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CLASSIFICATION OF DEER HABITAT IN THE PONDEROSA PINE FOREST OF THE BLACK HILLS, SOUTH DAKOTA

John F. Thilenius

ABSTRACT

The ponderosa pine forest was classified into 13 habitat units by cluster analysis of a similarity matrix based on the vegetation, soil, and site attributes of 100 randomly located sample stands. Habitat units were defined at a minimum similarity of 60 percent. The comparative use of the habitats by deer was evaluated by analysis of variance of long-term (9 years) data on deer pellet group densities in the sample stands.

Keywords: Wildlife management, forest-wildlife relations, synecology, *Pinus ponderosa*.

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Classification of Deer Habitat in the Ponderosa Pine Forest of the Black Hills, South Dakota

by

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[1]*Central headquarters maintained at Fort Collins in cooperation with Colorado State University; research reported here was conducted at Rapid City, South Dakota, in cooperation with South Dakota School of Mines and Technology. The cooperation of South Dakota Game, Fish, and Parks Department is gratefully acknowledged. Author is presently located at Laramie in cooperation with the University of Wyoming.*

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Almost 70 percent of the Black Hills of western South Dakota and eastern Wyoming is covered by forest where *Pinus ponderosa* is the only overstory tree. In 1968, the deer herd using this forest was estimated at over 120,000 animals (Richardson and Schwarting 1969). The majority of these are white-tailed deer (*Odocoileus virginianus dacotensis),* but mule deer *(O. hemionus hemionus)* are also present.

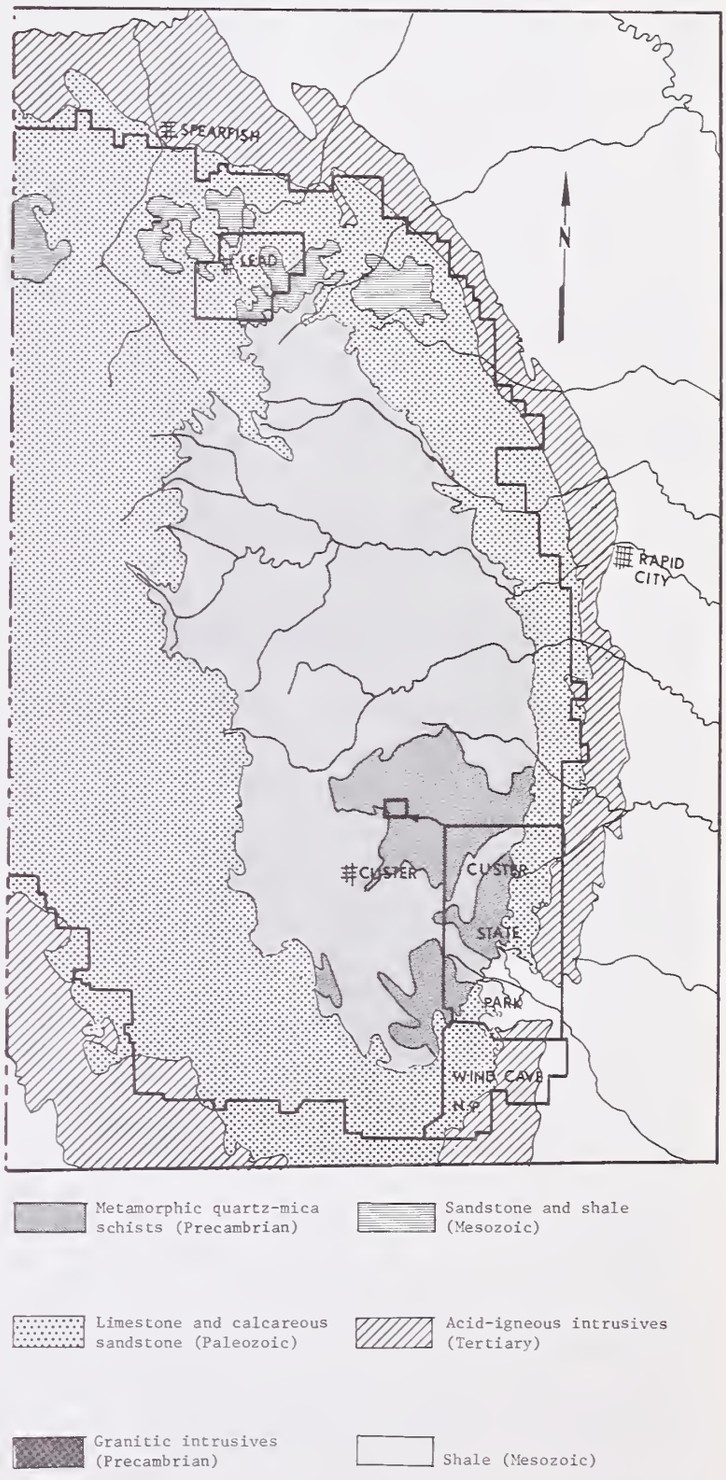
For many years, the South Dakota Game, Fish, and Parks Department has determined deer population trends in the Black Hills by annual counts of deer pellet groups in sample areas distributed throughout the Black Hills National Forest. The wide geographic distribution of these sample areas and the long-term index of deer use on them provided a unique opportunity to define and classify habitats in the ponderosa pine forest, and to evaluate habitat-deer relationships.

STUDY AREA

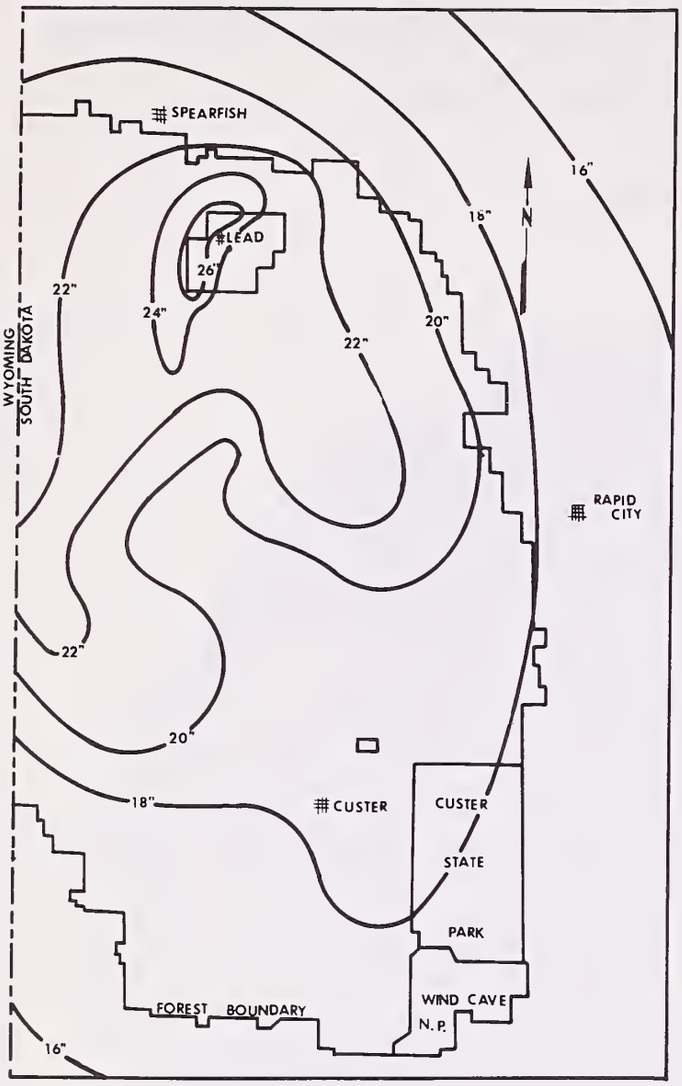
Physiography and Geology

The Black Hills are an elliptically shaped, uplifted dome, over 1.8 million acres in area. The drainage pattern is radial-dendritic, but the majority of the permanent streams flow eastward.

The geology of the Black Hills consists of a series of concentric formations (map 1). The central formation is a region of highly dissected topography composed of metamorphosed Precambrian quartz-mica schists with a general elevation between 4,000 and 5,500 feet. A large amount of surface rock is exposed. Surrounding this is a formation of Paleozoic limestone. The topography here is gently rolling, especially in the northwestern section where the limestone forms a plateau generally above 6,000 feet elevation (map 2). Several points on this plateau exceed 7,000 feet. Along the eastern edge of the Black Hills the same formation rarely exceeds 5,000 feet elevation. Steep cliffs, several hundred feet high, occur along the discontinuity between



Map 1.—Geology of the Black Hills.



Map 2.—Elevation pattern in the Black Hills.

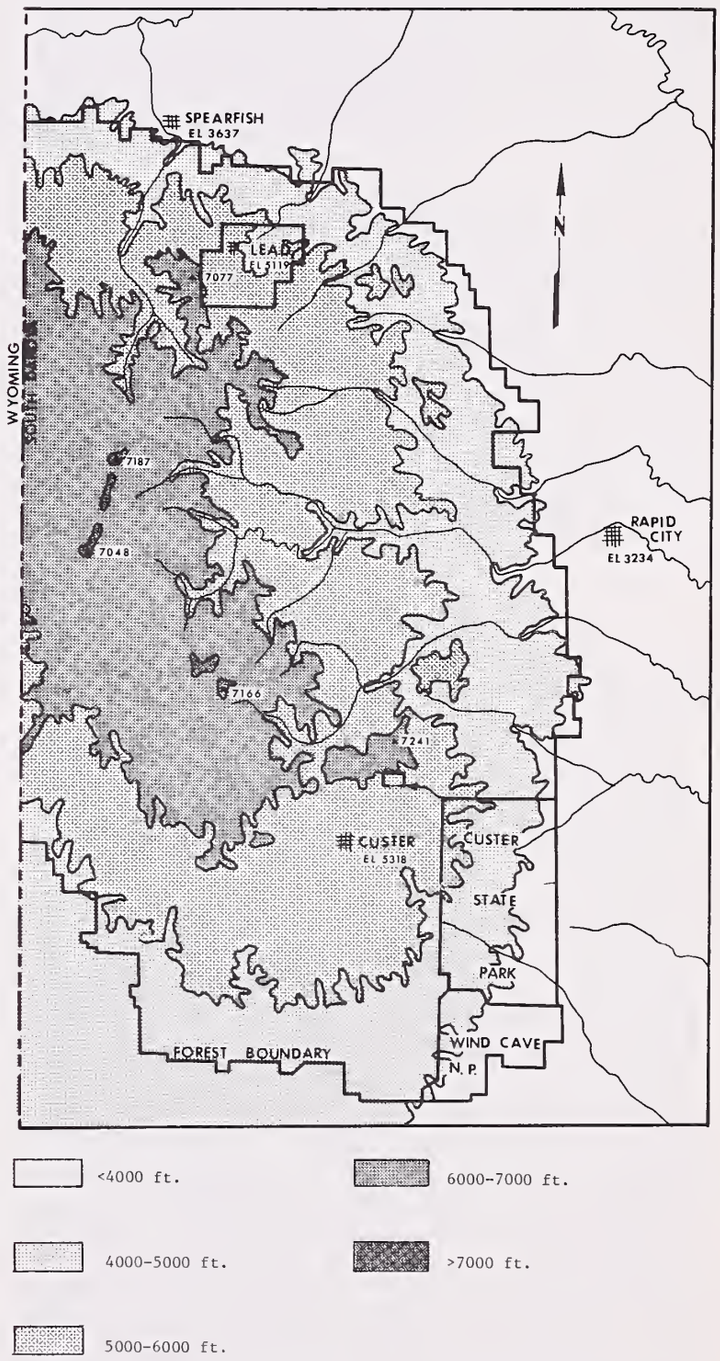
the limestone and adjacent formations, and along river canyons.

