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Title: ECOLOGY OF CURLLEAF MOUNTAIN-MAHOGANY (CERCOCARPUS LEDIFOLIUS NUTT.) IN EASTERN OREGON AND ADJACENT AREAS

Abstract approved: Signature redacted for privacy.

Dr. Richard K. Hermann

Cercocarpus ledifolius (curlleaf mountain-mahogany), a small, hardwood evergreen tree, was studied to provide information on germination and initial seedling growth characteristics, and the species' relationship to its environment and associated vegetation.

Exceptional germination for this species resulted from both a wet cold treatment at 4°C for 170 days (88 percent), and a 15-minute soak in a 30 percent solution of H_2O_2 (64 percent). Total and partial embryo excision indicated two possible deterrents to germination: mechanical impedance by the seed coat or a gas diffusion block by the membrane surrounding the embryo. The latter was concluded to be the most likely deterrent.

Planting techniques must provide for seed coat deterioration by fall seeding (which allows moist winter conditions to do this) or by a brief, strong chemical treatment before spring planting. A

pronounced specialization was demonstrated for rapid root growth in relation to top growth of seedlings for at least 120 days following germination. Under optimum laboratory conditions, the six most vigorous seedlings extended roots an average 1.13 m in 120 days, but developed only 4 cm^2 of leaf area and 2.35 cm of shoot height, indicating a high potential for re-establishment of natural stands after decimation by fire or logging, or in the face of grass and shrub competition. Seedling stem diameter immediately above the root crown was an indicator of root vigor. Seedlings with the largest diameter stems were deepest rooted.

Relationships among Cercocarpus ledifolius ecosystems were examined and 12 habitat types with their attendant plant associations, phases, and successional stages were delineated. Associations and their phases occurred due to topo-edaphic influences. No serious competition between C. ledifolius and other tree species existed in associations described. Where conifers occurred they were uncommon and not expanding their territory. Graminoids were the most predominant understory group in all associations based on dominance and constancy, with south slope associations generally having higher values than those on north slopes. Soil development was weak with no significant differences in solum development noted between exposures. However, percent surface stone on southerly exposures was twice that on the northerly, and percent buried stone volume in the solum was almost one-third greater on southerly exposures.

The survival of _C. ledifolius_ and the communities in which it was dominant were dependent on fire resistant rocky sites. Trees in these niches were larger and older than those on nearby non-rocky sites and provided an available seed source in case fire decimated adjacent stands.

Ecology of Curlleaf Mountain-Mahogany (*Cercocarpus ledifolius* Nutt.) in Eastern Oregon and Adjacent Areas

by

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ECOLOGY OF CURLLEAF MOUNTAIN-MAHOGANY (*Cercocarpus ledifolius* Nutt.) IN EASTERN OREGON AND ADJACENT AREAS

INTRODUCTION

Little is known and little has been written about *Cercocarpus ledifolius*,[1/] yet it is a common species that grows extensively near important vegetation communities which have been studied for many years.

The close-grained wood is used for fence posts, novelty items, charcoal, and firewood. Plants are used to a limited extent as ornamentals and have been cultivated since about 1879 (U. S. Forest Service, 1948). Its economic importance has recently increased due to its value as food and cover for those big game animals managed intensively for hunter recreation.

As a hardwood tree, *C. ledifolius* occupies a unique position at the lower edge of the conifer zone in the Northwest, occurring in extensive narrow belts between the *Pinus ponderosa* forests and high desert steppe. Where the species occurs at higher elevations, it is generally restricted to rocky outcroppings in conifer stands or narrow rocky cliffs (Figure 1). The species occurs in the high

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[1/] Scientific names of plants from Hitchcock et al., 1955-69. Common and scientific names are listed in Appendix B.

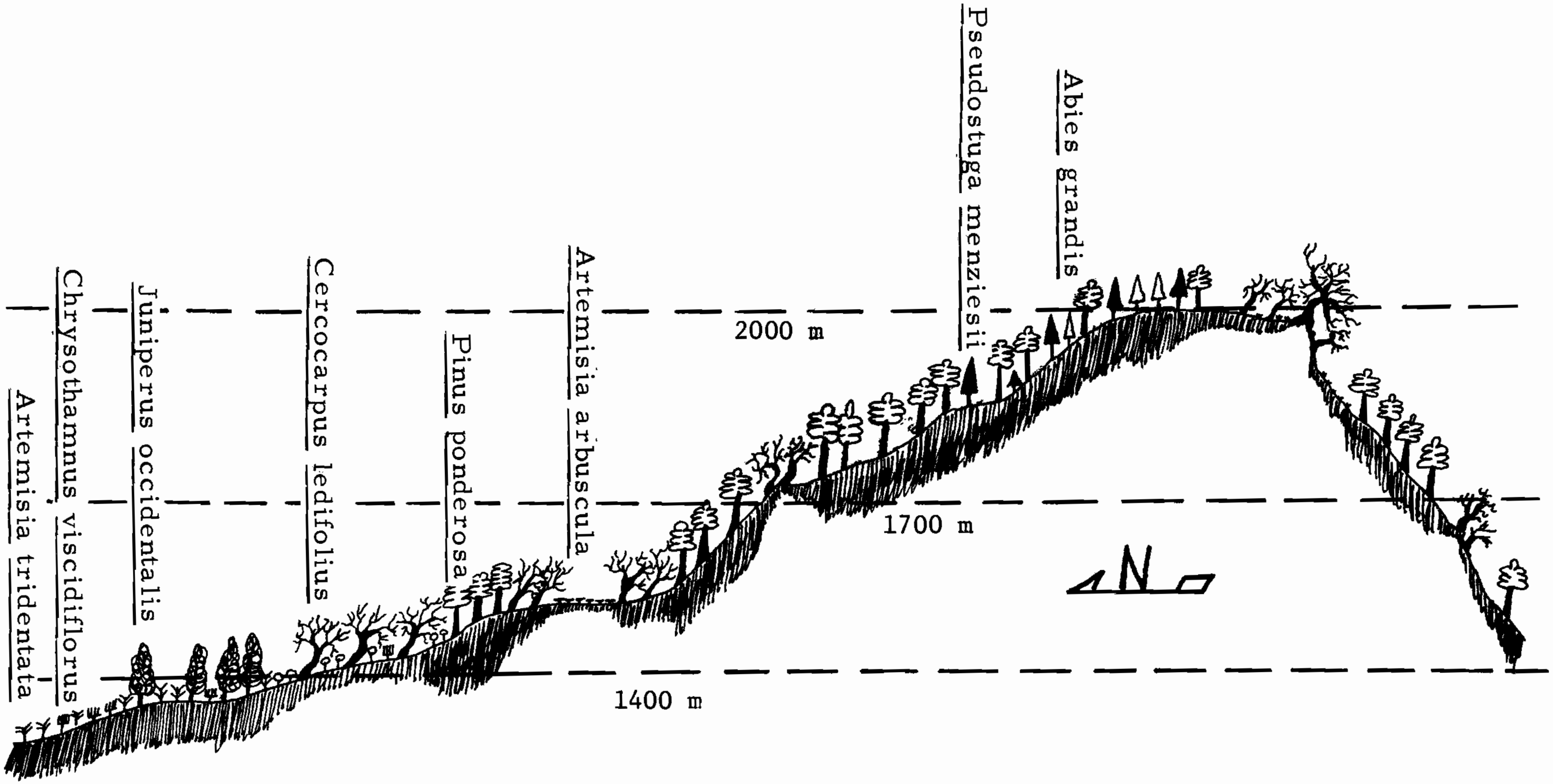

Figure 1. Profile of the occurrence of <u>Cercocarpus</u> <u>ledifolius</u> in the conifer zone. Gross elevation exposure, soil depth, and interspecies relationships are illustrated. Slanted shading below the horizon line indicates a general (and exaggerated) soil depth relationship.

desert steppe above the *Artemisia tridentata* zone. In these mountainous areas, it occurs in extensive stands on moderately deep soil and in small stringers on rocky ridges and cliffs (Figure 2). *C. ledifolius* frequently grows in pure stands and is the only native broadleaf evergreen tree occurring within the study range.

The objective of this study was to provide basic ecological information on *Cercocarpus ledifolius* for germination and initial seedling growth characteristics, and how the species related both to its environment and associated vegetation. As our society changed, the demand for, and value of, various natural resources also changed. *C. ledifolius* increased in importance; however, information on it was lacking. Few tree or other species of higher plants, which exhibited vegetation dominance in ecosystems, have been bypassed by research as has *C. ledifolius*. This study developed some new information on seed dormancy, seed stratification and seedling growth, as well as the first extensive correlation of ecosystems dominated by *C. ledifolius*.

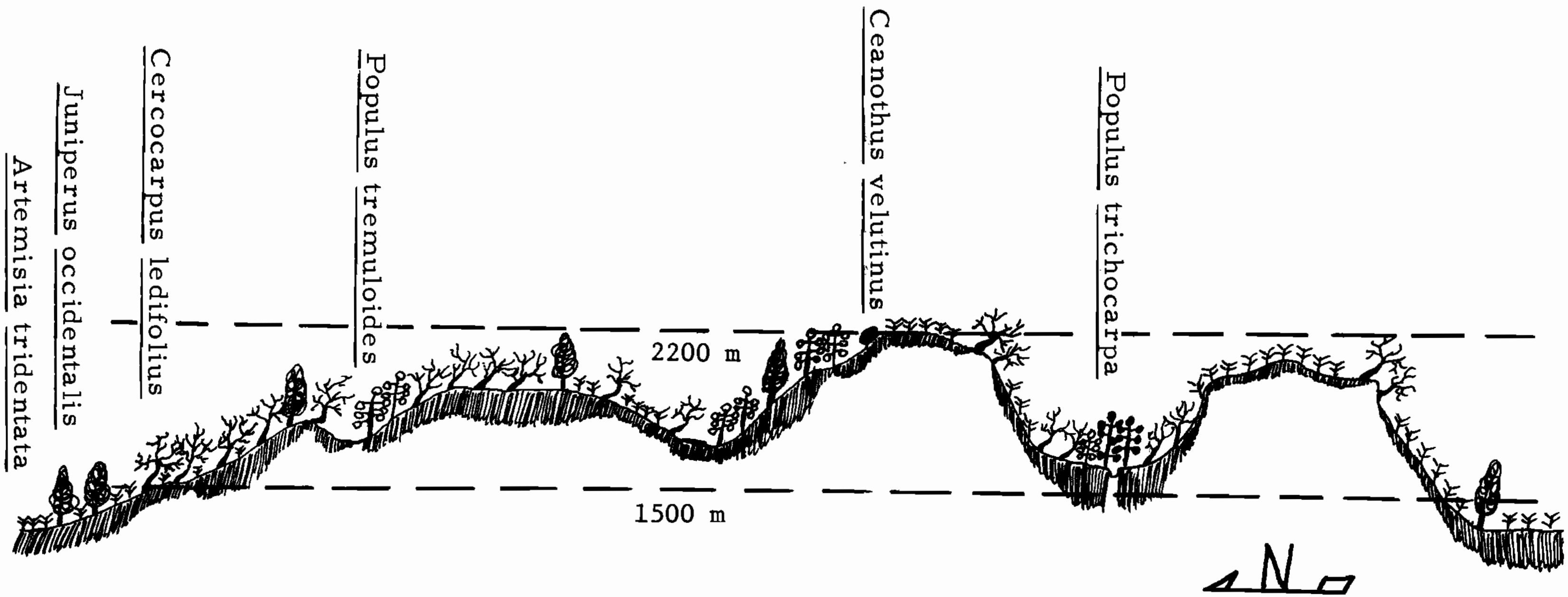

Figure 2. Profile of the occurrence of Cercocarpus ledifolius in the high desert steppe. Gross elevation, exposure, soil depth, and interspecies relationships are illustrated. Slanted shading below the horizon line indicates a general (and exaggerated) soil depth relationship.

PAST WORK

Tree Description

Cercocarpus ledifolius is a species of the family *Rosaceae*, within the section *Sanguisorbeae*, and the monogeneric tribe *Cercocarpeae*. All members of the genus are closely related. Most distinguishing characteristics intergrade freely between species, and hybridization is common at this level (Martin, 1950).

Cercocarpus ledifolius is an evergreen montane xerophyte typically taking a tree form; however, it sometimes occurs as a large shrub. Individuals reach 8 m in height (Hitchcock et al., 1961). According to Pomeroy and Dixon (1966), the largest known plant, considering a combination of measurements, is 7.3 m tall, has a crown spread of 20.4 m, and a stem circumference of 3.2 m 46 cm above the ground (Figure 3). Fruit of *Cercocarpus ledifolius* is distinguished by a feathery style 5 to 8 cm long. The seed has a conspicuous hilum, membranous testa, and an embryo that fills the seed cavity. Flowering occurs during May and June, fruit ripens from June through August, and seed is dispersed during late summer (U. S. Forest Service, 1948). *C. ledifolius* has smooth gray bark on young stems and twigs and dark gray rough bark on young-mature and mature boles and stems. Leaves are leathery,

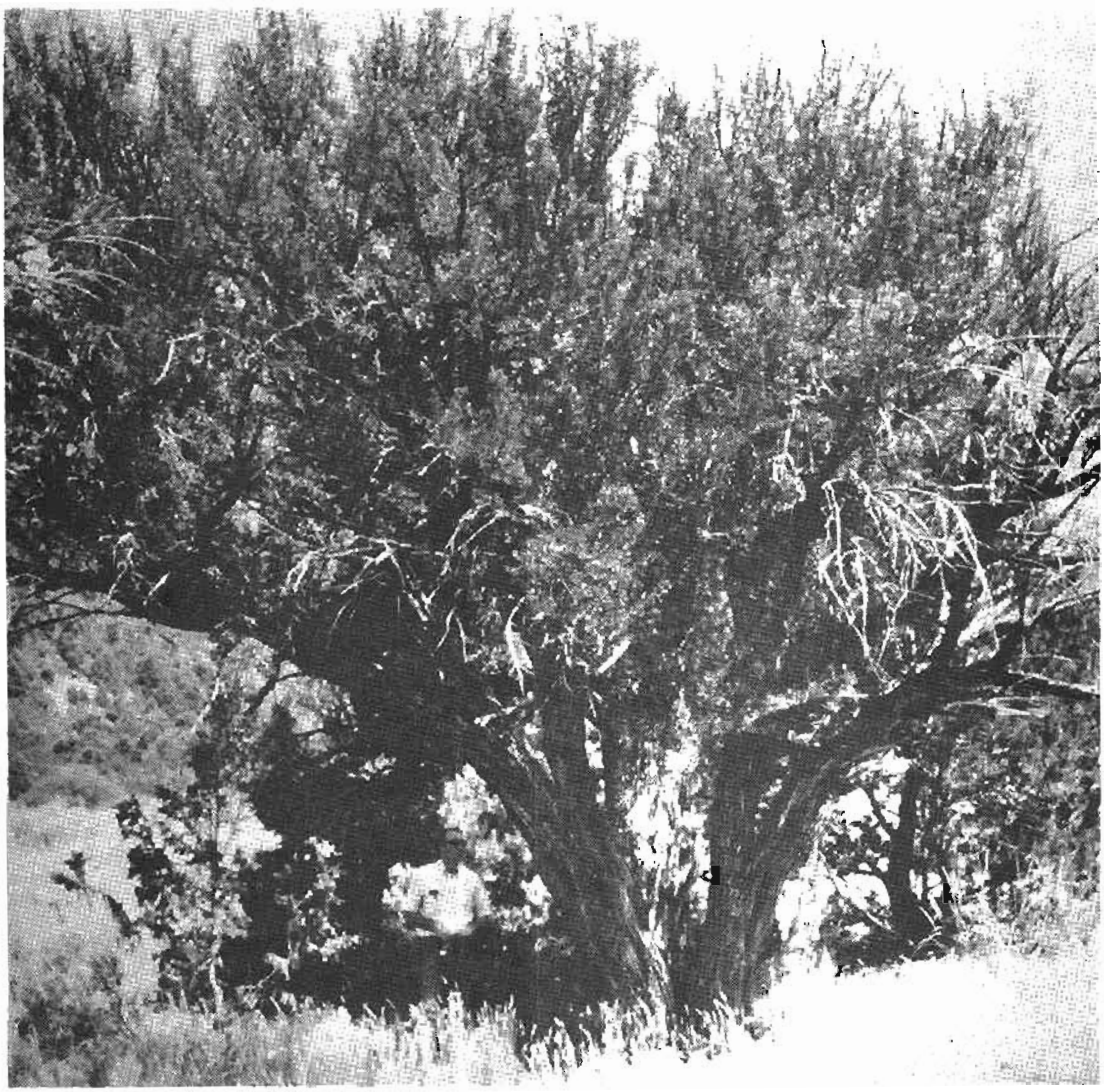

Figure 3. Photograph of the largest known Cercocarpus ledifolius, located on the Humbolt National Forest, Nevada.

eliptical or lanceolate and revolute, with smooth dark green upper surfaces, and pubescent and pale green under-surfaces. Leaf length ranges from 2 to 3 cm and width is about 6 mm (Sampson and Jespersen, 1963). Britton and Shafer (1908) reported specific gravity of wood of this species as 1.07.

Distribution

Range of the genus *Cercocarpus* extends from southeastern Washington and southern Montana south into southern Mexico. From east to west the genus occurs from the west edge of southern Oregon and California to the western portions of South Dakota, Nebraska, Oklahoma, and Texas (Figure 4). *Cercocarpus ledifolius* generally occurs on stony soils from desert foothills to mountain slopes and ranges from extreme southeastern Washington, central Idaho, and southern Montana, south to Baja, California (Martin, 1950; Hitchcock et al., 1961; Abrams, 1944). In Oregon it occurs primarily east of the Cascade Mountain range, but occurs occasionally in the Siskiyou Mountains of southwestern Oregon.

Anatomy

Very little anatomical work has been done on *Cercocarpus ledifolius*. The only work that has been found is in a comparative study of wood anatomy of 55 species, including *C. ledifolius*, by

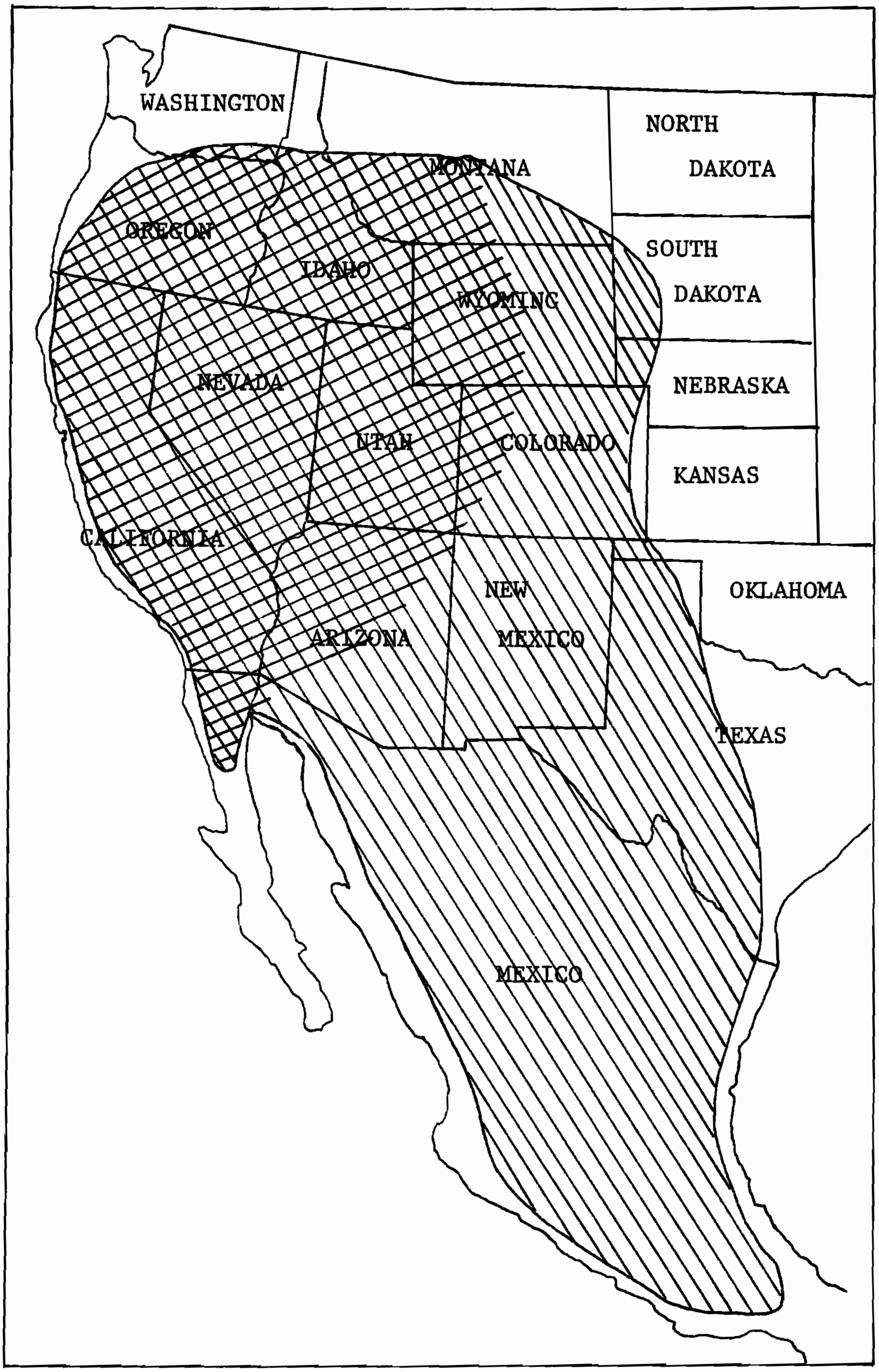

Figure 4. Distribution of the genus Cercocarpus (all shading) and the species C. ledifolius (crosshatching.

Dale (1968). Vessels are present as solitary cells, in pairs or as aggregates. The annual rings are not found to be initiated by a band of large vessels. This is one reason why ring counting is somewhat difficult in this species. The vessels grade into smaller sizes as the growing season progresses. However, there is no abrupt change in size. Also, spacing of vessels remains unchanged during the growing season. Perforation plates are simple, axial parenchyma cells are absent or sparse and diffuse, and rays are one, two, or rarely three cells in width.

Cercocarpus ledifolius is considered a xerophyte (Daubenmire, 1959; Martin, 1950; Green, 1934; Sampson and Jespersen, 1963; U. S. Forest Service, 1948; Abrams, 1944). As a xerophyte it would be expected to have many of those inherent features which provide it with built-in protection against droughty environmental conditions. The most common of these features are found in the leaf. Leaves may possess a thick cuticle, thick cell walls, well-developed palisade parenchyma, sunken stomates, and/or a thick covering of epidermal hairs (Devlin, 1966). Daubenmire (1959) was the only author noted who discussed xerophytic characteristics of *Cercocarpus ledifolius* specifically. He considered both the permanently revolute margins of the blades, and the stomatal openings protected by pubescence on the underside of the leaves as typical xerophytic characteristics.

Germination and Initial Growth

Land managers are continually attempting to use this species in the rehabilitation of rangelands because of its forage value. This may explain why studies conducted on *C. ledifolius* have been concerned mainly with germination and seedling establishment. Available information includes data on seeding habits, seed collection, cleaning and storage, planting (both in the nursery and in the field), seed dormancy, germination, propagation of cuttings, and germination inhibitors.

The U. S. Forest Service (1948) provided the following information and recommendations on methods of collecting and planting seed of *Cercocarpus ledifolius*: (1) Before natural dispersal takes place, seed should be collected by shaking it from the tree onto canvas--fruit is usually dry at this time so no further drying is necessary. (2) Leaves and other debris should be separated from seed by winnowing; if removal of the hairy style is desired, it can be done by rubbing the entire fruit over a screen and then fanning.

In this study it was also found that cleaned seed averaged 97, 000 per kg but varied from 88, 200 to 110, 250. Findings also showed the purity of commercial seed to be approximately 49 percent. One fruit lot of questionable identity (probably *C. montanus*) yielded 10 kg of cleaned seed per 45 kg of fruit; however, no information of this type was available for *C. ledifolius*. Although no seed storage data was available for *C. ledifolius*, it was reported that one lot of *C. montanus* retained high viability after 5 years of dry storage in burlap bags in a warehouse.

Seed dormancy has produced problems in regeneration ever since *C. ledifolius* was first considered for rehabilitation use. Germination is very slow without pretreatment. In one series of tests of germinative capacity of untreated seeds, the U. S. Forest Service (1948) determined that it took approximately 263 days of germination. It was suggested that dormancy probably could be overcome by stratifying the seed in moist sand or peat for 30 to 90 days at 6° C. Woolfolk (1959), working with *Cercocarpus ledifolius* in California, found that germination could be improved from less than 8 percent for untreated seeds to almost 40 percent by soaking the seed in concentrated sulfuric acid for 5 minutes followed by a 4-hour soaking in a 3 percent thiourea solution. An added benefit of the thiourea treatments was the almost complete elimination of mold development on seeds during tests. A full listing of experimental variations are included in Table 1.

A total of 29 combinations of four basic treatments; thiourea, sulfuric acid, hot water, and refrigeration were tried. The thiourea treatment was a simple soak of seed in a 3 percent solution. The sulfuric acid soak was followed with a tap water rinse, a

Table 1. Treatment effects on germination of <u>Cercocarpus ledifolius</u> seed (Woolfolk, 1959).

Test number	Treatment	Germination in 30 days (Percent)
	1. Thiourea (3 percent solution	
1	4 hours	22
2	8 hours	15
3	16 hours	14
4	24 hours	19
	2. Sulfuric acid (concentrated)	
5	30 minutes	31
6	60 minutes	16
7	90 minutes	0
	3. Sulfuric acid-thiourea	
8	5 minutes acid, 1 hour thiourea	14
9	5 minutes acid, 2 hours thiourea	28
10	5 minutes acid, 4 hours thiourea	39
11	10 minutes acid, 1 hour thiourea	13
12	10 minutes acid, 2 hours thiourea	14
13	10 minutes acid, 4 hours thiourea	28
14	20 minutes acid, 1 hour thiourea	11
15	20 minutes acid, 2 hours thiourea	14
16	20 minutes acid, 4 hours thiourea	35
	4. Hot water-thiourea	
17	0 hours thiourea after boiling water bath	0
18	4 hours thiourea after boiling water bath	1
19	8 hours thiourea after boiling water bath	T
20	16 hours thiourea after boiling water bath	0
	5. Refrigeration	
21	0° C, 1 day	2
22	0° C, 2 days	1
23	0° C, 4 days	1
24	0° C, 8 days	0

Table 1. Continued.

Test number		Treatment	Germination in 30 days (Percent)
25		5° C, 1 day	2
26		5° C, 2 days	1
27		5° C, 4 days	3
28		5° C, 8 days	2
	6.	No treatment	
29		Control	7

neutralizing soak in dilute bicarbonate of soda, and then another tap water rinse. The hot water treatment was a boiling water soak where the water was allowed to cool to room temperature before removal of seeds. Seeds from the hot water bath were subsequently treated with thiourea. Seeds from all treatments except refrigeration were air-dried for about 24 hours following treatment and before being set out to germinate. Each test consisted of eight replications of 50 seeds each on moist blotters in sterilized covered petri dishes. For testing purposes they were held for 30 days at 16° and 20° C. Seeds were considered germinated if the radicals were at least 6 mm long. Any questionable germinants were planted in vermiculite at 6 mm depth, and those which emerged were considered to have germinated.

The complete lack of germination with the hot water treatments indicated permanent damage to the embryo. Prechilling had no beneficial effect. It appeared to have had a depressing or retarding effect. Woolfolk (1959) also reported that at least one causative factor in *Cercocarpus ledifolius* seed dormancy might have been the presence, in the seed coat, of saponin--a substance that he reported had been proven as a germination inhibitor of other species. Moore's (1963) findings gave tentative evidence that cyanide was the active inhibitor in extracts from *C. montanus*. He demonstrated that the extracts inhibited germination and growth in radishes, lettuce, sunflower, cucumber, tomato, peas, and oats. The exact identification of the inhibitor was not made but extracts were amber in color, had no measurable difference in hydrogen-ion concentration or osmotic concentration from distilled water, and were stable at room temperature for over 6 weeks.

The U. S. Forest Service (1948) suggested that germination tests be made for 20 to 60 days in sand or soil flats using 1, 000 pretreated seeds per test, and keeping temperatures at 20°C at night and 30°C during the day. For nursery and field practice it was recommended that untreated seed be planted in the fall and seed treated to break dormancy in the spring. In either case, instructions were to plant 6 mm deep, covering the seed with screened sand. The long feathery style created a problem if left intact when sown. In this case it was suggested that the seed be soaked for 30 minutes to straighten the style; otherwise, as the dry twisted "tail" became moist in the soil, it would uncurl and twist the seed to the surface. It was suggested that the soil be kept moist until germination of the seeds. It was noted that damping off could be a problem in alkaline soils.

For field planting of seedlings, the U. S. Forest Service (1948) recommended that 2-year-old stock be planted on well-drained soils in sunny locations. There was only a brief mention of propagating cuttings, with no data on procedures. The only statement on the subject was that "*Cercocarpus* species may also be propagated by cuttings of half-ripened wood under glass."

Establishment, survival, and yield studies of *Cercocarpus ledifolius* among other species, were conducted in the upper and lower edges of the juniper-pinyon belt of central Utah by Plummer et al. (1959). The upper elevation was 2226 m and the lower was 1768 m. Precipitation varied from 28 to 43 cm and soil fertility from low to high, with soil organic matter varying from less than 2 to more than 7 percent. Direct seeding, seedling transplants, and transplants of nursery stock and wild seedlings were conducted. Success ratings were expressed as high (H), medium (M), low (L), and none (N). It was shown that in general *C. ledifolius* was difficult to establish, had relatively poor survival, and yield was consistently poor. The only exceptions were establishment and survival of nursery and wild seedlings at the upper elevation, and direct seedings at the lower elevation. Plummer also reported that 97 kg of seed were collected and cleaned, resulting in a collection with approximately 73 percent purity at a cost of $7.90 per kg.

No information was found for *C. ledifolius* concerning sprouting after wildfire. However, Plumb (1961) reported that *C. betuloides* was observed after being burned in a wildfire on the San Dimas Experimental Forest in California. Plants were observed on sites at 640, 945, and 1,250 m elevation in mountainous terrain approximately 4-1/2 months after a fire. From an average of 14 plants selected at random on each site, observations showed sprouting was 78, 57, 58, and 64 percent, respectively.

Nutrition

The most thorough nutritional study done to date on *C. ledifolius* was conducted by Hickman (1966) in south-central Oregon where he was studying a group of plant species occurring in forest edge communities. *Cercocarpus ledifolius* was growing in association with *Pinus ponderosa* and *Festuca idahoensis* at the upper edge of a mule deer (*Odocoileus hemionus hemionus* Raf.) winter range. The area was also a spring range for cattle. Table 2 illustrates the completeness of the analysis; it included a determination of apparent digestibility (dry matter disappearance--DMD), using a 48-hour digestion period in rumen fluid from a steer. The amount of crude protein varied narrowly between 8.8 and 11.4 percent throughout the year; during the spring and summer periods it was 10.2 to 11.4 percent and the rest of the year it ranged between 8.8 and 9.7 percent. Ash content stayed between 3.4 and 4.7 percent throughout the year. Calcium ranged between 1.18 and 1.51 percent, phosphorus ranged between 0.16 and 0.26 percent, the calcium-phosphorus ratio varied from 4.54:1 to 9.44:1, crude fiber ranged from 14.0 to 20.1 percent, crude fat ranged from 5.45 to 8.46

Table 2. Analyses of <u>Cercocarpus ledifolius</u> (Hickman, 1966). Data are in percent except for the Ca:P ratio.

