

Taxonomic Determination, Distribution, and Ecological Indicator Values of Sagebrush within the Pinyon-Juniper Woodlands of the Great Basin

N. E. WEST, R. J. TAUSCH, K. H. REA, AND P. T. TUELLER

Highlight: Various sagebrush taxa are major understory components of most Great Basin pinyon-juniper woodlands. Improved understanding of their identification, distribution, and ecological indicator significance is necessary to interpret site differences for these ranges. Morphology within sagebrush taxa is so variable that chromatographic determination is more easily and objectively relied upon for identification. Big sagebrush is so widespread and likely genetically diverse that sub-specific designations are more helpful in reading site conditions. The various sagebrush taxa are found in particular situations in Great Basin woodlands. Climatic differences explain the basin-wide distributions much more than geologic, landform, or soil conditions. Soils and exposure become more important on the local scale. Presence of a particular sagebrush taxon within pinyon-juniper woodlands can be used for comparisons of site favorableness provided one understands the general distribution of the other sagebrush taxa.

Pinyon-juniper woodlands occupy about 7.1 million ha (17.6 million acres) within the Great Basin (Beeson 1974). It has been difficult to classify these woodlands into smaller units of landscape designed to satisfy management needs. One of the major problems that has impeded progress toward more detailed synecological classifications is the very low floristic diversity in these woodlands (West et al. 1978). The major species appear to be nearly ubiquitous. A search for discriminatory species forces one to look at the less abundant taxa. Less abundant taxa pose considerable sampling problems. Woody sagebrush (*Artemisia*), however, constitutes one major understory genus offering possibilities as differential indicators if sub-species of big sagebrush are distinguished. By relating sagebrush taxa, including the big sagebrush sub-species, to site similarities and differences, there seems to be some hope of including a major understory genus in synecological classifications that managers can use.

This report summarizes our current understanding of the geographic distribution of sagebrush taxa and their relationships to environmental factors within Great Basin pinyon-juniper woodlands. Our objective was to further synecological investi-

gations in the woodlands and not to define the overall distribution of sagebrushes in the Great Basin. Additional sampling would be necessary to accomplish such broad goals.

Methods

Field Collection

Data were taken from a random selection of 66 of the approximately 200 mountain ranges of the Great Basin (West et al. 1978). We had three levels of sampling: rapid for 46 mountain ranges, intermediate for 17, and intensive for two.

On all mountain ranges we followed a strategy of locating stands on broad, even slopes falling in cardinal directions, and elevationally placing them at regular intervals up and down the slope from the 2,000-meter contour which is common to nearly all woodland belts. This technique was used to allow for direct gradient analysis (Whittaker 1973) of the data.

In establishing the upper and lower type boundaries, we determined that a stand had to have at least 25 pinyon and/or juniper trees per hectare (10/acre), and that, of these, at least one tree had to be of the mature form-size-age class (Blackburn and Tueller 1970). These criteria kept the sampling from extending too far into ecotones, yet allowed for a good coverage of the main woodland belt.

The sampling plot was 20 × 50 meters, oriented perpendicular to the contour. We recorded data on land form, soils, vegetation, and land use. Details of the data collected varied with different intensities of sampling (Beeson 1974; Nabi 1978); however, taxonomic vouchers of sagebrush were collected at each site.

Data Analysis

Sagebrush specimens were segregated morphologically following the work of Winward (1969) and Brunner (1973). However, chromatographic differentiation was also done following the methods and interpretations developed by Hanks et al. (1973) and Stevens and McArthur (1974). Specimens were number coded and the morphologic and chromatographic methods of determination were applied independently without knowledge of the taxonomic placement by the other method. Tabular comparisons of the results were then made. Chromatographic determinations were used as the most objective and repeatable identification of the taxa involved.

Distributions and environmental relationships were derived from the plot data.

Results and Discussion

Overall Occurrence

Of the 375 pinyon-juniper woodland plots on 66 mountain ranges from which we obtained data, 97% had at least trace amounts of some sagebrush. Only the McCullough Range in extreme southern Nevada failed to have sagebrush associated with the woodlands we sampled there. In 83% of the inter-

Authors are, respectively, professor, graduate research assistant, and former research technician, Department of Range Science, Utah State University, Logan 84322; and professor, Renewable Resource Center, University of Nevada, Reno 89507. Rea is currently research ecologist, University of California, Los Alamos Scientific Laboratory, Environmental Studies Section, Los Alamos, New Mexico 87544.