There are two major intrusions in the Black Hills. In the south-central portion is an intrusive massif of Precambrian granite weathered into vertical cliffs and rock spires. Harney Peak (7,241 feet), the highest elevation in the Black Hills, is an isolated summit here, but the general elevation is between 5,500 and 6,500 feet. Along the northern edge of the Black Hills are several intrusions of Tertiary acid-igneous rocks which form a rugged topography characterized by barren talus slopes. Terry Peak (7,071 feet) is the highest point in this region; most of the area, however, is between 5,000 and 6,500 feet elevation.

Encircling the periphery of the Black Hills is a region of complex geology. The outer portion of this region is a low, narrow hogback ridge of Mesozoic hard sandstone and shale. Between this hogback ridge and the central mass is a valley formed from reddish colored Triassic and Permian soft shale and sandstone. This "Red Valley" also almost completely encircles the central mass. Most of this region is below 4,000 feet elevation.

Climate

The precipitation pattern of the Black Hills is closely related to elevation (maps 2 and 3). Mean annual precipitation is over 26 inches at high elevations in the northern region, but



Map 3.—Precipitation patterns in the Black Hills.

less than 18 inches in the foothills and southwestern Black Hills (Orr 1959). Most precipitation comes as rain in May, June, and July, although yearly snowfall may exceed 100 inches at high elevations on the limestone plateau.

The temperature regime is typical of a continental climate. Mean annual temperatures in the ponderosa pine forest zone are from 41° F. to 48° F. with an extreme range of 112° F. to -40° F. Strong temperature inversions are common during the winter, and the temperature at 5,000 feet or higher may be several degrees above freezing while the temperature at 3,000 feet is in the subzero range.

Forest Vegetation

The extent of ponderosa pine forest in the Black Hills generally coincides with the 4,000-foot contour, the outer edge of the limestone formation, and the 18-inch isohyete. There are approximately 1.2 million acres of forest dominated solely by *Pinus ponderosa,* and the general appearance of the Black Hills is that of a monoculture of this tree. Almost the entire forest is in a disturbed condition from logging, livestock grazing, mining operations, wildfire, and fire protection.

Only four other species of arboreal conifers are endemic to the Black Hills. *Picea glauca* comprises about 4 percent of the timber volume. It is most abundant at high elevation in the northern Black Hills and in the granite area near Harney Peak. In some areas it is an overstory dominant, but more often grows codominant or subordinate to *Pinus ponderosa. Pinus contorta* var. *latifolia* occurs intermixed with *Pinus ponderosa* in one 90-acre stand in the central Black Hills. *Pinus flexilis* is present as a subordinate tree to *Pinus ponderosa* and *Picea glauca* in one isolated 6-acre stand near Harney Peak. In the southern Black Hills, *Juniperus scopulorum* may be codominant with *Pinus ponderosa* along the foothills.

Deciduous tree species are poorly represented in the ponderosa pine forest. Only three species, *Populus tremuloides, Betula papyrifera,* and *Quercus macrocarpa,* are important. *Populus tremuloides,* the most abundant, grows as a subordinate tree under the *Pinus ponderosa* canopy, along the ecotone between the forest and grassland at high elevation in the northern Black Hills, and as a dominant tree on old forest fire burns in the limestone and igneous regions. *Betula papyrifera* is much less abundant than *Populus tremuloides* and is more common on mesic sites. It usually has a multistemmed growth form. *Quercus macrocarpa* occurs both as a tree and as a shrub, along the foothills of the Black Hills.

While the number of species of overstory trees in the Black Hills is limited, the understory is rich in species. Understory shrubs typical of different flora are: *Ostrya virginiana* (Eastern deciduous forest), *Symphoricarpos occidentalis* (Great Plains grassland), *Juniperus communis* (Northern coniferous forest), *Cercocarpus montanus* (Mountain brush-type), *Arctostaphylos uva-ursi* (Western coniferous forest).

Many graminoids (grasses, sedges, and rushes) and forbs are present. The most common graminoids are: *Poa pratensis, Danthonia intermedia, Oryzopsis asperifolia, Andropogon scoparius, Agropyron griffithsi,* and *Carex* spp. Important forbs are *Achillea millefolium, Campanula rotundifolia, Galium biflorum, Antennaria neglecta,* and *Viola adunca.* The legumes *Vicia americana* and *Lathyrus ochroleucus* are also common under the *Pinus ponderosa* canopy.

LITERATURE

Although the taxonomy of Black Hills vegetation has been covered by Rydberg (1932) and McIntosh (1949), there has been very little published on the synecology of the region. Hayward (1928) gave an outline of the plant communities based on the theories of F. E. Clements (1936). All of the ponderosa pine forest was classified in a single category, "western yellow pine association: Rocky Mountain montane forest climax." McIntosh (1949) repeats Hayward's scheme in the plant ecology section of his paper.

In the only other paper dealing directly with synecology in the Black Hills, Leedy and Youngberg [2] described three *Pinus ponderosa* communities and one *Picea glauca* community. Although their work was based entirely on reconnaissance information, they did provide morphological descriptions of the soils underlying these communities.

Radeke and Westin (1963) described three classes of gray wooded soils occurring as the substrate of ponderosa pine forest. These soils have developed from a variety of parent materials. As yet, they have not been correlated or

[2] *Leedy, J.D., and C. T. Youngberg. Coniferous forest communities in the Black Hills, South Dakota. (Unpublished report, Wheaton Coll. Sci. Sta., 8 p., n.d.)*

named. A report from the U.S. Soil Conservation Service (1959) gave detailed information on the field characteristics and chemical-physical properties of the profiles described by Radeke and Westin.

The only study directly concerned with the types of deer habitat in the Black Hills was done by R. R. Hill (1946). He confined his work to the northern section and described seven types of habitat in very general terms. Important browse species occurring in the various types were listed and rated for preference, but no indication of species dominance or abundance was provided, nor was the importance of different types of deer habitat discussed. Hill's classification of Black Hills deer habitat is:

1. Mature or dense ponderosa pine *(Pinus ponderosa).*
2. Open ponderosa pine.
3. Northern white spruce *(Picea glauca).*
4. Birch-Aspen *(Betula papyrifera-Populus tremuloides).*
5. Oak *(Quercus macrocarpa).*
6. Recent burns.
7. Open parks.

The details on the establishment of the pellet group density transects and the sampling procedures used by the South Dakota Game, Fish, and Parks Department are presented in a Pittman-Robertson Job Completion Report (Hart 1957). In 1956, 53 transects (one in each township in the Black Hills National Forest), each 2,000 feet long and 10 feet wide were established. Since initial establishment the length has been decreased to 1,000 feet, the width to 6 feet, and the number of transects doubled. Six transects have been abandoned because they have been heavily grazed by sheep or logged.

At the time of establishment, data were collected on slope aspect, slope angle, overstory type (pine, deciduous, open, pine-deciduous, pine-deciduous-spruce, doghair pine), understory type (grass, browse, forbs, litter, or any combination of these four), and percent ground visibility (poor, 0-24 percent; fair, 25-49 percent; good, 50-74 percent; excellent, 75-100 percent) of each 100-foot segment. These data have been misplaced and were not available.

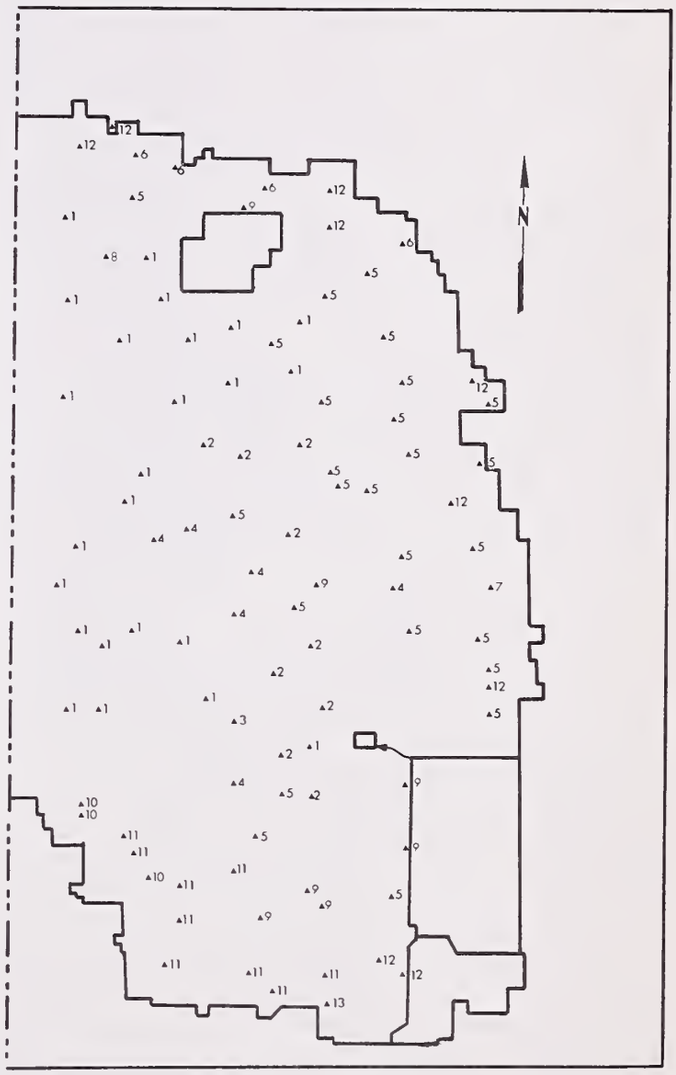
A summary of this preliminary data in the report indicated (1) no relationship between pellet group density and overstory type of ground visibility; (2) a weak relationship between pellet ground density and understory type, with the browse type having the highest use; (3) a preference for southerly slopes with low angles (0-10 percent). These conclusions were based on only a single year's sample and some of the categories used, for example, browse type, are vague.