Date	Moisture	Crude protein	Ash	Calcium	Phosphorus	Ca:P	Crude fiber	Crude fat	Appar. dig.
Late Feb.	42	9.1	3.4	1.51	0.16	9.44	15.2	8.46	37.0
Late March	44	9.4	3.9	1.37	0.19	7.21	16.1	7.70	--
Mid-April	47	9.7	3.8	1.34	0.19	7.05	14.0	8.33	35.9
Early May	49	10.4	4.4	1.31	0.23	5.70	--	--	--
Mid-May	50	11.0	4.4	1.44	0.23	6.26	14.6	7.67	31.9
Early June	53	11.4	4.7	1.37	0.25	5.48	17.0	7.22	--
Late June	57	11.1	4.3	1.18	0.26	4.54	20.1	6.21	25.2
Early July	54	10.7	-	1.18	0.24	4.92	20.0	5.45	--
Mid-July	53	10.2	4.5	1.40	0.19	7.37	19.3	7.21	33.7
Mid-Sept.	41	9.6	4.1	1.24	0.16	7.75	19.4	7.20	35.0
Late Oct.	40	9.7	4.1	1.29	0.18	7.17	16.7	7.90	36.9
Late Nov.	40	9.0	4.0	--	--	--	15.9	8.32	--
Late Dec.	43	8.8	3.7	1.29	0.16	8.06	--	--	29.7

percent, and apparently digestibility varied from 25.2 to 37.0 percent.

In California, Bissell and Strong (1955) collected samples of *C. ledifolius* monthly throughout the year for determining crude protein content. Percentages ranged between 6.2 and 12.3 with the highest occurring between May and August.

There was only one study noted which dealt with nitrogen fixation by root nodules of *Cercocarpus ledifolius* (Youngberg and Hu, 1972). These authors collected plants from a stand at the edge of the *Pinus ponderosa* zone in central Oregon. The plants were without nodules. They were placed in pots of a soil type in which other species were known to have nodulated readily. After 8 months of greenhouse growth, 46 percent had nodules with caralloid morphology. The isolated endophyte had streptomyces characteristics. Foliage nitrogen content was highest in nodulated plants.

Insect Occurrence

Only two studies were noted which dealt with insects that occurred on or attacked *C. ledifolius*. Kraft (1960) found 14 species of insects on *C. ledifolius* throughout eastern Oregon. These insects were discovered incidentally in conjunction with a study primarily pointed toward insects affecting *Purshia tridentata*, and were not considered a complete collection (Table 3).

Table 3. A tabulation of insects found on *Cercocarpus ledifolius* including order, family, genus, and their relationships to the plant (Kraft, 1960).

Species	Relationship or part of plant attacked	Known or possible economic importance
Order Hemiptera		
Family Anthocoridae		
Orius tristicolor (white)	Insect predator	This small bug was considered important as a predator on aphids, chermids, and other small arthropods.
Family Miridae		
Plagiognathus spp.	Leaves and twigs	Potentially great. Three species were found. No observable damage was noted, however, these bugs were considered by Kraft as factors in the degeneration of range plants.
Ectopiocerus sp.	Leaves	Unknown
Clamydatus sp.	Leaves	Unknown
Order Homoptera		
Family Psyllidae		
Euphalerus adjustus Tuth.	Unknown	Unknown
Euphalerus sp.	Unknown	Unknown
Psylla brevistigmata acuta Grawf.	Unknown	Unknown
Psylla insignita Tuth.	Unknown	Unknown

Table 3. Continued.

Species	Relationship or part of plant attacked	Known or possible economic importance
Psylla magna Grawf.	Unknown	*P. magna* was reported as being the most abundant and widespread species of the six species of chermids found.
Psylla omani Tuth.	Unknown	Unknown
Order Coleoptera		
Family Scolytidae		
Renoci's heterodoxus Cys.	Bark, cambium	Secondary attacker. In most stands, Kraft reports several trees being attacked by this bark beetle. He observed that the beetles attack weakened limbs and kill them. The damage could be detected by severe yellowing of leaves. By the second or third year of attack, the branches died and the beetle mines became very extensive. Healthy limbs apparently defended themselves by secreting a resinous exudate in each attempted entrance hole made by the beetles.

Table 3. Continued.

Species	Relationship or part of plant attacked	Known or possible economic importance
Family Burprestidae		
Dicerca horni Crotch	Wood, cambium	Great. This species was reported as a common destructive pest in the West. The larvae were reported to mine the wood and cambium of injured, dying and dead limbs. Both larvae and adults were reported mining in the dead wood and in living cambium of an injured limb.

Furniss and Barr (1967) conducted a bionomics study on the insect species Anacamptodes clivinavia profanata, a leaf defoliator. The insect totally destroyed 46 percent of a 2, 429 hectare stand of C. ledifolius over a period of 3 years in southwestern Idaho. The authors concluded that starvation, rather than disease or predation, was the major reason why the insect population finally died out.

Ecosystem Relationships

Information on Cercocarpus ledifolius in relation to site and associated plants was sketchy. Hickman (1966), working in south-central Oregon, sampled a community dominated by Pinus ponderosa with a secondary canopy of C. ledifolius and an understory of Festuca idahoensis. This type of community was found in an ecotone between the P. ponderosa-Purshia tridentata-F. idahoensis community and the high desert steppe. Elevation was 1, 433 m, and annual precipitation approximately 36 cm. This was the same community Dealy (1971) described as the Pinus ponderosa-Cercocarpus ledifolius/ Festuca idahoensis "ecosystem." Dealy (1971) described two C. ledifolius "ecosystems" in the same area; one strongly dominated by F. idahoensis with a scattering of Artemisia tridentata and a lesser composition of Chrysothamnus viscidiflorus, Amelanchier alnifolia, Ribes cereum, and Tetradymia canescens, and a second with the same tree dominant but two additions to the shrub layer; Purshia tridentata and C. nauseosus, and a grass layer with codominants of F. idahoensis and Agropyron spicatum. The diagnostic perennial forb for each "ecosystem" was Hieraceum cynoglossoides and Balsamorhiza sagittata, respectively. Scheldt and Tisdale (1970) placed Cercocarpus ledifolius of Idaho in a zonal position between the grassland or sagebrush-grass vegetation of the plains and lower slopes, and the forest zones of Pinus ponderosa and Pseudotsuga menziesii.

Green (1934) found C. ledifolius in association with chaparral and one-leaf pinyon pine, and occasionally in pure stands on arid mountain slopes. Tidestrom (1935), in discussing floras of Utah and Nevada, described C. ledifolius as having occurred in the upper pinyon, yellow pine, and aspen belt. He stated that in central Nevada it largely replaced the yellow pine and aspen in the middle mountain belt. Here it formed a conspicuous belt between pinyon pine and white pine colonies. Julander (1955) placed it as a major species in the mountain shrub type along with Gambel oak (Quercus gambellii) and Artemisia tridentata. Sampson and Jespersen (1963) found it growing with a great variety of plants ranging from sage-brush and the pinyon-juniper association to the subalpine forest. Oosting (1948) placed C. ledifolius in a climax community with oak. He stated that north of the latitude of Denver, Colorado, oak became spotty and C. ledifolius, along with C. parviflorus and other species of the genus, became dominant. He also stated this was a transitional community between conifer forests of the lower Rocky Mountain slopes and treeless plains and plateaus.

The vegetation of the Rocky Mountain and Great Basin was described by Weaver and Clements (1938) as having Cercocarpus ledifolius as a dominant constituent. They felt climax expression of this complex was restricted primarily to elevations between 1, 521 and 2, 439 m in Colorado, northern New Mexico, and eastern Utah. They placed it in a subclimax form, poorer in species members and reduced in stature, along the foothills from South Dakota to Texas and from the north to the south extremities of the Great Basin.

Soil Relationships

Soil information was sketchy or absent in most geographic areas where C. ledifolius was studied. Most authors only described soils as being arid and rocky (Sampson and Jespersen, 1963; Green, 1934) or rocky and immature (Scheldt and Tisdale, 1970). Dealy (1971) described soils from three "ecosystems" in southcentral Oregon. Soil under one community dominated by Pinus ponderosa with C. ledifolius as a single low canopy constituent, was described as a shallow phase of Tournquist loam[2/] occurring under the

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[2/] Tentative.

adjacent *P. ponderosa/Purshia tridentata/Festuca idahoensis* "ecosystem". The other two soils were described under dominant stands of *C. ledifolius* in a position adjacent to and below the *P. ponderosa* zone. Both were moderately shallow stony loams over cracked basalt. Neither had a well developed B horizon.

ORIGIN AND HISTORICAL DISTRIBUTION

In ecological studies of a species such as Cercocarpus ledifolius, it is important to review its historical and evolutionary origins. From this information we may be able to understand relationships of C. ledifolius to its environment and to competing species. Such insights may help us understand why it is present on shallow, rocky soils instead of on adjacent sites with deeper, more productive soils.

This literature search on the history of C. ledifolius began with the earliest relevant records, including genera citations, and traces developments to the present.

Phylum Origin

Many students who studied the history of western North America floras (Axelrod, 1939, 1940; Chaney, 1944; Berry, 1929) believed that plants, particularly in the phylum Angiospermae, consistently moved more typically in a north-south direction than any other. Axelrod (1959), in discussing migration of early angiosperms, stated that the phylum originated in and dispersed from tropical latitudes (45° N and 45° S) in pre-Cretaceous times. There was no record of the genus Cercocarpus during that time; however, the general location of the phylum did set the stage for evolutionary development of the genus Cercocarpus during more recent times.

Madro-Tertiary Flora

The Madro-Tertiary flora was first identified in rocks of the Miocene and possibly Oligocene epochs in the southern part of the western United States (Chaney, 1944). During this period the Cascade Range of Oregon and the northern Sierra Nevada of California were low and had little influence on the climate of western North America. The southern Sierra Nevada and Sierra Madre mountains had a much greater climatic influence and produced a dry area in the southwest United States (including the southern Great Basin) and northern Mexico where the xerophytic Madro-Tertiary vegetation could develop. Representative genera included Mexican Arbutus, Cercocarpus, Ceanothus, Pinus, Populus, Prosopis, Quercus and Prunus. Formations such as oak-pinyon woodland, savanna, chaparral (including Cercocarpus), and desert scrub were present (Axelrod, 1940).

During the Miocene epoch, the Madro-Tertiary flora began expanding up the east edge of the rising Rocky Mountains. To the west a warm, moist climate supported a rich, temperate forest flora including such genera as Alnus, Fagus Lithocarpus, Thuja-like species, Abies-like species, and Sequoia (Chaney, 1944).

During this late Tertiary period there was extensive uplifting of the north Sierra Nevada and Cascade ranges. This reduced rainfall 25-30 cm below that which occurred during the Miocene epoch (Axelrod, 1940). As drying occurred, the precipitation changed to a dry summer-wet winter pattern and seasonal temperature fluctuations became extreme. In effect, the climate became more optimal for Madro-Tertiary species and too hot and dry for the rich, temperate forest flora.

Migrating northward, this xerophytic vegetation, including *Cercocarpus*, attained its greatest distribution during the late Tertiary period. It ranged north through the Great Basin as far as the Columbia Plateau, west to California and east to Oklahoma.

In discussing the Great Basin area during the late Tertiary period, Axelrod (1940) placed the north Mexico xerophytes in three general communities. In the north was relict redwood forest flora (montane forest), in the central area, oak-juniper woodlands, including *Cercocarpus*, and in the south, desert border vegetation. Interestingly, he placed *Cercocarpus* in both the woodland and chaparral or desert border formations.

Eyre (1963) placed *Cercocarpus ledifolius* in the chaparral formation which moved as far north as the foothills of the Rocky Mountains in Wyoming and was situated ecologically just below the woodland formation. Eyre also described the chaparral as having typically occupied a narrow belt where mean annual precipitation was 38-51 cm. As mentioned earlier, Axelrod (1940) assigned Cercocarpus to both the chaparral and woodland communities and estimated "woodland" rainfall at roughly 36-46 cm annually. Eyre assigned the same genus to chaparral and gave approximately the same annual precipitation.

Cercocarpus, at least the ancestor of C. ledifolius, could reasonably be assumed a member of the chaparral formation since C. ledifolius currently fits best there. This was further supported by Heit (1971), whose studies seemed to indicate an inhibiting substance or chemical in the seed coat of C. ledifolius which delayed seed germination. This phenomenon commonly occurred among highly xerophytic species as a protection against germination until sufficient moisture had fallen to have assured establishment.

During the late Tertiary, the uplift of mountain axes continued, reducing the rainfall and creating more severe temperature conditions. Summer precipitation diminished and many chaparral elements retreated south. The northern temperate flora was eliminated as such, and genera such as Sequoia retreated to isolated spots. The regular woodland dominants retreated to the southwest United States and north Mexico as summer rains disappeared from the western Great Basin. Axelrod (1940) believed the Great Basin sagebrush (Artemisia sp.) now occupies the area of the late tertiary woodland (includes Cercocarpus). He believed the Artemisia was seral in early Pliocene, moving north with the woodland in late Miocene. He also felt that the Great Basin sagebrush was clearly post-lower Pliocene in its development as the climax formation.

The time and location at which Cercocarpus ledifolius originated could only be inferred from genus origins. The species identified by Berry (1929) as C. praeledifolius was discovered as fossil remains in two separated Miocene floras, one the Tehachapi on the western border of the Mojave desert in California (Axelrod, 1939), and the other the Latah (Chaney and Axelrod, 1959) of the Columbia plateau. The Latah flora was identified near Spokane and Grand Coulee, Washington, and Coeur d'Alene and Whitebird, Idaho, and dated as of the Miocene epoch.

Species Migration

If C. praeledifolius was the ancestor of C. ledifolius, there were two possible routes by which C. ledifolius could have migrated into its present range. The first and most likely was the route which was traced above; movement north with the main stream of Madro-Tertiary vegetation through the Great Basin and Columbia plateau. The alternative was through a migration of C. praeledifolius from the East as a cordilleran element. Berry's

(1929) identification of C. praeledifolius as a component of the Latah flora in northern Washington and Idaho caused Axelrod (1939) to speculate that, since this flora was placed in the late Miocene epoch, its occurrence may have been a little early to have moved north through the intermountain region. If this were true, then it could have moved in from the East as a cordilleran element, a part of the Madro-Tertiary flora that began an early (Miocene epoch) northern movement up the east side of the Rocky Mountains. In a later article, Chaney and Axelrod (1959) questioned the identification of C. praeledifolius from the Latah flora. The species was not totally rejected; first, because collections were sufficient to warrant further analysis, and second because there were some southern oaks and madrones of Madro-Tertiary origin in the flora which were acceptably identified.

Ecological Position

In the Northwest, Cercocarpus ledifolius occupied a narrow belt between the high desert steppe and the conifer zone, or a comparable precipitation zone in the mountains of the high desert. This position reflected the mean annual rainfall of 36-46 cm Eyre (1963) and Axelrod (1940) assigned to chaparral and woodland communities in which C. praeledifolius occurred during the Tertiary period. As was mentioned earlier, the Cascade Mountains increased in height during the late Tertiary, reducing the interior rainfall. As summer precipitation diminished, many chaparral and woodland elements retreated south. C. praeledifolius was able to adapt to a narrow moisture belt and remain. C. ledifolius, evolving in this position, seemed to be boxed into a narrow ecotone from which expansion appeared difficult either up in elevation, due to physical size and competition of conifers, or down due to unfavorable moisture conditions.

Cercocarpus ledifolius occupied a range closely approximating the maximum extension of the Madro-Tertiary flora. Since the fossil species C. praeledifolius closely resembled C. ledifolius, and since there was no other intermediate fossil species found, it appeared that our current species developed from C. praeledifolius, beginning its evolution in or near the Pliocene epoch.

METHODS

Study Area

This study was conducted in Washington, southwestern Idaho, most of Oregon east of the Cascade Mountains, northwest Nevada, and northeastern California. The area was divided into physiographic units by Dicken (1955). They are illustrated in Figure 5.

Blue Mountains

The Blue Mountain region of the Northwest extended from the Deschutes plateau edge north to southeast Washington and through northeastern Oregon. This included the Ochoco, Strawberry, Elkhorn, Greenhorn, Wallowa, and Blue Mountains proper. The region had variable relief with mountain ranges separated by faulted valleys and synclinal basins which contained Late Cenozoic beds and igneous flows. The Wallowa Mountains exhibited the most extreme relief (Baldwin, 1959).

Cercocarpus ledifolius occurred throughout the north portion of this region in small patches and stringers on dry rocky slopes of ridges within the conifer zone. In the Ochoco, Greenhorn, and Strawberry mountains, large stands occurred at the lower edge of the *Pinus ponderosa* zone.

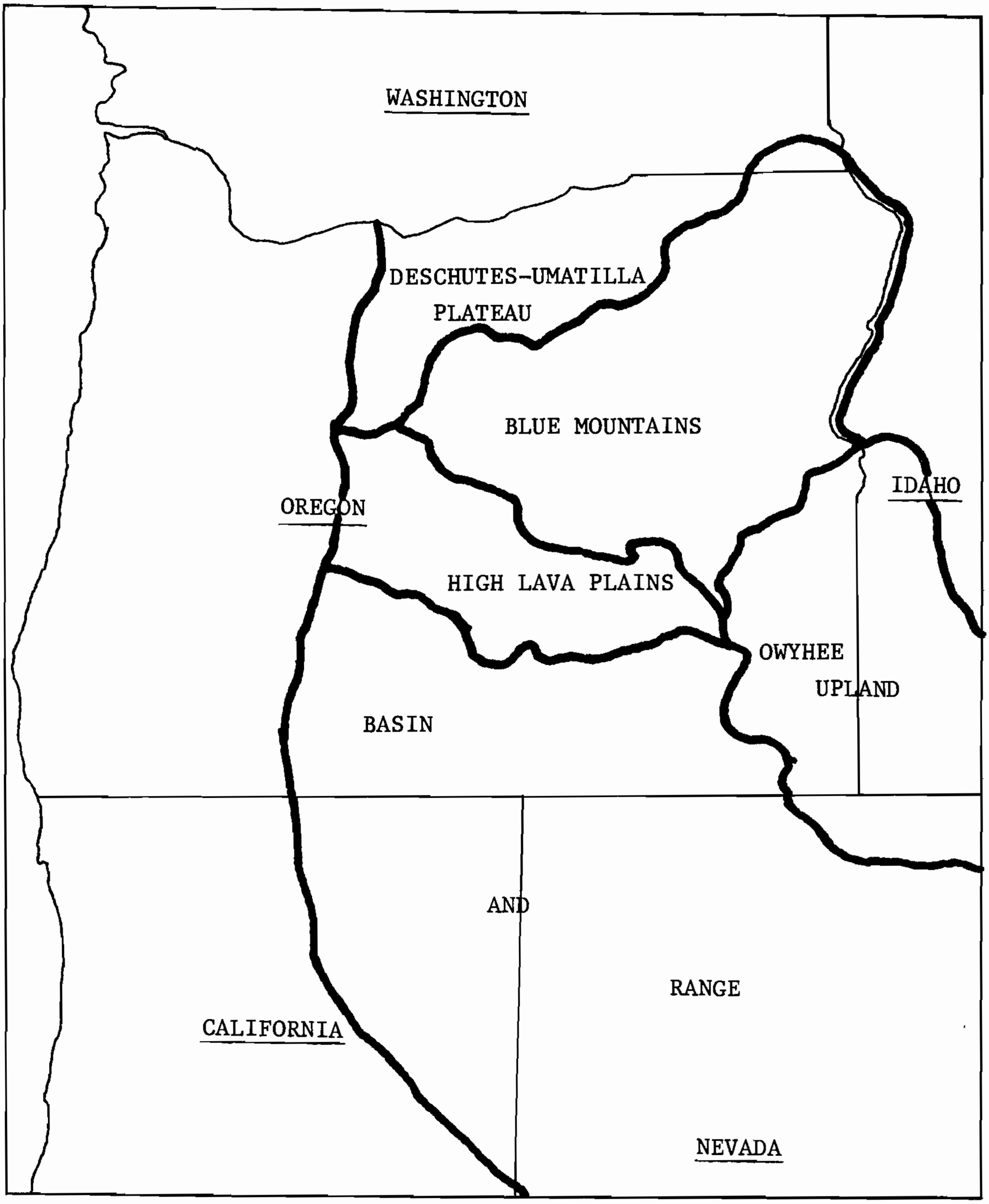


Figure 5. Physiographic divisions of the study area. After Dicken (1955).

Basin and Range Province

The Basin and Range province, according to Baldwin (1959) ranged from the eastern edge of the Cascade range, east through parts of California and Idaho, Utah, Arizona, and New Mexico. The area of Oregon was characterized by north-south fault block mountains, and basins with internal drainage. Most of this portion of the province uplands was over 1220 m in elevation with several mountains rising over 1900 m. The Steens Mountains were the highest, rising to 2948 m.

At the west edge of the Basin and Range province, *Cercocarpus ledifolius* grew in large groves along the lower edge of the Fremont National Forest. From there the species occurred commonly throughout the prominent mountains of the high desert steppe.

Owyhee Uplands

The Owyhee Uplands was situated against the Basin and Range province on the west and south, and ranged from Ontario, Oregon, south into the Owyhee River drainage of Malheur County, Oregon, and Owyhee County, Idaho. Mahogany Mountain, in the southern portion of these uplands, was a 1989 m high ridge of rhyolite which had one of the most extensive stands of *C. ledifolius* in the study area. The species extended along the ridge top for several thousand acres in an almost continuous blanket, and occurred on moderately shallow to moderately deep well-drained gravelly loam soils.

Germination and Initial Growth

Laboratory and field studies were conducted to begin characterizing the germination and establishment portion of *Cercocarpus ledifolius*' life history. Viability tests were conducted and X-rays were taken by the Oregon State University Seed Testing Laboratory on seed from a stand growing on basalt soils in the northwest corner of the Basin and Range Province. Two seed collections from the same trees were made 2 years apart.

The same seed lots were used for studies of stratification, germination, establishment, and root extension.

Stratification tests were conducted both in the laboratory and under natural conditions. Laboratory methods consisted of petri dish samples treated with moisture and a 4° C temperature, each on filter paper, on sterile quartz gravel and on charcoal. Some samples were immersed in aerated and distilled H_2O for 170 days at 4° C and then placed in petri dishes for germination. Others were imbibed, placed in cheese cloth bags, held at 4° C for 170 days, and then germinated in petri dishes at 20° C. One treatment consisted of soaking 200 seed samples in a 30 percent solution of

H_2O_2 for 5, 10, 15, 30, and 60 minutes each, with seeds placed in a 20°C environment for germination. Twenty-eight embryos were excised from their seed coats, one-half of which were placed in each of two petri dishes on wet filter paper and germinated at 20°C under normal fluorescent room lighting. Also, 28 seeds were partially excised by removing the symphysis along one side of each seed coat and cutting off the radical tip of each; then the seeds were germinated in a 20°C environment with normal fluorescent room lighting.

For a natural winter stratification, three replications of 1,000 unstratified seeds were placed outdoors in November in flats of a soil taken from a _Cercocarpus ledifolius_ site.

A root extension study was conducted on newly germinated seedlings of _C. ledifolius_ to determine rate of root growth under optimum spring conditions. Twenty-four 7.6 x 122 cm pyrex tubes were used in a randomized block design, 4 tubes per block. A lightly packed mixture of loam from a _C. ledifolius_ site and peat moss was used in a ratio of 4 to 1. Soil moisture was kept at field capacity throughout the study. A growth chamber was programmed for a spring environment with a 14-hour photoperiod and day-night temperature levels of 24° and 5°C respectively. The study was concluded when the roots of the first plant reached the end of the tube.

Ecosystem Sampling

Stands of Cercocarpus ledifolius were located in as many different geographical locations and as many widely differing conditions as possible within the physiographic divisions illustrated in Figure 5. Approximate stand locations are illustrated in Figure 6. Plot size was a 30 m diameter circle for all measurements. Four 15 m transects equally spaced, radiated from the plot center. Transects sampled crown cover (Dealy, 1960) and stem density of trees, including general tree age categories, and in certain cases tree stem sections for aging. General tree age categories are as follows:

1. Established seedling - stem less than 5 mm in diameter, some branching, smooth bark.
2. Young - well branched, bark still smooth.
3. Mature - well developed tree of any size. Bark dark grey, rough and fissured.
4. Overmature - Large trees with crowns more than 25 percent dead.

Species were recorded in the large plot and placed in a dominance rating for tree, shrub, grass, and forb layers (Tansley and Chipp, 1926). Dominance ratings and their criteria are as follows:

5. Very abundant - clearly dominant in its own vegetation layer.

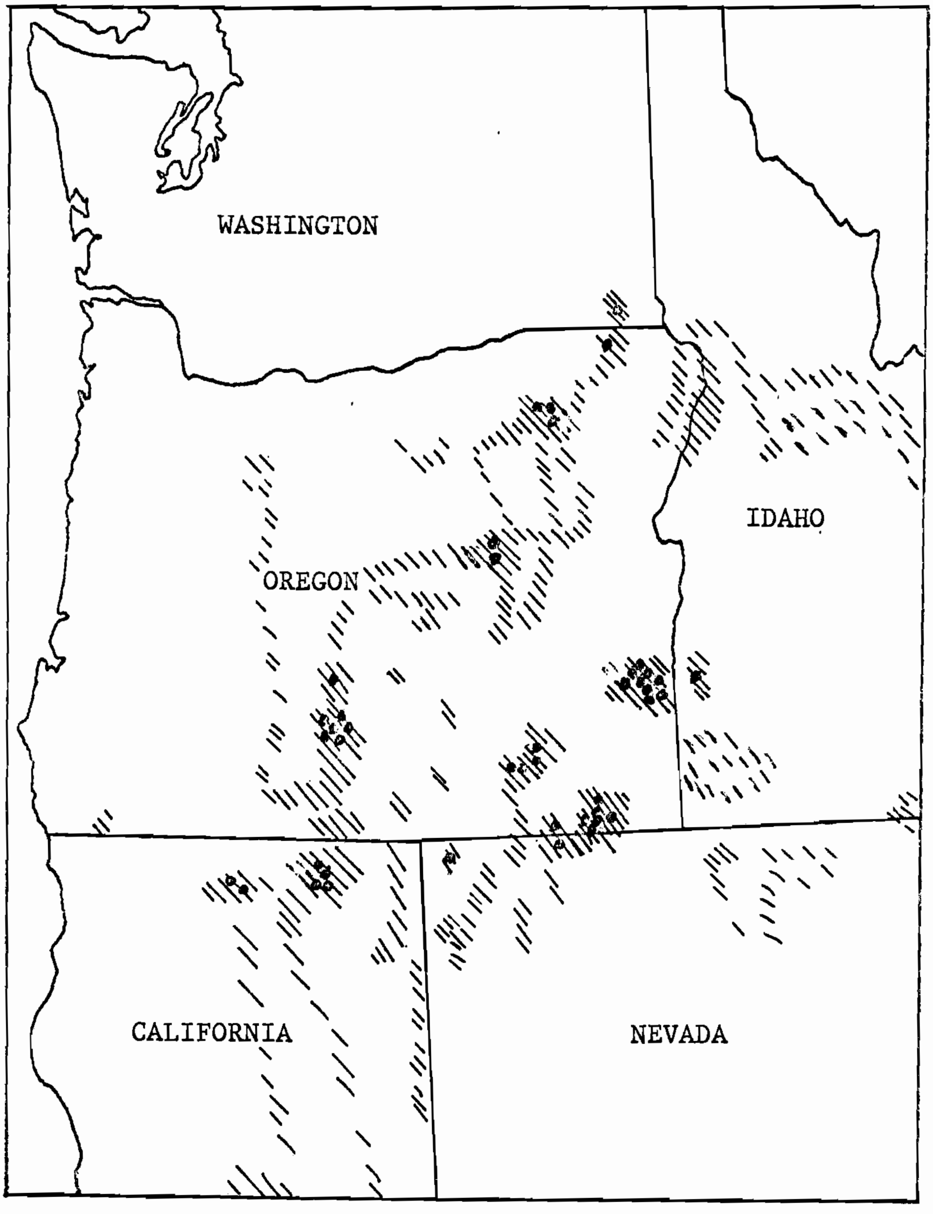


Figure 6. Distribution of Cercocarpus ledifolius (dashes), and descriptive study plots (dots) in the study area.

4. Abundant - codominant with at least one other species in its own vegetation layer.

3. Frequent - common, can stand in one spot and see it wherever you turn.

2. Occasional - must walk around to observe it. Not readily noticeable.

1. Rare - must hunt through vegetation to find it.

Constancy figures were derived by calculating the percentage of stands within an association, phase, or successional stage in which a species occurred compared to the total number of stands.

The associations, their phases, and seral communities in which species were found were named using dominant species to convey general physiognomy of plant layers (Daubenmire, 1970). Seral communities were relegated to specific associations only if enough characteristics were still present for identification.

Site characteristics such as degree of slope, position on slope, directional exposure, elevation, landform, and soil characteristics were recorded. Soil analysis followed standard procedures of the SCS Soil Survey Manual (U. S. Soil Conservation Service, 1951).

GERMINATION AND INITIAL GROWTH

Seed Production

Seed production of *Cercocarpus ledifolius* was cyclic in our study range. Observations of two areas for 12 years revealed only 3 years of high seed production. Production resulted in a late summer mass of plumed seeds which gave most trees a strikingly frosty appearance rather than typically dark green. After seed fall, the ground under and around edges of groves was almost solid white, with wind-drifted seeds piled up to 25 cm deep in rocky pockets.

Production in interim years varied from almost no seed to approximately 50 percent of that of high years.

Seed and Seedling Predation

Severe seed predation by insects occurred on *C. ledifolius* soon after seed fall in late August and September. The insect was not identified, however its damage to seed was characterized.

The seed coat was attacked along the relatively soft and narrow seed coat symphysis running the full length of the seed and was typically chewed away for approximately two-thirds its length, beginning at the radical tip. Occasionally, seeds were opened up from end to end or only at the cotyledon end. All or part of the embryo was removed. This damage occurred while plumes were still attached, seeds were in a vertical, seed down position, and while seeds were still in the upper, dry litter layer.

Predation was so complete that almost 100 percent of the seeds in heavily concentrated masses under trees were destroyed. I do not know whether damage to this degree was common every year of production or was related to insect cycles. I observed it several times in the last 12 years. Conversely, 90 percent of seeds which were scattered into openings nearby escape this predation. However, this was a very small proportion of the total seed supply.

Seedling predation by insects was observed only rarely in the cotyledon stage and not at all in older stages. Although damage was noticed, no insect identification was possible. Both notching of the cotyledon leaves and complete severing of the stem near the ground were observed. I was not able to quantify this damage so its influence on seedling establishment remains to be determined.

