Ecological Relationships between Pinyon-Juniper and True Mountain Mahogany Stands in the Uintah Basin, Utah

LARRY R. GREENWOOD AND JACK D. BROTHERSON

Highlight: Ecological relationships between true mountain mahogany and pinyon-juniper stands in the Uintah Basin, Utah, were measured to detect differences between the two community types. The mountain mahogany community is dominated by grasses and shrubs, while the pinyon-juniper vegetation consists primarily of trees and annual plants. Soil depth is greatest in the pinyon-juniper areas. Slickrock often covers as much as 80% of the mountain mahogany stands. Soil was sampled from beneath and between the mahogany shrubs and the pinyon and juniper trees. The pH of soil from beneath mahogany shrubs was significantly ($P < 0.001$) more alkaline than that from beneath pinyon and juniper trees. Soluble salt concentration was significantly ($P < 0.05$) less in soil from beneath mountain mahogany shrubs than in soil from between shrubs. A reverse situation occurred in the pinyon-juniper stands.

Native shrubs contribute substantially to the vegetative cover, available forage, and community stability of ranges of western North America. As the human population increases and public demands on these vital land resources increase, precise knowledge of the ecological requirements of the natural plant cover will become increasingly useful.

True mountain mahogany (*Cercocarpus montanus*) is widely distributed in western United States. The shrub ranges from South Dakota, Nebraska, and Oklahoma, through Colorado, Wyoming, and New Mexico, to Utah, Arizona, and Nevada. Its major habitat is found in the Rocky Mountains and the eastern Great Basin, where it grows on mountain slopes and rocky bluffs between 1,000 and 3,000 meters (3,500 to 10,000 feet) elevation (Martin 1950; Medin 1960; Pyrah 1964). The species is widespread and occupies a diversity of ecological situations in Utah.

Communities of true mountain mahogany (Fig. 1) are found throughout the Uintah Basin of Utah. Many of these communities are located among the pinyon-juniper (*Pinus edulis* and *Juniperus osteosperma*) woodlands (Fig. 2) of that area. Formations of soil-free sandstone, commonly called slickrock, are often a dominant feature of these communities. The mountain mahogany plants grow on the sandstone, in cracks and soil pockets, where they apparently are able to obtain enough moisture and essential nutrients for growth and survival.

Medin (1960) found true mountain mahogany growing on sandstone and shale in Colorado. His results indicated soil depth was by far the most significant factor influencing annual production of this shrub. He also found that the clay content of the A-horizon proved to have a significant impact on the species in sandstone areas.

Nixon (1977) concluded that true mountain mahogany reproduced best on shallow, dry soils. Anderson (1974) and Brooks (1962) both found that mahogany often occupied harsh, rocky sites having shallow and undeveloped soils. The Soil Conservation Service (1971) indicates that true mountain mahogany is

Fig. 1. *Typical view of a birchleaf mountain mahogany community.*

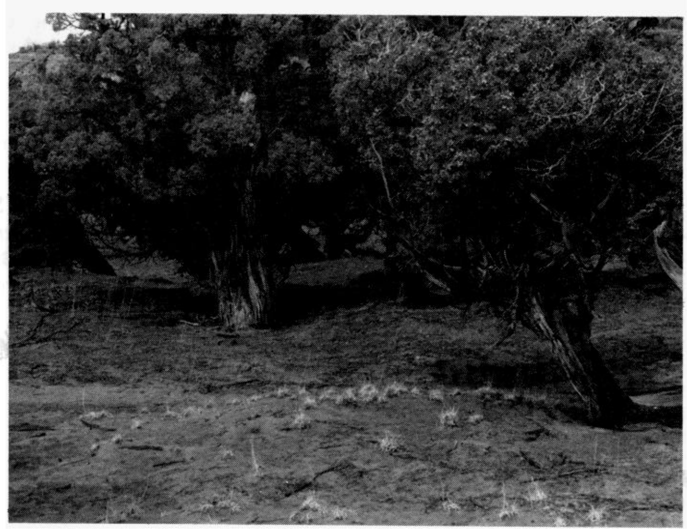

Fig. 2. *Typical view of pinyon-juniper community.*

Authors are range conservationist, Bureau of Land Management, Richfield, Utah; and assistant professor of botany and range science, Department of Botany and Range Science, Brigham Young University, Provo, Utah 84602.