Other literature pertinent to methods and techniques are given in the appropriate sections.

METHODS

Field Sampling

The ponderosa pine forest was sampled at 100 locations within the Black Hills National Forest (map 4). All sample sites were located on transects used by the South Dakota Department of Game, Fish, and Parks to determine the size of the Black Hills deer herd by annual counts of deer pellet group densities. The transects, established several years prior to the start of this study by Department personnel,



Map 4.—Location of sample stands in the Black Hills National Forest.

were located in a restricted random manner, two in each survey township within the boundaries of the Black Hills National Forest.

Each treatment is a belt of one hundred 6- x 10-foot plots (total length 1,000 feet). Vegetation, soil, and site vary considerably within these long belt transects. To minimize this variation, a homogeneous area representative of the most predominant habitat crossed by the transect was selected in the field as the location for the samples used in this study.

A 60- x 100-foot macroplot was established in the selected location by measuring a randomly selected distance (to the nearest 10 feet) from the starting point of the transect. This distance was restricted so the macroplot was within the selected area. Each macroplot represents a relatively homogeneous, independent, random sample of the vegetation, soil, and site attributes of the ponderosa pine forest on which there is a long-term index of the intensity of deer use.

Three randomly located plots 10 x 100 feet were established within the macroplot to subsample the floristic attributes. On each of these, the frequency of graminoids, forbs, low shrubs (< 1.5 feet tall), and tree seedlings (< 0.5 foot tall) was recorded on one hundred 1-foot-square quadrats arranged in a belt transect along the centerline of the plot. The frequency of tall shrubs (> 1.5 feet tall) was recorded on a belt transect of twenty-five 4- x 4-foot quadrats coincident with the belt transect of 1-foot-square plots. Trees were sampled by dividing the 10- x 100-foot plot into ten 10- x 10-foot quadrats and recording the frequency by 4-inch d.b.h. (stem diameter at 4.5 feet above the ground surface) classes. Plot sizes were selected to give average frequencies between 20 and 80 percent for the most frequent taxa (Hyder et al. 1965). Frequency data from all three plots were combined for analysis.

A soil pit was excavated near the center of the macroplot and the soil described to the standards of the U.S. Soil Survey (U.S. Bur. Plant Indus., Soils and Agr. Eng. 1951). The elevation, slope aspect, slope angle, position on the slope, relief features, and percentage of ground surface covered by rock, litter, and bare ground were recorded for each macroplot. The presence of natural and man-caused influences such as fire, wildlife, logging, grazing, mining, and so forth, was also recorded. Geological formations were determined by reference to Darton's (1951) geological map of the Black Hills and from the material excavated from the subsurface horizons (C and R) of the soil. The precipitation regime was established by reference to Orr (1959).

Analytical Methods

The synecological units of the ponderosa pine forest were determined by grouping the sample plots into sets whose members were similar in vegetation, soil, and site attributes. Table 1 gives the analytical attributes utilized, their units of measurement, and method of encoding. To determine similarity, a numerical cluster analysis procedure was used. The essentials of this program are as follows:

1. An rxc table is prepared with the attribute data as the rows (r) and the sample plots as the columns (c).
2. The diverse attribute data are standardized by setting the maximum attribute value for each row equal to 100 and scaling all other values accordingly: that is, all data are transformed to a relative proportion of the maximum value, and thus become additive.
3. An initial matrix of similarity is computed between all possible combinations of sample plots. Sorensen's (1948) coefficient of similarity, $K = (2c/a+b)\ 100$ is used as the index of similarity. In this formula, "a" is the sum of all standardized attribute data for one sample plot, "b" is this sum for another sample plot, and "c" is the sum of the lower value for each attribute common to the two sample plots. The range of K is 0 to 100, with 100 equal to complete similarity. Bray and Curtis (1957) sampled the same area repeatedly, and found the average value of K to be 82. They concluded that because of sampling error, maximum K is approximately 80 to 85 instead of 100.
4. The initial matrix of similarity is subjected to cluster analysis by the weighted pair-group method (Sokal and Sneath 1963) as follows:

   a. The two sample plots in the matrix having the highest similarity are selected and combined into a single unit or cluster.
   b. A new matrix of similarity is computed between this cluster and the remaining unclustered sample plots. A simple average, $K = K_{ij} + K_{hj}/2$, replaces the two K values of the clustered sample plots. K_{ij} equals the index of similarity between one member (i) of the established

Table 1.--Attribute coding for computer analysis

A. Vegetation
1. Frequency of overstory trees (by species and d.b.h. class) in percent.
2. Frequency of large shrubs (by species) in percent.
3. Frequency of small shrubs, grasses, sedges, and forbs (by species) in percent.

B. Soil
1. Number of mineral horizons present.
2. Depth of solum in inches.
3. Thickness of the O1 horizon (litter) in inches.
4. Thickness of the O2 horizon (humus) in inches.
5. Thickness of the A1 horizon in inches.
6. Hue of the A1 horizon, scaled to give the highest value to red and the lowest to yellow.
   a. 10R = 64
   b. 2.5YR = 32
   c. 5YR = 16
   d. 7.5 YR = 8
   e. 10YR = 4
   f. 2.5Y = 2
   g. 5Y = 1
7. pH of the A1 horizon to the nearest 0.1 pH unit (electrometrically determined).
8. Texture of the A1 horizon specified by a particle size "ratio-of-10" derived by rounding off the average percentage of sand (2.0mm - 0.05mm), silt (0.05mm - 0.002mm), and clay (-0.002mm) in the 12 textural classes given in the Soil Survey Manual (1951). The sum of the numerals equals 10 in all classes.
   a. Sand = 910
   b. Loamy sand = 811
   c. Sandy clay loam = 712
   d. Sandy loam = 541
   e. Sandy clay = 514
   f. Loam = 442
   g. Clay loam = 334
   h. Silt = 181
   i. Silt loam = 172
   j. Silty clay loam = 163
   k. Silty clay = 154
   l. Clay = 118
9. Percentage of coarse fragments (+2mm) in the A1 horizon.
10. Effervescence with HCl of the A1 horizon.
    a. Violent 8
    b. Strong 4
    c. Slight 2
11. Thickness of the A2 horizon (eluviation zone) in inches.
12. Hue of the A2 horizon (see Item 6).
13. pH of the A2 horizon (see Item 7).
14. Texture of the A2 horizon (see Item 8).
15. Percentage of coarse fragments in the A2 horizon.
16. Effervescence with HCl of the A2 horizon (see Item 10).
17. Thickness of the B2 horizon (illuviation zone) in inches.
18. Hue of the B2 horizon (see Item 6).
19. pH of the B2 horizon (see Item 7).
20. Texture of the B2 horizon (see Item 8).
21. Percentage of coarse fragments in the B2 horizon.
22. Effervescence of the B2 horizon (see Item 10).
23. Hue of the C horizon (see Item 6).
24. pH of the C horizon (see Item 7).
25. Texture of the C horizon (see Item 8).
26. Percentage of coarse fragments of the C horizon.
27. Effervescence of the C horizon (see Item 10).

C. Site
1. Slope aspect in degrees from true north.
2. Slope angle in percent.
3. Elevation in feet.
4. Position in percentage of slope below the nearest ridge.
5. Macrorelief of general area.
   a. Level = 0
   b. Undulating = 5
   c. Rolling = 15
   d. Hilly = 30
   e. Steep = 50
6. Microrelief in immediate vicinity of plot.
   a. Concave = 1
   b. Flat = 2
   c. Convex = 3
7. Percentage of ground covered by rocks.
8. Percentage of ground covered by litter.
9. Percentage of bare ground.

cluster (i+h) and an unclustered sample plot (j), and K_{hj} is equal to this index for the other member of the established cluster.

c. Steps "a" and "b" above are repeated until all sample plots have been clustered.

The results of cluster analysis are presented in a dendrogram (fig. 1). The vertical axis of the dendrogram merely separates the sample plots and has no scale. The horizontal axis is scaled in units of K (percentage similarity). Junction points between stems along the horizontal axis indicate the sample plots to the left of the junctions are alike at the K value shown on the horizontal axis scale.

The number of groups of sample plots to be designated is determined by drawing a line across the dendrogram parallel to the vertical axis at a designated level of K. The number of stems cut by this line indicates the number of units present. In this paper these units are called "Habitat Units" (hereafter abbreviated "HU").

The level of K at which HU are designated is variable and depends primarily on the use to which the classification is to be put and the ecosystem under consideration (West 1966). Mathematical or statistical tests to determine significant gaps in continuity are not yet available, and the usual statistical tests of significance are not applicable (Sokal and Sneath 1963). Whatever level of K is selected, it must be applied uniformly across the whole dendrogram; in other words, it is not permissible to designate one HU at K = 60 and another at K =70 (Sneath 1962).

RESULTS

The similarity relationships of the 100 stands sampled are shown in figure 1. This dendrogram is based on 334 attributes of vegetation, soil, and site, and is arranged so the stands occurring at high elevation in the central and northern Black Hills are uppermost.

Habitat Units have been designated at two levels of similarity. These are $K > 54$ and $K > 60$. At $K > 54$ (54 percent minimum internal similarity in vegetation, soil, and site attributes) three HU are present.