Damage of seedlings by rodents was not observed. However, Hammer and Maser (1973) reported heavy use of green leaves and twigs of the species by the dusky-footed woodrat (<u>Neotoma fuscipes</u> Baird) when plants were available near colonies. Scheldt and Tisdale (1971) collected cottontail rabbits (<u>Silvilagus nuttallii</u>) in Idaho and found leaves and fine stems in their stomach contents.

Viability and Seed Examination

Viability tests were conducted using tetrazolium chloride (TZ) in eight 200 seed samples, four samples from a 2-year-old seed collection and four from a current year collection from the same location. Both collections were cleaned and kept at room temperature in cloth bags. The same two collections were examined by X-ray for internal abnormalities. Because the process of cleaning broke approximately 40 percent of the feathery styles (twisted awn-like appearance) from the ovaries leaving an entry hole at the base of the seed, half of each sample was selected for broken seed coats.

Viability tests resulted in 80 percent for unbroken and 76 percent for broken seeds in the 2-year-old collection. The current year collection was 72 percent viability for unbroken seeds and 75 percent for broken ones. X-ray examination and viability results are presented in Table 4. Since there seemed to be little difference in viability between collections or among samples, and since viability differences of broken and unbroken samples between collections were reversed, I could only conclude that breaking the style in cleaning was of little or no importance in reducing viability. Lower viability in the current collection, even with a higher percentage of "good" seed in the unbroken sample, indicated that if the viability difference between collections was real, it must have been due to

Table 4. Results of X-ray and viability tests of broken (B) and unbroken (U) *Cercocarpus ledifolius* seeds.

Seed characteristics X-ray	Percent			
	2-year-old		Current year	
	B	U	B	U
Good	13	84	13	88
Questionable development	0	6	2	5
Abnormal development	10	6	7	4
Empty	4	2	1	3
Broken	73	2	77	0
Insect damage	0	0	0	0
Total	100	100	100	100
Viability (TZ)	76	80	75	72

causes other than those tested. Prudence seemed to indicate the 2-year-old collection with a mean viability of 78 percent be used in germination and root growth studies.

Stratification and Germination

A germination test was conducted first using 1,000 imbibed seeds, 100 on moist filter paper in each of 10 petri dishes at 20° C. This temperature was used because soil temperature was observed to reach this level during germination of seeds in natural stands. At the end of 30 days no germination had occurred. Seeds were left for 60 days with no germination evident.

Next, a simple cold, wet stratification test at 4° C was conducted in a dark environment with double the number of seeds and petri dishes. At the end of 60 days one-half of the seeds were removed and germinated at 20° C for 30 days. Twenty percent germination was observed. Germination was considered accomplished if radicals were extended 5 mm. The test was extended to 60 days with no further germination. Because radicals of many of the seeds which did not germinate were swollen and slightly extended beyond the seed coat (1 to 2 mm), continuing the stratification process with the second half of the seeds seemed promising.

At the end of 75 days, the seeds remaining in stratification began germinating. Because of this occurrence it was decided to leave the seeds under stratification conditions indefinitely to determine how many seeds would germinate. At the end of 90 days 1 percent had germinated. At 120 days, 59 percent had germinated, at 135 days, 91 percent, and at 270 days, 113 percent had germinated, using the original viability test figure of 78 percent.

To test completeness of germination, remaining seeds were placed for 20 days in a growth chamber programmed for a spring environment with a 24-hour temperature range from 4° to 24° C and a 14-hour photoperiod. Four more seeds germinated for a total of 884 or 113.3 percent. Results are presented in Table 5. This 1,000 seed sample was taken from the same seed lot which had tested 78 percent viability in the OSU Seed Laboratory Tests (Table 4). Since our test resulted in higher germination than the Seed Laboratory tests indicated was possible (tests indicated only 78 seeds out of 100 were viable), I decided to run all further tests based on our figure of 88 percent. This seems to be a more realistic base from which to determine germination characteristics of *Cercocarpus ledifolius* than total seeds. Otherwise, part of the percentage figure of germinated seed would actually be based on some dead seed material which had no potential for producing germination results.

Because two authors (Woolfolk, 1959; Heit, 1971), although showing no evidence, suggested the possible presence of chemical

Table 5. Germination success of <u>Cercocarpus</u> <u>ledifolius</u> seeds stratified on wet filter paper at 4°C. Germination percentages were calculated from 78 percent viability figures obtained from TZ tests of the Oregon State University Seed Testing Laboratory.

100 seed samples	30-day strat.	60-day stratification		270-day stratification	
		No. seeds	%	No. seeds	%
1	0	26	33	88	113
2	0	32	41	92	118
3	0	22	28	93	119
4	0	14	18	86	110
5	0	14	18	89	114
6	0	10	13	87	112
7	0	11	14	89	114
8	0	11	14	90	115
9	0	8	10	86	110
10	0	11	14	80	103
$\bar{x}$	0	15.9	20	88.0*	113

*Significant difference at .001 level.

germination inhibitor in the seed coat or covering of C. ledifolius, stratification tests were conducted with imbibed seeds being placed on wet charcoal, in cheesecloth bags (both moist and submerged), on wet filter paper, and on sterile quartz gravel. The strategy was to subject seeds to a condition on filter paper where they were in continuous standing water, i.e., they were one-third submerged for the entire test. I hoped that this might allow any water soluble inhibitory substance to leach out of the seed covering. The same strategy was applied to seeds on charcoal with the same submergence in water, and cheesecloth bags. Seeds placed on sterile quartz gravel were imbibed and kept in an environment of 100 percent humidity but were not permitted to touch standing water. Results are presented in Table 6.

The percent germination of seeds from the quartz gravel treatment was so much lower than all other treatments that I did not feel it necessary to include it in the analysis. The other four treatments were tested with analysis of variance. There were no significant differences among means at the 5 percent level. Treatments on wet filter paper and quartz gravel appeared most and least successful respectively.

A 15-minute soak in H_2O_2 gave best results with 64 percent germination followed by a 30-minute soak giving 54 percent, then 5 minutes for 46 percent, 10 minutes for 41, and 60 minutes for 0

Table 6. Percent germination of Cercocarpus ledifolius seeds stratified at 4°C for 170 days.

Samples	Percent germination using 88 percent viability				
	Wet filter paper	Charcoal	Moist bags	H_2O Immersed bags	Quartz gravel
1	84	72	69	69	.02
2	84	77	67	59	.00
3	94	76	70	60	.08
4	85	69	61	48	.07
5	89	70	64	44	.05
$\bar{x}$	87	73	66	56	.04

Table 7. Stratification test of Cercocarpus ledifolius seeds using a 30 percent solution of H_2O_2 and 5 soak periods. Germination was carried out at 20°C. Results are based on 88 percent viability.

20 seed samples	Treatments				
	5 min.	10 min.	15 min.	30 min.	60 min.
1	7	6	12	11	0
2	11	6	10	8	0
3	5	8	11	13	0
4	9	9	12	6	0
Σ	32	29	45	38	0
$\bar{x}$ %	46	41	64	54	0

(Table 7). All germinants emerged either beginning with the radical through the seed coat tip, or both radical and cotyledons through the dissolved symphysis which ran lengthwise along one side of the seed coat.

Excised embryos began germinating within 3 days of treatment. Cotyledons began enlarging with some turning reddish brown on the ventral surfaces and all turning green on the dorsal surfaces before radicals began extension. Germination in petri dishes was 92 and 83 percent, averaging 88 percent. Germination was complete in 14 days.

Partially excised embryos, those where the seed coats were opened at the symphysis, began germinating within one week. Germination was incomplete although radicals attempted to extend both from the radical end of the seed coat and through the symphysis.

Germination of many seeds in all tests except those with excised and partially excised embryos, appeared to proceed in three stages. The first was growth and extension of the root radical 1 to 2 mm beyond the seed coat tip; the second stage was a variable rest period extending as long as 6 to 8 weeks; the third, a resumption of radical extension concluding with complete germination.

A sample of 500 germinants was planted in soil taken from a _Cercocarpus ledifolius_ site to test success of seedling emergence. Emergence was 98 percent to the full cotyledon stage. Two percent of the 98 percent emerging seedlings failed to completely shed the seed coat. The distal one-third to one-half of the cotyledon pair were entrapped permanently by this incompletely-shed seed coat. This did not hinder continuous growth of seedlings nor development of normal leaves. Seed coats which entrapped cotyledons were less deteriorated than those which were left in the soil upon normal seedling emergence.

Seeds planted in flats and placed in the field for natural stratification began germinating on April 14 and continued for 20 days. From 3, 000 seeds planted, 570 or 19 percent germinated. Individual flat germination was 16, 20, and 22 percent.

Root Growth

Cercocarpus ledifolius appeared to be a deep-rooted species in its native habitat. Observations during the community relationship phase of this study revealed roots of at least 5 mm diameter growing downward at the 1. 2 m depth on the best soil sites. No valid depth relationships could be established on severe rocky sites except the observation that roots must have reached a considerable distance into the rock cracks to enable the species to survive.

Field observations of germination for 3 years established mid-April as the beginning of seedling emergence. This held true for sites both below the 42d parallel in northern California and at the

45th parallel near La Grande, Oregon. Mid-day soil temperatures in the top 3 cm at germination microsites were consistently between 12° and 20°C when germinants were in the cotyledon stage, i.e., before there was any evidence of the start of normal leaf development.

The growth chamber study to determine speed of seedling root growth for 24 seedlings showed, in 35 days, a mean tap root extension of 0.34 m; in 62 days 0.58 m; in 92 days 0.76 m; and in 120 days 0.97 m (Table 8). Because Cercocarpus ledifolius, as well as most perennial species, establishes itself in a natural community through relatively few vigorous and tenacious representatives, we might pay particular attention to the few individuals which make the greatest root extension over a given time.

Thirty-five days from germination, roots of 6 seedlings had reached a mean of 0.40 m depth, in 62 days 0.65 m, in 92 days 0.94 m, and in 120 days 1.13 m (Table 8).

The comparison of seedling height to root extension showed a weak negative correlation ($r = .4402$), significant at 0.5 (Figure 7). The mean top height and root length was 2.35 cm and 97.19 cm respectively. The best correlation found between the above ground portion of plants and their root length was seedling stem diameter just above the root crown. Correlation was $r = 0.8209$, significant at .001 (Figure 8).

Comparisons were also made of top height to top weight, and

Table 8. Mean root length of all *Cercocarpus* *ledifolius* seedlings and the six best performers at four growth steps over a 120-day period.

Number of seedlings	Days from Germination 35	62	92	120
	- - - - - - -	Mean root length--meters	- - - - - - - -	
24	0.34	0.58	0.76	0.98
Range	0.11-0.41	0.39-0.67	0.57-1.11	0.63-1.17
s.d.*	0.097	0.079	0.137	0.155
6	0.40	0.65	0.94	1.13
Range	0.40-0.41	0.60-0.67	0.87-1.11	1.08-1.17
s.d.	0.066	0.244	0.098	0.038

*Standard deviation.

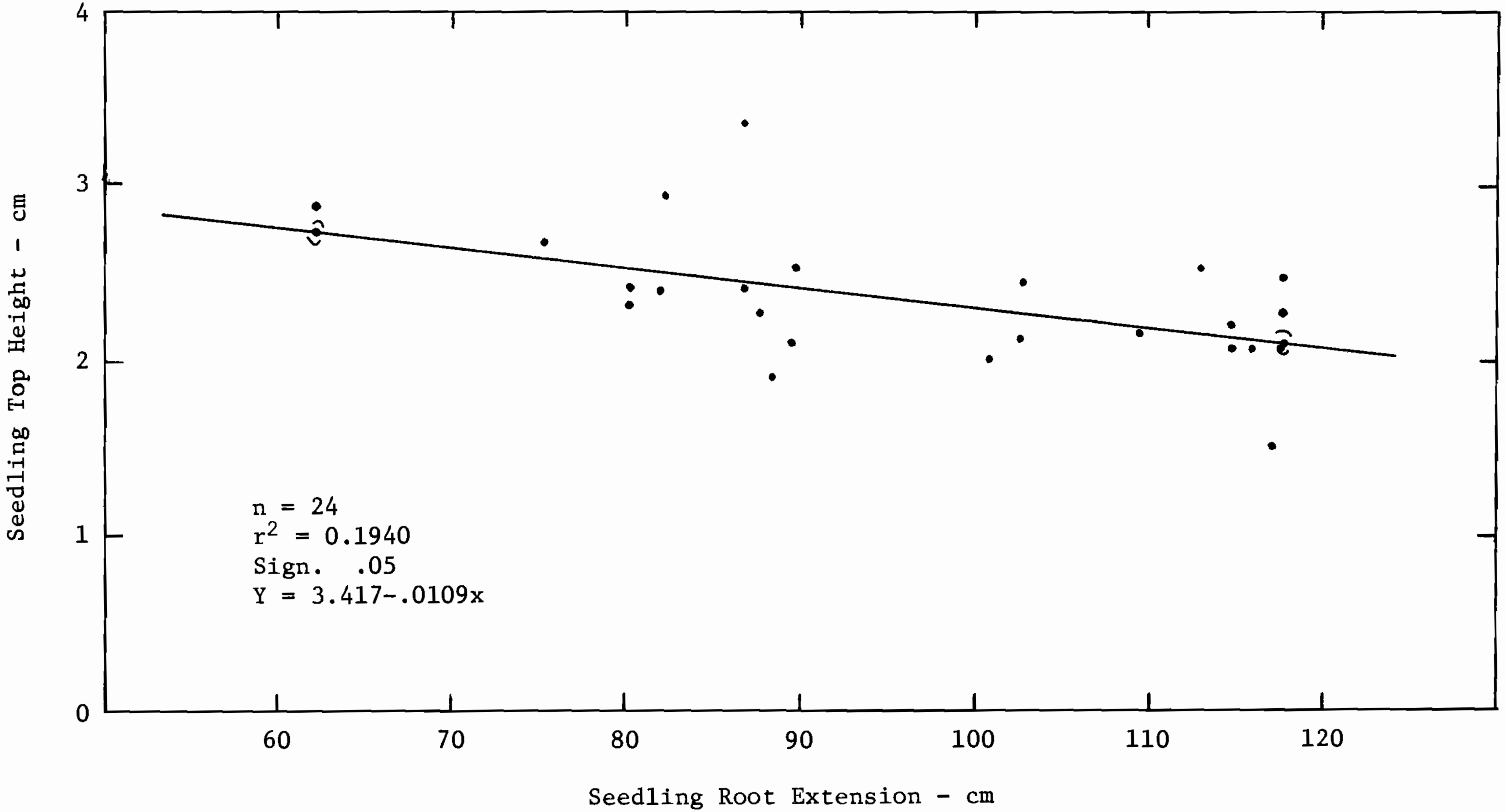


Figure 7. Comparison of Cercocarpus ledifolius seedling height growth to root extension in a growth chamber environment.

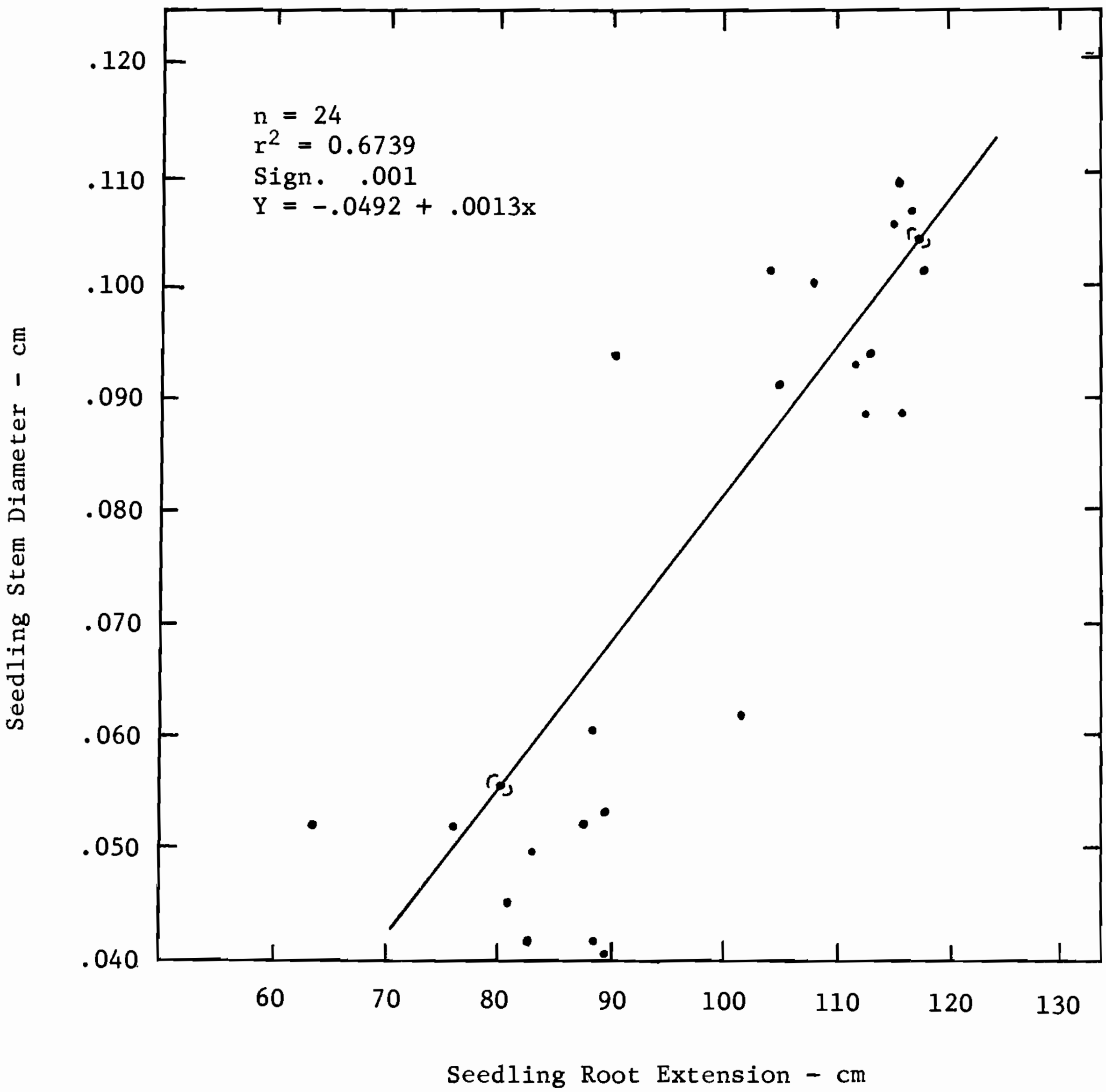


Figure 8. Comparison of Cercocarpus ledifolius seedling stem diameter to root length in a growth chamber environment.

top height to total weight. No correlations were apparent.

Discussion

There are at least two factors related to seed availability which could be considered restrictive to seedling establishment of *Cercocarpus ledifolius*; 1) cyclic seed production and 2) insect predation. Of the two, cyclic seed production may be the most important. There are years in which almost no seed is produced, thus a barrier is established. Insect predation occurs primarily under mature *C. ledifolius* trees in the dry litter layer, and not in adjacent openings where *C. ledifolius* litter is absent. How important intraspecific moisture and light competition and insect damage under *C. ledifolius* canopies might be to seeds and seedlings is not known. However, intraspecific competition is generally high in perennial plants indigenous to our study area due to arid growing season conditions; therefore I would expect poor regeneration under mature stands even without predation.

The occurrence of established seedlings directly under mature trees is rare. Usually they occur nearby where both insect damage and competition with other plants of their own species are minimal. This is significant since the expansion of a stand such as *C. ledifolius* is dependent on regeneration outside the canopy. Only seed germinating outside the canopy seems to have a good opportunity for establishment. In this location, root development may be a primary reason why C. ledifolius can maintain a foothold in the environment.

There was no germination of Cercocarpus ledifolius seed in the laboratory without stratification. However, seed germinated readily in the laboratory with a series of various prolonged cold, wet treatments. This pointed to physiological seed dormancy or mechanical impedance to germination, or both as factors influencing germination and establishment in the field.

The successful immediate germination of excised embryos without other treatments eliminated prechilling and germination inhibitors in the embryo itself as factors in physiological dormancy.

Seeds treated with simple cold, wet treatments on wet filter paper, with wet charcoal, or with H_2O immersion resulted in measurable deteriorated seed coats prior to germination. Coats of seeds placed on quartz gravel and not allowed to touch standing water showed insignificant seed coat deterioration and significantly less germination than other treatments. This indicated a regulation of germination by an inhibitor in the seed coat, mechanical impedance, depriving the seed of gases, or some combination of these factors. This was further indicated by the three-stage germination observed, where the radicals emerged 1 to 2 mm, paused for a variable time period, and then continued. During the pause in radical extension, the paper-like membrane surrounding the embryo remained intact. The membrane was observed to be ruptured when the radical began further extension as a continuous activity of germination. Whether it was necessary for the membrane to rupture before germination could continue or whether rupturing was simply a mechanical result of radical extension was not determined. If the membrane was a factor in preventing gas absorption by the embryo, then the pause in radical extension would seem to have been due to the intact membrane.

According to Devlin (1966) and Evanari (1949), a hard seed coat caused dormancy in three ways: (1) restricting imbibition of water, (2) deprivation of gases, and (3) mechanical restriction of embryo growth. I rejected the first one for Cercocarpus ledifolius seed since many of the seeds under test had the style broken from the seed coat base, opening an orifice directly to the embryo, allowing H_2O to move through freely. These seeds took as long to germinate as closed seeds. Mechanical impedance might have been involved as indicated by results of the H_2O_2 and acid tests as reported in the literature, where germination began soon after treatments. In the H_2O_2 treatment, a high degree of emergence was attempted through the relatively soft symphysis in the seed coat which was effectively deteriorated.

This still left possible factors of mechanical impedance, inhibition of gas absorption or a chemical inhibitor. Devlin (1966) stated the location of inhibitors in the seed was highly variable between species and could occur in any part. Since germination of excised embryos began in a wet environment within 3 days at 20°C with no other treatment, resulting in 88 percent germination, no effective inhibitor in the embryo itself was indicated.

This led me to open the seed coat along the symphysis and clip the radical end of the seed coat exposing the embryo but allowing any inhibitor to remain effective in the coat itself. Embryos began expanding within 24 hours at the radical tip and within 5 days at the symphysis. I concluded there was no effective chemical inhibitor in the seed coat. This was contrary to observations by both Heit (1971) and Woolfolk (1959).

The full and partial excision tests indicated that seed coat mechanical impedance or gas inhibition were the only factors which might have been effective in inhibiting seed germination in *Cercocarpus ledifolius*. I tended to reject mechanical impedance of the embryo by the seed coat because the coat itself did not seem to have the extremely hard characteristic of seeds such as *Brassica*, *Amaranthus*, *Alisma*, or *Lepidium* which are known to prevent germination by mechanical impedance (Meyer et al., 1966). Unbroken seeds of *C. ledifolius* imbibed H_2O readily and in the imbibed state were relatively soft and easily dissected.

The most likely reason for dormancy in the seed of *C. ledifolius* seemed to be the prevention of gas diffusion through the membrane surrounding the embryo itself. I feel there should be further research in this area to clarify the results of this study.

C. ledifolius seedlings seemed to have ample vigor. There was no indication of weakness in any emergent seedlings, nor any propensity toward damping off. Only 19 percent of 3,000 seeds germinated under field conditions but they were all strong and healthy. I do not know why germination was low in the field germination test. Such low field germination rates could indicate a potential restriction to establishment or expansion of the species; however, abundant seed crops are produced frequently enough to provide adequate seed despite low germination rates. A long life span of individuals once established, possibly 600 or more years (estimated from data presented in the last section of this study), probably precludes the necessity for high success in any one year. Lack of high germination rates, however, would be a real concern to land managers who might need to reestablish destroyed stands by planting.

The test of root growth in the growth chamber revealed a rapid potential extension of seedling tap roots. Solum firmness in the upper 30 cm of glass tubes was estimated as firm or firmer than natural soils examined on deep soil sites, whereas firmness in the lower tube levels appeared less.

In 93 days, the root extension averaged 0.76 m, and in 120 days 0.98 m. The six most vigorous seedlings extended their roots an average 1.13 m in 120 days. Germination usually began in mid-April when soil moisture was high and temperatures cool. It seemed, for establishment, that these conditions must have continued long enough for roots to reach permanent, deep soil moisture or for the entire season at a level allowing survival. In fire-maintained grasslands around Cercocarpus ledifolius stands where deep rooted species were not common, summer-long moisture levels in the lower portion of the soil profile should have been higher in relation to similar situations where deep rooted shrub species were present. If fire was an active restriction to stand expansion from rocky sites, there may have been an accordion-like expansion and contraction of stands, with the expansion occurring between fires when seasonal moisture and temperature conditions were optimum. On the other hand, where old stands were adjacent to deep rooted shrubs such as Artemisia tridentata, establishment may have been more difficult.

The root extension study was conducted with a 10-hour dark period. This was comparable to the natural dark period at the 44th parallel for 120 days beginning April 15. At the end of the study, length of shoots and roots averaged 2.35 and 97.19 cm respectively. Shoots only averaged 4 cm^2 of leaf area for photosynthesis and transpiration at the end of the study. Field observations of current year seedlings showed little difference from growth chamber seedlings in shoot size or leaf area 90 days after germination. Live, current year natural germinants were observed as late as July 20. Seedling germination and growth data, both laboratory and field, indicated a high degree of specialization for rapid and extreme root extension in relation to top growth for at least the first 120 days after germination.

RECENT HISTORY OF *CERCOCARPUS LEDIFOLIUS* STANDS

Logging

Both cattle and sheep industries were common in the study area by 1880 (Oliphant, 1948). Pioneers who developed these industries in the High Lava Plains, Basin and Range Province, and Owyhee Uplands portions of the study area, had limited sources of fuel for heating. Wood supplies were gathered from nearest sources. The only species commonly available were *Juniperus occidentalis* and *C. ledifolius*. *J. occidentalis* was valuable for construction of ranch buildings, corrals, and fences. *C. ledifolius* was highly valued for firewood and had limited value otherwise.

In this regard I interviewed two pioneers, Mr. Chavez, in the Basin and Range Province, and Mr. Jesse Strode, in the Owyhee Uplands who verified that *C. ledifolius* was logged intensively for firewood. At the turn of the century, Mr. Strode's family, as did others around him, cut a minimum of "four, four-horse wagon loads" (approximately 8 cords) of *C. ledifolius* annually. During this study, this area, Mahogany Mountain (one of my primary sample areas), had large acreages of *C. ledifolius*, mostly in dense, small stemmed thickets, indicating a second growth stand. Remnant cut stumps were still observable.

There may have been some utilization of *C. ledifolius* for firewood by settlers in the conifer zone but I saw no evidence. Since conifers provided abundant supplies of wood which was much softer and easier to harvest, I believe the settlers would have used this instead of *C. ledifolius*.

Animal Use

From about 1880, livestock grazing was intensive in the study area. Cattle, sheep, or both were grazed in the vicinity of virtually all *Cercocarpus ledifolius* stands (Hazeltine, et al., 1961; Strong, 1940).

Mule deer (*Odocoileus hemionus hemionus*) were native to the area and have fluctuated in numbers since 1880. Populations were low near the turn of the century, but have increased in recent years (Mace, 1957). California bighorn sheep (*Ovis canadensis californiana*) were native to the high elevations of the Basin and Range Province and Owyhee Uplands, but were extirpated by 1900 due to hunting and losses from disease and parasites brought in by domestic sheep (Dasmann, 1962). Although bighorns have not been a factor influencing *C. ledifolius* for the last 75 to 85 years, they may have played a role historically.

Perhaps coincidentally, bighorns disappeared shortly before the re-establishment of many current *C. ledifolius* stands. Other factors influenced stands during the period--livestock were grazing the understory; deer, heavy users of young C. ledifolius plants, were low in numbers; and settlers severely logged mature stands. These factors created a situation favorable for stand regeneration.

Tree Age--Stem Diameter Relationships

Trees in stand A (Figure 9) were located on a 25 percent northeast slope at 1890 m elevation on Whitehorse Mountain, Malheur County, Oregon. Soil was a moderately shallow, well drained gravelly loam from basalt parent material. Precipitation was estimated as 50 cm. Stand B was located on a 5 percent south slope at 2000 m elevation in the Trout Creek Mountains in northwestern Nevada. Soil was a shallow, well drained gravelly loam with parent material derived from rhyolite. Precipitation was approximately 45 cm.

Stem cross sections were selected from each stand to provide maximum variations in size. Seventeen samples were taken from stand A and 28 from stand B. Diameters ranged from 5 to 25 cm and ages from 30 to 128 years.

Linear regression was used to analyze both populations (Figure 9). Data revealed a positive relationship between individual tree ages and their stem diameters 46 cm above the ground.

Values for r were 0.9153 and 0.6815 for stands A and B, respectively.

Stand A was on a more moist site than stand B as indicated by the larger average stem diameters for given ages.

Discussion

Except for large diameter relics on rocky outcroppings in and adjacent to sample stands throughout the study area, trees larger than the largest in Figure 9 (25 cm) were rare. In fact, approximately 90 percent of all trees were less than 15 cm in diameter. This indicated that even considering variations in size-to-age relationships due to site differences, most stands have been established since 1875. This corresponded to low deer numbers, the advent of intense livestock use of grasses and forbs, and the heavy utilization of mature *Cercocarpus ledifolius* for firewood in the Basin and Range Province and Owyhee Uplands.