This work was partially supported by the Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture. This paper is approved as Utah Agr. Exp. Sta. Tech. Paper No. 2230. The technical assistance of Lynne Smith and Robert Bayn is gratefully acknowledged.

Manuscript received August 24, 1977.

mediate and intensively studied plots, sagebrush was found to be the dominant shrub in terms of relative shrub cover. (The rapid sampling utilized only cover abundance scales.) Thus, sagebrush taxa are both widespread and important under Great Basin pinyon-juniper woodlands.

Nine *Artemisia* taxa have been found as woodland understory components: mountain big sagebrush [*Artemisia tridentata vaseyana* Rydb.] Beetle; basin big sagebrush [*A. tridentata tridentata* (Nutt.) Ward]; Wyoming big sagebrush (*A. tridentata wyomingensis* Beetle); black sagebrush (*A. nova* A. Nels.); low sagebrush (*A. arbuscula* Nutt.); silver sagebrush (*A. cana* Pursh); Louisiana sagebrush (*A. ludoviciana* Nutt.); pigmy sagebrush (*A. pygmaea* A. Gray); and fringed sagewort (*A. frigida* Willd.). The latter four species are only occasional components of Great Basin pinyon-juniper woodlands and will not be considered further.

We found that 81% of the plots which had sagebrush present had only one species or sub-species of sagebrush (Table 1). Conversely, 19% had more than one *Artemisia* taxon present. The relative abundances of the various taxa can be read from the diagonals of matrix in Table 1. Most of the co-occurrences involved two taxa. Only two plots we sampled had more than two sagebrush taxa represented. The different taxa, although often existing on adjacent sites, seem to have fairly closely circumscribed environmental requirements. Competitive exclusion of one taxa or the other from the "sagebrush niche" at each site is probably intense since there seem to be abundant opportunities for the light seed to be windblown across considerable distances.

Influence of Taxonomic Definitions and Methods

There is much dispute about the existence and identification of specific and sub-specific taxa in the genus *Artemisia*. The five most important taxa were once considered sub-species of *A. tridentata* (Hall and Clements 1923). These five taxa are placed in two species in some more modern taxonomic treatments (Holmgren and Reveal 1966). If more precise indicator values are to be developed for sagebrushes, plants must be delineated at the sub-specific level because species are so widely distributed, occupy a variety of sites, and probably possess considerable ecotypic variation.

The genus *Artemisia* is a polyploid complex with considerable morphological variability (Stebbins 1975). The necessity of going to the more objective chromatographic means of taxonomic placement is illustrated in Table 2, where morphological and chromatographic identifications are compared. Using chromatography as the final arbiter, we correctly identified to sub-species only 42.8% of the specimens when using morphological criteria. Only 78% of the species were apparently identified to morphologically based species designations. *A. arbuscula* was misidentified most often. At one time or another,

Table 1. Percentage occurrence and co-occurrence of various *Artemisia* taxa in Great Basin pinyon-juniper plots having at least one *Artemisia* plant. Principal diagonal of the matrix indicates the percentages of plots that have only one taxon present. Abbreviations such as A.t.t. = *Artemisia tridentata tridentata*, etc., correspond to the full names given in the left hand column.

Taxa	A. t. t.	A. t. w.	A. t. v.	A. n.	A. a.
<i>A. t. tridentata</i>	19.9	1.5	2.5	2.3	0.3
<i>A. t. wyomingensis</i>		13.6	1.8	3.0	0.8
<i>A. t. vaseyana</i>			32.4	3.8	2.8
<i>A. nova</i>				13.8	0.8
<i>A. arbuscula</i>					1.0

