2).

Ages were determined for 59 plants from 20 transect locations. The plants ranged from 6 to 100 years old with a mean age of 35.0 ± 2.69 . The limited amount of data concurrent with difficulty in accurately aging plants of this species resulted in an erratic columnar shaped age-class frequency distribution (Figure 19). Only 6.7 percent of the plants sampled were less than 10 years old while most (53.1 percent) were between 15 and 40 years.

Young plants 10 years old or less were apparently lacking on most of the browse transects from which collections were made. None of the 12 locations for which samples representative of the youngest, average, and old plants had plants less than 5 years old and only two had plants less than 10 years of age (Figure 19). Seven plants (58.3 percent) in the young group were over 15 years old. The large amount of overlap between the age-distributions of the average and old groups suggests considerable difference in age-structure of individual maple stands associated with the transects.

Plants from this species were inferred to have an average life span when compared to plants of the other species (Table 3).

Rubber Rabbitbrush. - This species occurs throughout Montana (Booth and Wright 1966), but is measured as a key browse plant only east of the Continental Divide (Figure 1). The plants range from 4 to 8 dm tall and usually occur in dry, often sandy, gravelly, or rocky open sites

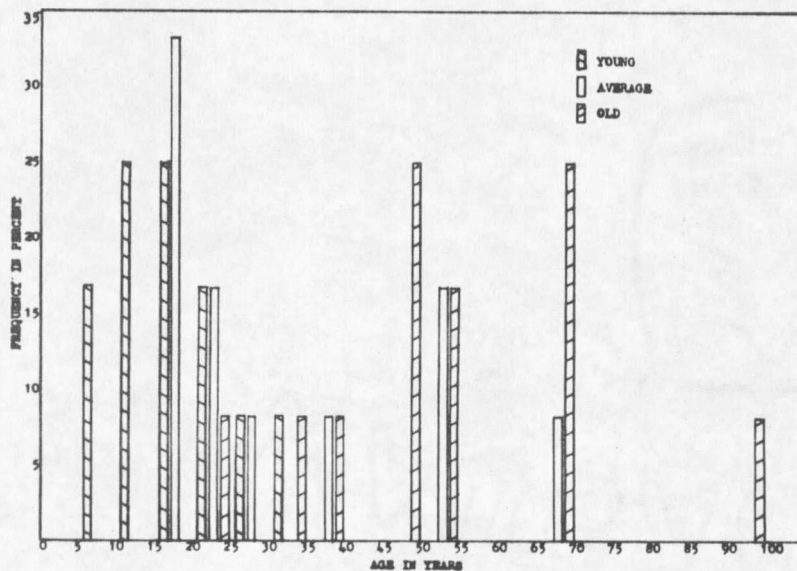
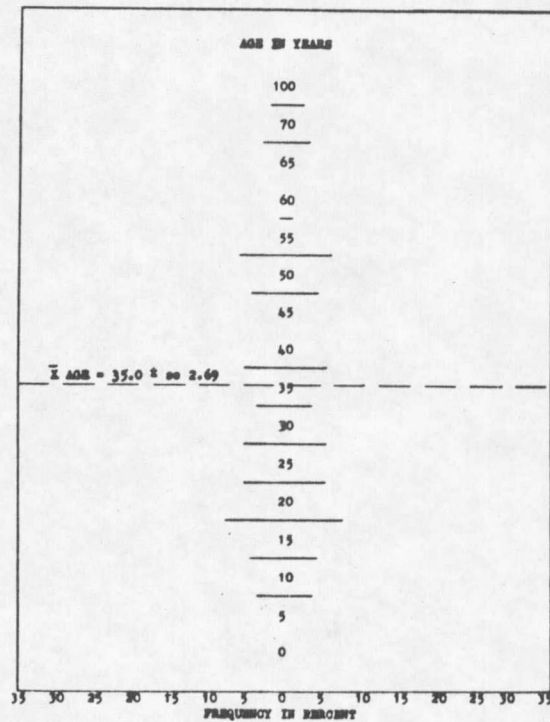


Figure 19. Age-class frequency distributions of 56 Rocky Mountain maple plants (top) and plants representing young, average, and old groups from 12 transect locations (bottom).

(Dayton 1931).

Only 45 plants were collected from 16 transect locations. Determined ages ranged from 4 to 45 years with a mean of $17.2 \pm se 1.43$. Predominant age-classes were III and V which comprised 31.8 percent and 18.2 percent of the collection, respectively (Figure 20). The age-distribution of 30 plants representing the young, average, and old population groups from 10 transects indicated relatively poor recruitment of young plants into rabbitbrush stands in recent years (Figure 20). The age-distribution of the youngest plant group showed only 50 percent of the transects to have plants between 0 and 10 years old. Although the data were limited, rubber rabbitbrush plants appeared to be the shortest-lived of any species in the collection (Table 3).

Common Juniper. - Plants from this species occur widely throughout Montana on dry, well-drained soil, but usually are not abundant. They often form mats .5 to 1 m in depth (Booth 1950). Its greatest importance as a browse plant is in the smaller mountain ranges of central Montana, primarily in District 4 and the northern portions of District 5 (Figure 2).

Age determinations were made for 139 juniper plants from 47 transect locations. Plants ranged from 9 to 124 years old with a mean age of $43.4 \pm se 1.92$. The narrow diamond-shaped figure formed by the age-class frequency distribution (Figure 21) shows less than 25 percent of the plants to be 25 years or less and over half (60.4 percent) of the

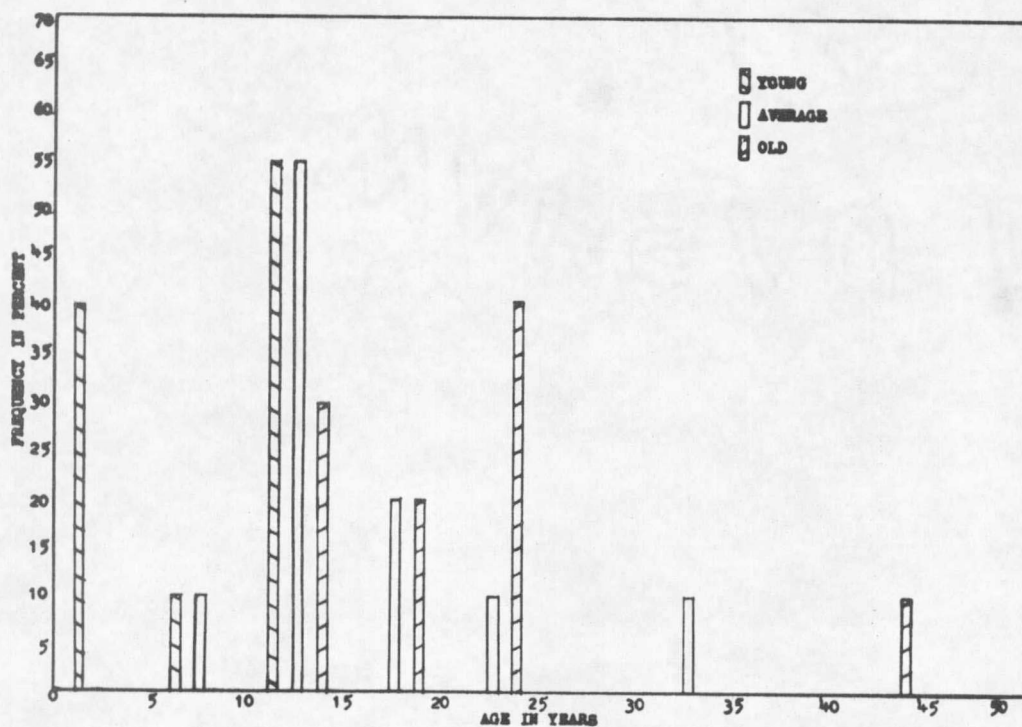
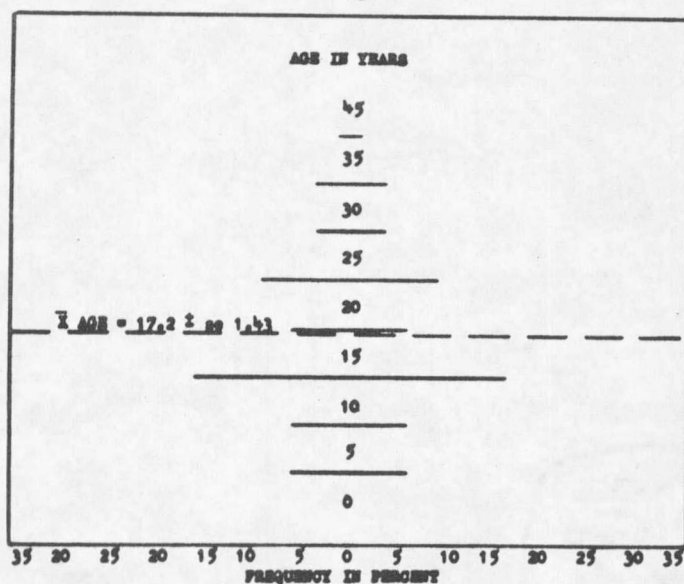


Figure 20. Age-class frequency distributions of 44 rubber rabbitbrush plants (top) and of plants representing young, average, and old groups from 10 transect locations (bottom).

plants to be between 25 and 60 years old.

The data suggested common juniper populations affiliated with browse transect locations to have a very low recruitment of young individuals. The age-class distribution of the youngest plants on 40 transects supported this, in that only one-third were 15 years old or less. Forty percent of the youngest plants were over 25 years old (Figure 21). Plants in the average group were predominantly (82.5 percent) 30 to 60 years old. The old representatives were erratically distributed between 25 and 125 years.

Plants of this species were ranked fourth in the longevity rating (Table 3).

Creeping Juniper. - Collections of this species were restricted to the northwestern portion of District 4 (Figure 2). Creeping or horizontal juniper is a prostrate plant usually less than .3 m high with long spreading branches generally occurring as large mats 3 to 5 m in diameter.