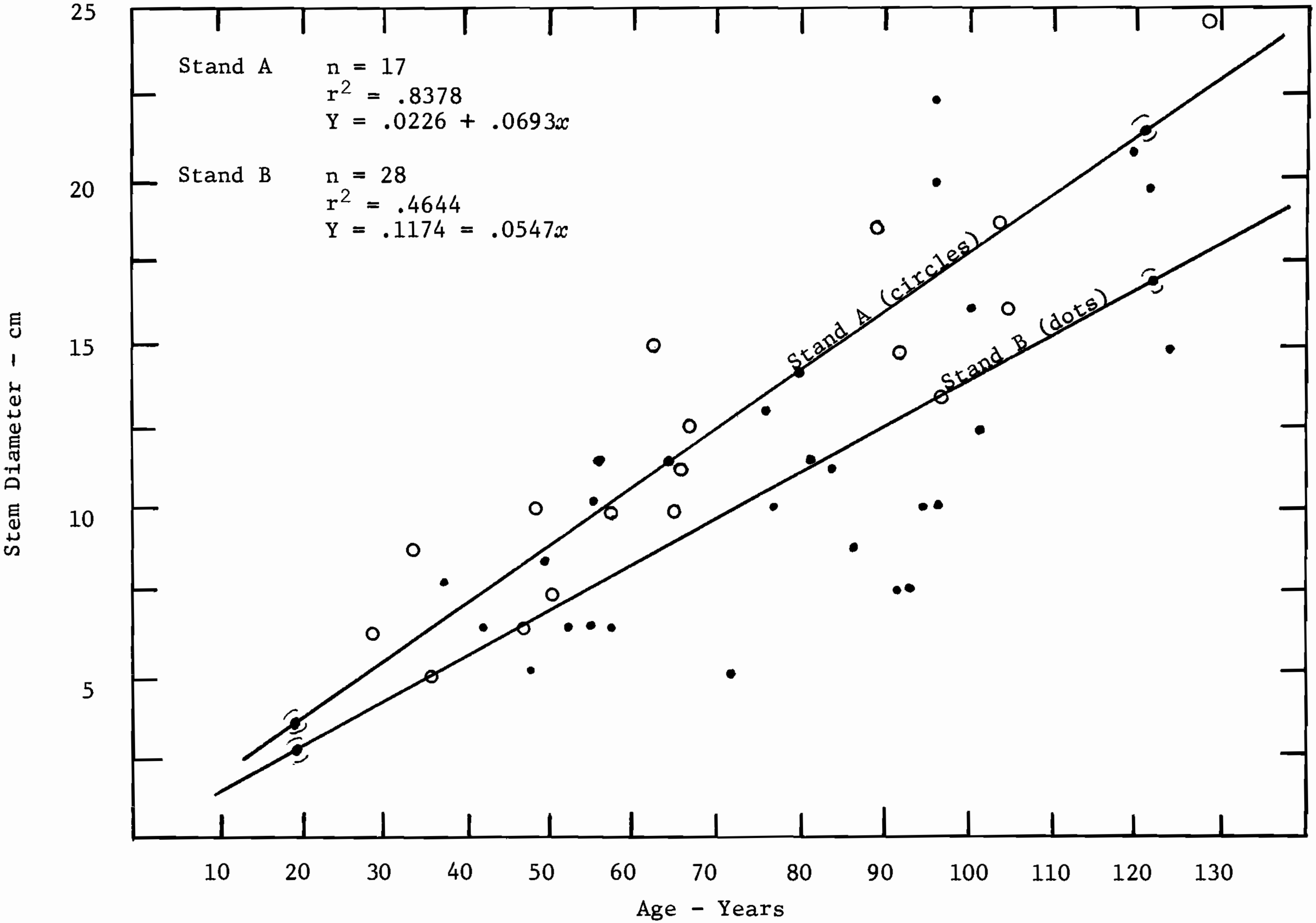


Figure 9. Regression curves showing Cercocarpus ledifolius tree diameters in relation to age for stands in the Whitehorse Mountains (stand A) and the Trout Creek Mountains (stand B).

ECOSYSTEM RELATIONSHIPS

Where the term ecosystem is used, it refers to a general unit of the landscape, including site, vegetation, soil, and animals. This follows Tansley (1935). Areas of relatively uniform vegetation with attendant site, soil, and climate constituents are referred to as habitat types following Daubenmire and Daubenmire (1968). Throughout this paper, habitat type will be abbreviated "h. t.," plural being "h. ts".

I identified and described 77 stands in order to characterize the diversity of environmental conditions under which Cercocarpus ledifolius occurred. Stand data are summarized for all ecosystems in Table 9 and appear in detail in Appendix A.

Few stands existed which were in an undisturbed condition because of long term grazing of the understory and browsing of both young C. ledifolius and shrubs by wild ungulates (Figure 10). Therefore, stand arrangement into plant associations, in some cases, was a projection based on remnant species of the understory recognized over a range of associations as being climax dominants or indicator species (Daubenmire and Daubenmire, 1968; Daubenmire, 1970; Eckert, 1957; Tueller, 1962; Poulton, 1955; McKell, 1956; Griffith, 1902, 1903; Sampson et al., 1951: Griffin, 1967, Driscoll,

Table 9. Mean values of Cercocarpus ledifolius ecosystems.

Item	Ecosystems														
Association[1]	Cele/ Artr/ Feid	Cele/Artr/ Agca		Cele/ Artr/ Poam	Cele/ Feid	Cele/ Feid- Agsp	Cele/ Elci	Cele/ Syal/ Feid	Cele/ Syor/ Poam	Cele/ Svor	Cele/ Syor/ Feid	Cele/ Syor/ Poam	Cele/Caru		Cele/ Caru- Feid
Phase										Basa		Arco			
Succession stage	Posa		Stle	Stle						Posa	Posa			Stle	Stle
Altitude (m)	1945	1616	1616	1844	1646	1682	1890	1405	1768	1899	1829	1854	1921	1747	1747
Exposure	WSW	SW	SW	SSW	NNE	WNW	W	SW	S	ENE	NW	NNE	ENE	ENE	NNE
Percent slope	13	37	35	14	8	27	23	13	30	25	21	31	15	28	35
Trees per hectare[2]	1067	1867	934	1687	-	-	1245	761	1546	1334	2221	1986	1800	1508	2669
Average percent live crown[2]	45	50	49	56	66	36	34	61	80	55	74	74	82	76	83
Average stand age[3]	2.8	2.5	2.7	2.0	3.0	3.0	3.1	3.0	3.1	2.8	3.0	3.0	3.0	2.8	2.7
	-----Species dominance/percent constancy x 10-----														
TREES															
Cercocarpus ledifolius	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10
Juniperus occidentalis	-	2/7	2/7	-	1/6	1/8	3/10	-	2/10	-	-	2/8	-	-	-
Pinus ponderosa	-	-	-	-	1/10	1/8	-	3/10	-	-	-	-	-	-	-
Populus tremuloides	-	-	-	-	-	-	-	-	-	-	-	1/2	-	-	1/3
SHRUBS															
Amelanchier alnifolia	-	2/7	2/7	1/3	1/2	-	3/7	-	1/2	1/3	2/3	2/6	3/10	2/10	2/10
Artemisia tridentata	5/10	5/10	5/10	5/10	2/8	2/10	-	-	2/10	4/10	3/10	3/10	-	1/3	-
Berberis repens	-	-	-	-	-	-	-	-	3/6	-	-	2/8	3/8	2/3	-
Ceanothus velutinus	-	-	-	-	-	-	-	-	-	2/1	-	-	-	-	2/3
Chrysothamnus nauseosus	3/10	2/10	2/7	3/10	-	1/6	3/7	-	2/10	2/7	2/5	2/10	1/2	-	1/5
Chrysothamnus viscidiflorus	3/6	3/10	3/10	3/10	1/4	1/8	2/3	-	-	3/10	5/5	2/4	1/2	1/3	2/8
Eriogonum heracleoides	-	2/3	1/3	2/10	-	-	-	3/3	-	1/3	-	-	2/2	1/3	1/3
Holodiscus dumosus	-	-	-	-	-	-	-	-	2/6	2/1	-	-	-	-	-
Prunus emarginata	-	2/3	1/3	-	-	-	3/3	-	3/8	-	-	1/2	3/6	3/7	2/10
Prunus virginiana	-	-	3/3	-	-	-	3/10	1/3	3/10	2/4	-	2/10	3/3	-	2/3
Purshia tridentata	-	1/7	1/7	-	-	1/2	-	-	-	-	-	-	-	-	-
Ribes cereum	-	2/7	2/10	2/3	1/2	1/2	2/10	3/10	1/10	2/3	-	2/2	-	2/10	3/10
Rosa gymnocarpa	-	-	-	-	-	-	3/3	-	-	2/1	-	-	1/2	-	2/3
Sambucus cerulea	-	-	-	-	-	-	-	1/3	-	-	-	-	-	-	-
Symphoricarpos albus	-	-	-	-	-	-	-	3/10	-	-	-	-	-	-	-
Symphoricarpos oreophilus	3/8	-	-	-	-	-	-	-	2/10	4/10	3/10	3/10	3/3	-	1/5
Tetradymia canescens	-	-	-	-	1/2	-	-	-	-	-	-	-	-	-	-
GRAMINOIDS															
Agropyron caninum	-	4/10	2/10	3/3	-	-	3/10	-	-	2/4	3/5	-	3/10	-	1/3
Agropyron spicatum	2/4	-	-	-	2/10	3/10	-	3/10	-	-	-	-	-	-	-
Bromus brizaeformis[4]	-	-	-	-	-	-	-	2/10	-	-	-	-	-	-	-
Bromus carinatus	-	2/10	2/7	-	2/4	2/4	-	3/10	2/10	3/4	-	2/10	-	-	-
Bromus tectorum[4]	3/10	3/10	3/10	2/8	1/8	3/8	3/10	2/10	3/10	3/10	3/10	-	-	-	-
Calamagrostis rubescens	-	-	-	-	-	-	-	-	-	-	-	-	5/10	3/10	3/10
Carex rossii	3/4	2/3	1/3	3/10	1/6	-	3/10	-	3/10	3/7	3/5	3/10	2/6	4/10	3/10
Elymus cinereus	2/4	-	-	-	-	-	3/10	-	-	2/8	3/5	-	-	-	-
Festuca idahoensis	3/10	-	2/3	-	5/10	5/10	3/3	5/10	-	-	3/10	-	-	-	4/10
Festuca octoflora	-	3/3	-	2/5	-	-	-	-	-	2/10	-	1/4	-	-	-
Koeleria cristata	-	-	-	-	2/8	2/10	-	-	-	-	-	-	-	-	-
Melica bulbosa	1/2	-	-	-	-	-	-	-	3/4	1/3	-	2/10	2/6	2/7	3/3
Oryzopsis hymenoides	-	-	-	-	-	-	3/7	-	-	-	-	-	-	-	-
Poa ampla	-	3/10	3/10	3/10	-	2/4	3/7	-	4/10	2/8	2/8	3/10	3/10	3/7	3/10
Poa sandbergii	5/10	-	-	-	2/10	3/10	-	3/10	-	3/10	4/10	2/10	-	-	-
Sitanion hystrix	3/10	3/10	3/10	3/10	2/10	3/10	3/7	-	4/10	3/10	4/10	5/10	3/10	3/10	3/10
Stipa comata	-	-	-	-	-	-	3/3	-	-	-	-	-	-	-	-
Stipa lemmonii	2/8	4/10	5/10	5/10	-	-	-	-	-	3/7	-	-	2/10	4/10	4/10
Stipa occidentalis	-	-	3/3	3/10	-	-	2/3	-	2/8	-	2/8	3/6	-	-	-
FORBS															
Achillea millefolium	-	3/10	2/3	3/5	2/4	2/8	-	4/10	-	2/4	-	2/10	2/10	2/10	2/8
Agoseris sp.	-	-	-	-	2/6	1/4	-	-	-	-	-	-	-	-	-
Agoseris heterophylla	2/4	1/3	1/7	3/10	-	-	2/7	-	-	2/1	-	-	3/10	2/10	3/10
Allium acuminatum	-	3/7	2/7	-	-	-	-	-	-	-	-	-	2/3	-	-
Antennaria stenophylla	-	-	-	-	-	-	-	2/10	-	-	-	-	-	-	-
Apocynum androsaemifolium	-	-	-	-	-	-	-	-	-	3/1	-	-	-	-	-
Arabis holboellii	2/8	2/10	2/7	2/10	-	-	-	-	2/10	2/7	3/8	2/2	-	-	-
Arnica cordifolia	-	-	-	-	-	-	-	-	-	-	-	5/10	-	-	-
Astragalus sp.	2/6	-	-	-	-	-	-	-	-	2/3	-	-	-	-	-
Astragalus filipes	-	-	-	-	-	-	-	4/10	-	-	-	-	-	-	-
Astragalus stenophylla	-	-	-	-	-	2/4	-	-	-	-	-	-	-	-	-
Balsamorhiza sagittata	1/2	5/10	3/10	2/8	2/2	3/8	3/10	-	-	5/10	3/8	-	3/10	-	-
Cirsium vulgare	-	2/10	3/10	5/10	-	-	-	2/10	-	1/1	-	-	-	1/10	2/5
Crepis intermedia	-	-	-	-	-	-	-	2/10	-	-	-	3/10	-	-	-
Delphinium sp.	-	-	-	-	-	-	-	1/3	-	-	-	-	-	-	-
Erigeron sp.	-	-	-	2/8	1/2	1/6	3/3	-	-	-	-	-	-	1/3	-
Eriophyllum lanatum	1/2	-	-	2/3	2/6	-	3/3	2/10	-	1/1	-	-	2/2	1/3	-
Geum triflorum	-	2/7	2/10	1/5	-	-	-	-	2/10	-	2/5	2/2	2/8	3/10	3/10
Habenaria unalascensis	-	-	-	-	-	-	-	-	-	-	-	-	2/8	-	-
Hieracium albertinum	-	3/10	2/7	1/5	3/10	-	2/3	1/10	-	-	-	2/10	5/10	2/10	2/10
Hydrophyllum capitatum	-	-	-	-	-	-	-	-	-	-	-	-	-	1/10	2/3
Lomatium sp.	-	2/7	1/3	1/3	-	-	-	-	-	-	2/3	-	-	-	-
Lomatium grayi	-	-	-	-	-	-	-	2/10	-	-	-	-	-	-	-
Lomatium triternatum	-	-	-	-	1/6	1/4	-	-	-	-	-	-	-	-	-
Lupinus sp.	-	-	-	-	-	-	-	-	3/8	-	-	-	-	-	-
Lupinus caudatus	-	-	-	-	-	3/2	-	2/7	-	-	-	-	-	-	-
Lupinus laxiflorus	-	3/10	2/10	2/5	-	-	-	-	-	-	-	-	-	-	2/3
Paeonia brownii	-	-	-	-	-	-	-	-	2/4	1/1	-	2/4	-	-	-
Penstemon speciosus	-	1/3	1/7	-	-	-	-	-	2/2	-	-	-	-	-	1/3
Phacelia heterophylla	1/2	2/10	2/10	1/5	1/2	-	2/7	-	3/10	1/7	2/3	-	2/2	-	-
Phlox sp.	2/6	-	-	3/10	2/10	2/6	-	-	2/2	2/1	-	3/8	2/3	-	-
Phlox viscida	-	-	-	-	-	-	-	2/10	-	-	-	-	-	-	-
Senecio integerrimus	3/10	1/3	2/7	1/3	-	-	2/10	-	3/10	3/10	5/10	3/8	2/8	2/7	2/8
Sidalcea oregana	-	-	-	1/5	-	-	-	-	-	-	3/3	-	-	-	-
Silene hookeri	-	-	-	-	-	-	-	-	-	-	-	-	2/8	2/3	-
Smilacina sp.	-	-	-	-	-	-	-	-	2/8	-	-	-	-	-	-
Taraxacum officinale	-	-	2/7	-	-	-	-	3/10	-	-	-	2/10	1/2	3/7	3/10
Thalictrum sp.	-	-	-	-	-	-	-	-	-	-	-	3/10	-	-	-
Tragopogon dubius	-	1/3	2/10	1/8	-	-	-	2/10	-	-	-	-	-	-	-
Viola nuttallii	-	2/10	2/10	3/10	-	-	-	-	2/8	1/10	-	-	3/10	5/10	5/10

Table 9. Continued.

Association	Cele/Artr/Feid	Cele/Artr/Agca		Cele/Artr/Poam	Cele/Feid	Cele/Feid-Agsp	Cele/Elci	Cele/Syal/Feid	Cele/Syor/Poam	Cele/Syor	Cele/Syor/Feid	Cele/Syor/Poam	Cele/Caru		Cele/Caru-Feid
Phase										Basa		Arco			
Succession stage	Posa		Stle	Stle						Posa	Posa			Stle	Stle
SOIL FACTORS															
Stoniness (%)															
Surface area	51	27	15	26	3	25	1	7	48	27	5	32	5	2	2
Buried volume	63	85	63	66	38	65	4	78	67	81	33	42	60	26	33
Underlying material 5/	bslt	rylt	rylt	rylt	bslt	bslt	rylt	bslt	bslt	rylt	rylt	bslt	rylt	rylt	rylt
Solum depth (cm)	42	50	51	81	59	51	–	31	61	41	53	49	45	31	45
Solum texture 6/															
A horizon	gl	gl	gl gsl	gl	l	gl	fs	l	l	gl	gl	l	gl	gsl	gsl
B horizon (or AC)	gcl	gcl	gcl fsl	gcl	cl	cl	fs	cl	cl	gcl	gsl	cl	gcl	scl	gl
Solum color 7/															
A horizon	5YR 2/2	10YR 2/2	10YR 2/2	5YR 2/2	10YR 2/2	5YR 2/2	10YR 5/3	5YR 2/2	5YR 2/1	10YR 2/1	10YR 2/2	10YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2

1/ Agca = Agropyron caninum; Agsp = Agropyron spicatum; Arco = Arnica cordifolia; Artr = Artemisia tridentata; Basa = Balsamorhiza sagittata; Caru = Calamagrostis rubescens; Cele = Cercocarpus ledifolius; Elci = Elymus cinereus; Feid = Festuca idahoensis; Poam = Poa ampla; Posa = Poa sandbergii; Stle = Stipa lemmonii; Stoc = Stipa occidentalis; Syal = Symphoricarpos albus; Syor = Symphoricarpos oreophilus.

2/ Cercocarpus ledifolius

3/ 2 = young trees; 3 = mature trees; 4 = overmature trees

4/ Annual

5/ bslt = basalt; rylt = rhyolite

6/ c = clay; f = fine; g = gravelly; l = loam; s = sand

7/ Moist color. For color code, see Soil Survey Manual (USDA, 1951)

Figure 10. Young Cercocarpus plants browsed heavily by deer and elk.

1962, 1964a, 1964b; Dean, 1960; Dealy, 1971; Culver, 1964; Berry, 1963; Anderson, 1956).

Heavy foraging on young Cercocarpus ledifolius plants by wild ungulates was a primary factor in delaying succession. However, once the stand grew out of reach, crowns resumed normal growth. This influence served to delay the occasional stand replacement necessary in mature communities.

The impact of wild ungulates on young trees was obvious (Figure 10). By contrast, use of the understory species in a mature stand by the same animals was revealed only through detailed measurement.

A single series of associations was considered in this study, all dominated by C. ledifolius. Seven associations were characterized by the dominant shrub species in the understory: Artemisia tridentata, Symphoricarpos albus, or Symphoricarpos oreophilus. Five associations were separated by the graminoid species dominant in the understory: Agropyron spicatum, Calamagrostis rubescens, Festuca idahoensis or Elymus cinereus. Two phases were separated from the various associations by forb species.

Successional stages may have association and phase designators of any dominance. However, their frequency of occurrence must be 100 percent for consideration as a designator. Successional designators are often species less palatable to wild or domestic ungulates than association and phase designators, or can successfully withstand heavy grazing, e.g., Stipa lemmonii, or Poa sandbergii.

The final portion of this section will treat six relic stands with trees 200+ years older than other stands studies. Also, several stands uncorrelated to h. ts. characterized in this study have been described to demonstrate further diversification of Cercocarpus ledifolius ecosystems in the study area.

Cercocarpus ledifolius/Artemisia tridentata/ Festuca idahoensis h. t.

Poa sandbergii Successional Stage

Site. This h. t. and successional stage of the association occurred in the Basin and Range Province near the Oregon-Nevada border at elevations between 1900 and 2000 m. Slopes were moderate (10 to 15 percent) and aspects ranged from west-southwest to west. Topography was mountainous and the ground surface rough. Precipitation was approximately 45 cm, with snow packs developing during severe winters (Table 9, and Appendix A, Table A1).

Vegetation. The single species overstory cover of Cercocarpus ledifolius averaged 45 percent. Artemisia tridentata was the dominant shrub. Chrysothamnus nauseosus occurred with 100 percent constancy, but was subordinate (mean dominance of 3) as a shrub component. Other shrubs common but with less than 100 percent constancy of occurrence were C. viscidiflorus and Symphoricarpos oreophilus.

Perennial graminoids were dominated by Poa sandbergii, followed by Sitanion hystrix, and then Festuca idahoensis, all occurring with 100 percent constancy. Stipa lemmonii occurred commonly but less frequently. Uncommon components were Carex rossii, Elymus cinereus, Agropyron spicatum, and Melica bulbosa. Bromus tectorum, occurring with 100 percent constancy was the only annual grass in this stage.

The only perennial forb which occurred with 100 percent constancy was Senecio integerrimus. Other species which occurred in over one-half the stands were Arabis holboellii, Phlox sp., and Astragalus sp.

Soil. The soil was a well-drained, moderately deep stony loam developed in basalt residuum. Surface area and buried volume of stone averaged 51 and 63 percent respectively.

The solum averaged 42 cm in depth with roots concentrated in the upper 25 cm. The following soil profile description is representative of soil in this phase (from 5 soil pits):

A01 2-0 cm. Cercocarpus ledifolius litter.

A1 0-8 cm. Dark reddish brown (5YR 2/2) moist; gravelly loam; fine granular structure; very friable, non-sticky, non-plastic; many very fine and fine roots; 30 percent volume of small gravels and 20 percent of large stones.

A3 8-25 cm. Dark reddish brown (5YR 3/2) moist; gravelly loam; fine subangular blocky structure, friable; slightly sticky, slightly plastic; common very fine, many fine and medium roots; 50 percent volume of basalt gravels and cobbles.

B 25-42 cm. Gravelly clay loam; sticky, plastic; medium roots common; 75 percent volume of decomposing basalt gravels and stones; fractured basalt bedrock appeared from 28 to 56 cm.

Cercocarpus ledifolius roots were commonly found penetrating cracks in the basalt bedrock. All horizons exhibited an abundance of decomposing mineral material, with both volume and material size increasing with depth.

Animal Presence. Cattle, horses, and deer utilized this type during the study. Cattle, sheep, and both wild and domestic horses have occurred in this area for approximately 110 years (Oliphant, 1948; Hazeltine et al., 1961; Strong, 1940). Settlers harvested the wood of *C. ledifolius* in this area for firewood during the late 1800's and until approximately 1930.

Ecological Analysis. *Chrysothamnus nauseosus* was prominent in local secondary successional communities. Here, as in one other successional community, it reached its highest combination of dominance and constancy. Another indication that the association on this h. t. was in a successional stage was the dominance of

Poa sandbergii over Festuca idahoensis. P. sandbergii is an early maturing graminoid, whereas F. idahoensis matures and flowers later in the summer. Livestock grazing generally reaches a peak of intensity after P. sandbergii has seeded and cured, but before this has occurred in F. idahoensis. Therefore, grazing would have a greater influence on reducing vigor in F. idahoensis by removing seed stalks and forage necessary for transmitting food reserves to the roots. Without these reserves, the following year's growth is weakened, thus allowing takeover by normally less competitive species. Senecio integerrimus appeared in this successional stage as an indicator of overuse (Hermann, 1966).

Cercocarpus ledifolius/Artemisia tridentata/ Agropyron caninum h. t.

Site. This h. t. occurred in the Owyhee Uplands at elevations near 1600 m. Slopes were steep (30 to 40 percent) with a southwest aspect. Topography was mountainous and the ground surface was moderately rough. Precipitation was 46 cm (7 years average), with a snowpack rarely developing.

Vegetation. Cercocarpus ledifolius was dominant in the overstory, averaging 50 percent crown cover. Juniperus occidentalis occurred as an occasional component in two-thirds of the stands.

Artemisia tridentata was the dominant shrub occurring with 100 percent constancy. *Chrysothamnus nauseosus* and *C. viscidiflorus* were subordinate species and were the only other shrubs which occurred with 100 percent constancy.

Agropyron caninum and *Stipa lemmonii* were the graminoid co-dominants. These and four subordinates occurred with 100 percent constancy. The annual *Bromus tectorum* commonly occurred in all stands. Fifteen perennial forbs occurred in this association, eight of which occurred with 100 percent constancy, *Balsamorhiza sagittata* being the most abundant.

Soil. The soil was a well drained, moderately deep gravelly loam derived from rhyolite residuum with colluvial influence. Surface area and buried volume of stone averaged 27 and 85 percent respectively.

Solum depth averaged 50 cm. Roots were concentrated in the upper 28 cm and tree roots extended into the fractures of bedrock. The following soil profile description was representative of soil under this phase (from three soil pits):

01 2-0 cm. *Cercocarpus ledifolius* litter.

A1 0-9 cm. Very dark brown (10YR 2/2) moist; gravelly loam; medium platey structure; non-sticky, non-plastic; abundant very fine, fine, and common medium roots; 25 percent volume of gravels 5 to 15 cm in size.

A3 9-20 cm. Dark brown (7.5YR 3/2) moist; gravelly loam; slightly sticky, slightly plastic; common very fine, fine and medium roots; 80 percent volume of angular cobbles and stones.

B 20-51 cm. Gravelly clay loam; slightly sticky; slightly plastic; common fine and medium roots; 80 percent volume of angular stones; fractured rhyolitic bedrock appearing at 40 to 60 cm depth.

The surface 20 cm of soil had abundant decomposing angular rhyolite gravels in all sizes. Volume and size of mineral material increased rapidly with depth.

Animal Presence. Cattle and deer were primary users of this area historically. Deer were present during the study in large numbers; however, browse damage was not noticeable. Early settlers of the surrounding ranchlands logged this area heavily in the late 1800's and early 1900's.

Ecological Analysis. Vegetation was not pristine. *Agropyron caninum* was still dominant or codominant in each stand. However, *Stipa lemmonii* appeared to have increased to almost equal status. *Poa ampla* was considered for use as h.t. designator but was rejected because this phase occurred on steep dry sites seemingly more suitable for *Agropyron caninum*. This was shown in the description of the following h.t. which was less steep (14 instead of 36 percent), was higher in elevation, and where *A. caninum* became rare. There, P. ampla was considered the h. t. designator. Cirsium vulgare had begun appearing as an uncommon component in this h. t., indicating some grazing abuse.

Stipa lemmonii Successional Stage

Site. The site in this h. t. has been previously described. Data is presented summarily in Table 9, and detailed in Appendix A, Table A 1.

Vegetation. The shrub component differed very little from the parent association. The primary difference in graminoids between this successional stage and the parent association was the increase in dominance of S. lemmonii and a decrease in both A. caninum and P. ampla. Primary changes in forbs were a reduction in dominance of Balsamorhiza sagittata, Hieraceum albertinum, and Achillea millefolium, and an increase in Cirsium vulgare, Senecio integerrimus, and Taraxacum officinale.

Soil. Soils were basically the same except for stand 6 of this successional stage. There the solum was a gravelly sandy loam; was slightly deeper and had a volume of 25 instead of 85 percent stone.

Animal Presence. Livestock use appeared to be more severe than in the parent h. t. There was no apparent change in deer activity or influence of early settlers.

Ecological Analysis. Livestock use resulted in an increase of Cirsium vulgare and Senecio integerrimus, species which were indicative of vegetation abuse in many areas of the Basin and Range Province and Owyhee Upland (Tidestrom, 1925; Hermann, 1966). Dayton et al. (1940) and my observations indicated that Hieracium albertinum was highly palatable and was a valuable indicator of vegetation abuse by livestock. The marked reduction of this species in this stage compared to its parent association confirmed the debilitated condition of the herbaceous layer. Taraxacum officinale showed a slight increase in this stage and so may have been an indicator of livestock abuse. Although it was considered by Hermann (1966) and Dayton et al. (1940) to be highly palatable to sheep and cattle, its ability to hold tenaciously to a site in the face of severe abuse (Dayton et al., 1940) made its increase here reasonable.

Cercocarpus ledifolius/Artemisia tridentata/Poa ampla h. t.

Stipa lemmonii Successional Stage

Site. This h. t. and stage occurred in the Owyhee Uplands at approximately 1850 m. The topography was mountainous and the ground surface rough. Slopes were moderate (10 to 15 percent), and aspects varied narrowly between south and southwest. Precipitation was approximately 48 cm with snowpacks occurring only during severe winters.

Vegetation. Cercocarpus ledifolius, the only tree species, had a crown cover of 56 percent. Artemisia tridentata was the dominant shrub. Three other species commonly occurred with 100 percent constancy. Two, Chrysothamnus nauseosus and C. viscidiflorus, were comparable in size to the dominant, and the third was a low shrub, Eriogonum heracleoides.

Perennial graminoids were dominated by Stipa lemmonii. Others occurring with 100 percent constancy were, in descending order, Sitanion hystrix, Carex rossii, Stipa occidentalis, and Poa ampla. Two annuals which occurred occasionally were Bromus tectorum and Festuca octoflora.

Five perennial forbs occurred with 100 percent constancy. The dominant was Cirsium vulgare. Others of significance were Agoseris heterophylla and Phlox sp. with 100 percent constancy, and Hieracium albertinum, Geum triflorum, Lupinus laxiflorus, and Lomatium sp. which were rare in occurrence.

Soil. The soil was a well drained, moderately deep gravelly loam which appeared to have been derived primarily from rhyolite residuum. Surface area and buried volume of stone averaged 26 and 66 percent respectively.

Solum depth averaged 81 cm. Roots were concentrated in the upper 50 cm with tree roots penetrating deeply between large stones of the C horizon. The following soil profile description was representative of soil under this successional stage (4 soil pits):

01 2-0 cm. Cercocarpus ledifolius litter.

A1 0-8 cm. Very dark brown (10YR 2/2) moist; gravelly loam; weak, fine subangular structure; non-sticky; non-plastic; abundant very fine, fine, and common medium roots; nodules common on C. ledifolius roots; 25 percent volume of gravels and cobbles; smooth boundary (6-10 cm).

A3 8-25 cm. Very dark gray brown (10YR 3/2) moist; heavy gravelly loam; medium subangular blocky structure; slightly sticky, slightly plastic; common fine, medium, and occasional large roots; nodules common on C. ledifolius roots; 25 percent volume of angular rhyolite gravels and cobbles; smooth boundary (14-20 cm).

B1 25-43 cm. Light gravelly clay loam; slightly sticky, slightly plastic; common fine, medium, and occasional large roots; angular cobbles and stones, 65 percent; wavy boundary (15-20 cm).

B2 43-81 cm. Gravelly clay loam; slightly sticky, slightly plastic; occasional fine, medium and large roots; 70 percent angular cobbles and stone; wavy boundary (38-45 cm).

C 81 cm +. Mixture of gravelly sandy loam with 80 to 90 percent stone.

The A1 horizon varied from gravelly loam to gravelly sandy loam. Nodules of Cercocarpus ledifolius roots were more common here than in any other south slope stands, occurring primarily between 8 and 43 cm depth.

Animal Presence. Historically, this area was logged and grazed heavily. Currently, cattle grazing appeared to be a moderate but significant factor, if not in influencing further deterioration, at least in preventing understory recovery.

Ecological Analysis. This h. t. had the most favorable site conditions of any of the h. ts. supporting associations dominated by the combination of C. ledifolius and Artemisia tridentata. Although percent slope, exposure and elevation were comparable to the C. ledifolius/A. tridentata/Festuca idahoensis h. t., the soil was deeper (81 instead of 42 cm) and surface stone was less (26 instead of 51 percent). The available soil moisture increase due to increased soil volume was shown by an increase in tree crown cover (56 instead of 45 percent), increase in graminoid dominance of the understory, and the appearance of Poa ampla and Stipa occidentalis in the species list. Carex rossii increased dramatically in the C. ledifolius/A. tridentata/P. ampla association, whereas F. idahoensis and P. sandbergii disappeared completely.

There were some significant shifts in the forb complement. _Viola nuttallii_, _Hieracium albertinum_, and _Cirsium vulgare_ appeared in this stage as new components; whereas _Senecio integerrimus_ almost disappeared.

The condition class of this association was indicated by a dominance of _Stipa lemmonii_, and stands of _Stipa occidentalis_ and _Sitanion hystrix_ which were of higher dominance than _Poa ampla_, the association designator. Also, _Cirsium vulgare_, an indicator of overuse, was the dominant forb. It was significant that _Senecio integerrimus_, noted as an indicator of overuse in the Great Basin (Hermann, 1966), was only a rare component in one stand. Either _C. vulgare_ assumed its role, or its palatability changed in this phase which was located in the Owyhee Uplands of the Snake River drainage rather than the Great Basin. Hermann (1966) said that _S. integerrimus_ was quite palatable in some areas outside of the Great Basin. Also livestock use differences may have been a factor, e.g., historical sheep use.