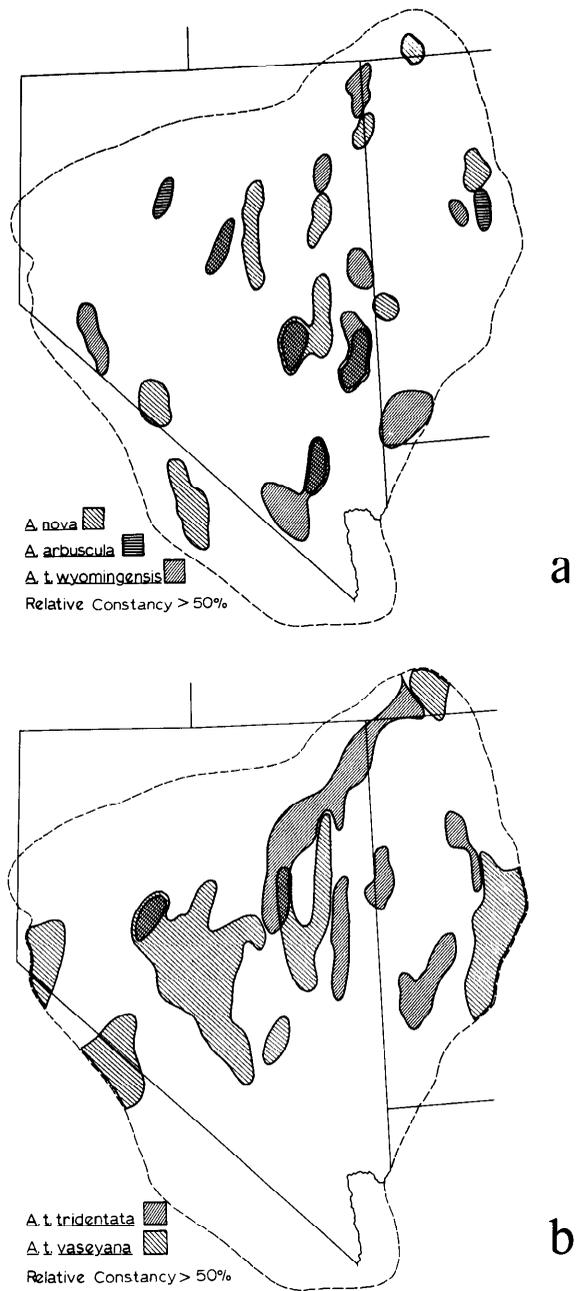


Fig. 1. Portions of the Great Basin where various *Artemisia* taxa occur in greater than 50% of the pinyon-juniper plots sampled per mountain range: (a) *A. nova*, *A. arbuscula*, and *A. t. wyomingensis*; (b) *A. t. tridentata* and *A. t. vaseyana*.

it was morphologically determined to belong in every other taxon. The overall "correct" placement of *A. tridentata* by morphological criteria at the species level, was 80%. more restricted than morphological determinations of that taxon. The overall "correct" placement by morphological criteria of *A. tridentata*, at the species level, was 80%.

The biggest problems were encountered in determining the correct sub-species of *Artemisia tridentata* (Table 2). Only 32.6% of the specimens were correctly placed by morphological characteristics alone. The biggest problem was the identification of *A. t. tridentata* as *A. nova* or *A. t. vaseyana*.

We felt that our use of morphologically based taxonomy was as proficient as most range scientists could apply. It is likely that

Table 2. Matrix comparing *Artemisia* determinations by morphologic and chromatographic means (numbers of specimens identified to same taxon by the two different methods).

Morphological determinations	Chromatographic determinations					Row totals
	<i>A. arbuscula</i>	<i>A. nova</i>	<i>A. t. tridentata</i>	<i>A. t. wyomingensis</i>	<i>A. t. vaseyana</i>	
<i>A. arbuscula</i>	6	4	1	6	4	21
<i>A. nova</i>	8	76	40	17	7	148
<i>A. t. tridentata</i>	2	1	12	22	20	57
<i>A. t. wyomingensis</i>	2	1	23	57	13	96
<i>A. t. vaseyana</i>	7	2	36	61	52	158
Column totals	25	84	112	163	96	480
p (agreement)	.24	.90	.11	.35	.54	
			371			
			p = .80			

Agreement at species level = 378; subspecies level = 203.
 p = (percentage agreement) at species level = 64.5%; subspecies level = 42.8%.

phenotypic variation is so overwhelming as to defy writing a morphologic key that will allow correct identification of 90% or more of the specimens encountered. Chromatography as a taxonomic criterion is very easy to apply to this group and can be used with accuracy. Distributional analysis based on morphologically determined specimens was done as outlined in the following. The distributions obtained were much less ecologically explainable than when the chromatographically determined designations were used.