Age determinations were made for 52 plants from 20 transect locations. The mean age was $56.7 \pm se\ 3.71$ years, with a range of 20 to 140 years. The collective age-class frequency distribution and the distribution of ages among young, average, and old plants at 13 locations (Figure 22) indicated a decided lack of reproduction of creeping juniper on browse transects. Only one of the 52 plants studied was 20 years old or less, and only six were less than 30 years of age. Age

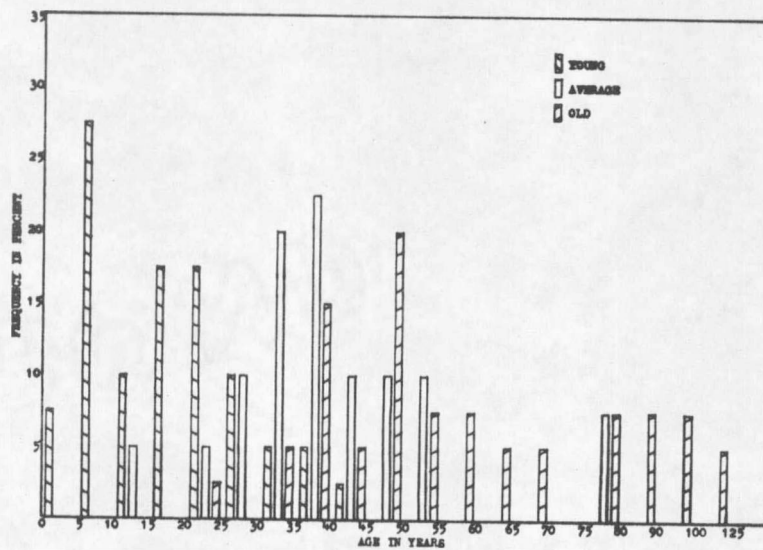
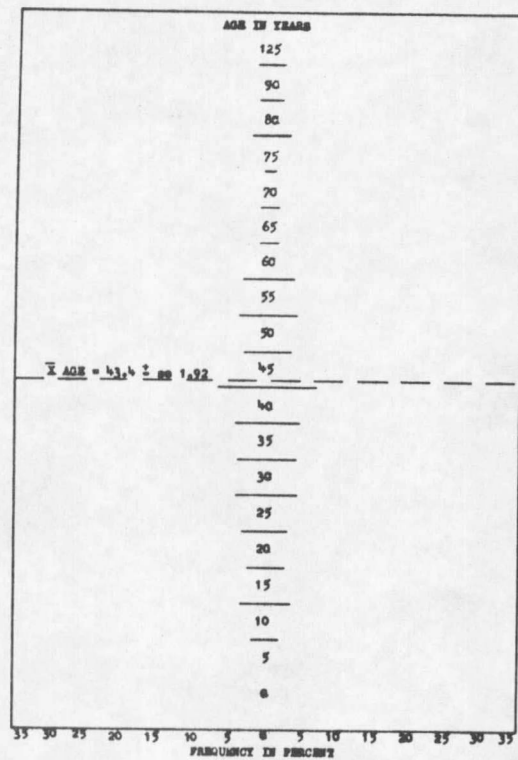


Figure 21. Age-class frequency distributions of 139 common juniper plants (top) and plants representing young, average, and old groups from 40 transect locations (bottom).

class VII predominated, comprising 21.2 percent of the collection. Percentages of plants in older age classes varied with no more than four plants in any one class. The youngest plants on the transects ranged from 20 to 85 years old, and nearly 50 percent (46.1 percent) were between 30 and 40 years old. Although lacking in reproduction the transects sampled appeared to be characterized by comparatively long-lived and hardy individual plants. Creeping juniper ranged second among the browse plants studied in mean longevity with an index rating of .051.

Chokecherry. - Chokecherry occurs commonly throughout Montana, but is measured as a key browse species primarily in the westcentral and southwestern portions of the State (Figure 1). Plants occur on mountain slopes, stream borders, and dry hills (Marks 1963). They often occur as tall, multi-stemmed shrubs ranging up to 10 m in height, but on many transects they occurred primarily or only as short, single-or-double-stalked sprouts from underground stems.

A total of 119 individual plants was collected from 39 transect locations. Ages ranged from 3 to 57 years with a mean of $14.3 \pm se$ 1.02. The age-class distribution for this collection indicated 52.1 percent of the plants were 10 years old or less (Figure 23).

A characteristically young age structure for chokecherry was also illustrated by the age-class distributions of plants representing the youngest, average, and old population segments at each of 32 transect

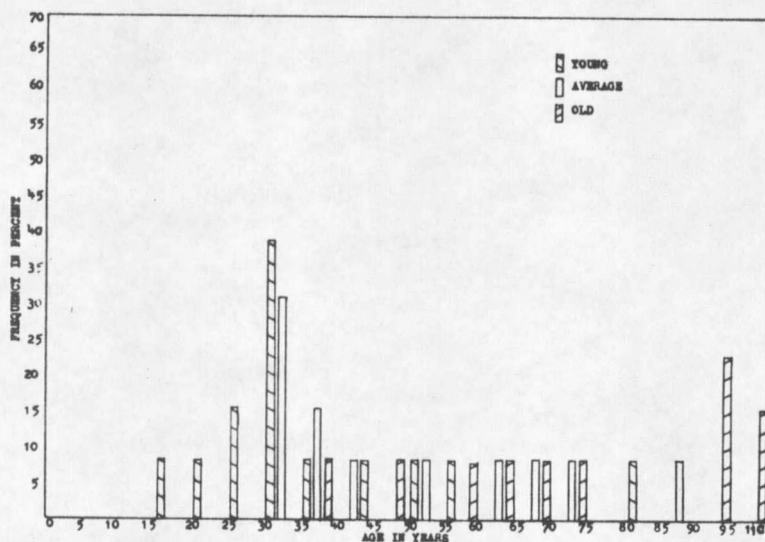
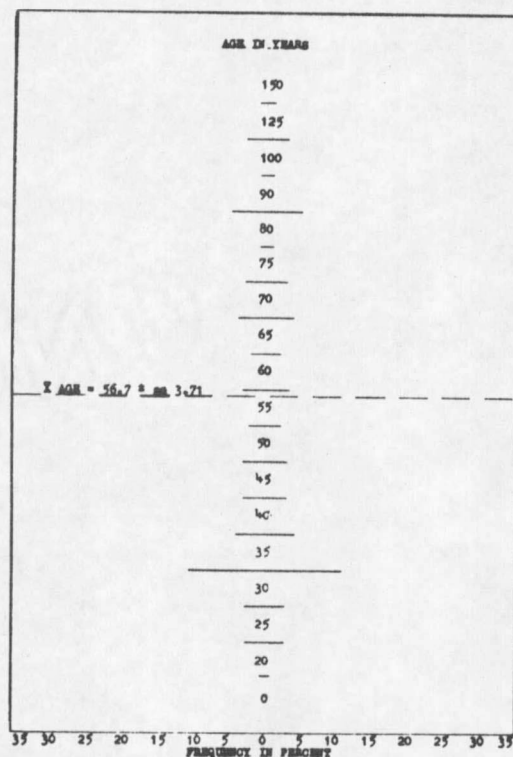


Figure 22. Age-class frequency distributions of 52 creeping juniper plants (top) and of plants representing young, average, and old groups from 13 transect locations (bottom).

locations (Figure 23). All plants in the young group were 10 years old or less and 53.1 percent were in age class I. Plants representing the average chokecherry bush were almost entirely (87.5 percent) between 6 and 15 years old and old group representatives were rather consistent in number between 6 and 40 years. The predominance of plants in the younger age classes probably reflects the prolific vegetative sprouting which characterized many chokecherry stands associated with browse transects; resulting in high recruitment of young plants individually subject to a high rate of attrition.

The calculated longevity index for chokecherry was .108, which placed this species in the relatively short-lived category as compared with the other browse plants studied (Table 3).

Silver Sagebrush. - Silver sagebrush generally occurs throughout Montana east of the Continental Divide. It is measured as a browse plant only in the southwestern and eastern portions of the State (Figure 2). Individual plants are usually 3 to 7 dm tall and are generally found growing on all slopes in rather dry, sandy, or gravelly loams on plains and in mountain valleys (Booth and Wright 1966, Dayton 1931).

The collection was limited to 35 plants from 15 transect locations. Interpretations of data were restricted to general age characteristics. The ages of individual plants ranged from 5 to 56 years and averaged $21.2 \pm se 1.98$ years. Most plants (73.5 percent) were in age classes II to V and none were less than 5 years old (Figure 24). The longevity

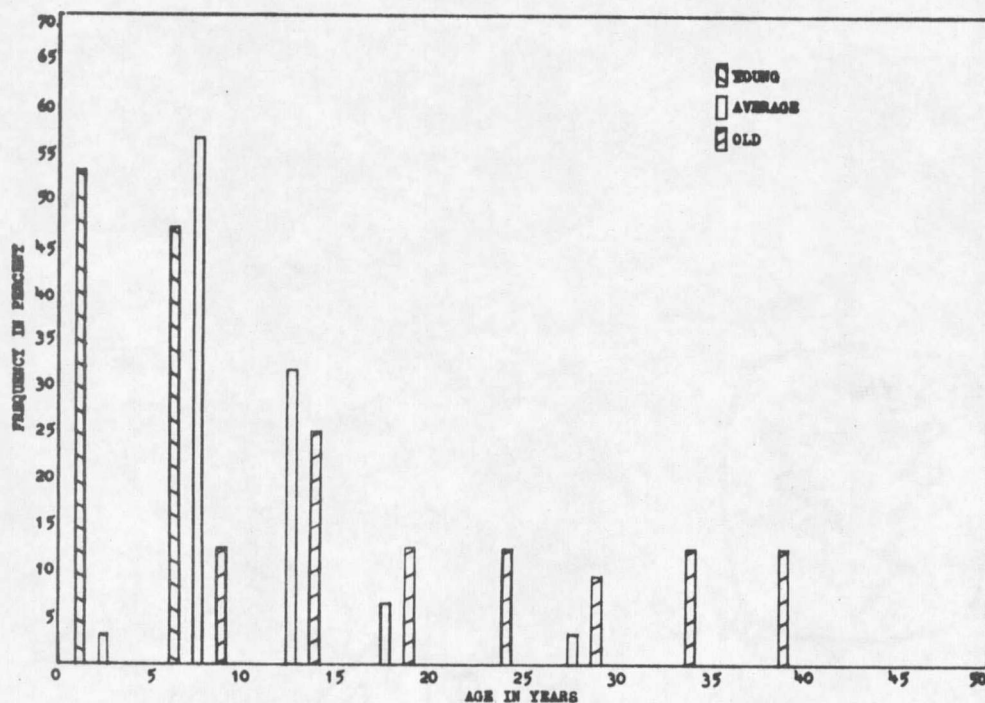
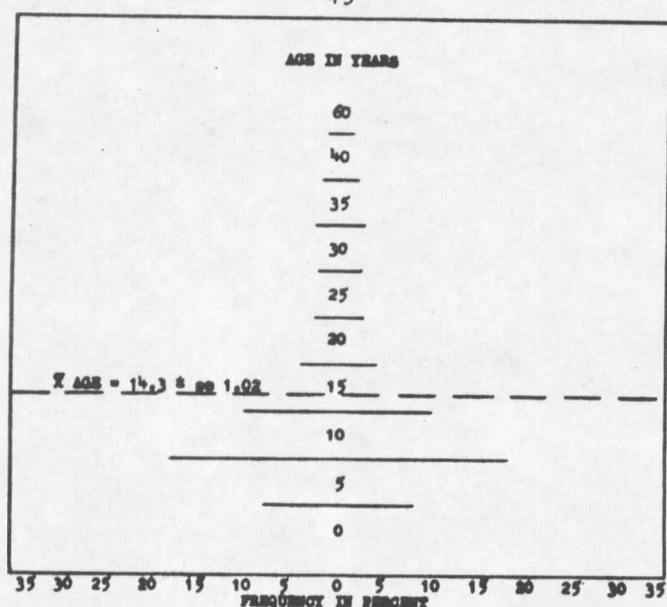


Figure 23. Age-class frequency distributions of 115 common choke-cherry plants (top) and of plants representing young, average, and old groups from 32 transect locations (bottom).

index for silver sagebrush was .088, ranking the species ninth in mean longevity among browse plants studied (Table 3).