Cercocarpus ledifolius/Festuca idahoensis h. t.

Site. This h. t. occurred at the edge of the conifer zone where the _Pinus ponderosa_ forest met the _Artemisia tridentata_ communities of the high desert steppe. Terrain was mountainous with slopes averaging 8 percent. Elevations ranged from 1400 to 1650 m.

Precipitation was approximately 45 cm with most coming during late fall, winter and spring. Winter snow was variable, some winters having heavy snowpacks, others almost none.

Vegetation. *Cercocarpus ledifolius* was the dominant tree species with crown cover averaging 66 percent. The largest trees occurred on inclusions of rocky outcroppings in this h. t. *P. ponderosa* and *Juniperus occidentalis* both occurred with 100 percent constancy and both were rare with a dominance of 1.

Shrubs, represented mainly by *A. tridentata* and *Chrysothamnus viscidiflorus*, were largely restricted to openings in the dense *C. ledifolius*.

The understory was strongly dominated by *Festuca idahoensis*. *Sitanion hystrix*, *Agropyron spicatum*, and *Poa sandbergii* occurred in all stands, and their dominance descended in the order of listing.

Soil. The soil was a moderately deep stony loam derived from mixed colluvium and residual weathered basalt. Surface area and buried volume of stone averaged 3 and 38 percent respectively. Solum depth averaged 59 cm and varied from 54 to 63 cm. Roots were concentrated in the upper 40 cm of soil with tree roots penetrating deeper into the rocks of the underlying basalt. A representative profile is (5 soil pits):

O1 2-0 cm. Loose leaves and litter primarily of *C. ledifolius* underlain by a thin layer of very dark brown partially decomposed material mixing with the mineral soil surface.

A11 0-9 cm. Very dark brown (10YR 2/2) moist; loam; fine to medium granular structure; non-sticky, non-plastic; abundant very fine, and fine roots; basalt cobbles 5 percent of the volume; clear smooth boundary (8-12 cm thick).

A12 9-23 cm. Very dark brown (10YR 2/2) moist; loam; fine granular structure; slightly sticky, slightly plastic; abundant fine, common medium, and few large roots; basalt cobbles 5 percent of the volume; clear wavy boundary (12-16 cm thick).

B21 23-38 cm. Dark brown (25YR 3/2) moist; light clay loam; weak, fine subangular blocky structure; slightly sticky, slightly plastic; common medium, fine, and few large roots; cobbles and stone 65 percent of the volume; clear, wavy boundary (13-18 cm thick).

B22 38-59 cm. Dark brown (7.5YR 3/2) moist; clay loam; sticky, plastic; moderate fine subangular blocky structure; few fine, common medium, and few large roots; stones 60 percent of the volume; clear, wavy boundary (15-21 cm thick).

C 59+ cm. Weathered basalt fragments from angular gravels to angular cobble size, and cracked basalt rock.

Animal Presence. This h.t. was utilized by both sheep and deer historically and currently. Because of a relative paucity of forbs and because *Cercocarpus ledifolius* forage was above the reach of both animals, the plant association on this h. t. was less suitable than most for ungulate foraging.

Ecological Analysis. This plant association appeared to be as near climax as any studied. There was no evidence that ungulates had abused the vegetation or soils; however, both sheep and deer were heavy users of forbs and may have been partly responsible for their paucity. Grasses appeared unused by ungulates.

This association had few established seedlings or young plants. However, low regeneration seemed to be adequate for replacement in a fully occupied, mature community.

Cercocarpus ledifolius/Festuca idahoensis-Agropyron spicatum h. t.

Site. Most site characteristics of this h. t. were similar to those of the C. ledifolius/F. idahoensis h. t. Steepness of slope showed the greatest difference, averaging 27 instead of 8 percent. Also exposure changed from NNE to WNW, and volume of solum stone changed from 38 to 65 percent.

Vegetation. This vegetation, though similar to the C. ledifolius/F. idahoensis association, differed mainly in its less dense stand of Cercocarpus ledifolius (36 percent), a larger shrub component, and an increase in the dominance of both Agropyron spicatum, and the annual Bromus tectorum. Balsamorhiza *sagittata* and *Achillea millefolium* were the principal forbs.

Soil. The soil was a moderately deep stony loam exhibiting 25 percent surface stone and 65 percent volume of cobbles and stone in soil profile. Soil had developed from mixed colluvium and residual weathered basalt. A representative soil profile, taken from 5 soil pits, is:

01 A thin intermittent layer of loose leaves and litter, primarily *C. ledifolius*.

A11 0.5 cm. Dark reddish brown (5YR 2/2) moist; gravelly loam; fine granular structure; non-sticky, non-plastic; abundant very fine, fine, and common medium roots; basalt cobbles 25 percent of the volume; clear smooth boundary (3 to 6 cm thick).

A12 5-20 cm. Dark reddish brown (5YR 2/2) moist; gravelly loam; fine granular structure; very friable, slightly sticky, slightly plastic; abundant very fine, fine, common medium and few large roots; basalt cobbles 30 percent volume; clear wavy boundary (12 to 18 cm thick).

B21 20-36 cm. Dark reddish brown (5 YR 3/2) moist; gravelly clay loam; medium granular structure; slightly sticky, slightly plastic; abundant fine, common medium, and few large roots; basalt cobbles are 60 percent of the volume; clear, wavy boundary (14-18 cm thick).

B22 36-51 cm. Reddish brown (5YR 4/4) moist; clay loam; moderate, fine subangular blocky structure; sticky and plastic; few fine, common medium and large roots; basalt cobbles and stone 65 percent of the volume; clear wavy boundary (17-21 cm thick).

C 51 cm +. Gravelly clay, with weathered basalt fragments of all sizes up to 20 cm and cracked basalt bedrock.

Animal Presence. Mule deer and domestic sheep, both currently and historically, were occupants of this h. t. Deer were present year around in most winters; however, in winters of heavy snow accumulation, they moved to high desert steppe sites. Sheep were driven through the h. t. sporadically during the summer and early fall.

Ecological Analysis. The plant association on this h. t. was in good condition; however, it appeared to have been used significantly by ungulates. Deer highlined (consumed all foliage as high as they could reach) the mature Cercocarpus ledifolius, and both deer and sheep kept the few young plants severely hedged.

The prominance of Agropyron spicatum here compared to the C. ledifolius/F. idahoensis association was probably due to an increased slope (27 percent), a stony soil (65 percent soil volume) with high gravel content, and a WNW exposure. These factors produced xeric conditions suitable for *A. spicatum* by increasing lateral drainage and reducing the soil volume, thus reducing available soil moisture.

Cercocarpus ledifolius/*Elymus cinereus* h. t.

Site. This h. t. occurred in the Owyhee Uplands and was characterized by elevations between 1800 and 1900 m and west to southwest exposures. Topography was mountainous and ground surface moderately smooth. Slopes averaged 23 percent, ranging from 10 to 35 percent. Precipitation was 56 cm, part of which was derived from heavy winter snowpacks.

Vegetation. *Cercocarpus ledifolius* was the dominant tree with 34 percent crown cover, and an average density of 1182 trees per hectare. Stand age was mature with all age classes represented except established seedlings. Within the *C. ledifolius* series, *Juniperus occidentalis* reached its best development here. It reached a dominance rating of 3 and a constancy of 100 percent.

The most prominent shrub in all stands was *Prunus virginiana*, followed closely by *Ribes cereum*. These were the only two shrubs which occurred with 100 percent constancy. *Amelanchier alnifolia* and *Chrysothamnus nauseosus* occurred commonly in 66 percent of the stands.

There was no clear dominant graminoid in this h. t. Three perennial species were of equal dominance (3) and constancy (100 percent). These were *Agropyron caninum*, *Carex rossii*, and *Elymus cinereus*. *Oryzopsis hymenoides* occurred with equal dominance but less constancy (66 percent). This was the only association where *Stipa comata* occurred.

Soil. The soil was an excessively drained, moderately deep, fine sand, underlain by rhyolite bedrock. The surface was almost devoid of stone, and stone volume in the soil mantle was less than 5 percent. The soil mantle averaged 84 cm deep to bedrock with roots concentrated in the upper 35 cm. Tree roots reached below 84 cm and into fractures of bedrock.

This was a variable soil which had little development. The surface horizon was a recently transported fine sand which had covered an earlier surface horizon. This was indicated by the abrupt color change from pale brown to black. The black color appeared to be a resultant staining by an old litter layer. This buried layer also was a concentration horizon for roots, whereas in the surface horizon they were uncommon.

Horizon colors ranged from yellows to grays and textures varied from fine sand to loamy fine sands between sites. It appeared that there had been a consistent, if infrequent, history of shifting and transportation of soil layers.

Animal Presence. This h. t. supported cattle and deer and has done so historically. There was also a population of bighorn sheep in this area until the 1880's. Although evidence of abuse, i. e. trampling of soil and vegetation, was not readily evident (possibly because evidence in loose sand is quickly obliterated), the scarcity of vegetation seemed influenced by a long history of ungulate use. A spotty understory in these areas was partly due to shifting sand, and the difficulty most species have in maintaining themselves in this situation.

Ecological Analysis. This h. t. and its attendant association occurred as an isolated unit within the study area; however, its uniqueness made it valuable for documenting an extreme in ecological amplitude of *Cercocarpus ledifolius*.

The fine sand had become somewhat stabilized but a situation still existed where naming a graminoid dominant for the association was difficult. *Elymus cinereus* was selected because it appeared to be most effective in maintaining establishment in a situation of soil instability. *Agropyron caninum*, a tufted perennial, was equal in dominance and constancy to *E. cinereus*, however since it was not rhizomatous and *E. cinereus* had short rhizomes, allowing more rapid adjustment to soil changes, the latter was selected. Also, *E. cinereus* may be considered as more suitable because its tall habit, coarseness, and bulk should enable it to withstand shifting of fine sands more effectively than others in the association.

Balsamorhiza sagittata and *Senecio integerrimus* were the only two forbs which occurred with 100 percent constancy. *S. integerrimus* was considered an indication of disturbance in the Basin and Range Province; however, in the Owyhee Uplands it may not have been as diagnostic.

From the species list, it was obvious that there was moderate soil stability in this h. t. as compared to typical sand dunes. These sites were fine sand pockets exposed on high elevation positions. Exposures were west to southwest, with stands facing the prevailing winter winds. Winter and spring were the primary seasons of extreme winds, and maximum sand movement probably occurred during this period. Sand movement seriously affecting vegetation might have been infrequent, coming only in years when snowpacks did not develop.

Cercocarpus ledifolius/Symphoricarpos albus/ Festuca idahoensis h. t.

Site. This h. t., occurring in the Blue Mountains of northeastern Oregon, was characterized by elevations near 1400 m on southwest slopes averaging 13 percent. Topography was mountainous and ground surface varied from rough to moderately smooth. The sites were typically ridgetops with outcroppings of basàlt, producing slope variations within stands from 0 to 40 percent. Precipitation was approximately 50 cm.

Vegetation. *Cercocarpus ledifolius* was the dominant tree with 61 percent crown cover and 762 trees per hectare. *Pinus ponderosa* was present as a common component of each stand; however, it occurred primarily as scattered individuals or small clumps furthest from the rocky outcroppings, and not as uniformly dispersed as *C. ledifolius.*

These were the oldest relic stands of *C. ledifolius* found in the study area. Largest trees measured were 64, 61, and 56 cm diameter, 46 cm above the ground. A rough age estimation of the largest tree was 600 years, based on tree ring counts of other large trees in the Blue Mountains. Limbs 1.83 m above the ground, 20 cm in diameter, were larger than 90 percent of all main stems of trees measured throughout the study area. The largest trees were found on the rockiest portion of the h. t.

Symphoricarpos albus was the dominant shrub. It and *Ribes cereum* were the only two shrubs occurring with 100 percent constancy Graminoids were dominated by *Festuca idahoensis*. *Agropyron spicatum*, *Poa sandbergii*, and *Bromus carinatus* were others occurring with 100 percent constancy and a descending order of dominance.

Eleven forbs were present in this association with 100 percent constancy. Achillea millefolium was dominant, followed in descending order by Astragalus filipes, Taraxacum officinale, and Antennaria stenophylla. A total of 13 perennial forbs were present.

Soil. The soil was a well drained, shallow stony loam on basalt bedrock. Surface stone averaged 7 percent and stone volume in the solum 78 percent. Solum depth averaged 31 cm. Roots were concentrated in the upper 15 cm with many roots growing below this level between stones. Tree roots penetrated cracked bedrock at 30 to 40 cm. The following soil profile description is representative:

01 2-0 cm. Loose Cercocarpus ledifolius litter with a thin layer of decomposing organic material mixed with the solum surface. Occasional patches of loose Pinus ponderosa litter.

A 0-15 cm. Dark brown (10YR 4/3) dry, and dark reddish brown (5YR 2/2) moist; loam; moderate, fine subangular blocky structure, breaking to single grain; slightly sticky, slightly plastic; soft, very friable; pH 6.2; abundant very fine and fine, and few medium roots; 5 percent cobbles and stone by volume; clear wavy boundary, (13-17 cm thick).

B 15-30 cm. Brown (7.5YR 4/4) dry, dark yellowish brown (10YR 3/4) moist; stony clay loam; moderate fine subangular blocky, breaking to single grain; slightly hard, sticky, plastic; pH 5.8; few fine, many medium roots; 75 percent cobbles and stone by volume; clear, wavy boundary (12-18 cm thick).

Dr 30-38+ cm. Partially decomposed stone and cracked basalt bedrock; Cercocarpus ledifolius and Pinus ponderosa roots penetrating cracks in bedrock.

This soil varied from the typical description to almost no soil in the rimrock section of the plots. C. ledifolius was found commonly on both sections.

Animal Presence. This h. t. had a long history of mule deer and Rocky Mountain elk use, and a recent history of domestic livestock use, primarily cattle. Vegetation on the h. t. did not appear to be abused by livestock; however, all established seedlings of C. ledifolius were heavily browsed by deer and elk. Graminoids and forbs appeared in vigorous form and litter did not appear disturbed to any extent.

Ecological Analysis. The vegetation was in good condition. Dominant tree, shrub, and graminoid species were stable and showed no evidence of being in a successional stage. C. ledifolius appeared in all age classes with both very old (400 to 600 years) and very young (1-20 years) age classes being in the minority.

The relic specimens of C. ledifolius all occurred on the rockiest sites; some of the largest appeared to be growing almost without soil (Figure 11). This illusion was typical of this species in many stands throughout the study area. Actually, roots of these specimens spread horizontally to utilize adjacent soil.

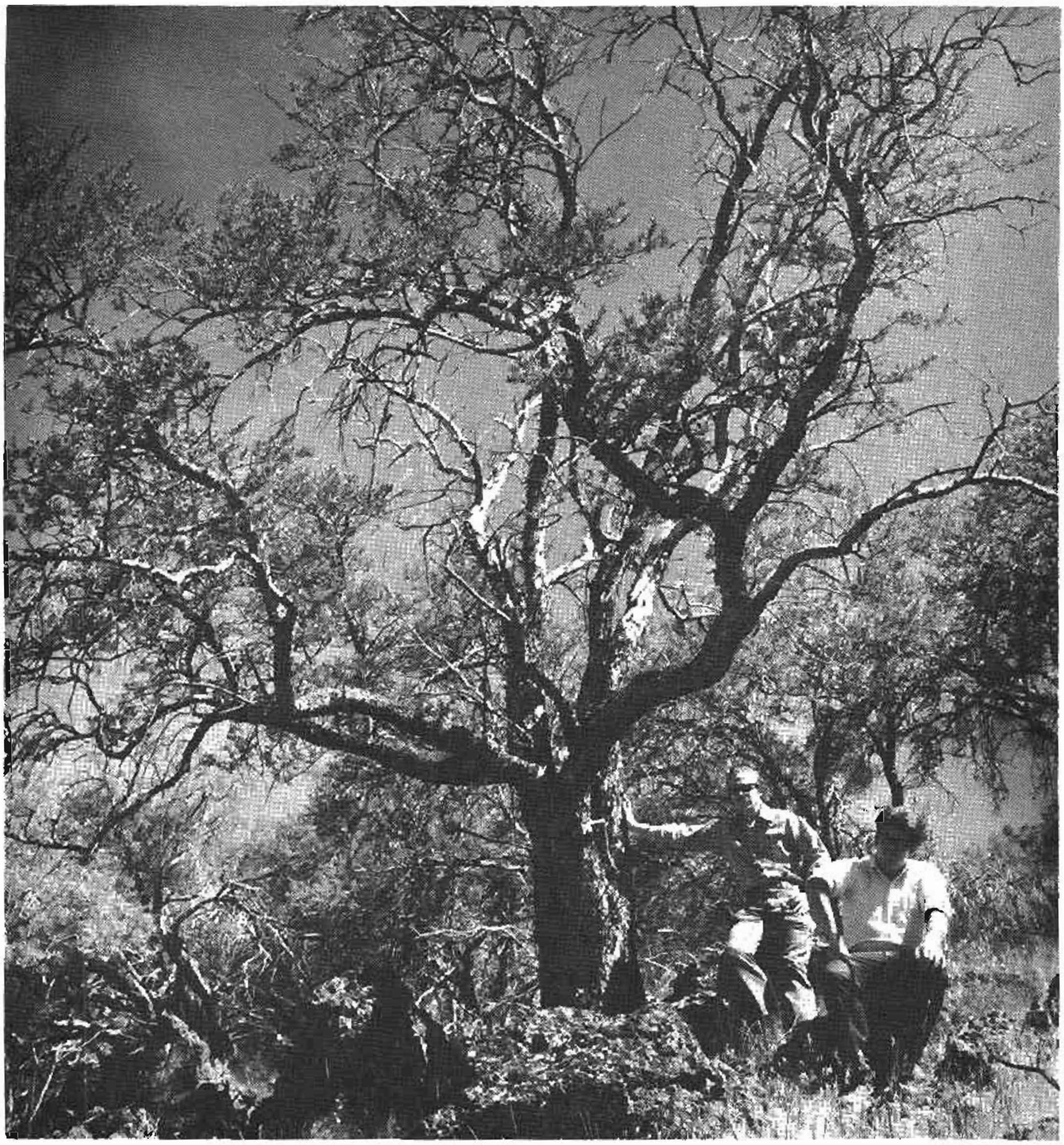


Figure 11. Illustration of a relic stand of Cercocarpus ledifolius showing the largest diameter tree (64 cm) yet discovered in the study area. Note smaller trees in the background on less rocky soil.

Although no charcoal was found in the solum mantle, fire scars were found on large *Pinus ponderosa* in the association. It appears highly probable that the survival of relic *Cercocarpus ledifolius* trees on rocky sites was due primarily to the difficulty fire had in approaching them.

Most established seedlings in this association were growing on the perimeter of the mature stands where they were vulnerable to fire. None were more than 20 cm tall, all were in a severely hedged condition, and of the few of typical size sampled by ring counts, none were more than 15 years old.

Cercocarpus ledifolius/Symphoricarpos oreophilus/Poa ampla h. t.

Site. This h. t. occurred in the Basin and Range Province and was characterized by elevations near 1800 m on south to southwest slopes of 25 to 35 percent. Topography was mountainous and the ground surface was moderately rough. Precipitation was approximately 50 cm, part of which was deposited as a winter snow-pack. Measured stands occurred on the toes of slopes in glaciated valleys of the Steens Mountains, a fault block rising to 2948 m in elevation, and some 1600 m above the surrounding plain of the Basin and Range Province.

Vegetation. *C. ledifolius* was the dominant tree species with

80 percent crown cover and 1598 trees per hectare. Stands were mature with all age classes present except established seedlings. _Juniperus occidentalis_ occurred with 100 percent constancy as an uncommon component.

Shrubs, in general, were of minor occurrence in this association. _Prunus virginiana_ was most common, followed by _Prunus emarginata_, _Chrysothamnus nauseosus_, _Symphoricarpos oreophilus_, and _Artemisia tridentata_, in descending order of importance. Other shrubs were present with less than 100 percent constancy.

Graminoids occurred, codominated by _Sitanion hystrix_ and _Poa ampla_. Between individually sampled stands, these species reversed dominance between a rating of 5 and 3, with the association averaging a codominant 4. Two other perennial graminoids occurring with 100 percent constancy, and in a descending order of dominance were _Carex rossii_ and _Bromus carinatus_.

No forb occurred with strong dominance; however, _Phacelia heterophylla_ was most common, followed by _Senecio integerrimus_, _Geum triflorum_, and _Arabis holboellii_. Ten other forbs occurred in this association with less than 100 percent constancy.

Soil. The soil was a well drained moderately deep, gravelly loam over basalt. The soil surface averaged 48 percent stone and buried volume of cobbles and stone were 67 percent. Parent material was primarily colluvium with some glacial influence as indicated by large rounded stones in the profile. The solum averaged 61 cm in depth. Roots were concentrated in the upper 40 cm; however, medium and large roots reached below 70 cm. The following soil profile description is representative (5 soil pits):

01 2-0 cm. Loose layer of <u>Cercocarpus</u> <u>ledifolius</u> leaves and litter with a thin layer of decomposing material mixed with surface mineral soil.

A11 0-5 cm. Black (5YR 2/1) moist; gravelly loam grading toward gravelly silt loam; non-sticky, non-plastic; abundant very fine, fine and few medium roots; cobbles and stones 35 percent of soil volume; pH 6.5; clear, smooth boundary (4-6 cm thick).

A12 5-16 cm. Black (5YR 2/1) moist; gravelly loam grading to gravelly silt loam; weak, medium granular structure; non-sticky; non-plastic; common very fine, fine, and medium roots; cobbles and stone 40 percent of soil volume; pH 6.5; clear, smooth boundary (9-13 cm thick).

B1 16-28 cm. Very dark brown (10YR 2/2) moist; heavy gravelly loam; weak, fine subangular blocky; slightly sticky; slightly plastic; common fine, medium, and few large roots; cobbles and stone 75 percent of soil volume; pH 6.2; clear, wavy boundary (10-14 cm thick).

B21 28-53 cm. Dark brown (7.5YR 4/4) moist; light gravelly clay loam; moderate fine subangular blocky structure; slightly sticky, slightly plastic; common fine and medium, few large roots; stones 80 percent of soil volume; pH 6.0; clear, wavy boundary, (22-28 cm thick).

B22 53-61 cm. Dark brown (7.5YR 4/4) moist; light gravelly clay loam grading to gravelly sandy clay loam; moderate, medium subangular blocky structure; slightly sticky; slightly plastic; few fine, medium and large roots; stones 80 percent of soil volume; pH 6.0; clear, wavy boundary (6-10 cm thick).

C 61-70+ cm. Primarily large stones surrounded by unconsolidated material consisting of gravels and a loamy sand.

Animal Presence. Historically, mule deer and bighorn sheep occurred in this area. For the last 100 to 120 years, cattle, sheep and horses grazed the valleys. During the study, sheep were trailed up and down the valleys each spring and summer.

Ecological Analysis. *Cercocarpus ledifolius* was not plentiful in the Steens Mountains; however, dense stands did occur along the glaciated valleys emptying westward out of the mountain range. These stands had a long history of heavy use as indicated by the increase of *Sitanion hystrix* dominance in relation to *Poa ampla*, the association designator, and by the abundance of *Chrysothamnus nauseosus*, a shrub species common on disturbed areas. *Symphoricarpos oreophilus* was chosen as a designator species over *Prunus virginiana* since I believe heavier use of the former by all classes of ungulates resulted in its low dominance rating compared to the latter.

P. ampla and *S. hystrix*, by close dominance relationship between stands, illustrated the degree of stand disturbance. In stands 47, 50, and 53, *S. hystrix* had a dominance rating of 5 and *P. ampla* 3. In stands 51 and 52, ratings were reversed, with *P. ampla* rated 5 and *S. hystrix* 3. *Bromus tectorum*, an annual graminoid, was sometimes considered an indicator of disturbance on the high desert steppe; however, in the *C. ledifolius* series, it seemed to be a ubiquitous species with little indicator value.

Arnica cordifolia Phase

Site. This phase occurred in the Basin and Range Province at over 1800 m on northerly aspects. It was found at the toe of slopes along glaciated valleys of the Steens Mountains. Slopes ranged from 25 to 40 percent. Precipitation was approximately 50 cm with snow packs common during winter. Terrain was mountainous and the ground surface moderately rough with surface stone averaging 32 percent.

Vegetation. *C. ledifolius* was the dominant tree on this phase with 100 percent constancy, 74 percent crown cover, and an average of 1980 stems per hectare. *Juniperus occidentalis* was present in 80 percent of the stands but was uncommon to rare.

Symphoricarpos oreophilus occurred as a common to uncommon species on all plots. Artemisia tridentata had the same dominance and constancy rating. Other shrubs with 100 percent constancy and in descending order of dominance were Chrysothamnus nauseosus and Prunus virginiana.

The dominant graminoid was Sitanion hystrix followed by Poa ampla, Carex rossii, Bromus carinatus, Melica bulbosa, and Poa sandbergii in descending order. All occurred with 100 percent constancy.

Forbs were strongly dominated by Arnica cordifolia, followed by Achillea millefolium, Thalictrum sp., Crepis intermedia, and Hieracium albertinum in descending order. These species occurred on all plots.

Soil. This was a moderately shallow, well drained loam over basalt. Depth was 47 cm and stone volume averaged 42 percent. Root concentration was in the top 28 cm. Small and medium tree roots penetrated to depths beyond 75 cm between close fitting stones. The following soil profile is typical (5 soil pits):

01 2-0 cm. Intermittent layer of loose Cercocarpus ledifolius leaves with a thin layer of decomposing material at the mineral soil surface.

A11 0-5 cm. Very dark gray (10YR 3/1)to grayish brown (10YR 4/2) dry, very dark brown (10YR 2/2) moist; loam grading to silt loam; non-sticky, non-plastic; soft, very friable; abundant very fine, fine, and few medium roots; 10 percent volume of cobbles and stone; fine gravel common; clear, smooth boundary (3-6 cm thick).

A12 5-15 cm. Dark brown (10YR 3/3) dry, very dark brown (10YR 2/2) moist; loam with angular gravels common; non-sticky, non-plastic; soft, friable; common very fine, fine and few medium and large roots; cobbles and stones are 35 percent of horizon volume; clear smooth boundary (8-12 cm thick).

B1 15-30 cm. Dark brown (10YR 3/3) dry, very dark brown (10YR 2/2) moist; loam with some gravel; slightly sticky, slightly plastic; soft, friable; common fine, few medium and large roots; cobbles and stones 45 percent of volume; clear, wavy boundary (13-17 cm thick).

B21 30-40 cm. Dark yellowish brown (19YR 3/4) dry, dark brown (10YR 3/3) moist; heavy loam to light clay loam with some gravels; slightly sticky, slightly plastic; slightly hard, friable; common fine, medium and few large roots; cobbles and stones 45 percent of volume; clear, wavy boundary (8-12 cm thick).

B22 40-47 cm. Brown (7.5YR 5/4) dry, dark reddish brown (5YR 3/3) moist; heavy loam to light clay loam with gravel; slightly sticky, slightly plastic; slightly hard, friable; few fine, medium and large roots; stones were 60 percent of the volume; clear wavy boundary (5-9 cm thick).

C 47-70+ cm. A matrix of a loam to sandy loam surrounding stones and gravels of various sizes; stone volume 85 percent of horizon; sand increases generally from the soil surface down through the C horizon.

Animal Presence. The primary animal influence on vegetation was use by cattle and sheep. This phase was in close proximity to a large year-around stream, permitting easy access by livestock. Before advent of the Taylor Grazing Act in 1934 (Federal control of grazing intensity), cattle and sheepmen competed for grazing rights. Griffiths (1902) observed sheep herds in the Steens Mountains during the summer of 1901 in large numbers, thus indicating considerable use of most h. ts.

Ecological Analysis. *Symphoricarpos oreophilus* was present as an equal with *Artemisia tridentata*, probably due to a history of use by livestock. Use by livestock was also indicated by the occurrence of *Chrysothamnus nauseosus* on all plots, with dominance ratings of 2 and 3. Considerable use was also indicated by the occurrence of *Sitanion hystrix* as a dominant over *Poa ampla* and *Bromus carinatus*. The forb *Senecio integerrimus*, an indicator of livestock use, was present in greater abundance than would be expected with no use.

Hieraceum albertinum was a forb highly palatable to livestock.

Its palatability, 100 percent constancy, but low dominance (slightly above a 2) suggested that it would be more abundant under less grazing pressure. *Arnica cordifolia*, although readily used, was not as well liked by wild or domestic ungulates, as *H. albertinum*. This I believe was indicated by the greater abundance of *A. cordifolia*.

This phase was very similar to the parent described earlier. The shrub and graminoid components were similar; however, there were interesting differences apparently tied to aspect differences. The shrub component of the parent, on a southern exposure site, was more dominant in the understory than in this phase, on a northern exposure site.

The reverse was true for the graminoids and forbs. Also, both *A cordifolia* and *H. albertinum* appeared in this phase with 100 percent constancy, and did not occur in the parent.

Labeling for separation at the phase level was difficult due to similarity of shrubs and graminoids. However, I felt that the variation was sufficient at that level and should be so accepted.

Cercocarpus ledifolius/Symphoricarpos oreophilus h. t.

Balsamorhiza sagittata Phase, *Poa sandbergii* Successional Stage

Site. This stage occurred in the Basin and Range Province on the Whitehorse Mountains near the Nevada border. Elevations ranged narrowly around 1900 m with exposures ranging from west through north and east, and slopes from 15 to 35 percent. Topography was mountainous and the ground surface stony and moderately rough. Precipitation was estimated to be 50 cm. Winter snowpacks normally occurred on most exposures.

Vegetation. Cercocarpus ledifolius was the only tree that occurred on this stage. Crown cover was 55 percent and trees per acre averaged 1429 per hectare. Artemisia tridentata and Symphoricarpos oreophilus were the codominant shrubs. Chrysothamnus viscidiflorus was the only other shrub which occurred with 100 percent constancy.

Poa sandbergii and Sitanion hystrix were the two most common graminoids; however, neither showed a clear understory dominance. Other prominent, but less dominant species, and ones which occurred with less than 100 percent constancy were P. ampla, Elymus cinereus, Carex rossii, and Stipa lemmonii. Two annuals which occurred with 100 percent constancy were Bromus tectorum and Festuca octoflora.

The most dominant forb was Balsamorhiza sagittata, followed by Senecio integerrimus and Viola nuttallii, all occurring with 100 percent constancy.

Soil. This was a moderately shallow, well drained gravelly loam overlying basalt. The soil surface had 27 percent stone and the stone volume in the soil was 81 percent. Solum depth averaged 41 cm with cracked bedrock depth varying from 46 to 84 cm. Root concentration zone averaged the top 33 cm of solum; however, medium and large roots penetrated throughout the complete soil profile and penetrated the tight fitting stone layers and cracked bedrock. The following soil profile description is representative (7 soil pits):

01 5-2 cm. Primarily undecomposed C. ledifolius litter.

02 2-0 cm. Decomposing organic matter, the lower edge mixing with mineral material of the soil surface.