HU-A (40 stands) is found in the high-elevation, moist region of the northwestern and western Black Hills. The ponderosa pine forest understory here has well-developed shrub and herb strata composed of mesophytic taxa, many of which are present at high frequency.

HU-B (31 stands) occurs at intermediate to low elevations in the northeastern and central

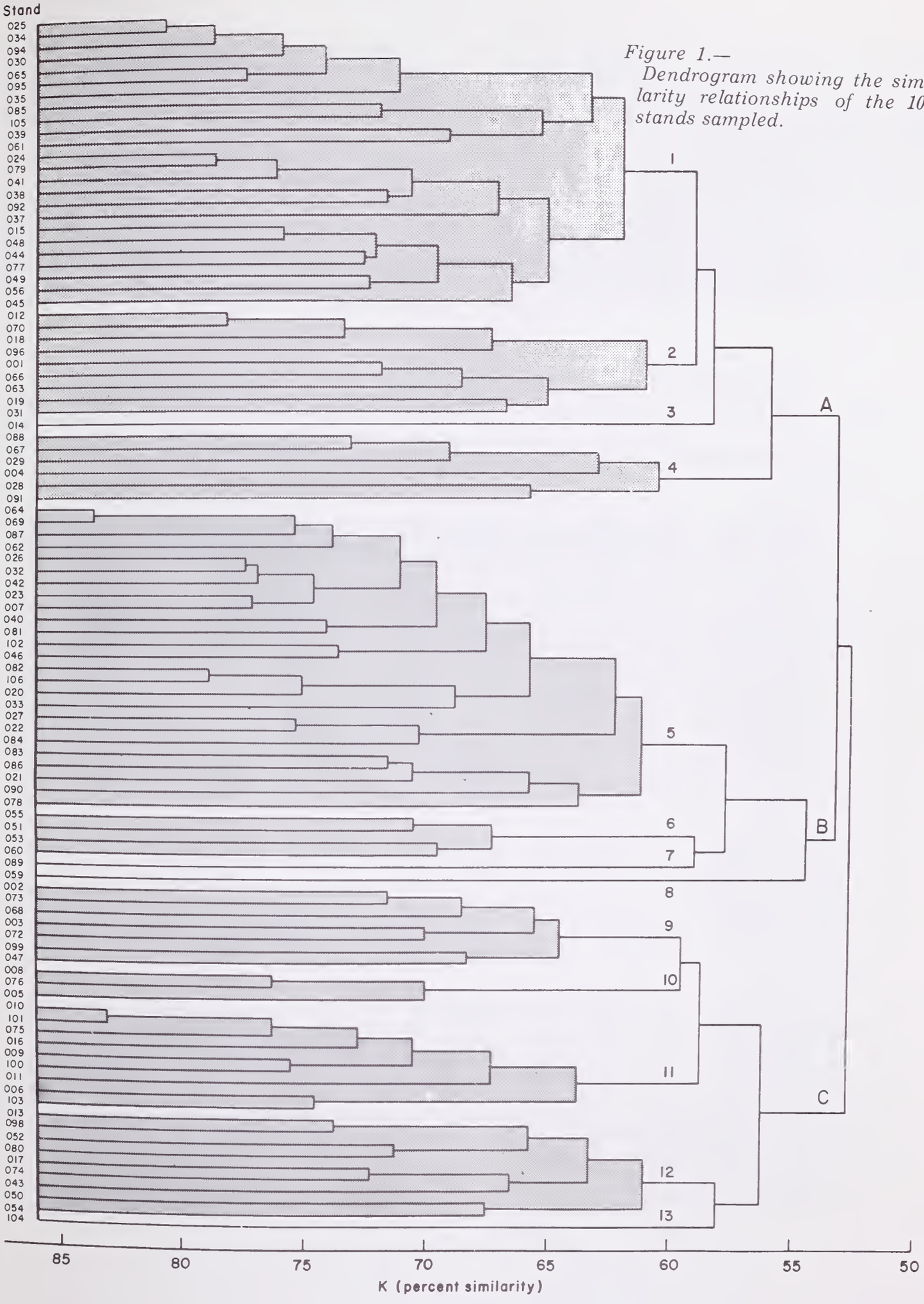


Figure 1.—Dendrogram showing the similarity relationships of the 100 stands sampled.

part of the Black Hills. Shrubs are still the most important taxa in the understory, but the more mesophytic taxa are much less frequent and a number of xerophytic taxa with prairie affinities are present.

HU-C (29 stands) is present along the northern foothills and in the relatively low-elevation region of the southern Black Hills. Graminoids are the most frequent taxa in the forest understory. Many forbs with prairie affinities are present, and shrub taxa tend to be those adapted to xeric environments.

While the HU designated at K>54 can be related in a general manner to the gross ecological and geographic features of the Black Hills, they are highly variable in taxa composition and other attributes. Since HU can be designated at any level of similarity, the internal homogeneity of HU is increased by raising the value of K. The rule followed is to select a level of similarity which maximizes the number of HU containing three or more sample stands. In HU with several stands, the range of within-HU attribute variability

Table 2.--Percent constancy (C), average percent frequency (F), and maximum percent frequency (M) of major taxa[1] in the habitat units (HU) defined at K≥60, with number of stands (n)

Taxa[2]	HU-1 (n=24)			HU-2 (n=9)			HU-3 (n=1)			HU-4 (n=6)			HU-5 (n=25)		
	C	F	M	C	F	M	C	F	M	C	F	M	C	F	M
	Percent														
OVERSTORY STRATUM															
Pinus ponderosa															
<4 inches d.b.h.	92	30	87	100	55	87	--	10	--	67	14	53	100	62	100
4-8 inches d.b.h.	88	20	50	100	22	73	--	76	--	67	8	17	88	30	90
8-12 inches d.b.h.	83	11	30	67	5	13	--	10	--	67	10	43	64	8	37
>12 inches d.b.h.	75	10	27	33	3	10	--	--	--	17	1	3	32	2	13
Picea glauca															
<4 inches d.b.h.	8	6	73	--	--	--	--	--	--	--	--	--	--	--	--
4-8 inches d.b.h.	21	4	53	--	--	--	--	--	--	--	--	--	--	--	--
Populus tremuloides															
<4 inches d.b.h.	54	10	37	44	14	67	--	--	--	17	1	3	20	5	47
4-8 inches d.b.h.	42	4	53	22	1	7	--	--	--	--	--	--	8	-1	3
Betula papyrifera															
<4 inches d.b.h.	--	--	--	22	2	10	--	--	--	--	--	--	12	1	7
4-8 inches d.b.h.	--	--	--	11	-1	3	--	--	--	--	--	--	--	--	--
Quercus macrocarpa															
<4 inches d.b.h.	--	--	--	--	--	--	--	--	--	--	--	--	12	2	7
4-8 inches d.b.h.	--	--	--	--	--	--	--	--	--	--	--	--	12	1	10
8-12 inches d.b.h.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
>12 inches d.b.h.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Juniperus scopulorum															
<4 inches d.b.h.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TALL SHRUB STRATUM															
Juniperus communis[3]	83	27	95	22	-1	3	--	56	--	50	4	12	56	6	36
Shepherdia canadensis[3]	58	6	56	67	14	47	--	66	--	--	--	--	56	6	52
Potentilla fruticosa	13	-1	4	--	--	--	--	85	--	--	--	--	4	-1	1
Symphoricarpos occidentalis	--	--	--	22	2	15	--	--	--	100	42	84	--	--	--
Prunus virginiana[4]	46	8	40	44	5	24	--	--	--	17	-1	1	60	8	72
Ostrya virginiana	--	--	--	--	--	--	--	--	--	--	--	--	8	-1	1
Quercus macrocarpa	--	--	--	--	--	--	--	--	--	--	--	--	24	1	17
Corylus cornuta	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cercocarpus montanus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rhus trilobata	--	--	--	--	--	--	--	--	--	--	--	--	12	-1	3
LOW SHRUB STRATUM															
Symphoricarpos albus	100	44	90	100	46	69	--	60	--	50	22	51	100	29	82
Rosa fendleri	96	20	49	100	23	59	--	22	--	100	20	39	80	13	67
Amelanchier alnifolia[5]	83	14	50	100	10	23	--	4	--	67	2	7	84	12	44
Spiraea lucida	63	18	66	78	16	49	--	--	--	33	1	4	68	17	65
Ribes inebrians	8	1	23	22	-1	3	--	--	--	67	-1	1	20	-1	11
Amorpha canescens	--	--	--	--	--	--	--	--	--	--	--	--	28	6	85
Yucca glauca	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

[1] All overstory species plus understory taxa with at least 67 percent constancy in a multistand HU or 20 percent frequency in a single-stand HU.

[2] Indicator taxa for each HU are underlined.

[3] Growing as a low shrub in HU-5.

[4] Growing as a low shrub in HU-12.

[5] Growing as a tall shrub in HU-2.

can be determined, and constancy[3] values for attributes can be computed. For the ponderosa pine forest a level of K > 60 best fits this rule.

[3] *Constancy is a relative expression of the presence and absence of a species in different stands of a community type, based on equal area samples. Frequency is a statistical expression of the representation (presence or absence) of a species in a series of subsamples within a given stand (Cain and Castro 1959).*

At K>60, 13 HU can be defined (fig. 1). The following section contains brief descriptions of each of the HU. It proceeds from the most mesic to the most xeric—from top to bottom on the dendrogram (fig. 1). The HU are designated serially from 1 to 13 and by a multinomial formed from the scientific names of indicator taxa in the overstory, tall-shrub, low-shrub, and herb strata. Table 2 gives the percent constancy and average and maximum percent frequencies for the major taxa in each HU.