Artemisia identifications in studies where chromatography has not been used must be viewed with considerable caution. Chromatography is not a panacea, however, since hybridization creates individuals and populations that are hard to place in categories by any criteria. How greatly the concentration of the plant substances being separated varies from year to year and with different sites where the same genotype is involved is unknown.

Distribution

The first step in understanding indicator significance of taxa is to look at their natural distributions. From maps of current distributions we can determine if the taxa can be related to specific niches along environmental gradients.

Presence or absence of each taxon within sampled woodlands of a given mountain range offers little explanation by itself. All we could see from such maps was that greatest overlap of taxa occurs in the middle of the Great Basin. However, mapping the high relative frequencies (>50%) (Fig. 1) and the presence and absence (Fig. 2) of various combinations of taxa allows some generalizations to begin emerging.

Artemisia tridentata vaseyana, although the most common sagebrush in the Great Basin pinyon-juniper woodlands, is lacking in most western Utah woodlands (Fig. 2a). Only the higher and larger masses of mountains have *A. tridentata vaseyana* in their pinyon-juniper woodlands. *Artemisia nova* is generally absent in the woodlands of the southern Great Basin, in western Nevada and in western Utah (Fig. 2a). The exceptions involve mountains of higher and larger masses. *Artemisia arbuscula* is found widely scattered over the Great Basin, but only in the woodlands that reach higher elevations (Fig. 2b). *Artemisia tridentata tridentata* is generally absent in the woodlands of the southern Great Basin. *Artemisia tridentata wyomingensis* is absent from woodlands in the north and high central Nevada ranges (Fig. 2b).

Basin-wide variations in woodland composition is not strongly related to geology or landform (Beeson 1974; West et al.

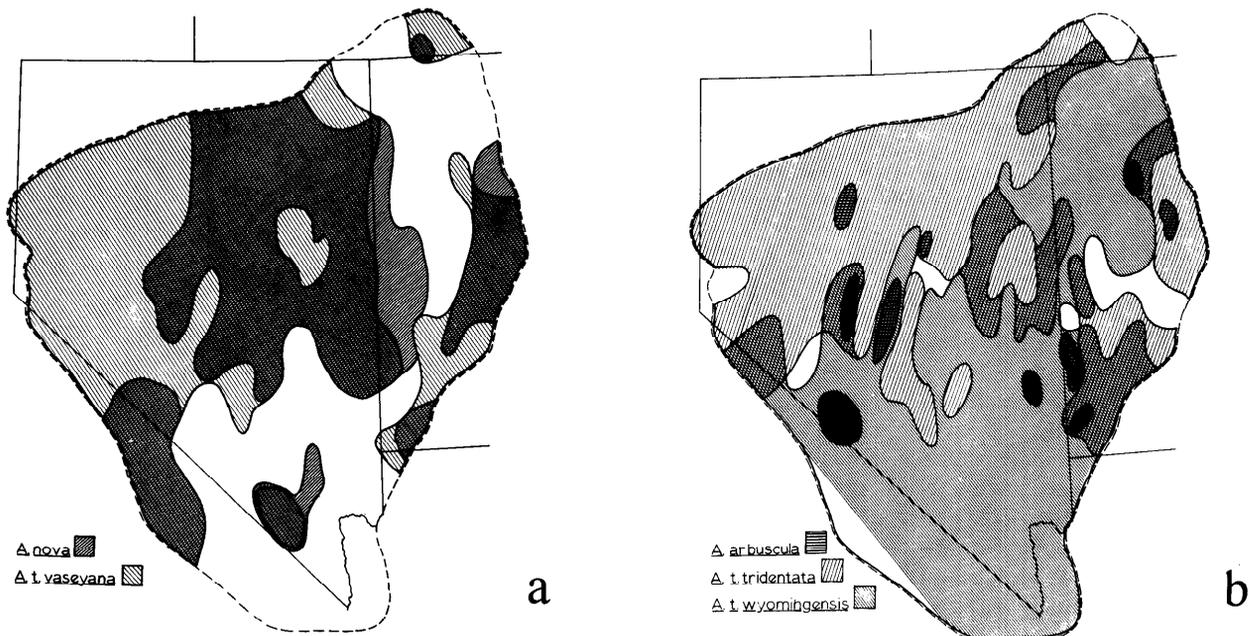


Fig. 2. Portions of the Great Basin where various *Artemisia* taxa are present or absent in the pinyon-juniper woodlands on the mountain ranges sampled.