Manuscript received June 21, 1977.

most abundant in Utah in areas with shallow soils having 35% or greater coarse fragments, which lie within the 10–23-inch rainbelt and on sites showing moisture deficiency in June. Similar situations are found in the Uintah Basin. Brooks (1962) also concluded that soil depth, moisture, and organic content were important in determining the specific habitat of true mountain mahogany.

The pinyon-juniper forest, with its scattered populations of true mountain mahogany, occupies a large portion of the lower elevations along the south slope of the Uinta Mountains. In winter, deer migrate into these lower stretches of pigmy forest and feed on native forage plants. True mountain mahogany and Utah juniper contribute to the forage base. Mountain mahogany is rated from good to excellent as browse for livestock and wildlife and is most valuable as feed for deer (Plummer 1969). Leaves are shed by mid October and are therefore a substantial source of forage only during the warm season. Protein ratios in the twigs and leaves are higher throughout the year than in many other shrubs (U.S.F.S. 1937; Medin 1960; Plummer 1969; S.C.S. 1971).

The objective of this study was to identify the ecological similarities and differences between pinyon-juniper forest and true mountain mahogany. A precise knowledge of such relationships and differences should be of value to managers when working within the confines of these vegetative zones.

Study Area

Stands of pinyon-juniper and true mountain mahogany were studied, in the Uintah Basin along the southern foodhills of the Uinta Mountains, north and east of Duchesne. In this region extensive forests of pinyon-juniper occupy areas where book-cliff type topography predominates. Hills and ridges are characterized by steep escarpments on one side and long gentle slopes on the other. Along the escarpment edges ledge outcropping occur and are occupied by stands of true mountain mahogany. Annual precipitation in the area is about 26 cm. The basin floor slopes gently away from these ridges toward the southeast. The elevation of the study area ranges between 1,500 and 2,000 m. The area has served as winter range for sheep and cattle grazing since 1920 and overgrazing is apparent. There is no evidence of fire in the area.

Methods

Twenty sites were selected where pinyon-juniper and true mountain mahogany communities occurred adjacent to each other. A 20 m × 20 m study plot (.04 ha) as established within each true mountain mahogany stand and the adjacent pinyon-juniper community. Care was taken to keep the pairs of study plots on the same slope, elevation, and exposure in order to facilitate analyses of environmental variables responsible for the vegetation pattern. Slope, exposure, and elevation for each study plot were determined. Exposure values were transformed according to Beers et al. (1966) in order to use the exposure in statistical analyses.

Study plots were delineated by a cord 80.0 m long with a loop tied every 20 m for each corner. The corners were secured by 18-inch steel stakes. Flagging, tied at equal intervals along the cord, aided in uniform placement of 25 quadrats (area per quadrat of 0.25 m^2) within each study plot.

Density and frequency of all plant species encountered were determined from the quadrat data. Cover values were estimated as suggested by Daubenmire (1959).

Percent frequency and percent cover were calculated for each plant species. Plants not occurring within any of the 0.25 m^2 quadrats, but still occurring inside the study plot, were regarded as trace species. These species were recorded and used in compiling an overall species list for the study area.