HU-6 (n=4)			HU-7 (n=1)			HU-8 (n=1)			HU-9 (n=7)			HU-10 (n=3)			HU-11 (n=9)			HU-12 (n=9)			HU-13 (n=1)		
C	F	M	C	F	M	C	F	M	C	F	M	C	F	M	C	F	M	C	F	M	C	F	M
Percent																							
100	22	43	--	10	--	--	44	--	100	17	47	100	9	20	100	29	63	89	18	43	--	-1	--
100	17	27	--	43	--	--	7	--	100	17	37	67	8	17	89	17	27	78	7	23	--	--	--
75	13	27	--	7	--	--	13	--	57	10	37	33	2	7	89	13	23	33	2	10	--	--	--
50	8	20	--	--	--	--	--	--	29	3	13	67	2	3	56	4	13	33	2	13	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	1	10	--	--	--
--	--	--	--	--	--	--	7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
100	53	90	--	23	--	--	--	--	--	--	--	--	--	--	--	--	--	56	8	20	--	--	--
50	3	7	--	7	--	--	--	--	--	--	--	--	--	--	--	--	--	11	6	3	--	--	--
--	--	--	--	10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	100	13	20	22	4	27	11	-1	1	--	--	--
50	2	9	--	--	--	--	8	--	--	--	--	33	2	7	--	--	--	22	4	29	--	--	--
--	--	--	--	--	--	--	57	--	14	1	7	--	--	--	--	--	--	11	-1	3	--	--	--
--	--	--	--	--	--	--	8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
25	2	8	--	1	--	--	--	--	43	13	76	--	--	--	--	--	--	33	22	100	--	--	--
100	66	83	--	54	--	--	77	--	28	8	43	33	8	24	--	--	--	78	29	88	--	--	--
75	5	20	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	-1	1	--	--	--
100	42	79	--	13	--	--	--	--	--	--	--	--	--	--	--	--	--	44	7	35	--	--	--
25	3	11	--	--	--	--	31	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	100	85	87	22	14	75	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	100	10	20	44	2	8	11	-1	1	--	--	--
100	56	81	--	69	--	--	36	--	57	25	84	100	27	57	67	21	60	56	13	63	--	--	--
75	2	5	--	--	--	--	25	--	57	19	56	100	2	2	78	4	20	89	3	7	--	--	--
100	37	69	--	2	--	--	87	--	43	4	16	33	1	3	33	2	13	56	13	46	--	--	--
100	25	36	--	13	--	--	36	--	14	-1	2	--	--	--	--	--	--	22	2	12	--	--	--
--	--	--	--	--	--	--	8	--	29	1	7	67	3	7	22	3	21	--	--	--	--	--	--
50	15	39	--	--	--	--	--	--	--	--	--	--	--	--	11	-1	-1	67	6	11	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	67	-1	1	11	-1	-1	33	7	41	--	--	--

Continued--

Table 2.--Percent constancy (C), average percent frequency (F), and maximum percent frequency (M) of major taxa[1] in the habitat units (HU) defined at K≥60, with number of stands (n)--Continued

Taxa[2]	HU-1 (n=24)			HU-2 (n=9)			HU-3 (n=1)			HU-4 (n=6)			HU-5 (n=25)		
	C	F	M	C	F	M	C	F	M	C	F	M	C	F	M
	Percent														
HERB STRATUM															
Shrubs															
Berberis repens	96	42	98	--	--	--	--	--	--	--	--	--	--	--	--
Arctostaphylos uva-ursi	92	47	91	100	56	91	--	--	--	17	8	48	88	39	87
Pinus ponderosa (seedlings)	71	4	56	100	4	10	--	--	--	83	1	3	100	9	30
Toxicodendron radicans	--	--	--	--	--	--	--	--	--	--	--	--	20	3	34
Artemisia frigida	--	--	--	22	6	48	--	--	--	33	3	17	8	-1	4
Graminoids															
Oryzopsis asperifolia	83	27	75	78	5	13	--	--	--	50	7	41	60	13	52
Danthonia intermedia	83	19	85	78	40	80	--	--	--	67	18	50	92	14	71
Poa pratensis	71	18	87	56	6	33	--	2	--	100	74	98	52	4	44
Carex concinna	71	7	29	67	7	25	--	--	--	--	--	--	80	15	83
Agropyron griffithsi	50	4	24	78	16	50	--	--	--	--	--	--	40	3	22
Carex foenea	63	10	67	67	24	70	--	--	--	17	-1	1	24	2	22
Bromus inermis	17	2	20	22	2	21	--	21	--	17	6	36	8	1	9
Carex heliophila	29	4	58	56	5	21	--	--	--	67	23	62	40	7	44
Stipa viridula	38	2	16	11	1	7	--	--	--	67	5	10	8	-1	6
Schizachne purpurascens	8	-1	4	22	1	8	--	--	--	--	--	--	4	-1	1
Koeleria cristata	17	-1	4	56	6	16	--	--	--	--	--	--	36	1	14
Andropogon scoparius	--	--	--	44	1	7	--	--	--	33	-1	2	44	7	56
Bouteloua curtipendula	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Agropyron smithii	4	1	16	--	--	--	--	--	--	33	4	13	8	1	13
Bouteloua gracilis	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Forbs															
Achillea millefolium	100	25	52	100	18	27	--	8	--	100	37	55	88	9	37
Fragaria vesca	100	26	57	89	16	33	--	34	--	100	12	29	68	6	36
Galium biflorum	100	22	58	89	6	13	--	20	--	67	20	52	64	3	23
Viola adunca	100	8	23	67	9	34	--	4	--	67	4	8	68	2	7
Vicia americana	96	10	29	22	1	7	--	--	--	67	8	31	36	2	14
Lathyrus ochroleucus	88	22	65	67	5	14	--	--	--	83	5	14	44	7	31
Campanula rotundifolia	88	3	13	100	6	13	--	--	--	67	4	9	76	3	12
Zizia aptera	79	6	17	44	2	9	--	-1	--	50	1	3	28	-1	7
Antennaria neglecta	79	4	18	100	11	21	--	--	--	100	10	16	84	5	30
Thermopsis rhombifolia	--	--	--	44	18	74	--	--	--	--	--	--	--	--	--
Erigeron subtrinervis	75	6	34	44	5	22	--	17	--	50	11	39	32	3	17
Lupinus argenteus	71	7	29	--	--	--	--	--	--	--	--	--	--	--	--
Monarda fistulosa	71	6	33	56	8	50	--	--	--	67	7	16	48	2	18
Aster laevis	67	6	28	56	8	25	--	--	--	--	--	--	44	2	20
Apocynum androsaemifolium	54	2	11	100	11	26	--	--	--	33	-1	1	84	6	34
Solidago occidentalis	29	1	10	78	8	22	--	--	--	--	--	--	68	4	40
Anemone patens	42	2	23	67	3	9	--	11	--	67	1	3	56	2	14
Astragalus alpinus	50	6	39	44	2	9	--	21	--	50	11	49	44	3	36
Clematis hirsutissima	13	3	52	--	--	--	--	21	--	--	--	--	4	-1	22
Solidago nemoralis	17	2	28	--	--	--	--	--	--	67	10	27	24	-1	5
Potentilla hippiana	8	-1	3	--	--	--	--	--	--	67	5	29	4	-1	3
Iris missouriensis	13	1	13	--	--	--	--	--	--	67	3	16	--	--	--
Antennaria rosea	54	1	8	56	4	22	--	--	--	67	1	5	52	1	7
Smilacina stellata	33	2	30	33	1	10	--	1	--	50	2	22	60	4	23
Maianthemum canadense	8	-1	3	--	--	--	--	--	--	--	--	--	--	--	--
Sanicula marilandica	13	-1	8	--	--	--	--	--	--	--	--	--	4	-1	1
Lupinus parviflorus	--	--	--	--	--	--	--	--	--	--	--	--	12	-1	2
Artemisia ludoviciana	38	5	24	--	--	--	--	--	--	50	15	46	12	-1	13
Phlox hoodii	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Zygadenus elegans	29	1	17	--	--	--	--	--	--	--	--	--	44	-1	5
Hymenoxys acaulis	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Musineon divaricatum	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Grindelia squarrosa	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Leucocrinum montanum	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Geum triflorum	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Phlox alyssiofolia	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Polygala alba	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Echinacea angustifolia	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chrysopsis villosa	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

[1] All overstory species plus understory taxa with at least 67 percent constancy in a multistand HU or 20 percent frequency in a single-stand HU.

[2] Indicator taxa for each HU are underlined.