Specific shading indicates the presence of a taxon: (a) *A. nova* and *A. t. vaseyana*; (b) *A. arbuscula*, *A. t. tridentata*, and *A. t. wyomingensis*.

1978). Floristic variations in vegetation considered at a coarse focus are also not strongly related to soils over the basin as a whole. Analysis of basin-wide occurrences of the major *Artemisia* taxa in relation to higher level soil taxonomic categories showed no close correlation between sagebrush taxa and particular kinds of soils when the total set of data is looked at together.

General patterns of vegetation, soils and distribution of *Artemisia* taxa in woodlands seem to be more closely related to patterns of moisture and temperature (Beeson 1974; West et al. 1977). These aspects of climate in turn are influenced by physiography and storm systems (Houghton 1969). Cross-sections of the Great Basin show low, dry areas in the west, south, and east. The central plateau of eastern Nevada had a wetter and colder climate than elsewhere within the Basin (Wernstedt 1960; Houghton 1969).

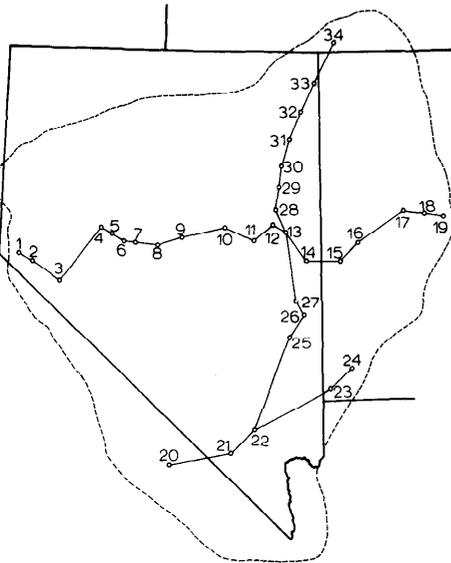


Fig. 3. Map locations sampled for elevational scaling of *Artemisia* occurrence in pinyon-juniper woodlands of the Great Basin.

List of Mountain Ranges in Figure 3: 1. Virginia Range, 2. Pine Nut Range, 3. Wassuk Range, 4. Clan Alpine Range, 5. Desatoya Range, 6. Shoshone Range, 7. Toiyabe Range, 8. Toiyabe Range, 9. Simpson Park Range, 10. Fish Creek Range, 11. White Pine Mountains, 12. Lower Egan Range, 13. Schell Creek Mountains, 14. Lower Snake Range, 15. Confusion Range, 16. House Range, 17. Sheeprock Mountains, 18. West Tintic Mountains, 19. East Tintic Mountains, 20. Panamint Mountains, 21. Spring Range, 22. Sheep Range, 23. Beaver Dam Mountains, 24. Pine Valley Mountains, 25. Wilson Creek Range, 27. Fortification Range, 28. Upper Egan Range, 29. Cherry Creek Range, 30. Spruce Mountains, 31. Pequop Mountains, 32. Toano Range, 33. Goose Creek Range, 34. Albion Mountains.

Relationships of *Artemisia* to environment, especially climate, are further illustrated by elevational considerations. Figure 3 indicates the locations of samples taken to examine these relationships. The first series (Fig. 4) is graphed by actual elevations and distances. The second series (Fig. 5) has simplified the patterns by graphing the percentage of plots where various sagebrush taxa occur. The relative elevational position of each has been maintained on the vertical scales. In both series the figures may be interpreted as cross-sections through a response surface to which the total data set could be fitted. Because data are available from very few climatic stations in the woodland belts, we must infer from elevations, slopes, and exposures that climatic relationships to *Artemisia* occurrences are likely.