A11 0-5 cm. Black (10YR 2/1) moist; loam grading to silt loam; moderate fine granular; non-sticky, non-plastic; soft, very friable; abundant very fine, fine and few medium and large roots; 35 percent cobbles and stone by volume; clear, smooth boundary (4-6 cm thick).

A12 5-20 cm. Black (10YR 2/1) moist; gravelly loam, grading to gravelly silt loam; moderate fine granular structure; slightly sticky, slightly plastic; soft, friable; common very fine, abundant fine, common medium and few large roots; 50 percent cobbles and stones by volume; clear smooth boundary (13-17 cm thick).

B 20-46 cm. Brown (10YR 4/3) moist; gravelly clay loam;

sticky, plastic; common fine, medium, and few large roots; several root nodules found in this horizon; 85 percent of the solum volume is stone; clear, wavy boundary (22-30 cm thick).

C 46-84 + cm. Decomposing stone with clay in cracks; few large C. ledifolius roots penetrate these cracks.

Animal Presence. Historically, domestic sheep and wild horse grazing was severe. The highest concentration of use was from the late 1880's through the 1930's when wild horses were brought under partial control; however, it wasn't until the late 1940's that wild horses were reduced to small scattered bands by market hunters. Cattle and horses used this area during the late spring and summer months and a small mule deer herd also occupied the area at the time of this study.

Ecological Analysis. Symphoricarpos oreophilus was heavily used by domestic sheep at the turn of the century in some areas until "there was nothing left but short, barked stumps and old, woody stems" (Griffiths, 1903). This was probably a function of lack of other forage, not of high preference. This overuse was particularly pronounced in the higher mountain summer ranges, where sheep competed with cattle for forage.

The present codominant position of Artemisia tridentata with S. oreophilus and the abundance of Chrysothamnus viscidiflorus were probably a result of past disturbance. This was further indicated by the prominence of such graminoids as Sitanion hystrix, Poa sandbergii, and Festuca octoflora, and the weak expression of Poa ampla, a normal dominant when disturbance was minor.

The forb Senecio integerrimus was quite prominent, again indicating disturbance. Balsamorhiza sagittata was the dominant forb which surprisingly maintained itself well in this disturbed area since it was utilized by livestock (Griffiths, 1903; Hermann, 1966). It was used at flower stage and younger and was ignored as it became older, drier and tougher. Its abundance may have been due to a very early season use by sheep and late season use by cattle. Griffiths (1903) stated that in areas lacking water, herders took sheep to high ranges in winter or early spring when snow was available as a water source. When snow disappeared the sheep were moved to watered ranges, probably moving in and out of those ranges before Balsamorhiza sagittata began much growth. Apparently the availability of water was closely related to use or abuse of the range.

Cercocarpus ledifolius/Symphoricarpos oreophilus/ Festuca idahoensis h. t.

Poa sandbergii Successional Stage

Site. The successional stage of this association occurred in the Oregon portion of the Basin and Range Province near the Nevada border. Elevation was about 1800 meters and exposures were northwesterly. Slopes were 20 to 25 percent. Terrain was mountainous and the ground surface smooth, with surface stone averaging 5 percent. Precipitation was estimated as 45 cm with winter snowpacks occurring during some winters.

Vegetation. *Cercocarpus ledifolius* was the only tree occurring in this stage of the association, averaging 74 percent crown cover and 2221 stems per hectare. No established seedling or young age classes occurred on sample plots.

Only two shrubs occurred with 100 percent constancy--*Symphoricarpos oreophilus* the dominant, and *Artemisia tridentata*, a common stand component.

Poa sandbergii, which was slightly dominant, and *Sitanion hystrix* were the two most abundant graminoids, both occurring with 100 percent constancy. Also *Festuca idahoensis*, the association designator, occurred with 100 percent constancy. *P. ampla* was the next most common with 75 percent constancy.

Senecio integerrimus was the strong dominant of this layer and was the only forb which occurred with 100 percent constancy. *Arabis holboellii* and *Balsamorhiza sagittata* followed in order of dominance and both occurred with 75 percent constancy.

Soil. In 75 percent of the type sampled, the soil (A) was a well drained, moderately deep gravelly loam grading toward a gravelly silt loam. Twenty-five percent of the type included a soil (B) of gravelly sandy loam. The surface of soil A included 5 percent stone and the solum volume averaged 27 percent stone. Parent material was colluvium. The solum averaged 53 cm in depth. Roots were concentrated in the upper 36 cm, and medium and large roots of C. ledifolius reached below 64 cm. The following profile description is representative of soil A (3 soil pits):

01 3-1 cm. Loose layer of C. ledifolius leaves and litter.

02 1-0 cm. Layer of partially decomposed organic matter mixed with the surface of the mineral soil.

A11 0-8 cm. Very dark brown (10YR 2/2) moist, varying to black (10YR 2/1) moist; coarse gravelly loam, high in silt; weak, fine granular structure breaking to single grain; non-sticky, non-plastic; abundant very fine, fine, and few medium roots; pH 6.0; clear, smooth boundary (6-10 cm thick).

A12 8-18 cm. Very dark brown (10YR 2/2) moist; gravelly loam, grading to gravelly silt loam; weak fine subangular blocky structure; non-sticky, non-plastic, abundant very fine, fine and common medium roots; cobbles and stone are 50 percent of the volume; pH is 6.0; clear, smooth boundary (8-12 cm thick).

11A 18-30 cm. Dark brown (10YR 3/3) moist; gravelly, sandy loam; fine subangular blocky structure; slightly sticky, slightly plastic; common fine and medium and few large roots; cobbles and stone of basalt and cinders make up 40 percent of the volume, with gravels of basalt, cinders and obsidian; pH was 6.5; clear, wavy boundary (10-14 cm thick).

IIAC 30-53 cm. Dark yellowish brown (10YR 4/4) moist; gravelly sandy loam to loamy sand; medium and large roots penetrated this horizon; 20 percent cobbles and stones.

IIC 53+ cm. Sand mixed with 90 percent volume of stone. Soil in this h. t. had variable texture in all horizons. Some 75 percent of sites sampled had soils with the sand component increasing with depth. Surface horizons varied from gravelly loam to gravelly sandy loam. The C horizon varied from gravelly sandy loam to loamy sand with 25 percent of the sites maintaining a gravelly loam texture throughout the profile with higher silt content in the surface horizon. Gravel content, stone distribution, and colors were consistent between sites. Soil pH increased slightly with depth from medium to slightly acid.

Animal Presence. The area was heavily used by sheep, horses, and predominantly by cattle during the late 1800's and early 1900's. Bighorn sheep were present prior to 1880. Cattle and horses used the area along with a small herd of mule deer during the period of the study.

Ecological Analysis. _Artemisia tridentata_ was below but very near the dominance of _Symphoricarpos oreophilus_. Heavy use by sheep since 1900 probably reduced the dominance of the latter. _Artemisia tridentata_ appeared in a weak crowned form, typical of the species in other associations with dense _Cercocarpus ledifolius_ crown cover. It would not be expected to gain in dominance, even with further abuse of the understory, because of the influence of dense tree crown cover.

Festuca idahoensis was selected as the association designator over _Poa ampla_ because of the history of grazing use. The White-horse Ranch, famous for its size and prominence (Oliphant, 1948) during the period 1885-1900, grazed large herds of cattle in this area. Cattle grazing in these high ranges occurred later in the growing season than sheep grazing. As the _Poa_ spp. in general matured earlier than _F. idahoensis_, their palatability tended to decline earlier in the season. The schedule of cattle grazing tended to favor maintenance of the _P. ampla_ stand. Since the dominance of relatively uncommon _P. ampla_ does not reflect this, I considered it a secondary species in a projected undisturbed stand.

I used _P. sandbergii_ as the successional stage designator over _Sitanion hystrix_ even though they showed equal dominance and constancy because the latter species seemed to be ubiquitous as well as having a dominance rating of at least 3 in all but two of the 15 study communities. Consequently, its diagnostic value was small.

Cercocarpus ledifolius/Calamagrostis rubescens h. t.

Site. This relatively undisturbed h. t. occurred on Mahogany Mountain in the Owyhee Uplands at approximately 1900 m and was characterized by east to northeast slopes averaging 15 percent. Topography was rolling and ground surface smooth. The 7-year average precipitation recorded near the mountaintop was 56 cm. However, the C. ledifolius sites which occurred in this area had high northeasterly aspects which accumulated deeper winter snow-packs from prevailing storms out of the southwest than did most other areas.

Vegetation. C. ledifolius was the only tree. Crown cover was 82 percent and average tree density was 3066 per hectare. Amelanchier alnifolia was the only shrub which occurred with 100 percent constancy; Berberis repens was next with 83 percent.

Graminoids were strongly dominated by Calamagrostis rubescens, with four others also appearing with 100 percent constancy. Poa ampla was second among graminoids in dominance.

Hieracium albertinum was the dominant forb, and was among 5 which attained 100 percent constancy. Viola nuttallii was second in dominance, followed closely by Balsamorhiza sagittata and

Agoseris heterophylla. The orchid *Habenaria unalascensis* was found only in this h. t. and at a constancy of 83 percent.

Soil. This was a moderately shallow (48 cm) well drained gravelly loam overlying cracked rhyolitic bedrock. Surface stone averaged 5 percent and buried stone volume 60 percent. Root concentration was in the upper 35 cm of the solum; however, medium roots extended throughout the soil profile and into the tight fitting stone layer in the C horizon. The following soil profile description is representative (6 soil pits):

01 6-2 cm. Layer of undecomposed leaves and litter of *Cercocarpus ledifolius*.

02 2-0 cm. Decomposed layer of organic material mixed with the mineral soil surface.

A11 0-8 cm. Dark reddish brown (5YR 2/2) moist; gravelly loam tending toward gravelly silt loam; non-sticky, non-plastic; soft, very friable; abundant very fine, fine, and few medium roots; 15 percent cobbles and stone by volume; clear smooth boundary (7-9 cm thick).

A12 8-28 cm. Dark reddish brown (5YR 2/2) moist; heavy gravelly loam; slightly plastic, slightly sticky; soft, friable; common, very fine, fine, and few medium and large roots; 60 percent cobbles and stone by volume; clear, wavy boundary (17-23 cm thick).

B 28-48 cm. Very dark grayish brown (10YR 3/2) moist; light gravelly clay loam; slightly plastic, slightly sticky; friable; common fine, and medium roots; cobbles and stone varied from 60 to 95 percent by volume; clear, wavy boundary (18-22 cm thick).

C 48-76 cm. Light yellowish brown (10YR 6/4) moist; gravelly sandy loam matrix surrounding cobbles and stones which made up 95 percent of the volume. Medium roots penetrated this horizon.

Animal Presence. Historically, bighorn sheep and mule deer inhabited the area, bighorns until the late 1800's, and deer through the period of the study. From about 1870 to 1934, domestic sheep and cattle used the area heavily. Since the Taylor Grazing Act of 1934 cattle have been the only domestic animals grazing the areas (Jesse Strode, personal communication). Before 1934, sheep were grazed from June to August, and cattle from June through October.

Ecological Analysis. From a personal interview with Jesse Strode, early day rancher who used the area, and the various historical writings referring to grazing in the Owyhee Uplands and Basin and Range Province (Oliphant, 1948; Hazeltine, et al., 1961; Griffiths, 1902, 1903; Strong, 1940), I determined that this association was grazed at least moderately through 1934. However, appearance of the understory vegetation indicated that a great deal of recovery had taken place. In fact, of all plant associations and phases on Mahogany Mountain, this was in the best condition. Calamagrostis rubescens, Poa ampla, and Agropyron caninum, were all present with 100 percent constancy and were either dominant or common (value of 5 or 3), and Stipa lemmonii, a successional dominant, was an uncommon species (value of 2).

Hieracium albertinum, a favorite sheep food (Dayton et al., 1940), and Agoseris heterophylla were present as dominant (value of 5), and common (value of 3) species respectively. Both were present on all sites. Habenaria unalascensis, an orchid, was found in 83 percent of these stands, but no where else in the study area. This is a delicate species and probably disappears quickly with heavy use, due to its rooting position close to the soil surface.

Stipa lemmonii Successional Stage

Site. This site varied from the parent h. t. in having steeper slopes (28 instead of 15 percent), and a situation at a lower elevation (174 m). Otherwise sites were comparable.

Vegetation. Crown cover of C. ledifolius in this successional stage was equal to that of the association. Average stand ages were approximately equal. There were no other tree species present.

The shrub species list varied slightly. Artemisia tridentata was present as a rare species on one plot but did not occur in the association, and *Ribes cereum* occurred uncommonly on all plots but also was not found in the association. Those species which occurred in the association and not in this successional stage were *Chrysothamnus nauseosus*, *Prunus virginiana*, *Rosa gymnocarpa*, and *Symphoricarpos oreophilus*. All of these species were rare to uncommon, and occurred only on a small percentage of the plots.

Agropyron caninum was the only graminoid occurring in the association that did not occur in this successional stage. *Calamagrostis rubescens* dropped from a dominance of 5 in the association to a 3 here. Both *Carex rossii* and *Stipa lemmonii* increased from a dominance of 2 to 4. *Sitanion hystrix* remained constant.

The primary differences in the forb layer between the association and this successional stage were the presence of *Cirsium vulgare*, the disappearance of both the orchid *Habenaria unalascensis*, and *Balsamorhiza sagittata*, the marked decrease in *Hieracium albertinum* and the increase in both *Taraxicum officinale*, and *Viola nuttallii*, all indicative of past grazing use.

Soil. Solum depth averaged 30 cm compared to 48 cm in the parent h. t. The volume of stone in the solum of this successional stage was only one-half that of the parent. Also, texture of the soil here indicated a higher sand content. Gravel content appeared to be consistent throughout both ecosystems.

Animal Presence. Animal presence was the same as described on the parent h. t.

Ecological Analysis. This successional stage generally showed a debilitation of the understory compared to the association. Some of this, i. e. the complete absence of Agropyron caninum and the appearance of Ribes cereum here, may have been due to other factors than animal abuse; however, these differences were not felt to be great enough to consider this stage to be under a different association.

The appearance of Cirsium vulgare, and the increase of Stipa lemmonii and Taraxicum officinale indicated an abuse of the understory by animals. The disappearance of the orchid Habenaria unalascensis may likely have been a product of soil abuse. This species was unique in having a fleshy tuber only a few cm below the soil surface. Where found in the association, it had a 4 to 6 cm layer of litter protecting it. Trampling of the litter and surface soil by large animals might have been destructive of this species' fragile habitat.

The stands analyzed for this successional stage occurred on the same mountain range but at lower elevations and a mile from the stands on the parent h. t. These differences placed the successional stage in closer proximity to the zone of cattle entry to the mountains in the spring. Cattle were turned loose near the base of the mountain about April 1 and moved at will throughout the mountains. Usually they did not move up the mountains until June, when forage at lower elevations ran out or dried up. This information was derived from personal observations and interviews with Jesse Strode, who had lived and ranched at the mountain base since 1900, and Duncan McKenzie, whose family owned and grazed livestock on most of the mountain during the same period.

It appeared, from the lateral branch characteristics of *Cercocarpus ledifolius*, that this successional stage showed a greater history of use than the association. Trees in the association had intact lateral branches which impaired cattle movement, whereas this successional stage appeared to have such branches rubbed or broken by cattle passage.

Cercocarpus ledifolius/Calamagrostis rubescens-Festuca idahoensis h. t.

Stipa lemmonii Successional Stage

Site. This stage was found in the Owyhee Uplands on Mahogany Mountain near 1750 m elevation. Topography was steep and mountainous and the ground surface moderately smooth. Exposure varied narrowly around northeast. Slopes varied between

30 and 40 percent, averaging 35 percent. Precipitation was approximately 50 cm.

Vegetation. *Cercocarpus ledifolius* was the only tree occurring in most stands of this successional stage. It occurred with 83 percent crown cover and 2669 trees per hectare. *Populus tremuloides* occurred as a rare species on one plot.

Ribes cereum was the most commonly occurring shrub, with *Prunus emarginata* and *Amelanchier alnifolia* following in that order. All were present with 100 percent constancy; however, none exhibited a dominant influence in the understory.

Festuca idahoensis and *Stipa lemmonii* were the codominant graminoids, both occurring with 100 percent constancy. *Carex rossii*, *Calamagrostis rubescens*, *Poa ampla*, and *Sitanion hystrix* occurred with 100 percent constancy and are listed in a descending order of dominance.

The most dominant forb was *Viola nuttallii*, followed by *Taraxicum officinale*, *Geum triflorum* and *Agoseris heterophylla*. *Hieracium albertinum* was present on all plots as an uncommon to rare component, and *Cirsium vulgare* occurred with 50 percent constancy also as an uncommon to rare species.

Soil. This was a very dark brown, moderately shallow (43 cm), well drained gravelly loam to gravelly sandy loam, overlying cracked, rhyolitic bedrock. Stone at the soil surface averaged less than 5 percent and stone volume in the solum averaged 33 percent. Root concentration was in the upper 30 cm of soil; however, Cercocarpus ledifolius roots extended to 1 m and penetrated rock cracks at that level. Parent material appeared to be colluvium with some aeolean influence.

Animal Presence. Bighorn sheep and mule deer inhabited the area; bighorn sheep until the 1880's, and deer through the period of the study. Domestic sheep and cattle used the area heavily from about 1870 to 1934. Since then only cattle have used the area (Jesse Strode, personal communication).

Ecological Analysis. This successional stage was a result of abuse by livestock grazing; however, it either recovered somewhat since 1934 or was never grazed to the extreme found in some ecosystems in the Owyhee Uplands. Cirsium vulgare, an indicator of severe abuse, was present only as an uncommon to rare species on 50 percent of the plots. Stipa lemmonii, a succession indicator, was codominant with the association designator on 75 percent of the plots but subordinate on the rest.

The appearance of Festuca idahoensis as a codominant in this association was puzzling since it did not occur in the C. ledifolius/Calamagrostis rubescens association. Neither field characteristics of soil nor site gave positive evidence as to why it was present. The basic vegetative differences, other than the presence of F.

idahoensis, between this association and the C. ledifolius/ Calomograstis rubescens association were the occurrence here of Ribes cereum, the absence of Berberis repens and Silene hookeri, and almost total absence of Agropyron caninum. Other differences appeared to be related to grazing pressure by livestock.

Berberis repens and Ribes cereum may have been indicators of a difference in available moisture. The disappearance and occurrence of these two species respectively, coupled with an increase of sand in the solum of this h. t. indicated a drier situation than the C. ledifolius/Calamagrostis rubescens h. t. Also elevation here was lower than the other by 174 m, possibly resulting in some less precipitation and winter snowpack.

Ecosystems with Relic Trees

These ecosystems, plus the three stands which made up the previously described Cerocarpus ledifolius/Symphoricarpos albus/ Festuca idahoensis association, had the oldest specimens of C. ledifolius noted in the study area. Four stands occurred in the Blue Mountains of northeastern Oregon, and two were in the Steens Mountains of the Basin and Range Province. Stands which included relic age trees were discovered on Mahogany Mountain in the Owyhee Uplands, but were not described. Trees there reached 51 cm in diameter, 46 cm above the ground. A conservative age estimate for this size tree is 350 to 450 years. The largest trees were found primarily in the rockiest sites (Figure 11).

Sites. Five of the six ecosystems described occurred at the edge of basalt rims at the top of steep canyon topography. Here, the ground surface changed from extremely rocky and rough at the canyon edges to smooth, as distance increased from the edge. The sixth ecosystem was the exception, occurring as a small stand on the west slope of the Steens Mountains. Ground surface was smooth to moderately rough. Elevations ranged from 1171 m in the Blue Mountains to 2271 m in the Basin and Range Province. Exposures of five of the six ecosystems were between south and southwest. Exposure of the sixth was northeast. Slopes were moderate, most being less than 15 percent and the steepest 25 percent. Estimated precipitation in both the Blue Mountains and the Basin and Range Province ecosystems was similar, near 50 cm.

Vegetation. Vegetation was previously described in three stands in the *Cercocarpus ledifolius*/*Symphoricarpos albus*/*Festuca idahoensis* association. The other three relic stands should be included under separate associations. Of the two in the Steens Mountains, one had an understory dominated by *Artemisia tridentata* and *Stipa occidentalis*, a graminoid successional here to *Poa ampla*, whereas the other stand was in a *Symphoricarpos oreophilus* association with a grass dominant, probably *Agropyron* *caninum*. The uncorrelated relic stand in the Blue Mountains had a shrub layer dominated by *S. albus*, and a graminoid layer dominated by a successional species, *Stipa occidentalis*. Subordinate species were *Carex geyeri*, *Danthonia californica* and *Poa sandbergii*.

Cercocarpus ledifolius grew in a similar pattern in the five stands characterized on rimrock sites. The largest trees occurred on the rockiest sites at the edge of the canyons. Younger, smaller trees occurred on what seemed to be better locations of deeper soil. Tree sizes ranged from 64 cm to 5 cm diameter. However, there was an abundance of 2 cm diameter established seedlings in the *C. ledifolius*/*S. albus*/*F. idahoensis* association. The largest tree mentioned, 64 cm, was established to be between 500 and 600 years old. This age was roughly estimated by extrapolation from another specimen in the Blue Mountains (stand 60 in Table A6) which was cut and aged by ring counts. It was 36 cm in diameter and 300 years old. The largest specimens discovered in the Basin and Range Province (stands 54 and 55, Table A6) were all near 55 cm in diameter and approximately 400 years old. Stand 60 (Table A6) was a decadent stand which was dominated by very old trees. It was disturbed by man. Apparently trees were used for firewood by hunters who left ample evidence of their presence. There were 41 trees left on the site, 18 young and 23 mature. Of the mature trees, three were between 48 and 52 cm diameter, and the rest much smaller. The site on which this stand occurred was the only one within the relic group where surface stone was scarce. It was a moderately smooth gravelly site at the canyon edge.

Soils. Soils under all relic stands were shallow and stony, with solum depths varying from 30 to 41 cm. All were gravelly loams, and all had developed a weak B horizon with some accumulated clays. The five relics which were located on canyon edges had soils developed from what appeared to be residual parent material from basalt. There may have been some influence from aeolean deposits. The sixth relic stand developed from mixed colluvium and residual material, both from basalt.

Animal Presence. Relic ecosystems in the Basin and Range Province were influenced by mule deer and bighorn sheep historically and by domestic sheep and cattle with very little control until 1934. Since then, sheep have been almost eliminated and cattle have been the primary domestic users. Communities showed evidence of severe abuse during the study period. Relic ecosystems in the Blue Mountains appeared to have had lighter use than those in the Basin and Range Province.

Ecological Analysis. There was a consistent trend throughout the relic stands in the relationship between tree age and site location. In all cases, the oldest trees were in the rockiest sites and younger trees spread out on what seemed to be better locations for soil development and plant growth.

It seemed clear that these relic stands held an important key to the survival of this species, and to some of the reasons why its distribution was restricted in most areas. The extremely rocky sites in which relic aged *Cercocarpus ledifolius* trees were found were sites very resistant to fire. From these sites, trees produced seed to regenerate the stands after fire had destroyed younger stands in adjacent, better growing sites. The trees were long lived and thus a seed source was available for hundreds of years, and the relics could survive the sequence of fires, grazing abuses, or other factors which might have delayed the establishment of new stands.

Uncorrelated Ecosystems

There were situations in the study area where *C. ledifolius* appeared to occur as a subordinate. I did not observe this situation in the Owyhee Uplands, nor in the Basin and Range Province, except at its western edge where the *Pinus ponderosa* zone occurs. This did occur in the Blue Mountains.

The appearance of subordination was misleading. What actually occurred was a change in site resulting in the development of an inclusion of *Cercocarpus ledifolius* within a conifer type. In stands 76 and 83 (Table A6) this was the case. Sites of these inclusions were rockier and had shallower soil than the surrounding conifer type. More accurately, the dominance had changed, and on the site of the inclusion _C. ledifolius_ was dominant and will probably always be dominant. This phenomenon occurred frequently throughout the _Pinus ponderosa_ zone of central Oregon and northeastern California.

Stands 57, 75, 77, and 84 (Table A6) exhibited the same situations as the above inclusions; however, here sites were extensive enough to be considered as dominant h. ts. of the area.

Habitat Type Correlation

Cover of _C. ledifolius_ varied with exposure, lower values being on south to westerly exposures and higher values on northerly exposures. Averages for associations are presented in Table 10.

There was one exception (Table 9). The _C. ledifolius_/_Symphoricarpos oreophilus_/_Poa ampla_ association occurred on southerly slopes with 80 percent crown cover. This association occurred at the toe of slopes in the bottom of narrow canyons or valleys emptying westward out of the Steens Mountains. The canyon walls shaded the low portions of the south slopes a greater portion of each day during winter than in other h. ts. The solum depth was greatest for any h. t. in this series. These site and soil factors combined to allow the development of a highly productive h. t. and

Table 10. Selected vegetation, site, and soil factors illustrating differences among habitat types.

Habitat Type	Stand[a/] age	Crown cover %	Altitude m	Aspect	Slope %	Su/Bu stone %	Solum depth cm
Cercocarpus ledifolius/Elymus cinereus	3.0	34	1,890	W	23	2/6	-
Cercocarpus ledifolius/Festuca idahoensis-Agropyron spicatum	3.0	36	1,682	WNW	27	25/65	51
Cercocarpus ledifolius/Artemisia tridentata/Festuca idahoensis	2.8	45	1,945	WSW	13	51/63	42
Cercocarpus ledifolius/Artemisia tridentata/Agropyron caninum	2.6	50	1,616	SW	36	21/74	51
Cercocarpus ledifolius/Symphoricarpos oreophilus, Balsamorhiza sagittata Phase	2.8	55	1,898	ENE	25	27/81	41
Cercocarpus ledifolius/Artemisia tridentata/Poa ampla	2.0	56	1,844	SSW	14	26/66	81
Cercocarpus ledifolius/Symphoricarpos albua/Festuca idahoensis	3.0	61	1,405	SW	13	7/78	31
Cercocarpus ledifolius/Festuca idahoensis	3.0	66	1,646	NNE	8	3/38	59
Cercocarpus ledifolius/Symphoricarpos oreophilus Arnica cordifolia Phase	2.9	74	1,854	NNE	31	32/42	49
Cercocarpus ledifolius/Symphoricarpus oreophilus/Festuca idahoensis	3.0	74	1,829	NW	21	5/32	53
Cercocarpus ledifolius/Calamagrostis rubescens	2.7	79	1,921	ENE	22	4/43	38
Cercocarpus ledifolius/Symphoricarpos oreophilus/Poa ampla	3.1	80	1,768	S	30	48/67	61
Cercocarpus ledifolius/Calamagrostis rubescens-Festuca idahoensis	2.7	83	1,747	NNE	35	3/32	45

[a/] 2 = young, 3 = mature, 4 = overmature.

attendant association here, similar to those found with normally more moist north slopes.

There was no serious competition noted in stands between *Cercocarpus ledifolius* and *Juniperus occidentalis*. Although *J. occidentalis* occurred as single trees or small stands within the *Pinus ponderosa* zone and on the high desert steppe in situations as moist as some *C. ledifolius* sites, the modal position of *J. occidentalis* in the landscape was on drier sites. This was surprising as *J. occidentalis* seemed more fire resistant than *C. ledifolius* due to its thick, cedar-like bark, and might have been better able to maintain a population where *C. ledifolius* stands were periodically destroyed by fire. This did not seem the case.

Driscoll (1964b) indicated the reverse, that *J. occidentalis* stands could also be reduced by fire. He placed *J. occidentalis* in a savanna zone, intermediate in moisture between the high desert shrub steppe and the *P. ponderosa* forest zone. This was essentially where *C. ledifolius* was placed (Dealy, 1971). These placements were reasonable. Even though this zone was narrow, the convergence of the two species was not recorded to my knowledge. It seemed apparent from the occurrence of *C. ledifolius* crowded against the lower *P. ponderosa* tree line, or growing in the more moist sites above the high desert shrub steppe (other than *Populus tremuloides*), that moisture requirements were higher than for *J. occidentalis*.

The majority of Driscoll's (1964b) samples of J. occidentalis were taken between elevations of 1200 and 1400 m at the high desert edge where precipitation was 20 to 25 cm. Elevation of C. ledifolius h.ts. sampled here were between 1400 and 1650 m at the lower edge of conifer zone and 1600 and 2200 m in the high desert, with precipitation at 45 to 65 cm.

Pinus ponderosa did not compete seriously with Cercocarpus ledifolius on C. ledifolius sites as they were somewhat separated by soil depth requirements. Where depths were adequate for P. ponderosa, the species was dominant and suppressed species such as C. ledifolius. Conversely, where shallow soils and inadequate moisture precluded P. ponderosa, C. ledifolius dominated the site.

Dealy (1971) examined soil depth relationships between P. ponderosa and C. ledifolius sites within the P. ponderosa zone of central Oregon. There, C. ledifolius grew at the perimeter of shallow-soiled rocky openings of Artemisia arbuscula, where soils were transitional in depth to the adjacent deep soil P. ponderosa sites.

With few exceptions, C. ledifolius stands described for plant associations had large, older relic trees growing on rocky outcroppings in or adjacent to younger groves. These are remnants of older burned or logged stands. Evidence of past fires, i.e., fire charred trees and charcoal bits, was noted through the study area.

There was probably an important fire/stand relationship. Relics and the seed dissemination from rocky sites were the reason that fire had not eliminated the species from otherwise suitable sites.