HU-6 (n=4)			HU-7 (n=1)			HU-8 (n=1)			HU-9 (n=7)			HU-10 (n=3)			HU-11 (n=9)			HU-12 (n=9)			HU-13 (n=1)		
C	F	M	C	F	M	C	F	M	C	F	M	C	F	M	C	F	M	C	F	M	C	F	M
											Percent												
100	73	82	--	--	--	--	34	--	--	--	--	--	--	--	--	--	--	11	1	7	--	--	--
50	1	4	--	--	--	--	24	--	43	14	37	33	-1	-1	33	1	6	11	2	19	--	--	--
75	12	29	--	9	--	--	-1	--	86	5	19	33	-1	1	78	9	25	78	5	19	--	-1	--
100	4	5	--	--	--	--	2	--	--	--	--	--	--	--	11	-1	-1	44	1	3	--	--	--
--	--	--	--	--	--	--	--	--	43	5	18	100	9	17	22	6	39	11	2	17	--	27	--
75	34	70	--	--	--	--	--	--	14	1	7	--	--	--	--	--	--	22	4	37	--	--	--
100	26	60	--	--	--	--	6	--	100	40	59	--	--	--	11	5	41	33	2	11	--	--	--
100	20	67	--	18	--	--	52	--	100	59	99	67	1	3	33	5	23	56	40	98	--	--	--
25	1	5	--	--	--	--	-1	--	43	7	29	33	2	7	33	1	7	11	-1	3	--	--	--
25	-1	1	--	--	--	--	14	--	71	8	39	100	24	46	--	--	--	44	2	11	--	--	--
75	16	34	--	75	--	--	1	--	57	11	41	67	11	20	67	17	72	33	4	25	--	--	--
--	--	--	--	--	--	--	--	--	14	-1	3	--	--	--	--	--	--	11	-1	5	--	--	--
50	12	37	--	--	--	--	--	--	43	1	4	--	--	--	22	-1	2	22	2	10	--	2	--
--	--	--	--	--	--	--	--	--	--	--	--	33	-1	-1	67	13	38	56	6	29	--	--	--
--	--	--	--	62	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	100	16	26	100	14	20	89	4	10	44	4	18	--	12	--
25	2	6	--	--	--	--	1	--	14	4	28	100	38	57	100	37	82	78	36	85	--	79	--
--	--	--	--	--	--	--	--	--	14	2	10	100	19	36	56	2	7	11	2	16	--	24	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	56	26	84	22	1	6	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	33	1	4	--	--	--	22	2	15	--	68	--
100	10	23	--	-1	--	--	15	--	100	12	15	100	3	4	78	5	13	44	5	34	--	--	--
75	2	4	--	--	--	--	--	--	29	1	6	33	-1	-1	44	2	6	--	--	--	--	--	--
50	4	10	--	21	--	--	55	--	57	7	28	67	4	10	44	3	16	44	6	26	--	--	--
100	5	10	--	--	--	--	33	--	57	1	2	33	-1	-1	44	2	8	44	-1	2	--	1	--
100	5	7	--	3	--	--	34	--	29	1	5	33	2	5	67	7	16	11	-1	6	--	--	--
100	11	31	--	6	--	--	3	--	14	-1	2	--	--	--	--	--	--	44	2	12	--	--	--
50	1	3	--	-1	--	--	5	--	71	4	11	67	-1	-1	67	2	4	56	1	7	--	3	--
25	-1	1	--	--	--	--	1	--	14	-1	2	--	--	--	44	2	12	--	--	--	--	--	--
75	1	2	--	-1	--	--	12	--	57	2	10	33	-1	-1	22	1	10	33	-1	3	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
75	2	4	--	--	--	--	5	--	29	5	37	--	--	--	--	--	--	22	-1	1	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
100	12	33	--	--	--	--	48	--	71	1	5	--	--	--	11	-1	-1	56	2	7	--	--	--
25	-1	1	--	--	--	--	12	--	29	4	19	67	-1	1	44	1	7	11	-1	5	--	--	--
50	2	5	--	2	--	--	15	--	57	4	21	--	--	--	11	-1	1	33	4	24	--	--	--
--	--	--	--	-1	--	--	8	--	86	2	7	100	7	8	67	10	32	44	-1	3	--	--	--
--	--	--	--	--	--	--	--	--	14	2	10	33	-1	-1	11	-1	4	--	--	--	--	--	--
--	--	--	--	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	71	5	14	--	--	--	11	1	8	33	1	5	--	--	--
--	--	--	--	--	--	--	--	--	14	-1	1	--	--	--	--	--	--	22	-1	3	--	--	--
--	--	--	--	-1	--	--	--	--	29	5	3	33	-1	1	--	--	--	--	--	--	--	--	--
25	1	4	--	--	--	--	--	--	71	4	20	67	3	7	78	2	5	11	-1	-1	--	--	--
75	3	6	--	44	--	--	20	--	43	5	30	33	2	7	--	--	--	33	-1	9	--	--	--
75	4	11	--	--	--	--	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
75	2	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
25	-1	2	--	--	--	--	--	--	29	3	11	33	-1	1	56	2	13	11	2	17	--	--	--
--	--	--	--	--	--	--	3	--	43	3	10	100	18	27	56	2	22	78	11	44	--	--	--
--	---	--	--	--	--	--	--	--	--	--	--	67	7	14	11	-1	1	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	29	-1	2	67	5	13	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	100	2	3	33	2	8	22	3	25	--	16	--
--	--	--	--	--	--	--	--	--	--	--	--	67	4	7	33	-1	2	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	67	1	1	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	67	1	1	78	2	5	--	--	--	---	--	--
--	--	--	--	--	--	--	--	--	--	--	--	67	-1	1	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	14	1	8	--	--	--	67	6	19	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	-1	5	--	--	--	--	29	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	26	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	20	--

HU-1: *Pinus ponderosa/Juniperus communis/ Symphoricarpos albus/Berberis repens* **(fig. 2).**

HU-1 is found on the limestone plateau of the northwestern and western Black Hills (map 4). The average elevation of the 24 sample stands is 6,315 feet (range: 5,675 to 6,775 feet). Most of the stands occur between the 22- and 24-inch isohyets, which makes this the most mesic HU of the ponderosa pine forest.

The relatively high constancy and frequency of all sizes classes of *Pinus ponderosa* indicates this HU provides good growing conditions for this species. The presence of *Picea glauca* and *Populus tremuloides* in many stands is a further indication of the mesic nature of this HU.

The understory in most of the stands is characterized by a tall-shrub stratum of *Juniperus communis* 3 feet or more in height, and a low-shrub stratum with *Symphoricarpos albus* as the most frequent species. Shrubs are also important components of the herb stratum. Dense mats of the prostrate, woody perennial *Arctostaphylos uva-ursi* are a common feature. However, the most characteristic shrub in the herb stratum is *Berberis repens*.

Many species of graminoids and forbs are present at high constancy and frequency in the herb stratum. Among the most important are *Oryzopsis asperifolia, Achillea millefolium, Fragaria vesca, Galium biflorum,* and the indigenous legumes *Vicia americana* and *Lathyrus ochroleucus*. It should be noted that except for *Berberis repens,* all of the important species in the HU also occur in several other HU. Because we are dealing with subdivisions of a larger entity with a common dominant attribute, that is, a forest dominated by *Pinus ponderosa*, the presence of many of the same species in several HU is not unexpected.

All of the soils described in this HU are developed from limestone parent material. They have well-developed sola with an A1/A2/B2/C horizon sequence. The average solum depth is 15.0 inches (range: 8.0 to 37.0 inches) and the reaction is neutral to basic through the entire solum, with strong effervescence with hydrochloric acid in the lower horizons.

Figure 2.—HU- 1: Pinus ponderosa / Juniperus communis / Symphoricarpos albus/Berberis repens

Figure 3.—HU- 2: Pinus ponderosa /Shepherdia canadensis / Symphoricarpos albus / Arctostaphylos uva-ursi

HU-2: *Pinus ponderosa/Shepherdia canadensis/Symphoricarpos albus/Arctostaphylos uva-ursi* **(fig. 3).**

HU-2 is present in the same general geographic region of the Black Hills as HU-1 (map 1), but at lower elevations (mean: 5,660 feet; range: 5,575 to 6,000 feet) and on noncalcareous geologic material. Annual precipitation for all stands is between 20 and 22 inches.

Constancy and frequency of the two smallest size classes of *Pinus ponderosa* are slightly greater than in HU-1. *Picea glauca* did not occur in any of the nine sample stands included in HU-2, but *Populus tremuloides* and *Betula papyrifera* are occasional members of the overstory canopy. *Betula papyrifera* is usually most abundant on and around outcrops of vertically oriented rock, a common feature of the HU-2 landscape.

Shepherdia canadensis is the most frequent member of the tall-shrub stratum, but it is present at relatively low constancy and frequency. *Juniperus communis* is much less frequent than in HU-1. The most important low shrubs are *Symphoricarpos albus, Rosa fendleri,* and *Amelanchier alnifolia. Arctostaphylos uva-ursi* is the shrub dominant in the herb stratum. *Berberis repens* is completely absent.

The constancy and both mean and maximum frequencies of graminoids and forbs are lower in HU-2 than in HU-1. *Danthonia intermedia* and *Agropyron griffithsi* are the most common graminoids. *Oryzopsis asperifolia* has relatively high constancy, but low frequency. *Achillea millefolium, Apocynum androsaemifolium, Antennaria neglecta,* and *Campanula rotundifolia* are high-constancy forb species. *Thermopsis rhombifolia,* present at high frequency in four of the nine stands included in the HU, is rare elsewhere in the ponderosa pine forest.

Soils in HU-2 are developed from either micaceous schists or metamorphosed rocks which are high in iron. All but one of the nine profiles described have the A1/A2/B2/C horizon sequence. The exception is located on a steep talus slope covered by an overlay of colluvium, and has an A1/C/R sequence. Soil reaction is acidic throughout the sola (mean: pH 5.7; range pH 5.1 to 6.1). The average depth to the C horizon is 15.2 inches (range: 4 to 27 inches).

HU-3: *Pinus ponderosa/Potentilla fruticosa/ Symphorocarpos albus/Fragaria vesca* **(fig. 4).**

HU-3 is represented by a single stand on the north side of an exposed limestone ridge at an elevation of 6,895 feet, the highest stand sampled.

The overstory is a stand of *Pinus ponderosa* predominantly in the 4 to 8 d.b.h. class. No other species of trees are present.

The understory is characterized by a well-developed tall-shrub stratum, with *Potentilla fruticosa* as the most frequent species. This is the only HU in the ponderosa pine forest where *Potentilla fruticosa* is present at more than 8 percent frequency. In the Black Hills, it usually grows on the ecotone between mountain grasslands and ponderosa pine-white spruce *(Picea glauca)* forest on the limestone plateau. It appears to be confined to soils derived from calcareous parent materials. *Shepherdia canadensis* and *Juniperus communis* are both present at high frequency in the tall-shrub stratum. The low-shrub stratum is dominated by *Symphoricarpos albus* with *Rosa fendleri* as a species of secondary importance.

The herb stratum is poorly developed. Both *Arctostaphylos uva-ursi* and *Berberis repens* are absent. Only five species of graminoids and forbs exceed 20 percent frequency, and only 13 herb species are present. Of these, *Fragaria vesca* is the most frequent.

The solum is stony throughout with a weakly developed, clayey surface (A1) horizon about 9 inches thick. Below 9 inches the soil is approximately 80 percent limestone rock with a range in pH of 7.7 to 8.1.

Figure 4.—HU- 3: Pinus ponderosa / Potentilla fruticosa / Symphoricarpos albus/Fragaria vesca

HU-4: *Pinus ponderosa/Symphoricarpos occidentalis/Rosa fendleri/Poa pratensis* **(fig. 5).**

HU-4 occupies the ecotone between dense ponderosa pine forest and adjacent meadows dominated by *Poa pratensis*. It is present at elevations averaging 5,900 feet (range: 5,100 to 6,450 feet) on a variety of geologic formations in the central region of the Black Hills. Average annual precipitation for all stands is 20 inches or more.

The *Pinus ponderosa* overstory is open, and the trees occur at much lower constancy and frequency than in any of the previously described HU.

The major species in the tall-shrub stratum is *Symphoricarpos occidentalis*. This species is indigenous to meadows at low to moderately high elevations in the Black Hills, and is common on the prairies to the east. It does not appear to be well adapted to calcareous soils since it is absent from the meadows on the limestone plateau.

The low-shrub stratum has *Rosa fendleri* and *Rosa suffulata* as the most important components. Since these two species were difficult to identify on the basis of vegetative characteristics they have been combined in table 2 under *Rosa fendleri*.