Generally, the higher and larger mountains, and thus wettest and coolest of pinyon-juniper woodland sites in the central Great

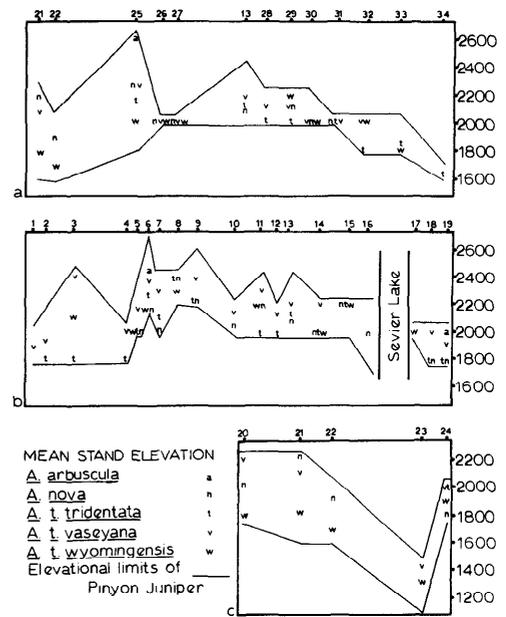


Fig. 4. Elevation distribution of major *Artemisia* taxa in pinyon-juniper woodlands of the Great Basin: (a) south-north cross section of the Great Basin; (b) west-east cross section in the central Great Basin; (c) west-east cross section in the southern Great Basin. Numbers arrayed across the top of graphs are locations shown in Figure 3. Vertical scales are elevations (m).

Basin, have *A. tridentata vaseyana*. To the north and west, *A. tridentata vaseyana* increases in dominance until at the north-western limits of the type it is the only woodland sagebrush present. *A. arbuscula* is widely scattered on cold, dry sites with shallow soils on the higher mountains all across the Great Basin. *A. tridentata tridentata* is lacking in the woodlands of the southern Great Basin. Where this taxon occurs on the northern ranges, it is on the relatively warmer, wetter sites with deeper

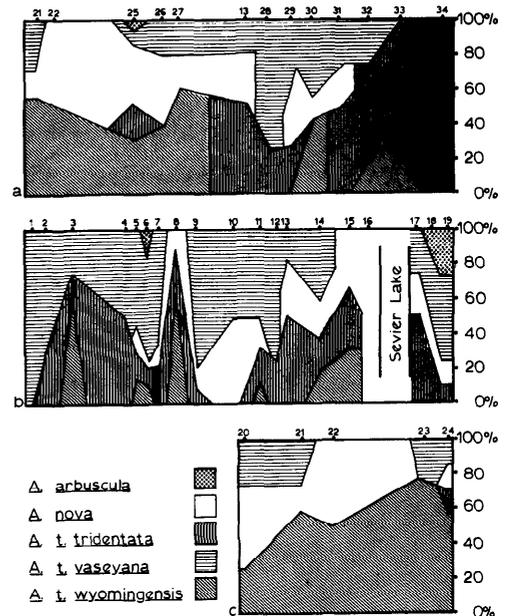


Fig. 5. Relative altitudinal arrangement of percentage of plots occupied by various sagebrush taxa in the pinyon-juniper woodlands of the Great Basin: (a) south-north cross-section of the central Great Basin; (b) west-east cross-section of the central Great Basin; (c) west-east cross-section of the Southern Great Basin. Numbers arrayed across the top of the graphs are locations shown in Figure 3. Vertical scale is percentage of stands occupied, from lowest to highest elevations possessing woodlands.

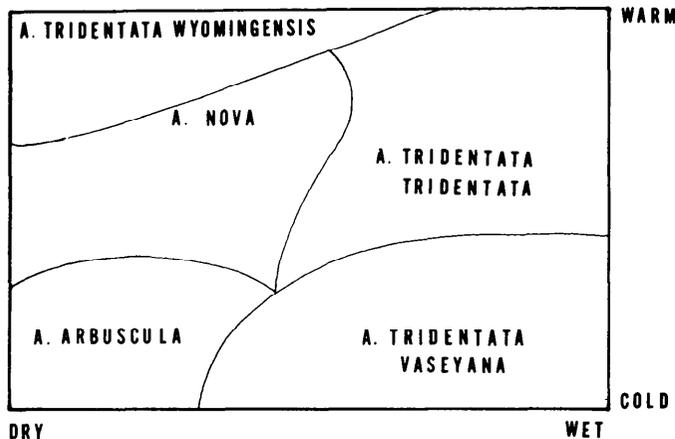


Fig. 6. Generalized occurrences of major woodland sagebrush taxa in relation to relative gradients of temperature and moisture over the Great Basin as a whole.