Miscellaneous Species. - A few samples were obtained for each of nine additional browse plant species. These included: redstem ceanothus (*Ceanothus sanguineus* Pursh); snowbrush ceanothus (*Ceanothus velutinus* Dougl.); red dogwood (*Cornus stolonifera* Michx.); hawthorn (*Crataegus* spp.); green rabbitbrush (*Chrysothamnus viscidiflorus* [Hook.] Nutt.); squaw currant (*Ribes cereum* Dougl.); willow (*Salix* spp.); Canadian buffaloberry (*Shepherdia canadensis* Nutt.); and western snowberry (*Symphoricarpus occidentalis* Hook.). The number of samples and age-class distributions for these species are presented in Table 4.

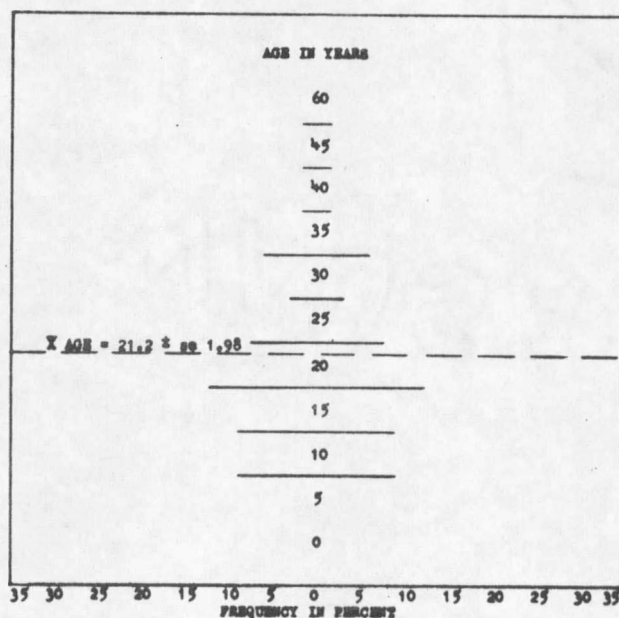


Figure 24. Age-class frequency distributions of 34 silver sagebrush plants.

TABLE 4. AGE CLASS FREQUENCY DISTRIBUTIONS OF MISCELLANEOUS BROWSE SPECIES.

Species	Sample Size and Range of Ages	NUMBER OF PLANTS IN 5-YEAR AGE CLASSES									
		I 0-5	II 6-10	III 11-15	IV 16-20	V 21-25	VI 26-30	VII 31-35	VIII 36-40	IX 41-45	X 46-50
Redstem ceanothus	13 6-43	--	2	5	3	1	--	--	1	1	--
Snowbrush ceanothus	3 9-29	--	1	1	--	--	1	--	--	--	--
Red dogwood	2 15-22	--	--	1	--	1	--	--	--	--	--
Crataegus	3 15-50	--	--	1	--	--	--	--	1	--	1
Green rabbitbrush	3 10-16	--	1	1	1	--	--	--	--	--	--
Squaw currant	3 6-20	--	1	1	1	--	--	--	1	--	--
Willow	11 9-48	--	1	2	2	3	1	--	--	1	1
Canadian buffaloberry	6 15-50	--	--	1	--	1	2	--	--	1	1
Western snowberry	1 N/A	--	1	--	--	--	--	--	--	--	--

Age Relationships

Age-Utilization and Plant Condition

Utilization. -- Age apparently had little or no influence on the intensity of browsing on individual plants of most species. Correlation coefficients (r) for relationships between plant age and the percentage of current leaders browsed were generally low and non-significant for plants of all species in the collection except antelope bitterbrush (Table 5). The significant (*) negative correlation for bitterbrush, though weak, suggested decreased utilization with age among plants in the collection. Although this could indicate decreased palatability and/or availability of current annual growth twigs of older plants, such interpretation may not be warranted on the basis of a single year's utilization and/or where the plants were collected from many ranges in which the browse plant populations differed in overall age structures and browsing pressures.

Plant Condition. -- Analysis of plant age relative to form class and decadency suggested that these parameters of plant condition may be influenced somewhat by age and browsing intensity.

Among seven species for which form class was recorded (Table 6), plants less than 25 years old were assigned to form classes 1 or 4 (little or no hedging) much more frequently than older plants; and, conversely, the percentages of plants severely hedged (form class 3 or 6) were generally greater among plants older than 25 years. The occurrence

of similar proportions of moderately hedged (form class 2 or 5) plants in both groups would seem to support the earlier conclusion of little or no relationship between plant age and leader use.

TABLE 5. LINEAR CORRELATION COEFFICIENT VALUES FOR RELATIONSHIP BETWEEN AGE AND PERCENT ANNUAL LEADER USE.

Browse Species	Number of Plants In Analysis	r_c	r_t
Rocky Mountain Maple	53	.07	.354
Western Serviceberry	470	-.12	-.128
Silver Sagebrush	32	.17	.449
Big Sagebrush	75	.29	.302
Curl-leaf Mountain Mahogany	165	-.03	-.208
Rubber Rabbitbrush	44	-.05	-.393
Common Juniper	127	.20	.228
Common Chokecherry	106	-.23	-.254
Antelope Bitterbrush	156	-.24*	-.208
Skunkbush Sumac	153	.14	.208

*Significant at the .01 probability level.

r_c = Calculated correlation coefficient.

r_t = Correlation coefficient of significance (Snedecor and Cochran 1971).

Percent crown dead generally increased with age among plants of 10 species for which sufficient data were available to warrant analysis (Table 7). Correlation coefficients were significant (*) for 8 of the 10 species ($P = .01$), but were generally weak, ranging from .24 for serviceberry to .55 for big sagebrush and common juniper. Thus while age doubtless had some influence on decadency in these plants, other factors evidently were equally or more important.

TABLE 6. NUMBERS AND PERCENTAGES OF PLANTS 25 YEARS OLD OR LESS AND OVER 25 YEARS OLD IN VARIOUS FORM CLASS ASSIGNMENTS.

Species	FORM CLASS ASSIGNMENTS			
	N	FC 1 & 4	FC 2 & 5	FC 3 & 6
Plants 0-25 Years Old:				
Western Serviceberry	285	68/23.9*	173/60.7	44/15.4
Big Sagebrush	60	26/43.3	31/51.7	3/5.0
Curl-leaf Mountain Mahogany**	83	25/30.1	23/27.7	33/39.8
Common Juniper**	39	12/30.8	19/48.7	8/20.5
Common Chokecherry	89	15/16.8	38/42.7	36/40.5
Antelope Bitterbrush	78	15/19.2	38/42.7	6/7.7
Skunkbush Sumac	65	18/27.7	27/41.5	20/30.7
Plants Older than 25 Years:				
Western Serviceberry	81	13/16	54/66.7	25/30.8
Big Sagebrush	48	6/12.5	23/47.9	19/39.6
Curl-leaf Mountain Mahogany**	95	4/4.2	23/24.2	60/63.2
Common Juniper**	92	4/4.4	36/39.1	52/56.5
Common Chokecherry	18	4/22.2	9/50	5/27.8
Antelope Bitterbrush	102	12/11.8	51/50.0	39/36.3
Skunkbush Sumac	125	22/17.6	59/47.2	44/35.0

* -- Number of plants/percentage of plants.

** -- Age groups for these species were 0-30 and over 30 years old.

To evaluate possible effects of browsing as well as age on decadency, plants of each of the eight species were divided into two groups -- one comprised of all lightly or moderately hedged plants, the other comprised of all severely hedged plants -- and compared for age-decadency relationships (Table 8). Mean percentages of dead crown and mean ages of plants were generally greater in the severely hedged group, but age-decadency correlation coefficients were generally weaker for all species except big sagebrush. Big sagebrush was also the only species for which

curvilinear regressions of plant age on percent crown dead were significantly ($P = .05$) different between groups. This, plus the fact that age -percent crown dead correlation coefficients were similarly significant or non-significant in the two groups for each species except chokecherry, suggested that estimates of percent dead crown may have only very limited value as a measure of browsing effects on plants of most of the species studied. McConnel and Smith (1971) reached a similar conclusion from work with antelope bitterbrush in Oregon.

TABLE 7. LINEAR CORRELATION COEFFICIENT VALUES FOR RELATIONSHIPS BETWEEN AGE AND PERCENT DEAD CROWN.

Browse Species	Number of Plants In Analysis	r_c	r_t
Rocky Mountain Maple	50	.28	.354
Western Serviceberry	470	.24*	.128
Silver Sagebrush	33	.11	.449
Big Sagebrush	78	.55*	.302
Curl-leaf Mountain Mahogany	172	.43*	.208
Rubber Rabbitbrush	31	.52*	.449
Common Juniper	129	.55*	.228
Common Chokecherry	107	.30*	.254
Antelope Bitterbrush	203	.27*	.181
Skunkbush Sumac	200	.26*	.181

*Significant at .01 probability level.

r_c -- Calculated correlation coefficient.

r_t -- Correlation coefficient of significance (Snedecor and Cochran 1971).

TABLE 8. LINEAR CORRELATION COEFFICIENT VALUES AND SIGNIFICANCE FOR RELATIONSHIP BETWEEN AGE AND PERCENT DEAD CROWN FOR PLANTS IN LIGHT-MODERATE AND SEVERELY HEDGED GROUPS.

Linear Regression Analysis:		Age on Percent Decadency for Plants Lightly or Moderately Hedged					Age on Percent Decadency for Plants Severely Hedged					Test Results for Significant Differences Between Linear Regression Slope Values of Each Group	
Browse Species	N	Mean Percent Dead Crown	Mean Age	r_c	r_t (P=.01)	N	Mean Percent Dead Crown	Mean Age	r_c	r_t (P=.01)		T_c	T_t
Rocky Mountain Maple	10	13.0	38.0	.27	.708	7	47.8	43.0	-.18	.798		.62	2.365
Western Serviceberry	121	5.5	14.3	.196	.228	70	34.3	19	.068	.302		.24	1.99
Big Sagebrush	31	9.8	15.4	.55*	.449	24	51.5	33.9	.69*	.496		2.56**	2.064
Curl-leaf Mountain Mahogany	78	9.2	31.3	.54*	.283	94	29.7	42.1	.37*	.254		.098	1.99
Common Juniper	69	15.4	38.9	.74*	.302	60	37.0	48.5	.36*	.325		.92	2.00
Common Chokecherry	66	15.1	14.2	.48*	.302	41	33.6	15.2	.12	.393		1.03	2.02
Antelope Bitterbrush	48	18.9	29.0	.21	.354	43	27.7	39.4	.097	.372		.50	2.02
Skunkbush Sumac	50	19.3	33.4	.28	.354	64	36.6	32.5	.30	.325		1.12	2.008

r_c -- Calculated correlation coefficient.

r_t -- Correlation coefficient of significance (Snedecor and Cochran 1971).

T_c -- Calculated T statistic.

T_t -- T statistic from table.

* -- Significant at .01 probability level.