Poa pratensis is by far the most important species in the herb stratum; all other graminoids are present at much lower constancy and frequency. The presence of *Stipa viridula* and

Figure 5.—HU- 4:
Pinus ponderosa /Symphoricarpos occidentalis / Rosa fendleri/Poa pratensis

Carex heliophila in two-thirds of the stands sampled indicates the grassland affinities of the herb stratum. The relationship to adjacent grasslands is supported by the presence of such forbs as *Solidago nemoralis, Potentilla hippiana,* and *Iris missouriensis,* all of which are common meadow species in the Black Hills.

The soils in HU-4 are much deeper than in any of the previously described HU. Average depth of the solum is 23.0 inches (range: 17.0 to 34.0 inches). All horizons are dark colored and high in organic material. All but one of the described profiles have an A1/A2/B2/C horizon sequence. The A2 horizon is missing from the exception. B2 horizons are clayey with strong, angular blocky structure; soil drainage appears to be restricted by this horizon. Average soil reaction in the B2 horizon is pH 6.4.

HU-5: *Pinus ponderosa/Symphoricarpos albus/Arctostaphylos uva-ursi* **(fig. 6).**

Twenty-five stands are classified in HU-5 which is the most widely distributed unit in the ponderosa pine forest (map 4). It occurs over a large range in elevation in the northeastern, central, and southern Black Hills. The mean elevation of the 25 stands is 5,000 feet (range: 3,725 to 6,100 feet). All but three stands are on noncalcareous geologic material—mainly the micaceous schists of the central region. Those on calcareous material are located along the eastern edge of the limestone plateau at elevations between 4,000 and 5,000 feet. A majority of the stands in this HU receive less than 22 inches average annual precipitation, and in several, precipitation is below 20 inches a year.

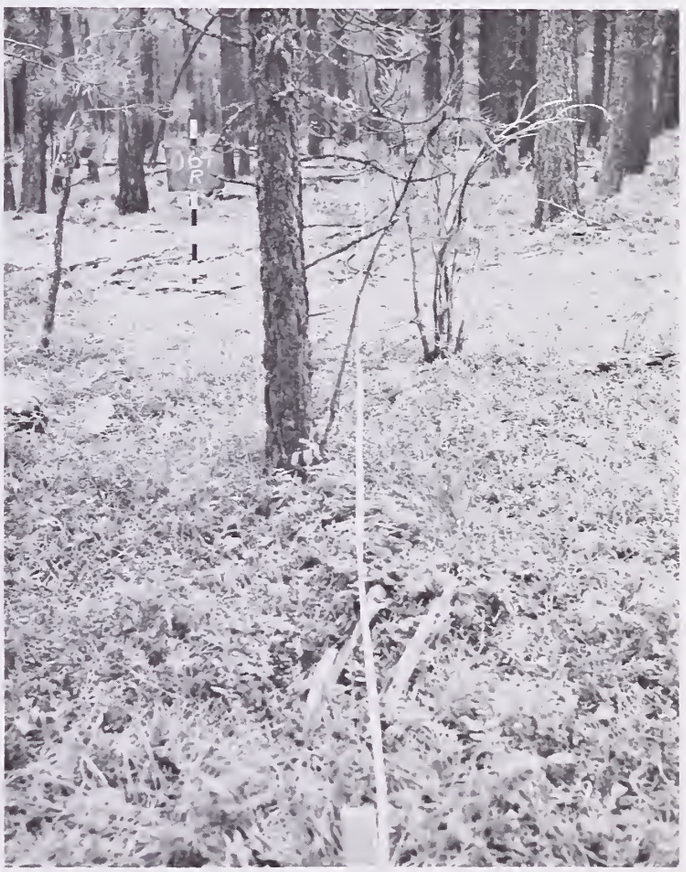


Figure 6.—HU- 5:
Pinus ponderosa/Symphoricarpos albus/Arctostaphylos uva-ursi

Pinus ponderosa trees in the < 4-inch and 4- to 8-inch d.b.h. classes are very common, and several stands have such a dense overstory of small d.b.h. trees that the understory is only minimally developed. These dense stands of *Pinus ponderosa* occur only in HU-5. The causes of their origin have not been determined, but interruption of the more or less cyclic pattern of forest fires which occurred previous to settlement of the Black Hills may be an important factor in their development. Seedlings of *Pinus ponderosa* reach their greatest constancy and frequency in this HU. *Populus tremuloides, Betula papyrifera,* and *Quercus macrocarpa* are occasional members of the forest overstory.

The understory is sparsely developed with a greater incidence of bare ground and litter, and a tall-shrub stratum is absent. *Juniperus communis* and *Shepherdia canadensis* are present in some stands, but do not exceed 3 feet in height and are widely scattered. *Symphoricarpos albus* forms an open low-shrub stratum, but its mean frequency is greatly reduced from that of the previously described HU. Mats of *Arctostaphylos uva-ursi* are a common feature of the herb stratum, although it too is slightly reduced in constancy and frequency when compared to the more mesic HU previously described.

Danthonia intermedia and *Carex concinna* are the most frequent graminoids. *Achillea millefolium* is again the leading forb species. There is a distinct reduction in the constancy and frequency of all the forb species, however, which reflects the more xeric environmental conditions generally present.

Average solum depth is 14.8 inches (range: 6.0 to 30.0 inches). Upper soil horizons are quite rocky and exposed, and vertically oriented rock outcrops are a common feature of the landscape. The subsoil is generally acidic except on limestone, where it may reach pH 8.5. The horizon sequences are either A1/A2/B2/C or A1/B2/C. An A2 horizon is present in 17 of the 25 profiles. All but one of the soils without an A2 horizon have B2 horizons; the exception has an A1/AC/C sequence.

HU-6: *Pinus ponderosa-Quercus macrocarpa/ Prunus virginiana/Symphoricarpos albus/Berberis repens* **(fig. 7).**

HU-6 is represented by four stands, all located along the northern edge of the Black Hills at elevations between 3,850 and 4,550 feet. All of the stands are on calcareous geologic material and lie between the 20- and 22-inch isohyets.

Small *Quercus macrocarpa* are the most frequent overstory species, but the average height of these trees is less than that of the intermixed *Pinus ponderosa*. Both species have been logged in the past. Many large-diameter stumps of *Quercus macrocarpa* are present, and many of the small trees have sprouted from old root crowns.

The tall-shrub stratum is well developed. *Prunus virginiana, Quercus macrocarpa,* and *Amelanchier alnifolia* all occur at high constancy and frequency, and may exceed 6 feet in height.

Figure 7.—HU- 6: Pinus ponderosa - Quercus macrocarpa / Prunus virginiana / Symphoricarpos albus/ Berberis repens

The first and last of these tall shrubs are present over much of the ponderosa pine forest, but are usually not over 1.5 feet tall. *Ostrya virginiana* forms a tall-shrub stratum over 10 feet high in three of the four stands. *Quercus macrocarpa* and *Ostrya virginiana* are sympatric along much of the northern edge of the Black Hills. The low shrub stratum is dominated by *Symphoricarpos albus* and *Spiraea lucida*. *Berberis repens* occurs at high frequency in the herb stratum and *Toxicodendron radicans* is present at low frequency in all stands.

Many graminoids and forbs are present at high frequency in the herb stratum in spite of the dense shrub strata. Many of these are species also found throughout the ponderosa pine forest, but two species, *Maianthemum canadense* and *Sanicula marilandica*, are rare except in this HU.

The soils in HU-6 are deeper than in most of the other HU of the ponderosa pine forest. The average solum thickness is 24.3 inches with a range of 14.0 to 29.0 inches. All four profiles are well developed with the A1/A2/B2/C horizon sequence and have neutral to basic reaction. The O1 horizon (litter) is thicker than in any other HU because of the accumulation of leaves from *Quercus macrocarpa* and the many deciduous shrubs.

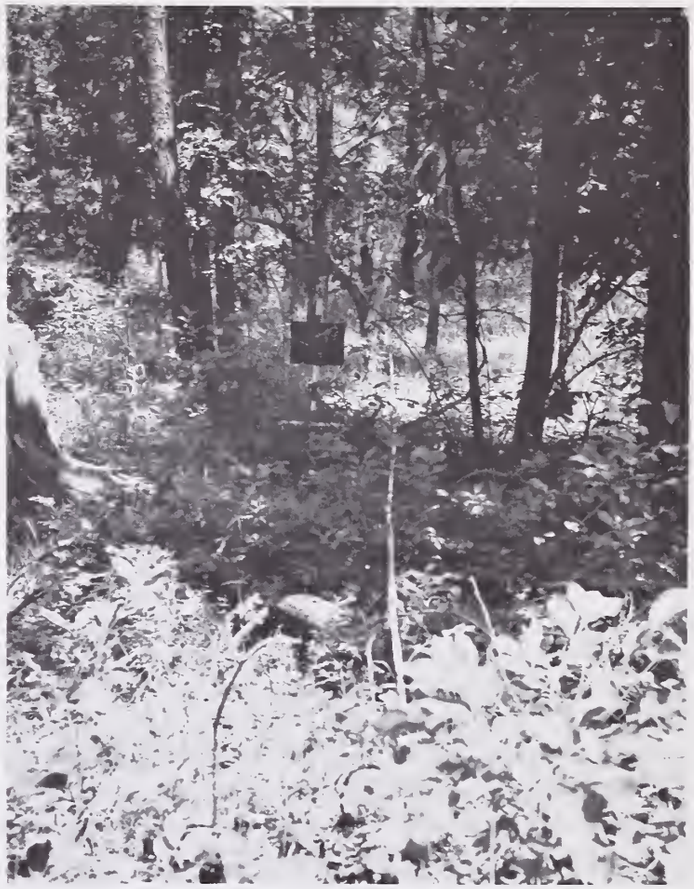


Figure 8.—HU- 7: Pinus ponderosa - Quercus macrocarpa / Prunus virginiana / Symphoricarpos albus/ Schizachne purpurascens - Carex foenea

HU-7: *Pinus ponderosa-Quercus macrocarpa/ Prunus virginiana/Symphoricarpos albus/Schizachne purpurascens-Carex foenea* **(fig. 8).**

HU-7 is represented by a single stand on the eastern edge of the central Black Hills at an elevation of 4,300 feet. It is related to HU-6 in several attributes, but differs in that it occurs on a very acidic soil, has a greater frequency of large-diameter *Quercus macrocarpa* in the overstory, and a herb stratum dominated by graminoids.