soils. *A. tridentata wyomingensis* is lacking in the woodlands of the northern Great Basin and high central Nevada ranges. It occurs in the driest, warmest woodland sites in the more southerly portions of the Great Basin. *A. nova* is generally absent from the more arid portions of the Great Basin in both western Nevada and western Utah, but occupies sites of intermediate favorableness elsewhere.

Ecological Indicator Values

The primary relationships of sagebrush taxa to effective moisture and temperature for the Great Basin woodland sites studied are summarized in Figure 6. *A. tridentata wyomingensis* occurs in the warmest and driest types of pinyon-juniper woodland. *A. nova* occurs in drier conditions where temperatures are intermediate. *A. arbuscula* is restricted to the coldest, driest woodland sites. *A. tridentata tridentata* occurs predominantly on the wetter, but still relatively warm woodland sites. *A. tridentata vaseyana* dominates woodland understory on the wettest, coldest sites.

The foregoing relationships characterize the coarse focus basin-wide patterns which appear to be largely responses to climate. In applying these generalizations, one must realize that environment is a complex of many interacting variables. Aspect may compensate for elevation in changing effective temperature and moisture. Slope, landform, and soils also alter the effective soil moisture levels. On particular mountain ranges and sites,

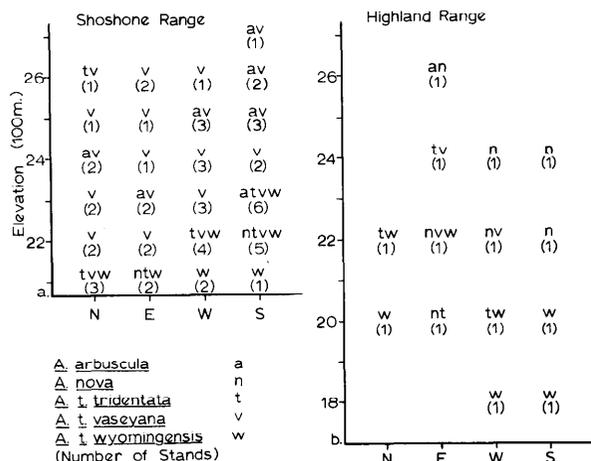


Fig. 7. Distribution of major *Artemisia* taxa in relation to elevation (m, vertical scale) on the Shoshone (No. 6, Fig. 3) and Highland (No. 25, Fig. 3) Ranges and exposure (direction, horizontal scale).

Table 3. Mean (\bar{x}) depth (cm) and standard deviation (s) of soil A horizon as related to taxa of *Artemisia* found in pinyon-juniper woodlands of Shoshone Mountains, Nevada, n=sample size.

Taxa	A. horizon depth (cm)		
	\bar{x}	s	n
<i>A. arbuscula</i>	25.6	12.2	11
<i>A. t. vaseyana</i>	32.2	17.2	42
<i>A. t. tridentata</i>	22.3	6.2	7
<i>A. t. wyomingensis</i>	19.3	5.6	9
<i>A. nova</i>	21.5	2.1	2

No differences are statistically significant.

geologic, micro-climatic, edaphic, or pyric factors definitely influence distribution of *Artemisia*. These kinds of interactions and site-to-site differences are illustrated and compared in the distribution patterns of *Artemisia* taxa found on the Shoshone Range of west-central Nevada and the Highland Range of east-central Nevada (Fig. 7). The Shoshone Mountains are typical of ranges located near the southwestern limits of pinyon-juniper woodlands. The Highland Range is located near the center of the Great Basin pinyon-juniper woodlands and borders the high central plateau region on its north and east sides and the Great Basin-Mojave Desert transition on its west and south slope. There is a 200 m elevational difference between the valley floors on the northeast and on the west.