Soil depth was determined with the use of a 1-m penetrometer. Three soil depth categories were measured at each plot: mean soil depth, soil depth beneath the major plants, and soil depth between the plants. Mean soil depth measurements were taken in five of the 25 quadrats in each study plot. These quadrats were located at each corner and at the center of the study plot. Depth was sampled five times in each quadrat, once in each corner and once in the center. The plant closest to the central point used for the mean soil depth measurement was chosen for measuring soil depth beneath plants. Soil depth was measured five times around the base of the plant. A quadrat was then placed between this plant and its nearest neighbor for the between-plant soil depth measurement. Depth was sampled five times in the quadrat as described above.

At the center of each quadrat used for mean soil depths, a cord 3.4 m long was attached to the pentrometer. Using the pentrometer as the center point, a circle with a diameter of 6.8 m was circumscribed. Individual plants of true mountain mahogany found within these circles were selected and measured as to their height, number of stems, size class, and age. Size classes used in this study were: seedling (< ⅛ inch diameter), young plant (⅛ to ¼ inch diameter), mature plant (> ¼ inch diameter), and decadent plant (25% or more dead branches). A single plant was selected within each circle for aging. A stem with the largest diameter was cut from this plant. Plants in each study plot were selected to form a gradient of stems from smallest to largest diameter. This same circle system was also used for obtaining height, diameter, and age class data for dominant plants in the adjacent pinyon-juniper plots.

Soil samples were taken within each study plot from two areas: beneath and between selective woody plants. The between-plant soil samples were taken to a depth of approximately 15 cm within the quadrats where between-plant soil depth was measured. Samples of the surface 15 cm of soil were also taken from beneath those plants where soil depth was measured. Samples of similar category in each study plot were combimed for analysis.

Soil samples were analyzed for texture (Bouyoucos 1951), pH, and soluble salts. Soil reaction was taken with a glass electrode pH meter. Total soluble salts were determined by a Beckman electrical conductivity bridge. A paste consisting of a 1:1 soil-to-water mixture (Russell 1948) was used to determine pH and soluble salts.

Results and Discussion

Discriminant analysis (Nie et al. 1975) was employed for site classification. Fifteen environmental parameters were used as variables in this analysis. Five of these parameters (see note, Table 1) were designated in the analysis as being the most useful

Table 1. Average values for selected environmental variables in mountain mahogany and pinyon-juniper stands.

Variables	Mean		**Significance
	Mt. mahogany	Pin.-Jun.	Level
Slope (%)	9.7	5.7	0.02
Exposure	0.9	0.9	0.4
4 Rock (% cover)*	16.0	3.0	0.0001
Mean soil depth per plot (dm)	1.3	2.3	0.001
Soil depth beneath plant (dm)	1.9	2.8	0.001
1 Soil depth between plant (dm)	1.3	2.6	0.001
3 Between-plant soil pH	7.7	7.6	0.4
2 Between-plant soil sol. salts (ppm)	256	186	0.2
Between-plant soil % sand	75	81	0.1
Between-plant soil % clay	11	9	0.3
5 Between-plant soil % silt	14	9	0.05
Beneath-plant soil pH	7.9	7.7	0.01
Beneath-plant soil sol. salts (ppm)	157	482	0.001
Beneath-plant soil % sand	81	83	0.3
Beneath-plant soil % clay	9	8	0.2
Beneath-plant soil % silt	10	9	0.4

* Numbers preceding variable name indicate the order in which those parameters were entered into the discriminant analysis.

** Significance level indicates importance of each variable as a contributor to the discriminant analysis of difference between vegetative types.

Table 2. Average percent frequency for the important plant species of the two communities.