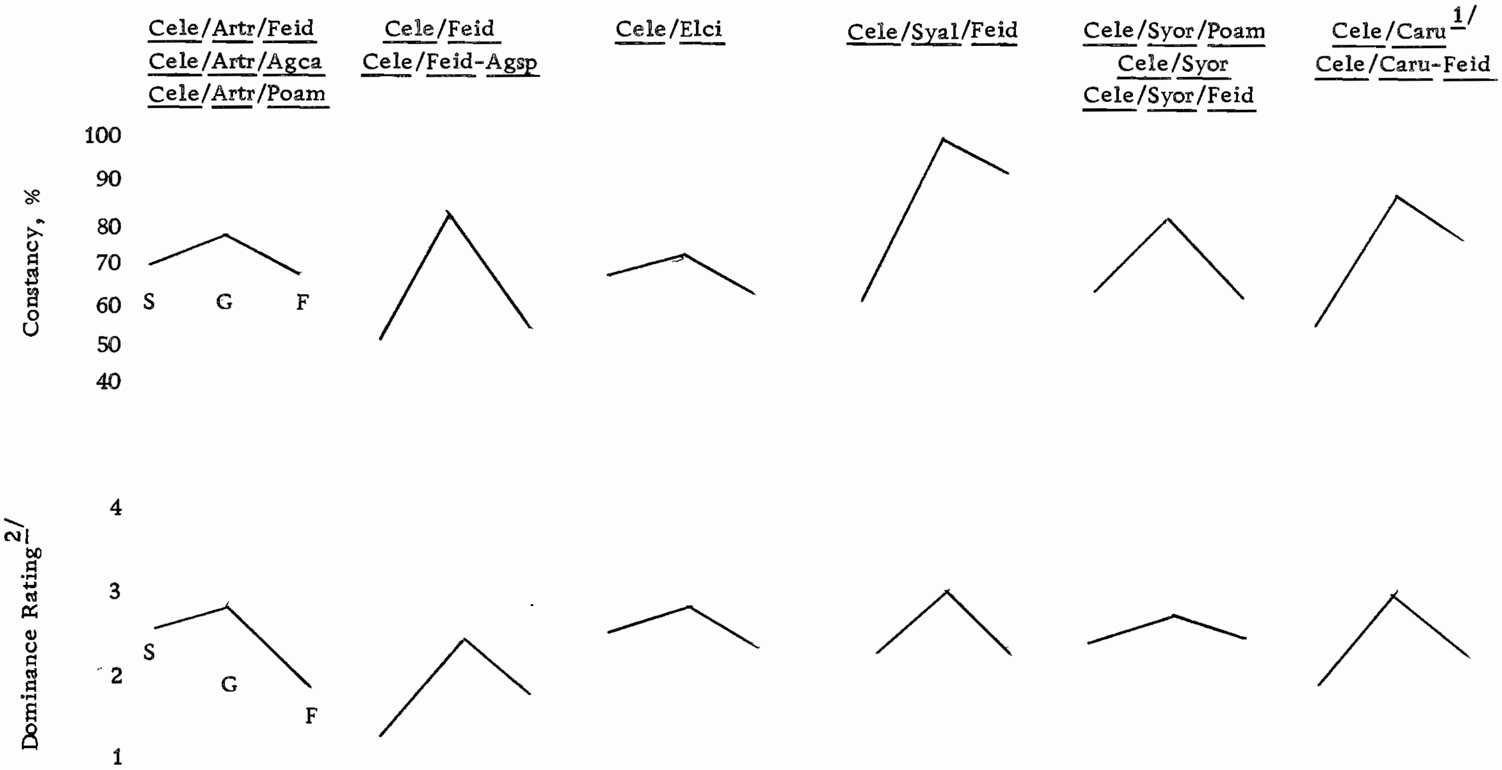
Shrubs were specifically oriented by aspect. Artemisia tridentata was expressed best on south slopes with most plants and the most vigorous ones occurring in C. ledifolius interspaces (Table 9). Symphoricarpos oreophilus had higher dominance and constancy on north compared to south slopes.

Shrubs primarily indicative of the successional status of an association, i.e., Chrysothamnus nauseosus and C. viscidiflorus, had their greatest expression on south slopes due to easier expression of shrubs as indicators of livestock abuse in tree interspaces. Prunus emarginata occurred more commonly on moist north slope h.ts. than P. virginiana. Ceanothus velutinus occurred exclusively on north slopes in areas of consistently heavy winter snow drifts. Berberis repens was also a north slope species. Ribes cereum occurred on all exposures but appeared to have some tie to rockiness of the soil.

Graminoids dominated the understory in all groups of similar plant associations in mean dominance (species pooled), and mean constancy (species pooled) as illustrated in Figure 12. South slope associations had higher shrub constancy and dominance, higher graminoid dominance, and higher forb constancy than north slope associations. North and south slope associations had equal constancy of graminoids and dominance of forbs (Figure 13). I believe the higher values on south slope associations were a function of increased light reaching the understory. Site involvement may not be that simple. Daubenmire (1968a) discussed factors such as temperature, relative humidity, and wind as interrelated influences on the understory, as overstory changed.

Soil development in this h. t. series was weak. No significant difference in solum development or depth was detected between exposures or slopes. However, percent surface stone doubled on south slopes compared to north slopes, and percent buried stone volume in the solum was almost one-third greater on south slopes. These differences, in combination with high solar insolation on south slopes, produced a more xeric vegetative environment than on north slopes.

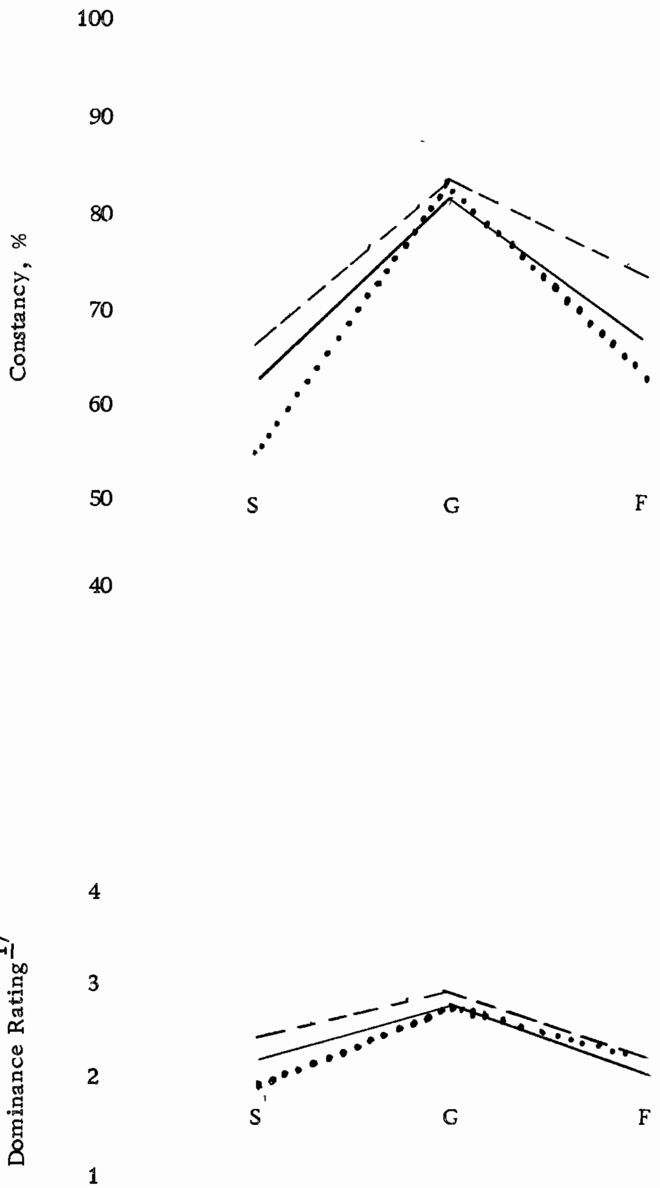
Most associations in this series occurred within the precipitation range of vegetation found adjacent to and below the conifer zone, or above the high desert shrub steppe vegetation. The *Cercocarpus ledifolius*/*Calamagrostis rubescens* and *C. ledifolius*/*C. rubescens*-*Festuca idahoensis* associations did not fit this pattern. Some understory species on these high elevation north slope situations were disjunct members of the conifer zone. In the Blue Mountains, *Calamagrostis rubescens* occurred most commonly in the mixed



1/ Agsp = Agropyron spicatum; Caru = Calamagrostis rubescens; Cele = Cerocarpus ledifolius; Elci = Elymus cinereus; Feid = Festuca idahoensis; Syal = Symphoricarpos albus; Syor = Symphoricarpos orcophilus

2/ 1 = rare; 2 = uncommon; 3 = common; 4 = codominant

Figure 12. Mean dominance and constancy values of shrubs (S), graminoids (G), and forbs (F) compared among groups of similar plant associations.



1/ 1 = rare; 2 = uncommon; 3 = common; 4 = codominant

Figure 13. Mean dominance and constancy values of shrubs (S), graminoids (G), and forbs (F) for all plant associations combined (solid line), associations on south slopes (dashed line), and associations on north slopes (dotted line).

conifer type (Pseudotsuga menziesii and Abies grandis) and the lodgepole pine (Pinus contorta latifolia) type successional to A. grandis (Hall, 1973). Berberis repens and Hieracium albertinum were common constituents of the conifer zone as was Agropyron caninum (the A. trachycalum complex), the orchid Habenaria unalascensis and Allium acuminatum (Strickler, 1965).

Four relic conifer stands were identified in the high desert steppe region of this area (Packard, 1972; Critchfield and Allenbaugh, 1969; Berry, 1963; and Jackman and Scharff, 1967). One, a small Pinus ponderosa stand (Packard, 1972), was within one mile of the ecosystems under discussion and might, with further study, show a more concrete connection between these ecosystems (as well as the general mountainous area) and the conifer zone.

SUMMARY AND CONCLUSIONS

I studied the ecology of Cercocarpus ledifolius to determine its germinative and initial growth characteristics and how it related to its environment and associated vegetation.

Germination experiments in the laboratory were conducted to determine why seed exhibited strong dormancy and was difficult to germinate. Initially, no germination was obtained from untreated seeds placed in a wet environment at 20°C for 60 days. However, 88 percent germination was obtained from seeds placed in a wet environment at 4°C for 270 days. Immediate germination of excised embryos with no other treatment indicated no chemical germination inhibitor in the embryo and no prechilling requirement. Embryos were then partially excised, which gave them an opportunity to expand but left most of the seed coat intact. They began swelling and attempted germination, indicating no effective chemical germination inhibitor in the seed coat. Although mechanical seed coat impedance of the embryo could have been a factor, the seed coat did not appear to have characteristics typical of other seeds which were known to have that characteristic so it was rejected. In germination tests, the membrane surrounding the embryo was observed to be intact after the root radical grew a short distance out of the seed coat and entered a rest period. When the radical continued the germination process, the membrane ruptured. This suggested a dormancy caused by the prevention of gas exchange between the embryo and the surrounding atmosphere. Further research is recommended to clarify this observation.

Seedling germination and root growth laboratory experiments indicated pronounced specialization for rapid root growth in relation to top growth for at least 120 days after germination. In 120 days, the six most vigorous seedlings extended their roots an average 1.13 m, but developed only 4 cm^2 of leaf area and shoot heights averaging 2.35 cm.

Relationships among *Cercocarpus ledifolius* ecosystems were examined and habitat types, attendant plant associations, their phases, and successional stages were delineated. No serious competition between *C. ledifolius* and other tree species was shown in plant associations described. Where conifers occurred, they were uncommon and not expanding their territory. *Juniperus occidentalis* occurred primarily at lower elevations and in a lower precipitation zone, whereas *Pinus ponderosa* occurred on soil deeper and less rocky.

Most associations and their phases were primarily a function of topo-edaphic influences. Soils were consistently moderately shallow and stony, and with expression of specific associations dependent on directional exposure.

Graminoids dominated the understory of all associations in dominance and constancy with those in south slope associations generally higher in dominance compared to those on north slope associations.

Soil development was weak with B horizons ranging from heavy loams to light clay loams. No significant difference in solum development between exposures was observed from field analyses. However, percent surface stone on south exposures was twice that on north exposures and percent buried stone volume in the solum was almost one-third greater on south exposures.

The existence of _Cercocarpus_ _ledifolius_ and the associations it dominated was dependent on fire resistent rocky sites which occurred in or adjacent to most ecosystems sampled. This was evident from the consistent occurrence of trees in these niches which were larger and older than those in the rest of the stands. Trees here provided an available seed source in case fire decimated adjacent stands. In most study locations 95 percent of the trees growing on non-rocky sites were less than 100 years old. This was correlated closely to the advent of fire control and livestock use of forage--forage which otherwise would have remained a source of fuel for natural fires.

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APPENDICES

APPENDIX A

STAND TABLES

Table A1. Stand tables grouped into associations, successional stages, and selected site characteristics.

Site and Vegetation	Vegetation Dominance Rating															
Association	Cercocarpus ledifolius/ Artemisia tridentata/ Festuca idahoensis					Cercocarpus ledifolius/ Artemisia tridentata/ Agropyron caninum						Cercocarpus ledifolius/ Artemisia tridentata/ Poa ampla				
Phase																
Succession stage	Poa sandbergii								Stipa lemmonii			Stipa lemmonii				
Stand number	39	40	41	42	43	1	4	5	2	3	6	22	23	24	26
State and county[1]	OMal	OMal	OMal	OMal	OMal	OMal	OMal	OMal	OMal	OMal	OMal	OMal	OMal	OMal	OMal
Township and section	39S30	39S31	39S31	39S30	39S31	27S4	27S4	27S4	27S4	27S4	27S5	27S8	27S8	27S8	27S8
Range	41E	41E	41E	41E	41E	45E	45E	45E	45E	45E	45E	45E	45E	45E	45E
Quarter	NE	SW	SW	NE	SW	SW	SW	SW	SW	SW	SW	NW	NW	NW	NW
Altitude (m.)	1980	1921	1921	1980	1921	1616	1616	1616	1616	1616	1616	1844	1844	1844	1844
Exposure and percent slope	WSW15	WSW15	W10	W10	WSW15	SW40	SW40	SW30	SW40	SW40	SW25	SW15	SSW10	S15	SSW15
Trees per hectare[2]	1052	1843	921	1186	921	921	1052	921	1317	790	1186	1643	1687	1993	1428
Ave. percent live crown[2]	46	48	32	62	37	48	54	49	40	52	55	45	53	62	63
Ave. stand age[3]	2.7	2.9	2.5	2.6	3.4	2.9	2.0	2.6	3.2	2.3	2.7	2.0	2.0	2.0	2.2
TREES															
Cercocarpus ledifolius	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Juniperus occidentalis	-	-	-	-	-	2	-	2	-	2	1	-	-	-	-
SHRUBS															
Amelanchier alnifolia	-	-	-	-	-	2	2	-	2	2	-	-	-	1	-
Artemisia tridentata	5	5	5	5	5	5	5	5	5	5	3	5	5	5	5
Chrysothamnus nauseosus	2	2	3	3	3	2	2	2	-	2	2	3	3	3	3
Chrysothamnus viscidiflorus	2	-	-	3	3	3	2	3	1	2	5	3	3	3	3
Eriogonum heracleoides	-	-	-	-	-	2	-	-	-	1	-	2	3	2	2
Prunus emarginata	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-
Prunus virginiana	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-
Purshia tridentata	-	-	-	-	-	1	1	-	1	1	-	-	-	-	-
Ribes cereum	-	-	-	-	-	-	-	2	2	2	2	-	-	-	2
Symphoricarpos oreophilus	2	-	3	3	3	-	-	-	-	-	-	-	-	-	-
GRAMINOIDS															
Agropyron caninum	-	-	-	-	-	4	5	4	2	3	2	-	-	3	-
Agropyron spicatum	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Bromus carinatus	-	-	-	-	-	2	1	2	2	2	-	-	-	-	-
Bromus tectorum[4]	3	3	3	3	3	3	3	3	3	3	3	2	-	3	2
Carex rossii	3	-	2	-	-	-	-	2	-	-	1	3	3	3	3
Elymus cinereus	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-
Festuca idahoensis	3	2	3	3	2	-	-	-	-	-	2	-	-	-	-
Festuca octoflora[4]	-	-	-	-	-	3	-	-	-	-	-	2	-	-	2
Melica bulbosa	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Poa ampla	-	-	-	-	-	3	3	3	3	2	2	3	3	2	3
Poa sandbergii	5	5	5	5	5	-	-	-	-	-	-	-	-	-	-
Sitanion hystrix	3	3	3	3	3	3	3	4	4	3	3	4	3	3	3
Stipa lemmonii	2	2	2	-	3	4	3	4	4	5	5	4	5	5	5
Stipa occidentalis	-	-	-	-	-	-	-	-	-	-	3	3	3	3	2
FORBS															
Achillea millefolium	-	-	-	-	-	2	3	3	-	-	2	3	-	2	-
Agoseris heterophylla	1	-	-	-	2	-	1	-	-	1	1	3	2	2	3
Allium acuminatum	-	-	-	-	-	-	2	3	2	-	1	-	-	-	-
Arabis holboellii	2	1	2	-	1	1	2	2	2	2	-	3	2	2	1
Astragalus sp.	3	-	1	-	1	-	-	-	-	-	-	-	-	-	-
Balsamorhiza sagittata	-	-	-	-	1	3	3	5	3	3	2	2	2	2	-
Cirsium vulgare	-	-	-	-	-	2	3	1	3	3	2	3	3	5	5
Erigeron sp.	-	-	-	-	-	-	-	-	-	-	-	2	-	3	2
Eriophyllum lanatum	-	-	1	-	-	-	-	-	-	-	-	2	-	-	-
Geum triflorum	-	-	-	-	-	-	2	2	2	2	1	1	-	1	-
Hieracium albertinum	-	-	-	-	-	3	3	3	-	2	2	1	1	-	-
Lomatium sp.	-	-	-	-	-	-	1	2	-	1	-	-	-	1	-
Lupinus laxiflorus	-	-	-	-	-	2	3	3	3	2	2	-	1	-	2
Penstemon speciosus	-	-	-	-	-	-	1	-	-	1	1	-	-	-	-
Phacelia heterophylla	-	-	1	-	-	2	3	2	2	2	2	-	1	1	-
Phlox sp.	1	-	-	3	3	-	-	-	-	-	-	3	3	2	2
Senecio integerrimus	2	2	3	3	3	1	-	-	2	-	2	-	-	1	-
Taraxacum officinale	-	-	-	-	-	-	-	-	2	-	1	1	-	1	-
Tragopogon dubius	-	-	-	-	-	-	1	-	2	2	1	2	-	1	1
Viola nuttallii	-	-	-	-	-	2	3	2	2	2	3	3	3	3	3

Site and Vegetation	Vegetation Dominance Rating															
Association Phase	Cercocarpus ledifolius/ Artemisia tridentata/ Festuca idahoensis					Cercocarpus ledifolius/ Artemisia tridentata/ Agropyron caninum						Cercocarpus ledifolius/ Artemisia tridentata/ Poa ampla				
Succession stage	Poa sandbergii								Stipa lemmonii			Stipa lemmonii				
Stand number	39	40	41	42	43	1	4	5	2	3	6	22	23	24	26
SOIL FACTORS																
Stoniness, percent																
Surface area	60	45	50	40	60	15	35	30	30	15	1	25	25	25	30
Buried volume	80	70	60	65	40	85	90	80	85	80	25	70	60	70	65
Underlying material[5/]	bslt	bslt	bslt	bslt	bslt	rylt	rylt	rylt	rylt	rylt	rylt	rylt	rylt	rylt	rylt
Solum depth (cm)	46	46	56	38	23	53	51	46	46	51	55	84	79	86	76
Solum texture[6/]																
A horizon	gl	gl	gl	gl	gl	gl	gl	gl	gl	gl	gsl	gl	gl	gl	gl
B horizon (or AC)	gcl	gcl	gcl	gcl	gcl	gcl	gcl	gcl	gcl	gcl	fsl	gcl	gcl	gcl	gcl
Solum color[7/]																
A horizon	5YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2	10YR 2/2	10YR 2/2	10YR 2/2	10YR 2/2	10YR 2/2	10YR 2/2	10YR 2/2	10YR 2/2	10YR 2/2	10YR 2/2

1/ O = Oregon; Mal = Malheur County

2/ Cercocarpus ledifolius

3/ 2 = young trees; 3 = mature trees; 4 = overmature trees

4/ Annual

5/ bslt = basalt; rylt = rhyolite

6/ c = clay; f = fine; g = gravelly; l = loam; s = sand

7/ Moist color. For color code, see Soil Survey Manual (USDA, 1951)

Table A2. Stand tables grouped into associations with selected site characteristics.

Site and Vegetation	Vegetation Dominance Rating												
Association / Phase	Cercocarpus ledifolius/ Festuca idahoensis					Cercocarpus ledifolius/ Festuca idahoensis-Agropyron spicatum					Cercocarpus ledifolius/ Elymus cinereus		
Stand number	65	66	67	68	69	70	71	72	73	74	27	28	29
State and county[1/]	OLak	OLak	OLak	OLak	OLak	OLak	OLak	OLak	OLak	OLak	OMal	OMal	OMal
Township and section	29S26	29S35	29S35	29S26	29S26	30S2	30S2	30S1	30S2	30S1	26S31	26S31	26S31
Range	16E	16E	16E	16E	16E	16E	16E	16E	16E	16E	45E	45E	45E
Quarter	SW	NE	NW	SW	SE	NE	SE	NW	NE	NW	SE	SE	SE
Altitude (m)	1646	1646	1677	1616	1646	1676	1707	1676	1676	1676	1890	1890	1890
Exposure and percent slope	N18	NE5	SE5	NE5	NNE5	NW10	W30	NE30	NW35	NE30	WSW35	W25	W10
Trees per hectare[2/]	-	-	-	-	-	-	-	-	-	-	526	1581	1440
Ave. percent live crown[2/]	69	53	49	75	86	23	30	37	57	35	29	44	30
Ave. stand age[3/]	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.8	3.5
TREES													
Cercocarpus ledifolius	5	5	5	5	5	5	5	5	5	5	5	5	5
Juniperus occidentalis	1	-	-	1	1	1	2	-	1	1	3	3	3
Pinus ponderosa	1	1	1	1	1	1	1	1	1	-	-	-	-
SHRUBS													
Amelanchier alnifolia	-	-	-	-	1	-	-	-	-	-	3	3	-
Artemisia tridentata	1	2	2	2	-	1	2	3	1	3	-	-	-
Chrysothamnus nauseosus	-	-	-	-	-	2	1	-	1	-	2	3	-
Chrysothamnus viscidiflorus	1	1	-	-	-	1	2	-	1	1	2	-	-
Prunus emarginata	-	-	-	-	-	-	-	-	-	-	-	3	-
Prunus virginiana	-	-	-	-	-	-	-	-	-	-	3	3	3
Purshia tridentata	-	-	-	-	-	1	-	-	-	-	-	-	-
Ribes cereum	1	-	-	-	-	1	-	-	-	-	3	2	2
Rosa gymnocarpa	-	-	-	-	-	-	-	-	-	-	-	3	-
Tetradymia canescens	-	1	-	-	-	-	-	-	-	-	-	-	-
GRAMINOIDS													
Agropyron caninum	-	-	-	-	-	-	-	-	-	-	3	3	3
Agropyron spicatum	2	2	2	2	1	4	4	3	3	3	-	-	-
Bromus carinatus	2	2	-	-	-	-	2	-	2	-	-	-	-
Bromus tectorum[4/]	-	1	1	2	1	3	3	3	-	3	3	3	3
Carex rossii	-	1	1	-	1	-	-	-	-	-	3	3	3
Elymus cinereus	-	-	-	-	-	-	-	-	-	-	3	3	3
Festuca idahoensis	5	5	5	5	5	4	4	5	5	5	3	-	-
Koeleria cristata	-	2	3	2	1	2	2	2	3	1	-	-	-
Oryzopsis hymenoides	-	-	-	-	-	-	-	-	-	-	3	-	3
Poa ampla	-	-	-	-	-	-	3	-	1	-	-	2	3
Poa sandbergii	3	1	1	1	2	3	3	2	3	3	-	-	-
Sitanion hystrix	3	3	2	3	1	3	3	3	2	3	3	2	-
Stipa comata	-	-	-	-	-	-	-	-	-	-	-	-	3
Stipa occidentalis	-	-	-	-	-	-	-	-	-	-	-	2	-
FORBS													
Achillea millefolium	1	2	-	-	-	2	2	-	2	1	-	-	-
Agoseris heterophylla	-	-	-	-	-	-	-	-	-	-	2	-	2
Agoseris sp.	-	2	1	2	-	-	-	1	-	1	-	-	-
Astragalus stenophyllus	-	-	-	-	-	-	-	3	-	1	-	-	-
Balsamorhiza sagittata	2	-	-	-	-	3	2	3	5	-	3	3	3
Erigeron sp.	-	-	-	1	-	-	-	1	1	1	-	3	-
Eriophyllum lanatum	1	2	2	-	-	-	-	-	-	-	3	-	-
Hieracium albertinum	3	3	3	2	3	-	-	-	-	-	-	2	-
Lomatium triternatum	-	-	1	1	1	-	-	1	-	1	-	-	-
Lupinus caudatus	-	-	-	-	-	-	-	-	-	3	-	-	-
Phacelia heterophylla	1	-	-	-	-	-	-	-	-	-	2	-	2
Phlox sp.	1	3	1	2	3	-	-	1	2	2	-	-	-
Senecio integerrimus	-	-	-	-	-	-	-	-	-	-	3	2	2
SOIL FACTORS													
Stoniness, percent													
Surface area	3	2	4	3	3	35	26	9	38	19	1	2	0
Buried volume	40	35	45	30	40	75	60	50	75	65	10	2	0
Underlying material[5/]	bslt	bslt	bslt	bslt	bslt	bslt	bslt	bslt	bslt	bslt	rylt	rylt	rylt
Solum depth, cm	58	61	54	63	60	50	53	55	48	51	-	-	-
Solum texture[6/]													
A horizon	l	l	l	l	l	gl	gl	gl	gl	gl	fs	fs	fs
B horizon (or AC)	cl	cl	cl	cl	cl	cl	cl	cl	cl	cl	lfs	fs	lfs
Solum color[7/]													
A horizon	10YR 2/2	10YR 2/2	10YR 2/2	10YR 2/2	10YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2	10YR 5/3	10YR 5/3	10YR 5/3

1/ O = Oregon; Lak = Lake County; Mal = Malheur County

2/ Cercocarpus ledifolius

3/ 2 = young trees; 3 = mature trees; 4 = overmature trees

4/ Annual

5/ bslt = basalt; rylt = rhyolite

6/ c = clay; f = fine; g = gravel; l = loam; s = sand

7/ Moist color. For color code, see Soil Survey Manual (USDA, 1951)

Table A3. Stand tables grouped into associations, phases and successional stages with selected site characteristics.

Site and Vegetation	Vegetation Dominance Rating														
Association	Cercocarpus ledifolius/ Symphoricarpos albus/ Festuca idahoensis			Cercocarpus ledifolius/ Symphoricarpos oreophilus/ Poa ampla					Cercocarpus ledifolius/Symphoricarpos oreophilus						
Phase									Balsamorhiza sagittata						
Succession stage									Poa sandbergii						
Stand number	79	80	81	49	50	51	52	53	30	31	32	35	36	37	38
State and county[1]	OUni	OUni	OUni	OHar	OHar	OHar	OHar	OHar	OMal	OMal	OMal	OMal	OMal	OMal	OMal
Township and section	4S29	4S29	4S29	34S8	34S8	34S8	34S8	34S8	40S5	40S5	40S5	39S9	39S9	39S9	39S9
Range	36E	36E	36E	$32\frac{3}{4}$E	$32\frac{3}{4}$E	$32\frac{3}{4}$E	$32\frac{3}{4}$E	$32\frac{3}{4}$E	42E	42E	42E	42E	42E	42E	42E
Quarter	SE	SE	SE	NW	NW	NW	NW	NW	NW	NW	NW	SW	SW	NW	NW
Altitude (m.)	1405	1405	1405	1768	1768	1768	1768	1768	1890	1890	1890	1921	1921	1890	1890
Exposure and percent slope	SW15	SW13	SW12	S35	S35	SW30	S25	S25	E35	E35	ENE20	W15	W15	ENE25	ENE30
Trees per hectare[2]	763	687	837	1867	1867	2001	1334	922	1317	2106	1185	922	1448	1580	1448
Ave. percent live crown[2]	60	55	68	82	85	78	78	76	53	56	54	51	54	61	57
Ave. stand age[3]	3.0	3.0	3.0	3.4	3.2	3.1	3.0	2.8	2.7	2.2	2.7	3.1	3.0	3.1	3.1
TREES															
Cercocarpus ledifolius	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Juniperus occidentalis	-	-	-	2	1	2	1	2	-	-	-	-	-	-	-
Pinus ponderosa	3	3	3	-	-	-	-	-	-	-	-	-	-	-	-
SHRUBS															
Amelanchier alnifolia	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1
Artemisia tridentata	-	-	-	2	2	1	2	2	4	5	3	4	4	4	3
Berberis repens	-	-	-	3	3	-	-	3	-	-	-	-	-	-	-
Ceanothus velutinus	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Chrysothamnus nauseosus	-	-	-	3	3	2	2	2	2	2	-	3	3	1	-
Chrysothamnus viscidiflorus	-	-	-	-	-	-	-	-	3	3	3	3	3	2	3
Eriogonum heracleoides	3	-	-	-	-	-	-	-	-	1	-	1	-	-	-
Holodiscus dumosus	-	-	-	3	2	-	-	1	-	-	-	2	-	-	-
Prunus emarginata	-	-	-	-	2	3	3	2	-	-	-	-	-	-	-
Prunus virginiana	-	-	1	3	3	3	3	2	-	-	2	-	-	2	1
Ribes cereum	2	4	3	2	1	1	2	1	-	-	2	-	-	-	1
Rosa gymnocarpa	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Sambucus cerulea	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Symphoricarpos albus	3	4	3	-	-	-	-	-	-	-	-	-	-	-	-
Symphoricarpos oreophilus	-	-	-	2	1	2	2	2	4	3	5	4	4	4	5
GRAMINOIDS															
Agropyron caninum	-	-	-	-	-	-	-	-	2	3	2	-	-	-	-
Agropyron spicatum	3	4	3	-	-	-	-	-	-	-	-	-	-	-	-
Bromus brizaeformis[4]	2	1	3	-	-	-	-	-	-	-	-	-	-	-	-
Bromus carinatus	3	2	3	2	2	2	2	3	-	3	2	3	-	-	-
Bromus tectorum[4]	3	2	2	2	3	3	3	2	3	3	3	3	3	2	3
Carex rossii	-	-	-	3	3	3	3	3	3	3	3	-	-	3	3
Elymus cinereus	-	-	-	-	-	-	-	-	2	2	2	2	3	-	2
Festuca idahoensis	5	4	5	-	-	-	-	-	-	-	-	-	-	-	-
Festuca octoflora[4]	-	-	-	-	-	-	-	-	3	3	1	2	2	2	3
Melica bulbosa	-	-	-	3	-	2	-	-	-	-	1	-	1	-	-
Poa ampla	-	-	-	3	3	5	5	3	2	2	2	2	2	-	3
Poa sandbergii	3	3	3	-	-	-	-	-	3	3	3	3	3	4	4
Sitanion hystrix	-	-	-	5	5	3	3	5	3	2	3	3	3	4	4
Stipa lemmonii	-	-	-	-	-	-	-	-	3	2	3	3	-	3	-
Stipa occidentalis	-	-	-	2	2	2	-	2	-	-	-	-	-	-	-
FORBS															
Achillea millefolium	5	4	4	-	-	-	-	-	-	2	-	-	-	3	2
Agoseris heterophylla	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Antennaria stenophylla	3	2	2	-	-	-	-	-	-	-	-	-	-	-	-
Apocynum androsaemifolium	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
Arabis holboellii	-	-	-	3	2	2	2	1	3	2	2	-	-	1	2
Astragalus sp.	-	-	-	-	-	-	-	-	-	1	-	-	3	-	-
Astragalus filipes	3	4	4	-	-	-	-	-	-	-	-	-	-	-	-
Balsamorhiza sagittata	-	-	-	-	-	-	-	-	5	5	4	3	3	3	3
Cirsium vulgare	2	2	2	-	-	-	-	-	-	-	1	-	-	-	-
Crepis intermedia	2	2	1	-	-	-	-	-	-	-	-	-	-	-	-
Delphinium sp.	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eriophyllum lanatum	2	2	2	-	-	-	-	-	-	1	-	-	-	-	-
Geum triflorum	-	-	-	3	2	2	2	1	-	-	-	-	-	-	-
Hieracium albertinum	2	1	1	-	-	-	-	-	-	-	-	-	-	-	-
Lomatium grayi	2	2	2	-	-	-	-	-	-	-	-	-	-	-	-
Lupinus sp.	-	-	-	-	3	3	2	3	-	-	-	-	-	-	-
Lupinus caudatus	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-
Paeonia brownii	-	-	-	2	2	-	-	-	-	-	1	-	-	-	-
Penstemon speciosus	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Phacelia heterophylla	-	-	-	5	3	3	3	3	-	1	2	-	1	1	1
Phlox sp.	-	-	-	2	-	-	-	-	-	-	-	-	2	-	-
Phlox viscida	2	2	2	-	-	-	-	-	-	-	-	-	-	-	-
Senecio integerrimus	-	-	-	3	3	2	3	3	3	3	4	3	3	3	3
Smilacina sp.	-	-	-	2	2	2	2	-	-	-	-	-	-	-	-
Taraxacum officinale	3	3	2	-	-	-	-	-	-	-	-	-	-	-	-
Tragopogon dubius	2	2	1	-	-	-	-	-	-	-	-	-	-	-	-
Viola nuttallii	-	-	-	3	2	2	-	2	1	1	1	2	2	1	2

Table A3. Continued.