** -- Significant at .05 probability level.

As a further test of age-browsing-plant condition interactions, I compared age-crown area relationships among light-moderately hedged, and severely hedged plants of eight species (Table 9). Plant crown area (dm^2) generally increased with age among plants of most species in both form class groupings but correlation coefficients for the age-crown area relationship became weaker for severely hedged plants. Curvilinear regressions were significantly different ($P = .05$) between plants in the two groupings for four of the eight species -- western serviceberry, big sagebrush, curl-leaf mountain mahogany, and skunkbush sumac. Crown areas for lightly and severely hedged plants of these species and the respective regressions are plotted in Figures 25 and 26. These data indicated that crown areas of individually lightly or severely browsed plants varied considerably and obscured the possible depressive effects of browsing on plant crown area with the possible exception of mountain mahogany. The large variation in crown areas for severely hedged plants of serviceberry (dwarf life-form), big sagebrush, and skunkbush was reflected in the nonsignificant correlations of age and crown area for plants within this group.

Age-Plant Growth Relationships. - The relationships between plant age and various parameters of plant growth, including plant volume, stem or root average cross-sectional diameter, maximum cross-sectional diameter, and cross-sectional area, were examined for 11 browse species.

Distributions of plant volume (dm^3) relative to age, together with

TABLE 9. CURVILINEAR CORRELATION COEFFICIENT VALUES AND SIGNIFICANCE FOR RELATIONSHIP BETWEEN AGE AND PLANT AREA (DM²) FOR PLANTS IN LIGHT-MODERATE AND SEVERELY HEDGED GROUPS.

Curvilinear Regression Analysis:	Age on Plant Area for Plants Lightly or Moderately Hedged					Age on Plant Area for Plants Severely Hedged					Test Results for Significant Differences Between Curvilinear Regression Slope Values of Each Group	
	Mean Plant Area dm ²	Mean Age	r _c	(P=.01) r _t		Mean Plant Area dm ²	Mean Age	r _c	(P=.01) r _t		T _c	T _t
Browse Species	N					N						
Rocky Mountain Maple	17	113.3	36.5	.29	.575	36	52.3	32.5	.53*	.418	.26	2.11
Western Serviceberry (Dwarf visually selected plants)	63	2.7	13.1	.34*	.325	40	6.5	16.4	-.07	.393	8.5**	2.02
Big Sagebrush	29	5.9	15.3	.87*	.456	24	19.9	33.9	.44	.496	4.9**	2.06
Curl-leaf Mountain Mahogany	76	25.1	21.0	.82*	.290	63	54.3	32.7	.73*	.320	2.8**	2.00
Common Juniper	69	32.8	38.9	.84*	.302	60	57.3	48.5	.62*	.325	1.25	2.00
Common Chokecherry	66	7.4	14.2	.78*	.310	41	9.0	15.2	.56*	.393	1.89	2.021
Antelope Bitterbrush	48	55.6	29.0	.44*	.354	43	65.9	39.4	.43*	.393	.872	2.014
Skunkbush Sumac	50	52.4	33.4	.77*	.354	64	86.5	32.5	.28	.325	3.1**	2.008

r_c -- Calculated correlation coefficient.

r_t -- Correlation coefficient of significance (Snedecor and Cochran 1971).

T_c -- Calculated T statistic.

T_t -- T statistic from table.

* -- Significant at .01 probability level.

** -- Significant at .05 probability level.

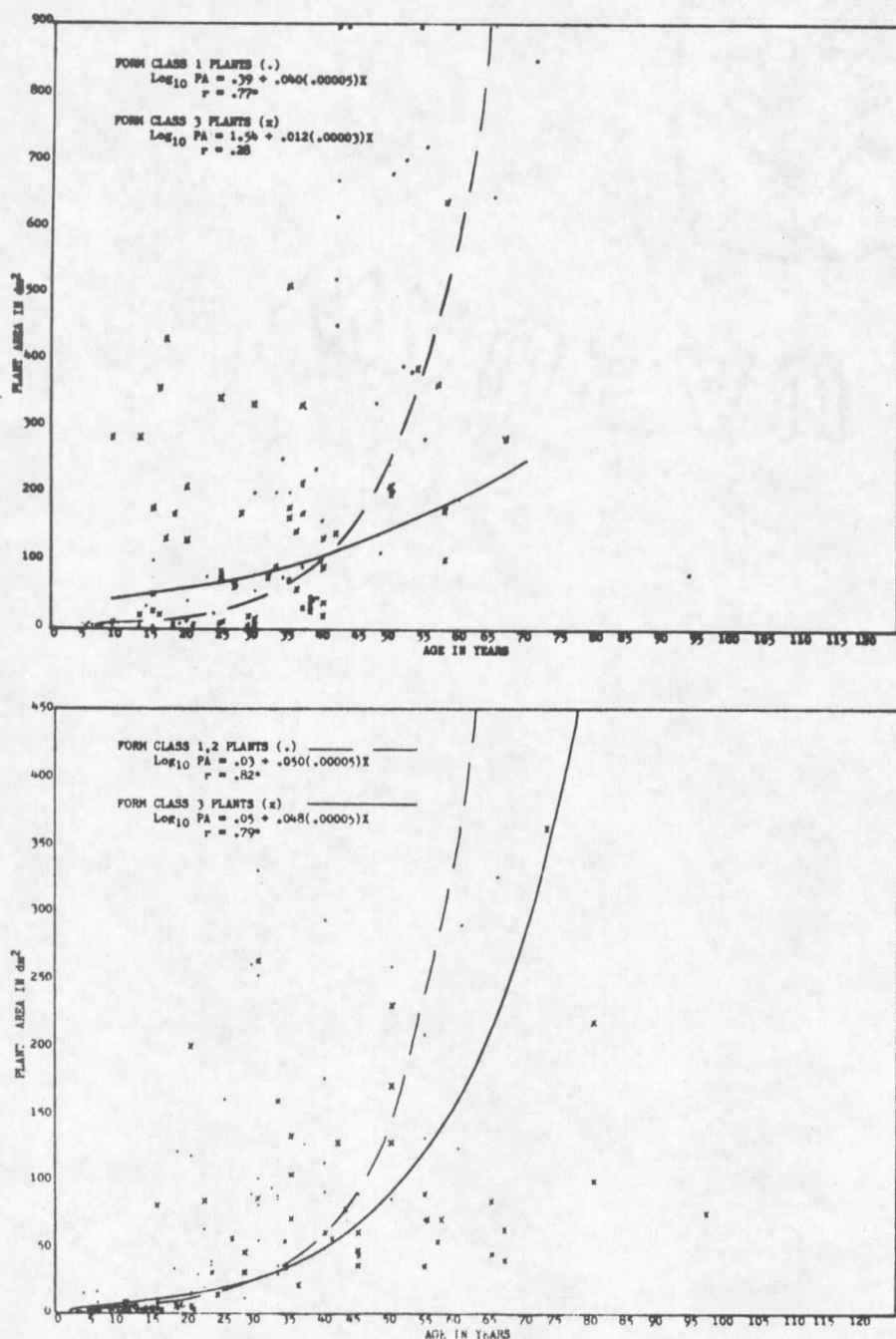


Figure 25. Crown area-age relationships for lightly (form class 1) and severely (form class 3) hedged plants of skunkbush sumac (top) and curl-leaf mountain mahogany (bottom).

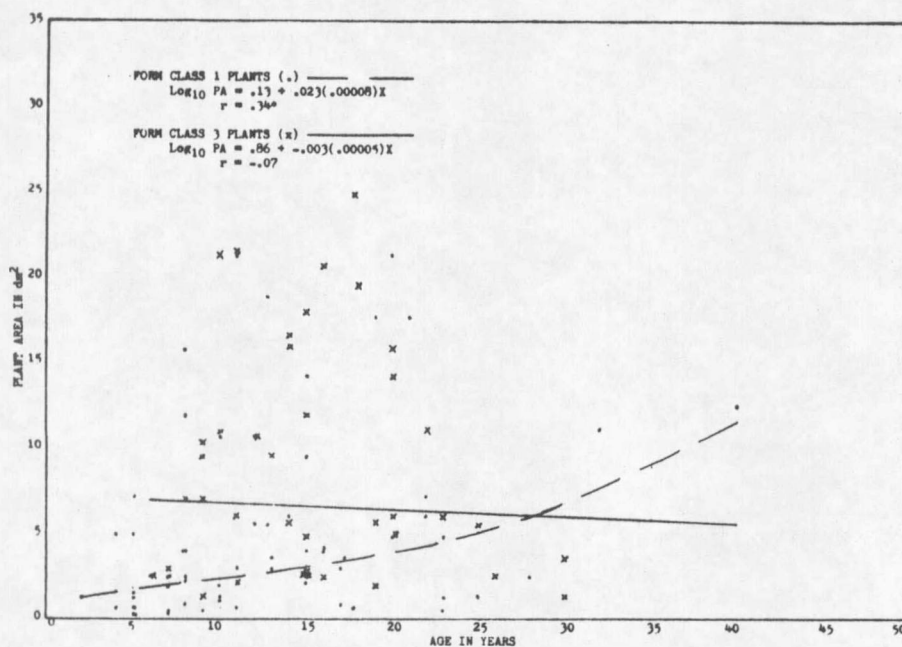
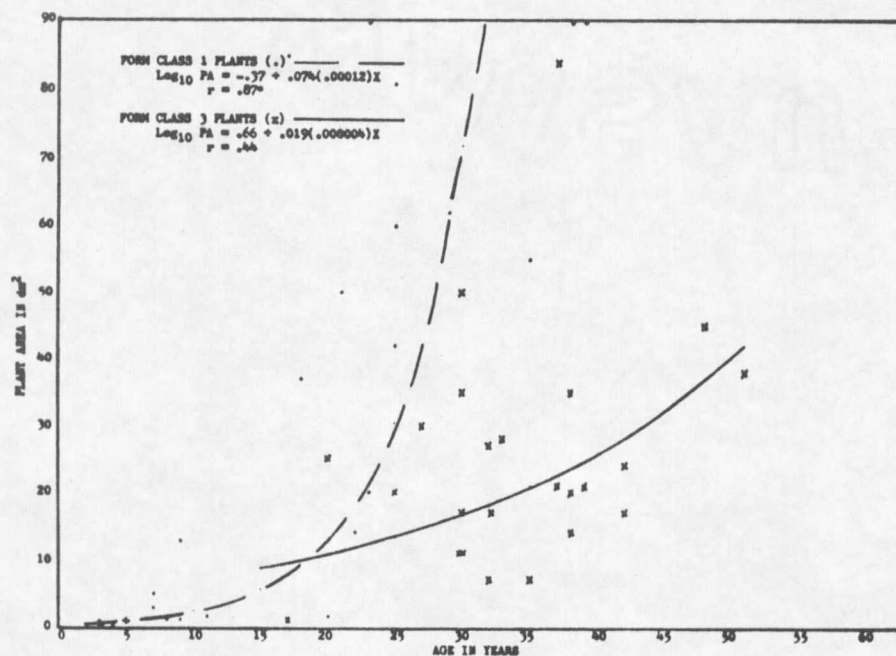


Figure 26. Crown area-age relationships for lightly (form class 1) and severely (form class 3) hedged plants of big sagebrush (top) and dwarf form of western serviceberry (bottom).

respective curvilinear regressions, for the 11 species are shown in Figures 27 through 32.