Species	Percent frequency	
	Mt. mahogany	Pin.-Jun.
Utah juniper (*Juniperus osteosperma*)	12.2	36.4
Pinyon pine (*Pinus edulis*)	4.2	5.8
Black sagebrush (*Artemisia nova*)	3.4	15.2
True Mtn. mahogany (*Cerocarpus montanus*)	22.8	.8
Green ephedra (*Ephedra viridis*)	4.0	2.2
Greasebush (*Forsellesia meionandra*)	1.8	.4
Pricklypear (*Opuntia erinacea*)	2.0	3.0
Plains pricklypear (*Opuntia polyacantha*)	7.8	19.0
Broom snakeweed (*Xanthocephalum sarothrae*)	3.6	1.4
Littleleaf rockcress (*Arabis microphylla*)	2.6	4.4
Kings sandwort (*Arenaria kingii*)	1.2	.6
Fremont goosefoot (*Chenopodium fremontii*)	13.2	37.8
Cryptantha (*Cryptantha breviflora*)	2.6	4.2
Nodding eriogonum (*Eriogonum cernuum*)	17.4	48.8
Ballhead gilia (*Gilia congesta*)	.6	1.6
Matted phlox (*Phlox caespitosa*)	3.4	2.8
Russian thistle (*Salsola iberica*)	1.2	5.2
Linear leaf mustard (*Schoencrambe linifolium*)	1.4	4.8
Little twistflower (*Streptanthella longirostris*)	3.8	9.6
Salina wildrye (*Elymus salinus*)	14.2	15.4
Galleta (*Hilaria jamesii*)	1.8	3.2
Indian ricegrass (*Oryzopsis hymenoides*)	9.4	10.2

classification discriminators. Table 1 lists the means for several variables in each in vegetative type and the probability that observed differences are due to chance. The variables listed as entering the discriminant analysis contributed the most to the overall discriminating process. The level of significance given for each variable indicates the value of that variable as a discriminator between the two vegetative types. Ninety-seven percent of the study plots were correctly classified into either the true mountain mahogany type or the pinyon-juniper type on the basis of environmental variables. The misclassified study plot was pinyon-juniper. The discriminant function generated in the analysis was highly significant ($P < 0.001$), with a Chi-square value of 47.05 at 5 degrees of freedom.

The pinyon-juniper sites supported a total living cover of 26.8%, while the true mountain mahogany sites had only 12.8% cover. True mountain mahogany had an average density of 1,225 plants/ha. Utah juniper averaged 382 plants/ha while pinyon pine averaged 62 plants/ha in the pinyon-juniper type. Eighty-one species of plants were identified from the study area. These included 2 trees, 18 shrubs, 51 forbs, and 10 grasses. Table 2 lists the most important species and their frequency values in the two communities. As can be seen, overall frequency values are low, indicating the general sparseness of vegetative cover on the sites.

Pinyon pine and Utah juniper trees were found in every study plot and were universally present throughout the study area. Average juniper tree density for the true mountain mahogany sites was 207 trees per ha, while the pinyon-juniper sites averaged 382 trees per hectare. Pinyon pine, however, exhibited greater density in the true mountain mahogany sites averaging 100 trees/ha and only 62 trees/ha in the pinyon-juniper type. This difference is partially explained in that 11 out of the 20 mountain mahogany study sites had pinyon pine seedlings growing beneath true mountain mahogany shrubs. The deeper soil and modified habitat around the shrubs apparently provided a route for pinyon tree invasion. Seedling juniper trees were also observed growing beneath true mountain mahogany shrubs. True mountain mahogany sites appear to provide an avenue for the establishment of pinyon and juniper, on shallow soil within slickrock areas.

Evidence for true mountain mahogany preference for slickrock areas is shown by a 16% mean cover value for rock in these communities, as compared to a 3% mean cover value for rock in the pinyon-juniper areas. Average density of true mountain mahogany in the relatively rock-free pinyon-juniper communities was 32 shrubs/ha, while on the rocky true mountain mahogany sites there was an average of 1,225 shrubs/ha. Thus true mountain mahogany communities dominate the harsh slickrock sites and may be important in long-term successional changes in this area.

The two communities differed slightly in mean number of plant species per .04 ha. True mountain mahogany sites averaged 15 species per .04 ha, while the pinyon-juniper sites averaged 17 species. However, when a Shannon-Weaver diversity index (Shannon and Weaver 1949) was calculated for the plant cover of each type, true mountain mahogany had an average diversity value of 0.30, while the pinyon-juniper type had an average value of 0.23. This indicates a slightly more diverse plant cover in the mountain mahogany type. The lower value for the pinyon-juniper type reflects the dominant influence of the trees.