Site and Vegetation	Vegetation Dominance Rating														
Association	Cercocarpus ledifolius/ Symphoricarpos albus/ Festuca idahoensis			Cercocarpus ledifolius/ Symphoricarpos oreophilus/ Poa ampla					Cercocarpus ledifolius/Symphoricarpos oreophilus						
Phase									Balsamorhiza sagittata						
Succession stage									Poa sandbergii						
Stand number	79	80	81	49	50	51	52	53	30	31	32	35	36	37	38
SOIL FACTORS															
Stoniness, percent															
Surface area	5	10	5	45	55	45	45	50	50	20	40	25	20	15	20
Buried volume	80	75	80	65	75	65	60	70	80	80	85	90	80	70	85
Underlying material 5/	bslt	bslt	bslt	bslt	bslt	bslt	bslt	bslt	rylt	rylt	rylt	rylt	rylt	rylt	rylt
Solum depth (cm)	30	25	38	69	53	56	66	61	46	25	46	41	30	46	51
Solum texture 6/															
A horizon	l	l	l	gl	gl	gl	gl	gl	gl	gl	gl	l	gl	gl	l
B horizon (or AC)	cl	cl	cl	cl	cl	cl	cl	cl	gcl	gcl	gcl	gcl	cl	gcl	gcl
Solum color 7/															
A horizon	5YR 2/2	5YR 2/2	5YR 2/2	5YR 2/1	5YR 2/1	5YR 2/1	5YR 2/1	5YR 2/1	10YR 2/1	10YR 2/1	10YR 2/1	10YR 2/1	10YR 2/1	10YR 2/1	10YR 2/1

1/ O = Oregon; Har = Harney County; Mal = Malheur County; Uni = Union County

2/ Cercocarpus ledifolius

3/ 2 = young trees; 3 = mature trees; 4 = overmature trees

4/ Annuals

5/ bslt = basalt; rylt = rhyolite

6/ c = clay; g = gravel; l = loam

7/ Moist color . For color code see Soil Survey Manual (USDA, 1951)

Table A4. Stand tables grouped into associations, phases and successional stages with selected site characteristics.

Site and Vegetation	Vegetation Dominance Rating								
Association	*Cercocarpus ledifolius/ Symphoricarpos oreophilus/ Festuca idahoensis*				*Cercocarpus ledifolius/Symphoricarpos oreopnilus/ Poa ampla*				
Phase					*Arnica cordifolia*				
Succession stage	*Poa sandbergii*								
Stand number	61	62	63	64	44	45	46	47	48
State and county1/	OMal	OMal	OMal	OMal	OHar	OHar	OHar	OHar	OHar
Township and section	40S5	40S5	40S5	40S5	34S9	34S9	34S9	34S9	34S9
Range	42E	42E	42E	42E	32 3/4E	32 3/4E	32 3/4E	32 3/4E	32 3/4E
Quarter	NW	NW	SW	NW	NW	NW	NW	NE	NE
Altitude (m)	1829	1829	1829	1829	1845	1845	1890	1845	1845
Exposure and percent slope	WNW20	NW25	WNW20	NW20	N25	NE35	NE30	NE25	NE40
Trees per hectare4/	1615	1615	2423	3231	2633	2423	1186	2692	1346
Ave. percent live crown2/	72	87	67	70	65	79	72	75	81
Ave. stand age3/	3.7	3.7	3.8	3.2	3.3	3.3	3.0	2.6	2.8
TREES									
Cercocarpus ledifolius	5	5	5	5	5	5	5	5	5
Juniperus occidentalis	-	-	-	-	-	1	2	1	2
Populus tremuloides	-	-	-	-	-	-	-	-	1
SHRUBS									
Amelanchier alnifolia	2	-	-	-	2	2	2	-	-
Artemisia tridentata	3	2	2	3	3	2	2	3	3
Berberis repens	-	-	-	-	2	2	2	-	2
Chrysothamnus nauseosus	2	-	2	-	2	2	3	2	3
Chrysothamnus viscidiflorus	-	5	2	-	2	-	-	-	2
Prunus emarginata	-	-	-	-	-	1	-	-	-
Prunus virginiana	-	-	-	-	2	2	2	3	2
Ribes cereum	-	-	-	-	-	-	2	-	-
Symphoricarpos oreophilus	3	3	3	3	2	3	3	3	2
GRAMINOIDS									
Agropyron caninum	-	-	2	3	-	-	-	-	-
Bromus carinatus	-	-	-	-	3	3	2	2	2
Bromus tectorum	3	3	3	3	-	-	-	-	-
Carex rossii	2	-	3	-	4	3	4	3	3
Elymus cinereus	2	3	-	-	-	-	-	-	-
Festuca idahoensis	3	2	3	2	-	-	-	-	-
Festuca octoflora	-	-	-	-	1	-	1	-	-
Melica bulbosa	-	-	-	-	2	3	2	2	2
Poa ampla	2	-	3	2	3	4	3	4	3
Poa sandbergii	5	5	3	3	2	2	2	2	1
Sitanion hystrix	2	3	5	5	4	4	4	4	5
Stipa occidentalis	-	2	3	2	4	-	2	-	2
FORBS									
Achillea millefolium	-	-	-	-	4	3	3	1	1
Arabis holboellii	3	4	3	-	-	2	-	-	-
Arnica cordifolia	-	-	-	-	4	5	5	5	5
Balsamorhiza sagittata	3	2	4	-	-	-	-	-	-
Crepis intermedia	-	-	-	-	4	2	3	2	2
Geum triflorum	2	2	-	-	-	-	2	-	-
Hieraceum albertinum	-	-	-	-	2	2	3	2	3
Lomatium sp.	-	-	-	2	-	-	-	-	-
Paeonia brownii	-	-	-	-	1	-	2	-	-
Phacelia heterophylla	-	-	2	-	-	-	-	-	-
Phlox sp.	-	-	-	-	-	2	3	3	2
Senecio integerrimus	5	4	4	5	-	3	3	3	2
Sidalcea oregana	-	-	3	-	-	-	-	-	-
Taraxacum officinale	-	-	-	-	2	2	2	2	2
Thalictrum sp.	-	-	-	-	3	3	3	3	3
SOIL FACTORS									
Stoniness, percent									
Surface area	5	5	5	5	25	20	35	45	35
Buried volume	50	40	10	30	15	25	50	60	60
Underlying material5/	rylt	rylt	rylt	rylt	bslt	bslt	bslt	bslt	bslt
Solum depth (cm)	56	64	46	48	48	41	51	51	46
Solum texture6/									
A horizon	gsl	gl	gl	gl	l	l	l	l	l
B horizon (or AC)	gsl	gl	gsl	gsl	cl	cl	cl	cl	cl
Solum color7/									
A horizon	10YR 2/2	10YR 2/2	10YR 2/2	10YR 2/2	10YR 2/2	10YR 2/2	10YR 2/2	10YR 2/2	5YR 2/1

1/ O = Oregon; Har = Harney County; Mal = Malheur County

2/ *Cercocarpus ledifolius*

3/ 2 = young trees; 3 = mature trees; 4 = overmature trees

4/ Annual

5/ bslt = basalt; rylt = rhyolite

6/ c = clay; g = gravel; l = loam; s = sand

7/ Moist color. For color code see Soil Survey Manual (USDA, 1951)

Table A5. Stand tables grouped into associations and successional stages with selected site characteristics.

Site and Vegetation	Vegetation Dominance Rating												
Association	Cercocarpus ledifolius/Calamagrostis rubescens									Cercocarpus ledifolius/Calamagrostis rubescens-Festuca idahoensis			
Phase													
Succession stage							Stipa lemmonii			Stipa lemmonii			
Stand number	16	17	18	19	20	21	7	8	10	11	12	14	15
State and county1/	OMal	OMal	Omal	OMal	OMal	OMal	OMal	OMal	OMal	OMal	OMal	OMal	OMal
Township and section	27S7	27S7	27S7	27S7	27S7	27S7	27S5	27S5	27S5	27S5	27S5	27S5	27S5
Range	45E	45E	45E	45E	45E	45E	45E	45E	45E	45E	45E	45E	45E
Quarter	NE	NE	NE	NE	NE	NE	SW	SW	SW	SW	SW	SW	SW
Altitude (m)	1921	1921	1921	1921	1921	1921	1747	1747	1747	1747	1747	1747	1747
Exposure and percent slope	NE10	E15	E15	NE15	ENE15	E20	ENE35	E35	NE15	N30	NNE40	NE35	NNE35
Trees per hectare2/	2238	1186	1448	2370	1975	1580	1536	1581	1406	1920	2174	1843	4739
Ave. percent live crown2/	96	69	90	84	77	77	62	83	83	89	74	85	84
Ave. stand age3/	3.0	3.2	2.6	2.9	2.9	3.2	2.8	2.4	3.3	2.8	2.6	2.4	2.9
TREES													
Cercocarpus ledifolius	5	5	5	5	5	5	5	5	5	5	5	5	5
Populus tremuloides	-	-	-	-	-	-	-	-	-	-	-	1	-
SHRUBS													
Amelanchier alnifolia	2	2	3	2	3	3	2	2	2	2	1	3	1
Artemisia tridentata	-	-	-	-	-	-	-	-	1	-	-	-	-
Berberis repens	3	2	3	3	-	3	2	-	-	-	-	-	-
Ceanothus velutinus	-	-	-	-	-	-	-	-	-	-	-	-	2
Chrysothamnus nauseosus	-	1	-	-	-	-	-	-	-	-	-	1	1
Chrysothamnus viscidiflorus	1	-	-	-	-	-	-	-	1	-	2	1	3
Eriogonum heracleoides	2	-	-	-	-	-	-	-	1	1	-	-	-
Prunus emarginata	3	3	1	3	-	-	3	-	2	2	2	3	2
Prunus virginiana	-	3	-	-	2	-	-	-	-	-	-	2	-
Ribes cereum	-	-	-	-	-	-	1	1	3	2	2	3	3
Rosa gymnocarpa	-	1	-	-	-	-	-	-	-	-	-	-	2
Symphoricarpos oreophilus	-	2	-	3	-	-	-	-	-	-	-	1	1
GRAMINOIDS													
Agropyron caninum	2	3	3	1	3	3	-	-	-	-	-	1	-
Calamagrostis rubescens	5	5	5	5	5	5	3	3	3	3	3	2	3
Carex rossii	2	-	-	2	2	3	4	4	4	3	3	3	3
Festuca idahoensis	-	-	-	-	-	-	-	-	-	4	4	4	5
Melica bulbosa	2	2	3	1	-	-	-	1	3	-	-	3	-
Poa ampla	3	3	3	2	3	3	-	2	3	2	3	2	3
Sitanion hystrix	2	3	3	3	3	2	3	2	4	2	2	3	3
Stipa lemmonii	3	2	2	2	2	3	4	4	4	4	4	4	3
FORBS													
Achillea millefolium	2	2	1	3	2	1	1	2	3	1	-	2	2
Agoseris heterophylla	2	3	3	3	3	3	3	2	1	3	3	3	3
Allium acuminatum	-	2	2	-	-	-	-	-	-	-	-	-	-
Balsamorhiza sagittata	3	2	3	3	3	3	-	-	-	-	-	-	-
Cirsium vulgare	-	-	-	-	-	-	1	1	2	1	-	2	-
Erigeron sp.	-	-	-	-	-	-	-	1	-	-	-	-	-
Eriophyllum lanatum	2	-	-	-	-	-	-	1	-	-	-	-	-
Geum triflorum	3	2	2	3	2	-	3	3	2	3	3	3	3
Habenaria unalascensis	2	-	3	2	1	2	-	-	-	-	-	-	-
Hieracium albertinum	5	3	3	5	5	5	3	1	2	1	2	1	2
Hydrophyllum capitatum	-	-	-	-	-	-	1	1	1	-	2	-	-
Lupinus laxiflorus	-	-	-	-	-	-	-	-	-	-	-	2	-
Penstemon speciosus	-	-	-	-	-	-	-	-	-	1	-	-	-
Phacelia heterophylla	-	2	-	-	-	-	-	-	-	-	-	-	-
Phlox sp.	2	-	-	-	-	1	-	-	-	-	-	-	-
Potentilla sp.	-	-	-	-	-	-	-	-	-	1	-	-	-
Senecio integerrimus	1	2	2	1	-	2	2	2	-	-	2	1	2
Silene hookeri	2	-	2	3	1	2	2	-	-	-	-	-	-
Taraxacum officinale	-	-	-	-	-	1	-	2	4	4	3	2	4
Viola nuttallii	3	3	3	3	3	3	5	5	4	4	5	5	4
SOIL FACTORS													
Stoniness percent													
Surface area	2	0	2	10	10	5	3	1	3	1	5	2	0
Buried volume	60	30	70	80	75	45	20	25	35	25	65	15	25
Underlying material4/	rylt	rylt	rylt	rylt	rylt	rylt	rylt	rylt	rylt	rylt	rylt	rylt	rylt
Solum depth (cm)	56	51	43	51	51	38	30	28	33	38	38	46	51
Solum texture5/													
A horizon	gl	gl	gl	gl	gl	gl	gsl	gsl	gl	gsl	gl	gsl	gsl
B horizon (or AC)	gcl	gcl	gcl	gcl	gcl	gcl	scl	gscl	gcl	gsl	gl	gl	gl
Solum color6/													
A horizon	5YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2	5YR 2/2

1/ O = Oregon; Mal = Malheur County

2/ Cercocarpus ledifolius

3/ 2 = young trees; 3 = mature trees; 4 = overmature trees

4/ rylt = rhyolite

5/ c = clay; g = gravel; l = loam; s = sand

6/ Moist color. For color code see Soil Survey Manual (USDA, 1951)

Table A6. Relic ecosystems and uncorrelated stands illustrating additional conditions under which *Cercocarpus ledifolius* occurs.

Site and Vegetation	Vegetation Dominance Rating											
	Relic Ecosystems			Uncorrelated Ecosystems								
Stand number	54	55	60	33	34	57	83	76	77	75	84	85
State and county[1/]	OHar	OHar	OWal	OMal	OMal	OGra	OGra	CMod	CSis	WGar	CSis	CMod
Township and section	32S34	33S36	5S8	40S4	39S32	14S15	14S22	42N7	44N15	9N16	43N10	45N36
Range	32E	32E	41E	41E	41E	31E	31E	9E	2W	42E	3W	8E
Quarter	-	-	NW	SW	NW	SW	-	SW	NW	NE	SW	SE
Altitude (m)	2271	1829	1509	1860	1860	1402	1433	1585	1372	1494	1490	1479
Exposure and percent slope	SSW10	NE25	S5	WNW10	WNW10	E5	NNE20	E30	00	WSW25	00	00
Trees per hectare[2/]	66	290	101	4213	3555	345	97	-	-	669	-	-
Ave. percent live crown[2/]	25	50	15	53	54	40	5	25	55	15	40	40
Ave. stand age[3/]	3.0	3.0	3.0	3.1	3.0	2.9	2.7	2.5	2.5	3.0	-	2.5
TREES												
Calocedrus decurrens	-	-	-	-	-	-	-	4	-	-	-	-
Cercocarpus ledifolius	5	5	5	5	5	5	3	5	5	5	5	5
Juniperus occidentalis	2	3	-	-	-	3	1	-	2	-	3	2
Pinus ponderosa	-	-	3	-	-	2	4	4	3	3	3	3
Pseudotsuga menziesii	-	-	3	-	-	-	4	-	-	3	-	-
Quercus kelloggii	-	-	-	-	-	-	-	3	-	-	-	-
SHRUBS												
Amelanchier alnifolia	-	-	-	-	-	-	-	2	-	1	-	-
Arctostaphylus patula	-	-	-	-	-	-	-	5	-	-	-	1
Artemisia tridentata	5	3	2	5	3	-	-	-	3	-	-	-
Berberis repens	1	-	-	-	-	-	2	-	-	-	-	-
Ceanothus prostratus	-	-	-	-	-	-	-	3	-	-	-	-
Ceanothus velutinus	-	-	1	-	-	-	-	-	-	-	-	-
Chrysothamnus nauseosus	2	-	-	-	1	3	-	-	2	-	2	2
Chrysothamnus viscidiflorus	2	1	-	3	3	-	-	-	3	-	3	-
Eriogonum heracleoides	-	-	-	-	-	-	-	-	-	-	-	1
Eriogonum microthecum	-	-	3	-	-	-	-	-	-	1	-	-
Haplopappus bloomeri	-	-	-	-	-	-	-	-	-	-	-	2
Holodiscus dumosus	1	-	1	-	-	-	-	-	-	-	-	-
Prunus emarginata	-	-	2	-	-	-	1	2	-	-	-	-
Prunus virginiana	-	-	-	-	-	-	-	-	-	-	-	2
Purshia tridentata	-	-	-	-	-	3	-	2	-	-	5	2
Ribes cereum	-	2	-	-	-	-	-	-	2	3	-	-
Rosa sp.	-	-	2	-	-	-	-	-	-	-	-	-
Symphoricarpos albus	-	-	5	-	-	-	5	-	-	-	-	-
Symphoricarpos oreophilus	3	5	-	3	3	-	-	-	-	-	-	-
GRAMINOIDS												
Agropyron caninum	-	2	-	-	-	-	-	-	-	-	-	-
Agropyron spicatum	-	-	-	-	-	3	-	-	-	3	2	3
Bromus carinatus	-	-	-	-	-	-	-	-	-	-	-	2
Bromus tectorum[4/]	-	3	-	3	3	4	-	3	5	-	5	2
Carex geyeri	-	-	2	-	-	-	-	-	-	-	-	-
Carex rossii	1	3	-	-	-	-	5	3	3	-	2	2
Danthonia californica	-	2	3	-	-	-	-	-	-	-	-	-
Festuca idahoensis	-	5	-	-	-	5	-	-	5	4	2	5
Festuca octoflora[4/]	-	-	-	3	3	-	-	-	-	-	-	-
Koeleria cristata	-	-	-	-	-	-	-	-	-	-	2	-
Melica bulbosa	-	-	-	1	1	-	-	-	-	-	-	-
Poa ampla	3	-	-	-	1	-	-	-	-	-	-	-
Poa sandbergii	3	-	3	5	3	1	-	-	3	4	-	-
Sitanion hystrix	3	3	-	3	3	3	-	5	3	-	3	3
Stipa lemmonii	-	-	-	2	-	-	-	-	-	-	-	-
Stipa occidentalis	5	-	5	-	-	3	-	-	-	-	-	-
Stipa thurberiana	-	-	-	-	-	-	-	-	-	-	5	-

Table A6. Continued.

Site and Vegetation	Vegetation Dominance Rating											
	Relic Ecosystems			Uncorrelated Ecosystems								
Stand number	54	55	60	33	34	57	83	76	77	75	84	85
FORBS												
Achillea millefolium	-	3	3	-	-	5	2	-	-	3	5	3
Agoseris heterophylla	-	-	-	-	2	-	-	-	-	-	-	-
Allium sp.	2	-	2	-	-	-	-	-	-	-	-	-
Antennaria sp.	-	-	5	-	-	-	-	-	-	-	-	-
Apocynum androsaemifolium	-	-	-	-	-	-	-	3	-	-	-	-
Arabis holboellii	-	-	2	1	-	-	-	2	-	-	-	-
Arnica cordifolia	-	-	-	-	-	-	5	-	-	5	-	-
Aster sp.	-	-	-	-	-	-	-	-	-	-	3	-
Astragalus sp.	2	-	-	3	3	-	-	-	-	3	-	1
Balsamorhiza sagittata	1	-	-	-	-	-	-	-	-	-	-	3
Besseya rubra	-	-	3	-	-	-	-	-	-	-	-	-
Brodiaea douglassi	-	-	-	-	-	2	-	-	-	3	-	
Crepis intermedia	-	2	3	-	-	3	1	-	-	-	-	2
Delphinium sp.	-	-	3	-	-	-	-	-	-	-	-	-
Delphinium bicolor	-	-	-	-	-	2	-	-	-	-	-	-
Erigeron sp.	2	-	3	-	-	-	-	-	-	-	-	-
Eriophyllum lanatum	3	-	-	-	-	-	-	3	-	-	3	-
Fragaria virginiana	-	-	-	-	-	-	3	-	-	-	-	-
Fritillaria pudica	-	-	-	-	-	-	-	-	-	2	-	-
Geum triflorum	-	-	2	-	-	-	1	-	-	-	-	-
Hieracium albertinum	-	-	-	-	-	-	-	2	-	-	-	-
Hydrophyllum capitatum	-	-	2	-	-	1	-	-	-	3	-	-
Lathyrus sp.	-	-	-	-	-	-	-	1	-	-	-	-
Lomatium sp.	-	-	-	-	-	-	-	2	-	3	-	-
Lomatium donnellii	-	-	-	-	-	2	-	-	-	-	-	-
Lupinus sp.	-	-	-	3	-	-	3	-	3	3	-	2
Lupinus laxiflorus	5	2	2	-	-	-	-	-	-	-	-	-
Paeonia brownii	-	-	2	-	-	-	-	-	2	-	-	-
Phacelia heterophylla	-	-	-	-	-	-	-	2	3	-	-	-
Phlox sp.	-	-	-	2	-	-	-	-	-	-	-	-
Phlox gracilis	-	-	-	-	-	-	-	-	-	-	3	-
Potentilla sp.	-	-	3	-	-	-	-	-	-	-	-	-
Senecio intergerrimus	3	5	3	3	3	-	-	-	-	-	-	2
Sidalcea oregana	-	-	-	-	-	-	-	2	-	-	-	-
Silene hookeri	-	2	-	-	-	-	-	-	-	-	-	-
Taraxacum officinale	-	-	-	-	-	2	-	-	-	-	-	-
Viola glabella	-	-	-	-	-	-	-	-	3	-	-	-
Viola nuttallii	-	-	-	-	2	-	-	-	-	-	-	-
Viola purpurea	-	-	-	-	-	-	-	3	-	-	-	3
Zigadenus venenosus	-	-	3	-	-	1	-	3	-	-	-	-
SOIL FACTORS												
Stoniness, percent												
Surface area	5	10	5	0	5	5	0	30	-	10	-	-
Buried volume	50	65	30	5	10	20	15	50	20	80	55	10
Underlying material5/	bslt	bslt	bslt	rylt	rylt	serp	-	bslt	bslt	bslt	bslt	bslt
Solum depth (cm)	45	25	48	38	64	30	50	45	30	30	50	81
Solum texture6/												
A horizon	gl	gl	gl	gl	gl	gsl	l	gl	gl	l	l	sl
B horizon (or AC)	gcl	gcl	cl	gcl	gcl	gcl	scl	gcl	cl	cl	cl	scl
Solum color7/												
A horizon	5YR 2/2	5YR 2/2	- -	5YR 2/1	5YR 2/1	5YR 2/1	- -	- -	- -	5YR 2/2	10YR 2/2	10YR 3/4

1/ C = California; O = Oregon; W = Washington; Gar = Garfield County; Gra = Grant County; Har = Harney County; Mal = Malheur County; Mod = Modoc County; Sis = Siskiyou County; Wal = Wallawa County

2/ Cercocarpus ledifolius

3/ 2 = young trees; 3 = mature trees; 4 = overmature trees

4/ Annuals

5/ bslt = basalt; rylt = rhyolite; serp = serpentine

6/ c = clay; f = fine; g = gravelly; l = loam; s = sand

7/ Moist color. For color code, see Soil Survey Manual (USDA, 1951)

APPENDIX B

LISTING OF SCIENTIFIC AND COMMON NAMES USED IN THE TEXT

SCIENTIFIC NAME	COMMON NAME
TREES	
Abies grandis (Dougl.) Lindl.	Grand fir
Alnus Hill.	Alder
Arbutus L.	Madrone
Calocedrus decurrens (Torr.) Florin.	Incense-cedar
Cercocarpus betuloides Nutt. in T. & G.	Birchleaf mountain-mahogany
Cercocarpus ledifolius Nutt. in T. & G.	Curlleaf mountain-mahogany
Cercocarpus montanus Raf.	Western mountain-mahogany
Cercocarpus parviflorus (Nutt.) Hook. & Arn.	Mountain-mahogany
Cercocarpus praeledifolius	Fossil mountain-mahogany
Fagus L.	Beech
Juniperus occidentalis Hook.	Western juniper
Lithocarpus Blume	Tanoak
Pinus contorta Dougl. ex Loud.	Lodgepole pine
Pinus ponderosa Dougl. ex Loud.	Ponderosa pine
Populus tremuloides Michx.	Quaking aspen
Populus trichocarpa Torr. & Gray	Cottonwood
Pseudotsuga menziesii (Mirb.) Franco	Douglas-fir
Quercus gambellii Nutt.	Gambel oak
Quercus kelloggii Newb.	California black oak
Sequoia Endl.	Redwood
Thuja L.	Redcedar
SHRUBS	
Amelanchier alnifolia Nutt.	Serviceberry
Arctostaphylus patula Green	Greenleaf manzanita
Artemisia arbuscula Nutt.	Low sagebrush
Artemisia tridentata Nutt.	Big sagebrush
Berberis repens Lindl.	Low Oregon grape
Ceanothus prostratus Benth.	Squawcarpet
Ceanothus velutinus Dougl. ex Hook.	Snowbrush
Chrysothamnus nauseosus (Pall.) Brit.	Gray rabbitbrush
Chrysothamnus viscidiflorus (Hook.) Nutt.	Green rabbitbrush
Eriogonum heracleoides Nutt.	Wyeth buckwheat
Eriogonum microthecum Nutt.	Slenderbush buckwheat
Haplopappus bloomeri Gray	Rabbitbrush goldenweed
Holodiscus dumosus (Hook.) Heller	Gland oceanspray
Prosopis L.	Mesquite
Prunus emarginata Dougl.	Bitter cherry
Prunus virginiana L.	Common chokecherry
Purshia tridentata (Pursh) DC.	Bitterbrush
Ribes cereum Dougl.	Wax current
Rosa gymnocarpa Nutt.	Baldhip rose
Sambucus cerulea Raf.	Blue elderberry
Symphoricarpos albus (L.) Blake	Common snowberry
Symphoricarpos oreophilus Gray	Mountain snowberry
Tetradymia canescens DC.	Gray horsebrush

SCIENTIFIC NAME	COMMON NAME
GRAMINOIDS	
Agropyron caninum (L.) Beauv.	Cutting wheatgrass
Agropyron spicatum (Pursh) Scribn. & Smith	Bluebunch wheatgrass
Bromus brizaeformis Fisch. & Mey.	Rattle brome
Bromus carinatus H. & A.	California brome
Bromus tectorum L.	Cheatgrass brome
Calamagrostis rubescens Buckl.	Pinegrass
Carex geyeri Boott	Elk sedge
Carex rossii Boott	Ross sedge
Danthonia californica Boland.	California danthonia
Elymus cinereus Scrib. & Mer.	Giant wildrye
Festuca idahoensis Elm.	Idaho fescue
Festuca octoflora Walt.	Sixweeks fescue
Koeleria cristata Pers.	Prairie junegrass
Melica bulbosa Geyer ex Porter & Coult	Oniongrass
Oryzopsis hymenoides (F. & S.) Ricker	Indian ricegrass
Poa ampla Merr.	Big bluegrass
Poa sandbergii Vasey	Sandberg bluegrass
Sitanion hystrix (Nutt.) J. G. Smith	Bottlebrush squirreltail
Stipa comata Trin. & Rupr.	Needle and threadgrass
Stipa lemmonii (Vasey) Scribn.	Lemmon needlegrass
Stipa occidentalis Thurb. ex Wats.	Western needlegrass
FORBS	
Achillea millefolium L.	Yarrow
Agoseris heterophylla (Nutt.) Greene	Annual agoseris
Alisma L.	Waterplantain
Allium acuminatum Hook.	Tapertip onion
Amaranthus L.	Pigweed
Antennaria stenophylla Gray	Narrowleaf pussytoes
Apocynum androsaemifolium L.	Spreading dogbane
Arabis holboellii Hornem.	Holboell rockcress
Arnica cordifolia Hook.	Heartleaf arnica
Astragalus filipes Torr. ex Gray	Threadstalk milkvetch
Astragalus stenophyllus T. & G.	Hangingpod milkvetch
Balsamorhiza sagittata (Pursh) Nutt.	Arrowleaf balsamroot
Besseya rubra (Dougl.) Rydb.	Besseya
Brassica L.	Mustard
Brodiaea douglasii Wats.	Douglas brodiea
Cirsium vulgare (Savi) Airy-Shaw	Bull thistle
Crepis intermedia Gray	Gray hawksbeard
Delphinium bicolor Nutt.	Little larkspur
Erigeron L.	Fleabane
Eriophyllum lanatum (Pursh) Forbes	Woolly eriophyllum
Fritillaria pudica (Pursh) Spreng.	Yellowbells
Geum triflorum Pursh	Redbell avens
Habenaria unalascensis (Spreng.) Wats.	Alaska reinorchid
Hieracium albertinum Farr	Western hawkweed

SCIENTIFIC NAME	COMMON NAME
FORBS (continued)	
Hydrophyllum capitatum Dougl.	Ballhead waterleaf
Lathyrus (Tourn.) L.	Peavine
Lepidium L.	Peppergrass
Lomatium donnellii C & R.	Donnell biscuitroot
Lomatium grayi C. & R.	Grays biscuitroot
Lomatium triternatum (Pursh) C. & T.	Nineleaf lomatium
Lupinus caudatus Kell.	Silvery lupine
Lupinus laxiflorus Agardh	Spur lupine
Paeonia brownii Dougl. ex Hook.	Browns peony
Penstemon speciosus Dougl. ex Lindl.	Royal penstemon
Phacelia heterophylla Pursh	Varileaf phacelia
Phlox gracilis (Hook.) Greene	Pink microsteris
Phlox viscida E. Nels.	Sticky phlox
Potentilla L.	Cinquefoil
Senecio integerrimus Nutt.	Western groundsel
Sidalcea oregana (Nutt.) Gray	Oregon checkermallow
Silene hookeri Nutt.	Hooker silene
Smilacina Desf.	Solomonplume
Taraxacum officinale Weber	Common dandelion
Thalictrum (Tourn.) L.	Meadowrue
Tragopogon dubius Scop.	Yellow salsify
Viola glabella Nutt.	Pioneer violet
Viola nuttallii Pursh	Nuttall violet
Viola purpurea Kell.	Goosefoot violet
Zigadenus venenosus Wats.	Grassy deathcamas