Although volumes generally increased with age, considerable variation was evident within and among the various species. Correlation coefficients for the plant age -- $\log_{10}$ plant volume relationship ranged from .41 for antelope bitterbrush to .80 for curl-leaf mountain mahogany (Table 10). They were significant (*) ($P = .01$) for all species except silver sagebrush, but relatively weak (.55 or lower) for mountain maple, the dwarf form of western serviceberry, antelope bitterbrush, and skunkbush sumac. The relatively low correlations and wide variations between plant volume and plant age for most species studied may reflect differences in browsing pressures and histories on the many different ranges from which the plants were collected, as well as differential effects of other environmental factors. Correlations between plant age and various parameters of stem and/or root growth, which were less directly influenced by browsing, were generally higher and less variable. Relationships between plant age and crown area, corrected crown area, and crown volume were also studied, but were similar to age-plant volume relationships and omitted from this report.

Mean cross-section areas, mean cross-section diameter and variances within age class for the 11 species are presented in Appendix, Table 15.

Curvilinear regression and correlation analysis showed highly sig-

TABLE 10. CURVILINEAR REGRESSION EQUATIONS AND CORRELATION COEFFICIENTS FOR AGE ON PLANT VOLUME (DM³) AND AGE ON OLDEST CROSS-SECTION MAXIMUM DIAMETER.

Relationship	Browse Species	N ^b	Curvilinear Regression Equations ^c	r _c ^d	r _t ^e
Age on Log ₁₀ Plant Volume ^a	Rocky Mountain Maple	53	Y = 2.05 + .031 (.000074)X	.51	.35
	Western Serviceberry	460	Y = .88 + .060 (.000016)X	.69	.12
	(all plants)				
	Dwarf Plants	301	Y = .80 + .039 (.000036)X	.44	.15
	Tall Plants	159	Y = 2.26 + .029 (.000015)X	.60	.21
	Silver Sagebrush	30	Y = 1.17 + .035 (.000216)X	.44 ^f	.45
	Big Sagebrush	127	Y = .41 + .035 (.000043)X	.72	.23
	Curl-leaf Mountain Mahogany	174	Y = .68 + .046 (.00001)X	.80	.19
	Rubber Rabbitbrush	41	Y = -.21 + .069 (.00029)X	.64	.39
	Common Juniper	133	Y = .44 + .037 (.000018)X	.75	.23
	Common Chokecherry	115	Y = .48 + .083 (.00011)X	.72	.23
	Antelope Bitterbrush	205	Y = 1.75 + .023 (.000015)X	.41	.18
	Skunkbush Sumac	209	Y = 1.59 + .028 (.00001)X	.55	.18
Age on Log ₁₀ Oldest Cross- Section Maximum Diameter	Rocky Mountain Maple	56	Y = .18 + .011 (.000004)X	.71	.33
	Western Serviceberry	470	Y = -.24 + .026 (.0000007)X	.83	.12
	Silver Sagebrush	31	Y = .001 + .019 (.000022)X	.73	.45
	Big Sagebrush	315	Y = .03 + .018 (.0000003)X	.72	.15
	Curl-leaf Mountain Mahogany	211	Y = -.07 + .017 (.0000007)X	.83	.18
	Rubber Rabbitbrush	44	Y = -.19 + .026 (.000027)X	.77	.37
	Common Juniper	139	Y = -.25 + .014 (.000002)X	.83	.23
	Creeping Juniper	52	Y = .005 + .007 (.0000003)X	.76	.35
	Common Chokecherry	115	Y = -.20 + .028 (.000003)X	.86	.23
	Antelope Bitterbrush	210	Y = .04 + .014 (.0000003)X	.75	.18
	Skunkbush Sumac	209	Y = .08 + .012 (.0000003)X	.78	.18

a -- Computed with the circle volume formula.

b -- Number of plants used in relationship.

c -- Variance of regression coefficient in parentheses.

d -- Calculated correlation coefficient.

e -- Correlation coefficient from table at .01 level of significance (Snedecor and Cochran 1971).

f -- Not significant at .01 probability level.

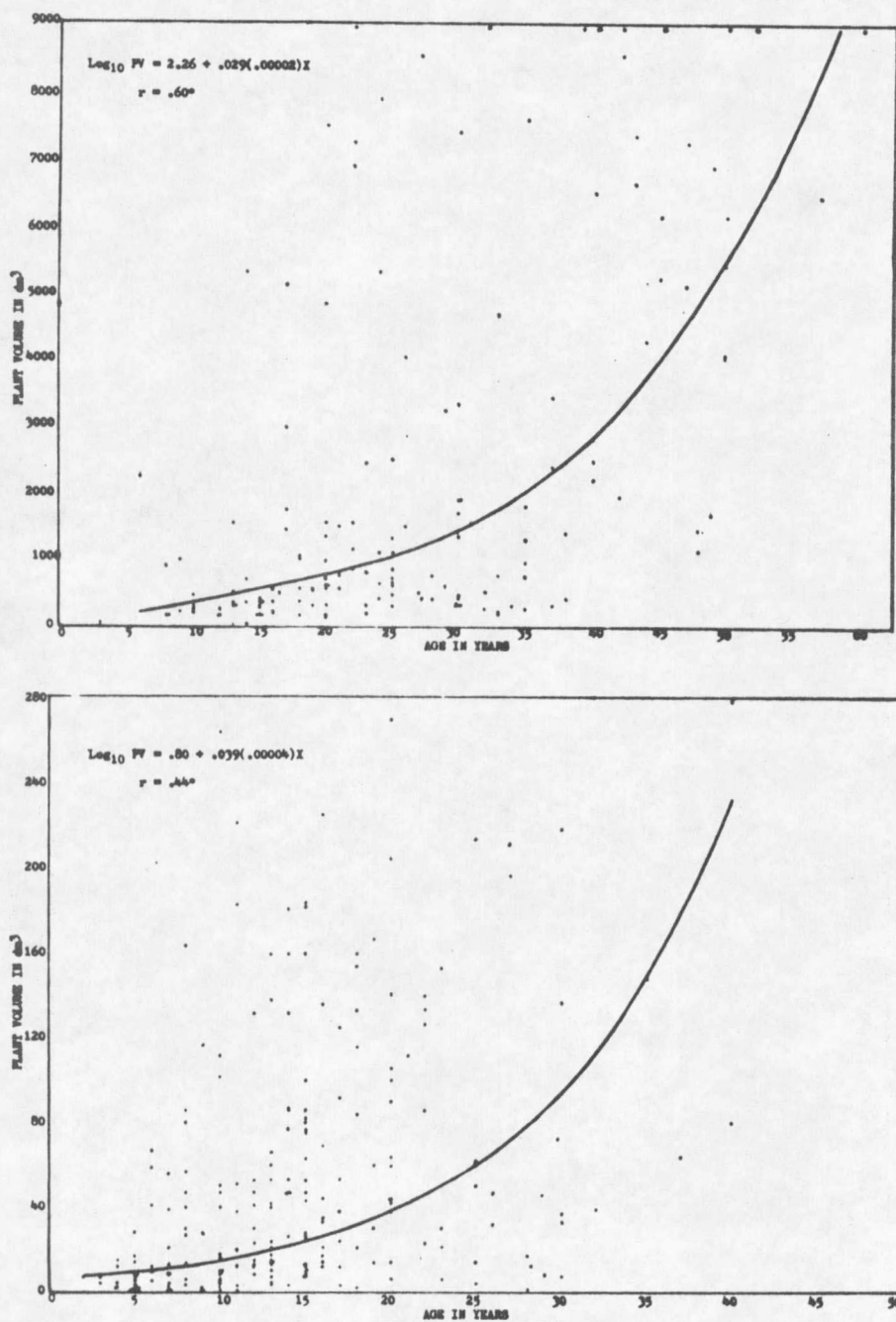


Figure 27. Plant volume-age relationships of western serviceberry tall form (top) and dwarf form (bottom).

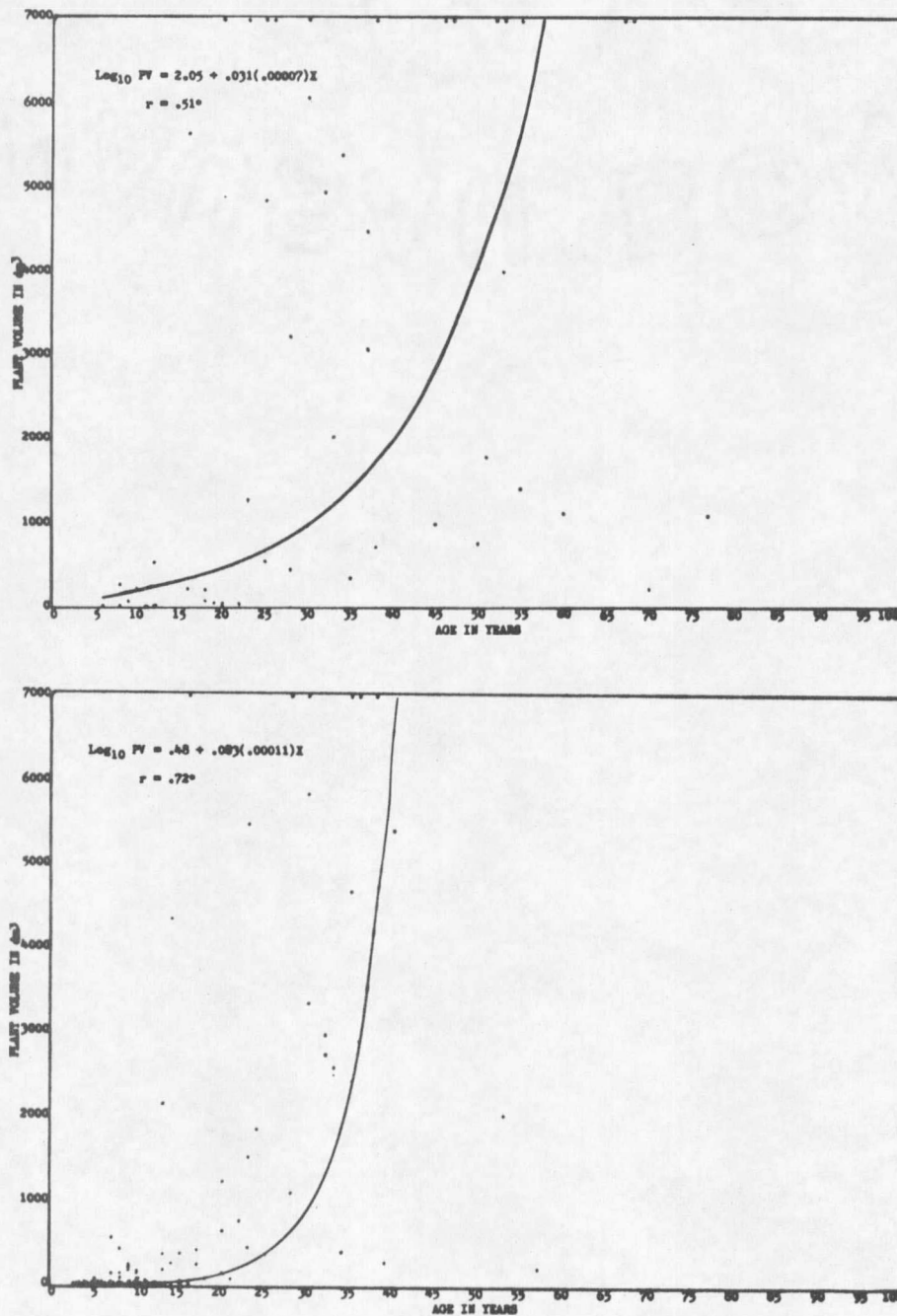


Figure 28. Plant volume-age relationships of Rocky Mountain maple (top) and common chokecherry (bottom).