There were differences in the species of plants found within the two types. Eleven plant species occurring on the pinyon-juniper sites were not found on the mountain mahogany sites. Also, nine species found on the mountain mahogany sites were not observed in the pinyon-juniper sites. Similarity indices (Ruzick 1958) were computed among all sites studied in the two types. The true mountain mahogany sites showed an average internal similarity index of 27.2, while the pinyon-juniper sites had an average of 35.4. When all mahogany plots were compared with all pinyon-juniper plots, an average similarity index of 20.9 was obtained. The larger the index value, the more similar the vegetative samples are; conversely, the smaller the index value, the more heterogenous is the sample. It is apparent that the pinyon-juniper community is internally more similar than the mountain mahogany community. The two communities are quite dissimilar with regards to each other.

Analyses of growth form showed important differences between pinyon-juniper and true mountain mahogany vegetations. Plant species were placed in five growth form groups: trees, shrubs, perennial forbs, perennial grasses, and annuals. Relative cover and frequency values were used for Chi-square analysis (Table 3). Based upon cover, there is a significant difference ($P < 0.001$) in the distribution of growth forms among the two communities. Frequency data also indicated a significant difference ($P < 0.01$) between the pinyon-juniper and the mountain mahogany sites. The pinyon-juniper type is a tree-annual forb association while the true mountain mahogany type is best characterized as a shrub-grass association.

A total of 100 mountain mahogany stems were aged by growth rings. If one ring equals a year, the stems ranged from 5 to 54 years old, with diameters ranging from 2 to 26 mm. Ring counts were significantly correlated ($P < 0.001$) with stem

Table 3. Community growth form data in terms of relative cover and frequency.

Life Form	Cover		Frequency	
	Mt. mahogany	Pin.-June.	Mt. mahogany	Pin.-Jun.
Tree	42	80	13	19
Shrub	41	13	34	16
Forb	1	1	10	11
Grass	13	4	20	13
Annual	3	2	24	41
Total	100	100	100	100

diameter and plant height.

Size class data suggest that 90% of the mountain mahogany shrubs and Utah juniper trees in the study area are mature or decadent. Only 10% of the individuals belonging to these two species were classed as seedling or young plants, indicating very little reproduction. Pinyon pine trees, however, showed good reproduction, with 35% of the individuals being classed as seedlings or young plants.

In the mountain mahogany sites (see Table 1), soil depth beneath the plants (1.9 cm) was significantly deeper ($P < 0.05$) than the soil depth between the plants (1.3 dm). The pinyon-juniper type also showed significant differences ($P < 0.001$) beteen soil depth beneath the plants (2.8 dm) and soil depth between the plants (2.3 dm).

Percent sand as slightly greater in pinyon-juniper study sites, while percent clay and percent silt were both greater in soils of the mountain mahogany study sites.

Average pH values for the soils from between the plants of the true mountain mahogany type was 7.7, while the pH of the corresponding class of pinyon-juniper soils was 7.6. Soil from beneath plants showed pH values significantly ($P < 0.001$) more alkaline under mountain mahogany (7.9) as opposed to pinyon or juniper trees (7.7). Lower pH under pinyon-juniper trees is apparently due to the acid-forming needles and their resultant influence on the soil.