Except on the lowest elevations and driest aspects, the sagebrush in the Shoshone Mountains is primarily *Artemisia t. vaseyana* with an occasional *A. arbuscula* (Fig. 7). *A. arbuscula* is generally on shallower soils than *A. t. vaseyana* (Table 3).

The Highland Range occurs in a warmer but climatically more complex region (West et al. 1978). Maximum precipitation occurs on the east slope. The north slope has been disturbed by mining activity. All *A. t. vaseyana* and all *A. nova*, except for one stand on the east slope, occur above 2,100 m (Fig. 7). Except for the climatically complex east slope, all *A. t. tridentata* and *A. t. wyomingensis* occur below 2,100 m (Fig. 7).

On both ranges there appear to be definite elevational and aspect controls on the distribution of sagebrush taxa. However, because of differences in the location of these ranges in the Great Basin and, as a result, differences in their general climates, the specific details of their distributions differ.

We conclude that one must understand the broader picture before precise indicator significance of each taxon can be worked out for local areas. In the absence of past climatic records, soils information and other inventory data on these ecosystems, we have to let plants tell us something of the effective environments on the wildlands they occupy. Sagebrush taxa, if identified by chromatography, appear to offer a major set of plant indicators that can be used to compare site favorableness within pinyon-juniper woodlands.

Literature Cited

- Beeson, D. W. 1974. The distribution and synecology of Great Basin pinyon-juniper. MS Thesis, Univ. of Nevada, Reno. 95 p.
- Blackburn, W. H., and P. T. Tueller. 1970. Pinyon and juniper invasion in black sagebrush communities in east-central Nevada. *Ecology* 51:841-848.
- Brunner, J. R. 1972. Observations on *Artemisia* in Nevada. *J. Range Manage.* 25:205-208.
- Hall, H. M., and F. C. Clements. 1923. The phylogenetic method in taxonomy: The North American species of *Artemisia*, *Chrysothamnus* and *Atriplex*. Carnegie Inst., Washington. Pub. No. 326. 355 p.
- Hanks, D. L., E. D. McArthur, R. Stevens, and A. P. Plummer. 1973. Chromatographic characteristics and phylogenetic relationships of *Artemisia tridentatae*. U.S. Dep. Agr., Forest Serv. Res. Pap. INT-141. 24 p.

- Holmgren, A. H., and J. L. Reveal. 1966.** Checklist of the vascular plants of the Intermountain Region. U.S. Dep. Agr., Forest Serv. Res. Pap. INT-32. 160 p.
- Houghton, J. G. 1969.** Characteristics of rainfall in the Great Basin. Desert Research Institute, Univ. Nevada System, Reno. 205 p.
- Nabi, A. A. 1978.** Variation in successional status of pinyon-juniper woodlands in the Great Basin. MS Thesis, Utah State Univ., Logan. 127 p.
- Stevens, R., and E. D. McArthur. 1974.** A simple technique for identification of some sagebrush taxa. *J. Range Manage.* 27:325-326.
- Stebbins, G. L., Jr. 1975.** Shrubs as centers of adaptive radiation and evolution. p. 120-140. *In:* H. C. Stutz (ed.) Proc. Symposium and Workshop on Wildland Shrubs. Brigham Young Univ. Press, Provo, Utah.
- Wernstedt, F. L. 1960.** Climatic fluctuations in the Great Basin 1931-1956. *J. Range Manage.* 13:173-178.
- West, N. E., R. J. Tausch, K. H. Rea, and P. T. Tueller. 1978.** Phyto-geographical variation within juniper-pinyon woodlands of the Great Basin. *In:* K. T. Harper (ed.) Intermountain biogeography: An interpretive synthesis. Great Basin Nat. Memoir (In press).
- Whittaker, R. H. 1973.** Direct gradient analyses. p. 71-74. *In:* R. H. Whittaker (ed.) Ordination and classification of communities. Vol. 5 Handbook of Vegetation Science. W. Junk, The Hague, Netherlands.
- Winward, A. H. 1969.** Taxonomic and ecological relationships of the big sagebrush complex in Idaho. PhD Diss., Univ. Idaho, Moscow. Univ. Microfilms, Ann Arbor, Mich. 80 p.