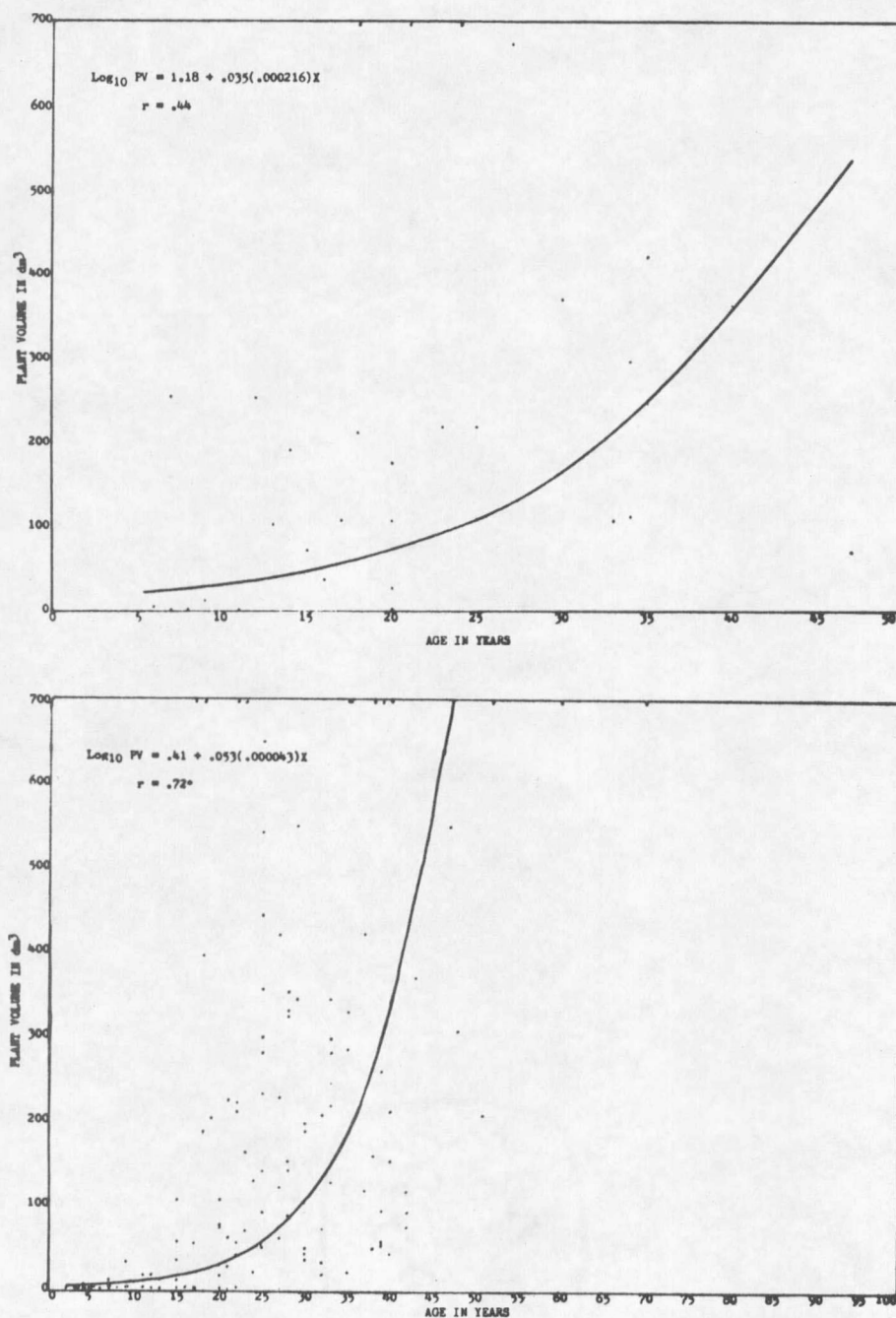


Figure 29. Plant volume-age relationships of silver sagebrush (top) and big sagebrush (bottom).

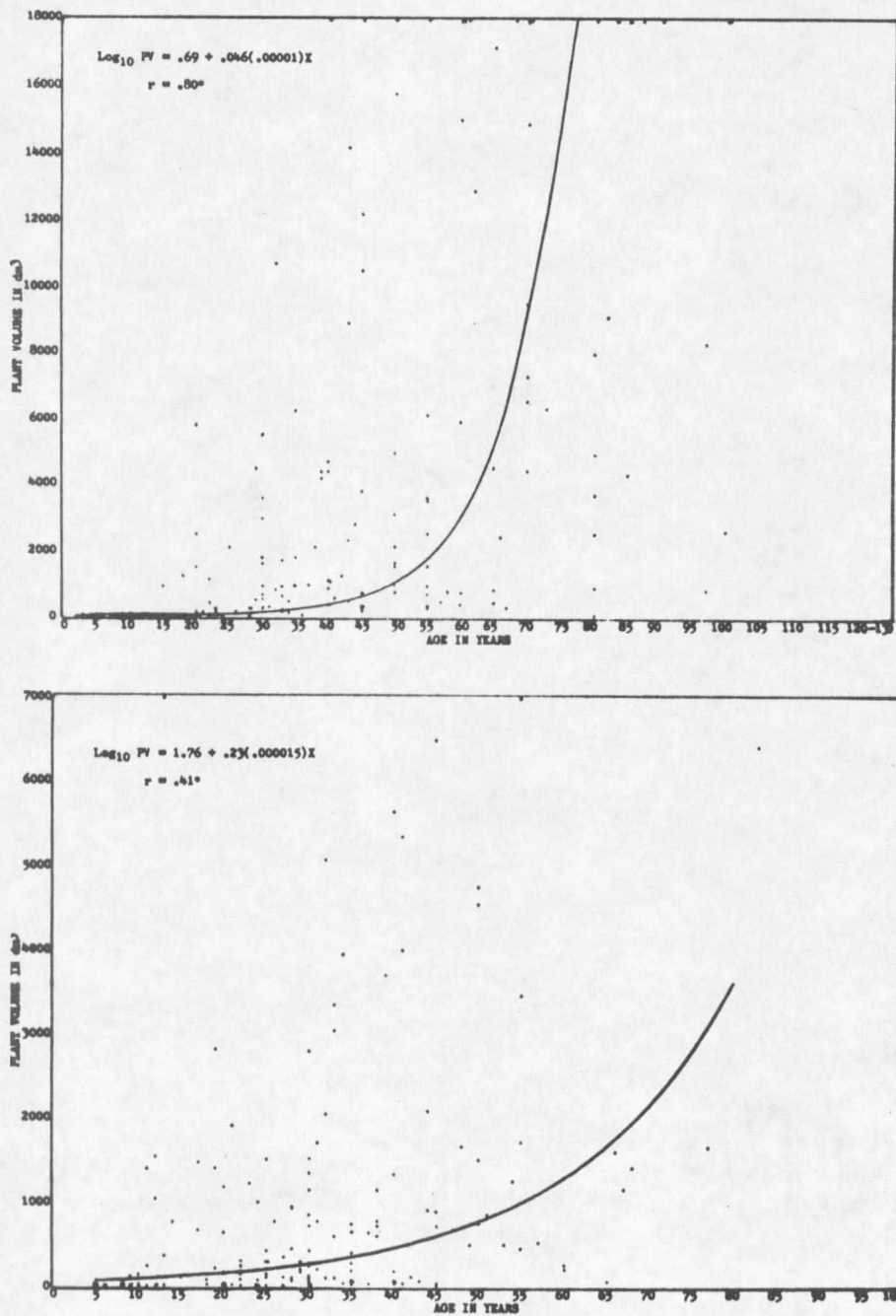


Figure 30. Plant volume-age relationships of curl-leaf mountain mahogany (top) and antelope bitterbrush (bottom).

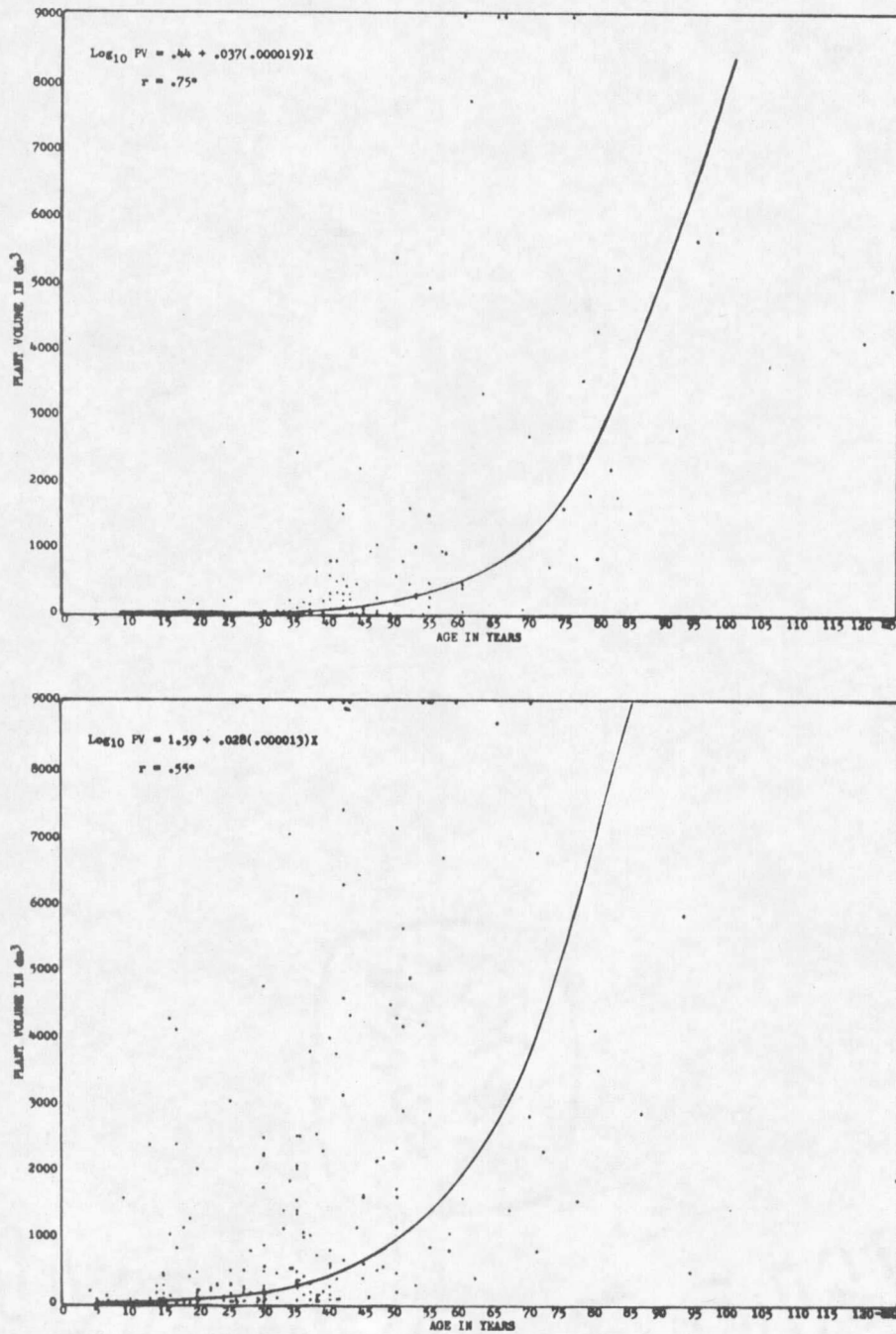


Figure 31. Plant volume-age relationships of common juniper (top) and skunkbush sumac (bottom).