Soluble salt concentrations also exhibited interesting relationships in the two communities. In true mountain mahogany study sites, soluble salts are significantly ($P < 0.05$) less in soil from beneath shrubs than in soil from between shrubs. In the pinyon-juniper communities, a reverse situation occurred, with soluble salts being significantly ($P \leq 0.001$) greater in soil beneath pinyon and juniper trees than in soil between trees. These differences may be explained in several ways. The deeper soils beneath the shrubs may allow for deeper leeching; thus taking the critical ions beyond the depth of our sample. True mountain mahogany shrubs may absorb the soluble salts and incorporate them into their stems and leaves. Leaves are shed each year and seldom remain in and around the plants because winds tend to blow them away. Soluble salts contained in the leaves would thus be removed from the site. Other losses would most likely occur through the utilization in summer and winter of leaves and stems by deer. Thus, a gradual depletion of soluble salts from the soil beneath the mountain mahogany shrubs may occur.

The pinyon-juniper sites are located back from the windy edges of slickrock areas. Large pinyon and juniper trees act as windbreaks, which collect blowing sand and organic material. Soluble salts would also be taken up by these plants into their vegetative parts. Leaves are continually shed, forming a thick layer of duff. Soluble salts contained in this duff are returned to the soil through the process of degradation and leaching. Thus, the salts in and around the trees are cycled from soil to tree, and back to soil again. The canopy and accumulated litter layer of pinyon and juniper trees also limits the amount of leaching that takes place in the soil beneath them. Precipitation reaching the soil beneath these trees is thus reduced and less leaching of the soil would be expected. Loss of soluble salts through wildlife feeding on the pinyon and juniper trees would be minimal.

Literature Cited

Anderson, D. L. 1974. Ecological aspects of *Cercocarpus montanus* Raf. communities in central Utah. Unpublished MS Thesis, Department of Botany and Range Science, Brigham Young University, Provo, Utah. 84 p.

Beers, T. W., P. E. Dress, and L. C. Wensel. 1966. Aspect transformation in site productivity research. J. Forestry 64:691-692.

Bouyoucos, G. J. 1951. A recalibration of the hydrometer method for making mechanical analysis of soils. J. Agron. 43:434-438.

Brooks, A. C. 1962. An ecological study of *Cercocarpus montanus* and adjacent communities in part of the Laramie Basin. Unpublished MS Thesis, Department of Botany, University of Wyoming, Laramie. 53 p.

Christensen, E. M. 1964. Succession in a mountain brush community in Central Utah. Proc. Utah Acad. of Sci. Arts and Letters 41(1):10-13.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Sci. 33:43-46.

Martin, F. L. 1950. A revision of *Cercocarpus*. Brittonia 7:91-111.

Medin, D. E. 1960. Physical site factors influencing annual production of true mountain mahogany, *Cercocarpus montanus*. Ecol. 41:454-460.

Nie, H. H., C. H. Hull, J. G. Jenkins, K. Steinbrenner, and D. H. Bent. 1975. Statistical Package for the Social Sciences, second edition. McGraw-Hill Book Co., Inc., New York, N.Y. 675 p.

Nixon, E. S. 1977. A mountain *Cercocarpus* population—revisited. Great Basin Natur. 37:97-99.

Plummer, A. P. 1969. Restoring big-game range in Utah. Pub. No. 683. Utah Div. of Wildl. Resources. 183 p.

Pyrah, G. L. 1964. Cytogenetic studies of *Cercocarpus* in Utah. Unpublished MS Thesis, Department of Botany, Brigham Young University, Provo, Utah. 80 p.

Russell, D. A. 1948. A laboratory manual for soil fertility students, third edition. Wm. Brown Co., Dubuque, Iowa. 56 p.

Ruzicka, M. 1958. Anwendung Mathematisch. Statisticher Methoden in der Geobotanik (Synthetische bearbeitung von aufnahmen). Biologia, Bratisl 13:647-661.

Shannon, C. E., and W. Weaver. 1949. The mathematical theory of communication. University of Illinois Press, Urbana. 65 p.

Soil Conservation Service. 1971. Plant handbook. Portland, Oregon. 100 p.

U.S. Forest Service. 1937. Range plant handbook. U.S. Dep. Agr. U.S. Govt. Printing Office, Washington, D.C. 120 p.