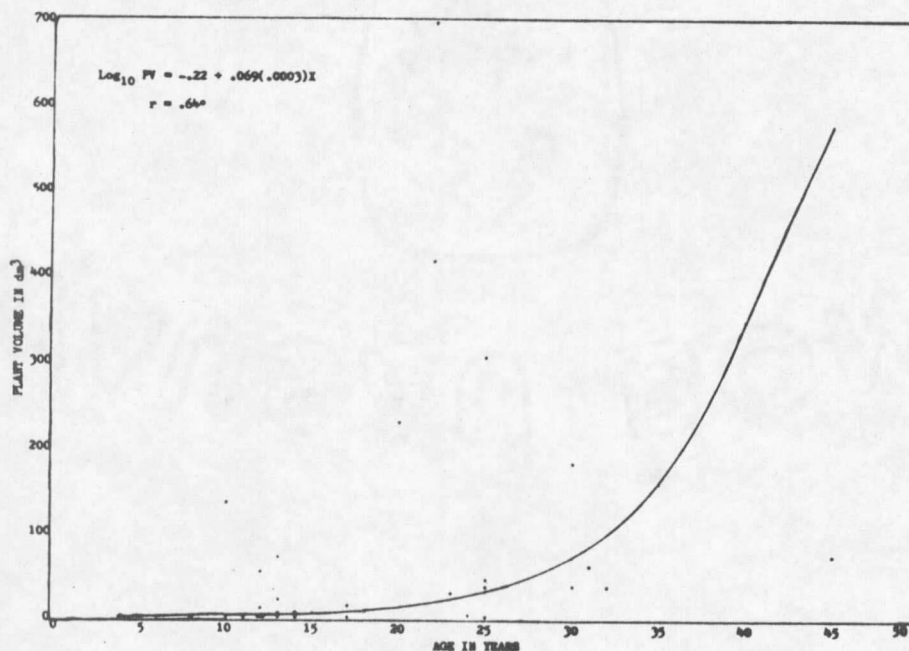


Figure 32. Plant volume-age relationships of rubber rabbitbrush.

nificant ($P = .01$) correlations between age and cross-section area and between age and cross-section diameter for all species (Table 11). Correlation coefficients ranged from a moderate .58 for silver sagebrush to .86 for common chokecherry. Correlations were generally highest for the plant age -- maximum cross-section diameter relation. In spite of these high correlation coefficients for all species, cross-section diameter and area varied considerably with age classes for some species; e.g., mountain mahogany (Figure 33, Appendix, Table 15). McConnell and Smith (1963) reported that maximum stem diameter at the root crown accounted for 86 percent of the variation in age among antelope bitterbrush plants in central Washington. These results suggest maximum stem

TABLE 11. CURVILINEAR CORRELATION COEFFICIENT VALUES FOR AGE AND OLDEST CROSS-SECTION AREA AND DIAMETER MEASUREMENTS FROM PLANTS IN 11 BROWSE SPECIES.

Relationship	Correlation	Browse Species										
		ACGL	AMAL	ARCA	ARTR	CELE	CHNA	JUCO	JUHO	PRVI	PUTR	RHTR
Age on Log ₁₀ Oldest Cross-Section Area ¹	r_c^2	.67	.84	.72	.68	.84	.73	.81	.76	.84	.73	.78
	r_t^2	.33	.12	.45	.15	.18	.37	.23	.35	.23	.18	.18
Age on Log ₁₀ Oldest Cross-Section Average Diameter	r_c	.71	.74	.58	.66	.84	.75	.83	.76	.86	.74	.75
	r_t	.33	.12	.45	.15	.18	.37	.23	.35	.23	.18	.18
Age on Log ₁₀ Oldest Cross-Section Maximum Diameter	r_c	.71	.83	.73	.72	.83	.77	.83	.76	.86	.75	.78
	r_t	.33	.12	.45	.15	.18	.37	.23	.35	.23	.18	.18

¹Computed with the circle area formula.

²Calculated correlation coefficient.

³Correlation coefficient from table at .01 level of significance (Snedecor and Cochran 1971).

ACGL = Rocky Mountain Maple; AMAL = Western Serviceberry; ARCA = Silver Sagebrush; ARTR = Big Sagebrush; CELE = Curl-leaf Mountain Mahogany; CHNA = Rubber Rabbitbrush; JUCO = Common Juniper; JUHO = Creeping Juniper; PRVI = Common Chokecherry; PUTR = Antelope Bitterbrush; RHTR = Skunkbush Sumac.

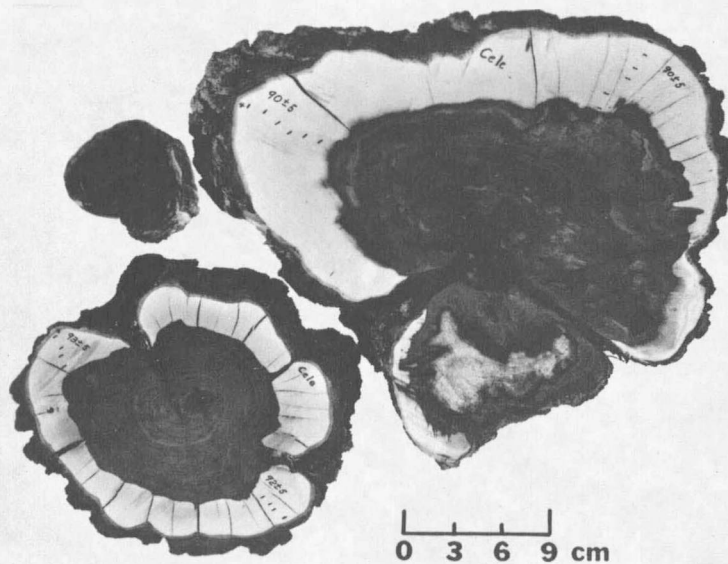


Figure 33. Variation of cross-section sizes from three curl-leaf mountain mahogany plants aged at 90 years.

diameter could have practical application for field use in estimating age of browse species having a single main stem.

Data presented in Appendix, Table 14, indicate considerable variation between annual growth ring widths and hence in uniformity of annual growth of plants within and between the various species. Although measurements were quite subjective, a slow rate of growth (rings generally less than 1 mm in width) appeared characteristic of most plants for the species studied.

Field Age Class-Assigned Age Comparisons. - Field age class measurements and/or estimates of young, mature, and decadent plants were indicated to be very crude indexes of plant age (Table 12). Although mean ages generally increased from young to decadent classes for all species, the differences were sometimes slight with considerable overlap (Table 12). Plants assigned to the young field-age class ranged from 2 years old in western serviceberry and big sagebrush to 38 years old in skunkbush sumac. Plants assigned to the mature class ranged from 3 years old in western serviceberry, big sagebrush, and common chokecherry to 160 years old in skunkbush sumac. Decadent plants ranged from 4 years old in western serviceberry and common chokecherry to 130 years old in curl-leaf mountain mahogany.

TABLE 12. COMPARISONS OF FIELD AGE CLASS ASSIGNMENTS TO KNOWN AGE OF PLANTS.

Field Age Class		Browse Species									
		ACGL	AMAL	ARCA	ARTR	CELE	CHNA	JUCO	PRVI	PUTR	RHTR
Young (Y)	N	2	43	--	13	28	2	19	17	7	6
	$\bar{X}$	24.0	7.8	--	9.7	10.9	7.0	14.7	5.6	6.9	12.7
	se	4.03	.7	--	.86	1.12	.98	.96	.36	.72	5.1
	R	20-28	2-25	--	2-12	3-28	6-8	9-26	3-9	5-10	5-38
Mature (M)	N	40	305	15	76	96	18	61	48	100	92
	$\bar{X}$	32.5	19.0	20.5	24.0	39.5	12.7	39.2	13.2	24.9	31.3
	se	3.1	.65	2.5	1.36	2.58	1.37	1.86	1.3	.85	2.1
	R	6-77	3-78	6-35	3-70	4-100	4-25	14-78	3-38	5-57	5-160
Decadent (D)	N	14	70	16	42	66	19	58	49	79	102
	$\bar{X}$	42.8	23.8	23.3	32.2	49.9	22.2	57.3	18.6	38.0	37.4
	se	6.1	1.8	.28	1.42	2.98	2.2	3.0	.59	1.70	1.72
	R	16-100	4-85	7-56	12-60	5-130	5-45	9-124	4-57	5-83	4-94

N = Number of plants in field age class.

$\bar{X}$ = Mean known age of plants in field age class.

se = Standard error of the mean.

R = Range of known age plants.

ACGL = Rocky Mountain Maple; AMAL = Western Serviceberry; ARCA = Silver Sagebrush; ARTR = Big Sagebrush; CELE = Curl-leaf Mountain Mahogany; CHNA = Rubber Rabbitbrush; JUCO = Common Juniper; PRVI = Common Chokecherry; PUTR = Antelope Bitterbrush; RHTR = Skunkbush Sumac.

APPENDIX

TABLE 13. NUMBER OF SAMPLES COLLECTED AND NUMBER OF SAMPLES AGED; MEAN NUMBER OF CROSS-SECTIONS AGED PER PLANT SAMPLE; MEAN NUMBER OF CROSS-SECTION SURFACES AGED PER PLANT SAMPLE; RANGE OF CROSS-SECTION SURFACES READ PER PLANT SAMPLE; PERCENTAGE OF SAMPLES WITH PARTIAL OR COMPLETE CORE ABSENCE; STAINS USED TO AID IN GROWTH RING COUNT; AND READING QUALITY CHARACTERISTICS FOR ALL BROWSE SPECIES WITH DATA SUFFICIENT FOR ANALYSIS.

	Browse Species											Totals
	ACGL	AMAL	ARCA	ARTR	CELE	CHNA	JUCO	JUHO	PRVI	PUTR	RHTR	
Total Number of Samples Collected and Aged ¹	59/ 59	500/ 470	35/ 34	329/ 321	211/ 210	45/ 44	140/ 139	54/ 52	119/ 115	217/ 211	221/ 210	1,930/ 1,865
Total Number of Cross-Sections Prepared	342	1,421	77	538	583	91	332	118	303	628	1,040	5,473
Number Cross-Section Surfaces Read/Sample	7.0	2.9	2.2	1.7	2.8	2.1	2.4	2.2	2.5	2.9	4.7	2.8
Range of Cross-Section Surfaces Read/Sample	2-57	1-21	1-6	1-6	1-10	1-6	1-18	1-5	1-14	1-13	1-25	1-57
Percent Samples w/Partial Core Absence	0	.5	11.8	24.5	0	7	5	5.8	0	4.2	13.8	--
Percent Samples w/Complete Core Absence	0	0	20.6	15.1	0	4.5	3	1.9	0	8.9	20.0	--
Stain Used to Aid in Growth Ring Count ²	--	--	K	K	L	K	K	K	K	K, Lt	K	--

TABLE 13. (CONTINUED).

	Browse Species											Totals
	ACGL	AMAL	ARCA	ARTR	CELE	CHNA	JUCO	JUHO	PRVI	PUTR	RHTR	
Reading Quality												
Characteristics:												
Percentage of												
Collection With												
Good Growth Ring	59.0	42.6	74.3	93.0	23.7	31.8	85.6	92.4	61.7	80.6	42.5	---
Quality												
Fair Growth Ring	29.0	47.4	17.1	7.0	45.4	47.7	13.7	3.8	33.9	19.4	42.5	---
Quality												
Poor Growth Ring	12.0	10.0	5.7	0.0	30.9	20.5	.7	3.8	4.4	0.0	15.0	---
Quality												
Questionable												
Quality Samples ³	0.0	6.0	2.9	2.4	.5	2.2	.7	3.7	3.4	2.7	5.0	---

¹Number of samples collected/number of samples used in analyses.

²K = Kerosene; L = Boiled Linseed Oil; Lt = Lacquer Thinner.

³All samples not felt to represent oldest portion of plant.

TABLE 14. ANNUAL GROWTH RING UNIFORMITY AND GROWTH RATE ASSUMPTIONS FOR ALL BROWSE SPECIES EXTENSIVELY AGED.

Growth Ring Uniformity		Browse Species										
		ACGL	AMAL	ARCA	ARTR	CELE	CHNA	JUCO	JUHO	PRVI	PUTR	RHTR
Sensitivity ¹	N	34	216	14	241	97	15	100	48	82	94	153
	%	59.6	58.5	41.2	75.3	52.4	36.6	71.9	92.3	71.3	50.5	76.1
Complacent ²	N	23	153	20	79	88	26	39	4	33	92	48
	%	40.4	41.5	58.8	24.7	47.6	63.4	28.1	7.7	28.7	49.5	23.9
Growth Rate Assumption												
Slow ³	N/%	38/	298/	25/	261/	128/	36/	121/	49/	97/	145/	171/
		68	81	73.5	81.5	69	88	87	94	85	78	85
Moderate ⁴	N/%	1/	5/	3/	7/	9/	0/	1/	0/	3/	10/	1/
		2.6	1.4	8.8	2.2	4.8	0	.7	0	2.6	5.4	.5
Rapid ⁵	N/%	0/	1/	1/	0/	0/	2/	0/	0/	0/	1/	0/
		0	.3	2.9	0	0	4.9	0	0	0	.5	0
Slow-Moderate	N/%	9/	49/	3/	43/	37/	2/	13/	3/	12/	25/	26/
		15.8	13.3	8.8	13.4	20.0	4.9	9.4	6.0	10.5	13.4	13.0
Moderate-Rapid	N/%	3/	6/	2/	5/	6/	0/	0/	0/	1/	1/	0/
		5.2	1.6	5.9	1.6	3.2	0	0	0	.9	.5	0
Slow-Moderate-Rapid	N/%	6/	10/	0/	4/	5/	1/	4/	0/	2/	4/	3/
		10.5	3.0	0	1.3	2.7	2.4	2.9	0	1.5	2.1	1.5

¹and ² After Glock (1937) relating annual ring growth sequences to environmental and physiological variations.

³Growth rings averaged 1 mm in width; ⁴ 1-2 mm; ⁵ 2 mm or more.

TABLE 15. MEAN CROSS-SECTIONAL AREA AND VARIANCE AND MEAN CROSS-SECTIONAL DIAMETER AND VARIANCE OF OLDEST CROSS-SECTIONS AGED PER AGE CLASS OF EACH SPECIES.

		5-YEAR AGE-CLASS INTERVALS															
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI
		0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80
Rocky Mountain Maple	Cross-Section Area ^a	$\bar{X}$	---	1.5	1.6	6.2	6.8	34.1	28.3	32.0	---	25.0	32.1	15.3	---	35.4	---
	S^2	---	.2	1.6	47.7	17.4	643.3	687.1	1040.2	---	205.5	317.8	---	---	711.8	---	---
	Average Cross-Section Diameter ^b	$\bar{X}$	---	1.4	1.3	2.3	2.8	5.3	4.7	---	5.6	6.2	4.8	---	6.5	---	6.9
	S^2	---	.1	.4	1.8	1.1	12.1	9.0	2.4	---	2.7	3.2	---	---	9.5	---	---
		51-85															
Western Service-berry	Cross-Section Area	$\bar{X}$	.3	.8	2.2	5.1	14.8	15.0	22.8	18.7	57.3	45.3	70.3	---	---	---	---
	S^2	.02	.7	5.4	52.2	328.7	168.0	459.0	216.0	4500.0	455.3	1856.0	---	---	---	---	---
	Average Cross-Section Diameter	$\bar{X}$	.6	1.0	1.5	2.3	3.8	4.0	4.9	4.6	7.6	7.0	9.2	---	---	---	---
	S^2	.02	.2	.4	1.3	4.9	3.3	5.3	3.7	18.2	4.7	9.7	---	---	---	---	---
Silver Sagebrush	Cross-Section Area	$\bar{X}$	---	.5	2.9	6.6	14.7	8.9	10.3	---	---	22.9	18.8	---	---	---	---
	S^2	---	.01	2.9	17.7	174.5	6.1	11.1	---	---	---	54.1	---	---	---	---	---
	Average Cross-Section Diameter	$\bar{X}$	---	.8	1.8	2.8	4.0	3.4	3.7	---	---	5.3	5.0	---	---	---	---
	S^2	---	.009	.6	1.0	3.7	.3	.4	---	---	---	.5	---	---	---	---	---
Big Sagebrush	Cross-Section Area	$\bar{X}$	.2	1.6	3.2	4.0	9.8	10.7	10.7	16.5	17.5	52.2	33.4	---	---	---	---
	S^2	.02	1.2	5.7	19.7	83.1	33.8	35.7	99.0	276.1	610.0	1072.1	---	---	---	---	---
	Average Cross-Section Diameter	$\bar{X}$	.5	1.5	1.9	2.5	3.2	3.6	3.6	4.4	4.4	4.8	5.9	---	---	---	---
	S^2	.05	.7	.6	1.0	2.0	1.2	1.0	1.8	3.5	7.8	8.7	---	---	---	---	---
Rubber Rabbitbrush	Cross-Section Area	$\bar{X}$	.1	1.0	2.1	3.7	9.4	12.5	7.5	---	5.2	---	---	---	---	---	---
	S^2	.004	.8	1.5	11.0	98.5	167.4	14.4	---	---	---	---	---	---	---	---	---
	Average Cross-Section Diameter	$\bar{X}$	.41	1.1	1.6	2.1	3.1	3.7	3.1	---	2.7	---	---	---	---	---	---
	S^2	.01	.3	.3	.7	2.7	4.7	.5	---	---	---	---	---	---	---	---	---
Common Chokecherry	Cross-Section Area	$\bar{X}$	.4	1.3	3.0	4.8	9.2	45.4	29.4	26.3	48.0	---	---	---	---	---	---
	S^2	.2	1.6	16.2	5.3	21.5	1845.3	406.9	283.4	1193.3	---	---	---	---	---	---	---
	Average Cross-Section Diameter	$\bar{X}$	.7	1.2	1.7	2.4	3.2	7.2	5.8	5.6	7.5	---	---	---	---	---	---
	S^2	.1	.3	.2	.4	.7	9.1	5.0	3.4	7.8	---	---	---	---	---	---	---
Antelope Bitterbrush	Cross-Section Area	$\bar{X}$	1.0	.8	3.1	3.7	4.1	7.1	9.6	11.7	18.7	22.2	20.8	20.4	27.4	---	---
	S^2	3.6	.8	8.1	10.5	8.7	22.8	65.5	190.0	483.7	124.4	74.5	39.4	136.5	---	---	---
	Average Cross-Section Diameter	$\bar{X}$	.5	.9	1.9	2.0	2.2	2.9	3.3	3.6	4.5	5.2	5.1	5.1	5.9	---	---
	S^2	.02	.2	.7	.7	.6	1.2	1.7	2.8	5.2	1.9	1.1	.5	1.2	---	---	---
Skunkbush Sumac	Cross-Section Area	$\bar{X}$	.5	.6	1.3	3.6	5.1	6.4	10.1	11.9	17.3	18.4	31.7	20.3	19.5	20.0	43.2
	S^2	.06	.1	.2	6.5	10.4	18.9	36.6	71.7	132.9	190.1	714.8	57.1	6.1	5.8	768.3	123.2
	Average Cross-Section Diameter	$\bar{X}$	.6	.9	1.3	2.0	2.5	2.8	3.5	3.7	4.6	4.6	6.0	5.1	5.0	5.2	7.3
	S^2	.01	.1	.1	.5	.6	.7	1.2	1.9	2.2	2.8	5.6	1.1	.1	.1	6.1	.8
		10-YEAR AGE-CLASS INTERVALS															
		0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-110	111-120				
Curl-leaf Mountain Mahogany	Cross-Section Area	$\bar{X}$	.4	3.5	16.8	42.2	47.9	80.7	95.3	102.7	274.3	183.8	---				
	S^2	.1	38.2	160.9	1729.5	1796.4	5776.8	4528.9	9729.8	32254.1	21186.5	---	---				
	Average Cross-Section Diameter	$\bar{X}$	.7	3.5	4.4	6.7	7.2	9.3	10.7	10.6	17.9	14.2	---				
	S^2	.1	20.4	3.1	10.0	10.8	19.2	14.5	23.4	35.6	42.7	---	---				
Common Juniper	Cross-Section Area	$\bar{X}$	.2	.6	1.8	3.2	12.6	18.1	50.9	27.5	67.1	43.7	23.9	101-125			
	S^2	.005	.4	6.9	7.2	187.9	187.4	2373.3	787.6	3003.0	18.1	3176.0	---	---			
	Average Cross-Section Diameter	$\bar{X}$	.5	.8	1.3	1.9	3.4	4.5	7.2	5.5	8.3	7.7	10.0	---			
	S^2	.008	.1	.5	.5	3.3	3.1	17.9	6.2	22.7	.1	12.5	---	---			
Creeping Juniper	Cross-Section Area	$\bar{X}$	---	---	1.2	2.9	4.2	4.9	7.5	10.2	12.8	12.4	11.6	101-140			
	S^2	---	---	1.8	9.2	2.5	3.2	22.9	26.9	19.8	2.0	36.5	---	---			
	Average Cross-Section Diameter	$\bar{X}$	---	---	1.1	1.8	2.3	2.5	3.0	3.7	4.0	4.0	3.8	---			
	S^2	---	---	.3	.7	.2	.2	.83	.5	.5	.04	1.1	---	---			

a -- Computed with circle area formula (dm^2).

b -- Computed by averaging 2 linear measurements (dm).

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Age distributions and
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