Quercus macrocarpa is codominant in the overstory with *Pinus ponderosa*. A few *Quercus macrocarpa* trees larger than 12 inches d.b.h. are scattered through the stand. Many large-diameter stumps suggest that *Quercus macrocarpa* may have been the dominant species prior to logging. *Pinus ponderosa* in the 4- to 8-inch d.b.h. class is presently the most frequent overstory species.

Prunus virginiana is the most frequent species in the tall-shrub stratum, and *Symphoricarpos albus* is the low-shrub dominant. Neither *Berberis repens* nor *Toxicodendron radicans* are present in the herb stratum. *Carex foenea* and *Schizachne purpurascens* both occur at high frequency in the herb stratum. *Schizachne purpurascens* is rare elsewhere in the ponderosa pine forest. The forb *Smilacina stellata* is also present with moderate frequency and gives the herb stratum a distinctive appearance.

The solum has an A1/A2/B2/B3 horizon sequence, and is more than 36 inches deep. The B2 horizon is very acidic (pH 4.5) which may account for the absence of *Berberis repens*. A litter horizon (O1) and a well-defined humus horizon (O2) are present.

HU-8: *Pinus ponderosa/Prunus virginiana/ Amelanchier alnifolia/Galium biflorum* **(fig. 9).**

HU-8 is represented by one stand at the base of a steep limestone cliff along one of the major streams (Little Spearfish Creek) in the northern Black Hills. This very mesic, protected, semiriparian site is between the 22- and 24-inch isohyets, although the elevation is only 5,200 feet.

The overstory is a rather open stand of small-diameter *Pinus ponderosa.* A few *Betula papyrifera* up to 15 feet tall are scattered through the stand. The tall-shrub stratum is composed of *Prunus virginiana, Shepherdia canadensis,* and *Corylus cornuta.* This is the only HU in the ponderosa pine forest where *Corylus cornuta* is present at high frequency. *Cornus stolonifera,* present at low frequency, indicates the mesic nature of this HU since in the Black Hills it grows only along streams.

The low-shrub stratum is well developed with *Amelanchier alnifolia* present at high frequency. *Symphoricarpos albus, Spiraea lucida,* and *Rosa fendleri* occur at moderately high frequency. *Berberis repens* and *Arctostaphylos uva-ursi* are prominent but do not dominate the herb stratum. *Poa pratensis* is the only graminoid to exceed 20 percent frequency. Several forb species are present at frequencies exceeding 20 percent. *Galium biflorum* is the herb stratum dominant. *Monarda fistulosa* is also abundant.

The soil is developed from limestone colluvium. The solum is 20.0 inches deep, rocky throughout, and has a basic reaction. An O1 horizon 1-1/2 inches thick and a 1/2-inch-thick O2 horizon are present. The horizon sequence is A1/A2/B2/R.

Figure 9.—HU- 8: Pinus ponderosa / Prunus virginiana / Amelanchier alnifolia / Galium biflorum

Figure 10.—HU- 9:
Pinus ponderosa / Poa pratensis - Danthonia intermedia

HU-9: *Pinus ponderosa /Poa pratensis-Danthonia intermedia* **(fig. 10).**

HU-9 is represented by seven stands, five in the southern Black Hills (map 4). The other two are located on exposed sites in old forest fire burns. The average elevation of all stands is 5,250 feet (range: 4,950 to 5,500 feet). Most lie between the 18- and 20-inch isohyets. Five of the stands occur on granitic material, one on calcareous material, and one on micaceous shale.

Pinus ponderosa is the only overstory species. The overstory canopy is open, and all d.b.h. classes are present at low frequency. Many of the trees are short with heavy limbs.

No shrub species are present at more than 67 percent constancy, and the general appearance of the HU is that of an open pine stand with a grassy understory. *Poa pratensis* is by far the most frequent species in the herb stratum; in one stand it occurred at 99 percent frequency. *Danthonia intermedia* and *Koeleria cristata* are also present in all stands, but always at lower frequencies than *Poa pratensis*. *Achillea millefolium* is the only forb species with 100 percent constancy. Most of the forbs present are species common to moderately moist grasslands at moderate elevations in the Black Hills.

Sola average 12.0 inches in thickness. The B2 horizon is absent from five of the seven soil profiles, and the general horizon sequence is A1/AC/C/R. One of the two soils with a B2 horizon is located on old forest fire burn in the central Black Hills. The other is in a moist draw on calcareous parent material. B2 horizons appear to develop more readily on calcareous than on noncalcareous parent materials.

HU-10: *Pinus ponderosa-Juniperus scopulorum/Cercocarpus montanus/Symphoricarpos albus/Andropogon scoparius* **(fig. 11).**

HU-10 is represented by three stands in the southwestern Black Hills (map 4). The mean elevation of the stands is 5,225 feet (range: 5,000 to 5,475 feet). Mean annual precipitation is 18 to 20 inches.

The overstory is characterized by an open stand of *Pinus ponderosa* with scattered *Juniperus scopulorum.*

The tall-shrub stratum is a dense stand of *Cercocarpus montanus.* Individual plants exceed 10 feet in height and grow so closely together that movement through the stand is very difficult. *Cercocarpus montanus* is very localized in the Black Hills. It grows only on the limestone formations along the southwestern, southern, and southeastern periphery of the Black Hills. In spite of the limited number of representative stands, this HU is a distinct unit, easily recognizable in the field. The three stands have a minimum similarity of K>70. HU-10 resembles the mountain brush type found at low to moderate elevations throughout much of the central Rocky Mountain region.

A number of other shrub species which are uncommon elsewhere in the ponderosa pine forest of the Black Hills are found in this HU. Among these are *Rhus trilobata, Ribes inerme,* and *Yucca glauca. Symphoricarpos albus* is frequent in the low-shrub stratum.

The major species in the herb stratum are graminoids and forbs with prairie affinities. *Andropogon scoparius, Agropyron smithii, Bouteloua curtipendula,* and *Koeleria cristata* are the more important graminoids. *Artemisia ludoviciana, Phlox hoodii, Anemone patens, Zygadenus elegans,* and *Hymenoxys acaulis* are present in all stands. The presence of *Musineon divaricatum, Grindelia squarrosa,* and *Leucocrinum montanum,* even with less than 100 percent constancy, is a further indication of the prairie affinities of the herb stratum.

The soil parent material under all stands is limestone. The horizon sequence is A1/AC/C/R, and soil texture is a stony or gravelly loam throughout the solum. Solum depths range from 7 to 31 inches, with strong hydrochloric acid effervescence in all horizons.

Figure 11.—HU-10:
Pinus ponderosa - Juniperus scopulorum / Cercocarpus montanus / Symphoricarpos albus / Andropogon scoparius

Figure 12.—HU-11:
Pinus ponderosa / Andropogon scoparius

HU-11: *Pinus ponderosa/Andropogon scoparius* **(fig. 12).**

HU-11 is confined to the southwestern part of the Black Hills, a relatively low and dry region with rolling topography. The ponderosa pine forest is interspersed among extensive dry prairies, and generally occurs along watercourses and the mesic aspects of hills and canyons. The average elevation of the nine stands representing this HU is 5,165 feet (range: 4,825 to 5,475 feet). Most of the stands are between the 18- and 20-inch isohytes, with several stands having less than 18 inches mean annual precipitation. The limestone plateau is very extensive in this part of the Black Hills, and all of the stands are located on this geologic formation.

The *Pinus ponderosa* overstory is relatively dense. Trees greater than 4 inches d.b.h. are frequent, as are seedlings. Larger *Pinus ponderosa* trees are usually limby and flat-topped. *Juniperus scopulorum* is sometimes present as a subordinate tree. Only two species of low-shrubs, *Rosa fendleri* and *Symphoricarpos albus,* are present. Neither exceeds 67 percent constancy and they occur only at low frequency and are rarely more than 1 foot in height.

The herb stratum is related to the surrounding prairie. *Andropogon scoparius* is the most frequent species and the only one with 100 percent constancy. *Koeleria cristata* is present in all but one stand, but never exceeds 10 percent frequency. The presence of *Leucocrinum montanum* and *Phlox alyssifolia* in many stands indicates the prairie affinities of the herb stratum.

Sola are relatively deep (mean: 19.7 inches; range: 10.0 to 26.0 inches) and have an A1/B2/C/R horizon sequence. Soil reaction is neutral to basic (pH 7.2 to 8.0) in the subsurface horizons and only slightly acid in the surface horizons. The surface horizons are relatively deep and dark colored from the presence of fibrous roots of graminoid species.

HU-12: *Pinus ponderosa/Prunus virginiana/ Andropogon scoparius* **(fig. 13).**

HU-12 is represented by nine stands on the periphery of the Black Hills at elevations below 4,700 feet (mean: 4,265 feet; range: 3,925 to 4,675 feet). The northern and extreme southern stands are on calcareous geologic material, while those in the east-central foothills are underlain by either granitic or metamorphosed formations. Mean annual precipitation for all stands is between 18 and 20 inches.

The overstory is open and trees are short with large limbs. Seedlings of *Pinus ponderosa* are relatively common. Small *Quercus macrocarpa* are present in several stands, and the general appearance of the overstory is that of an impoverished HU-6. *Juniperus scopulorum* was present in one stand.

The understory is also quite open and without a tall-shrub stratum. The low-shrub stratum has *Prunus virginiana* as the most frequent species; plants are almost always under 2 feet high when mature. *Rosa fendleri* is the second most constant shrub. Both *Symphoricarpos occidentalis* and *S. albus* are present, but at low constancy, although occasionally at high frequency. *Amorpha canescens* is also common in the low shrub stratum.

Andropogon scoparius is the most frequent species in the herb stratum. *Lupinus parviflorus* and *Artemisia ludoviciana* are also common constituents.

Soil depths are variable. Two of the stands have soils with shallow sola (1.5 and 12.0 inches) and an A1/C/R horizon sequence. The other seven stands have deep sola (mean: 28.1 inches; range: 23.0 to 41.0 inches) with an A1/B2/C/R sequence. The subsoil reaction on the soils developed from limestone is as high as pH 9.0. On noncalcareous soils the subsoil is acidic (pH 6.0 to 6.6).

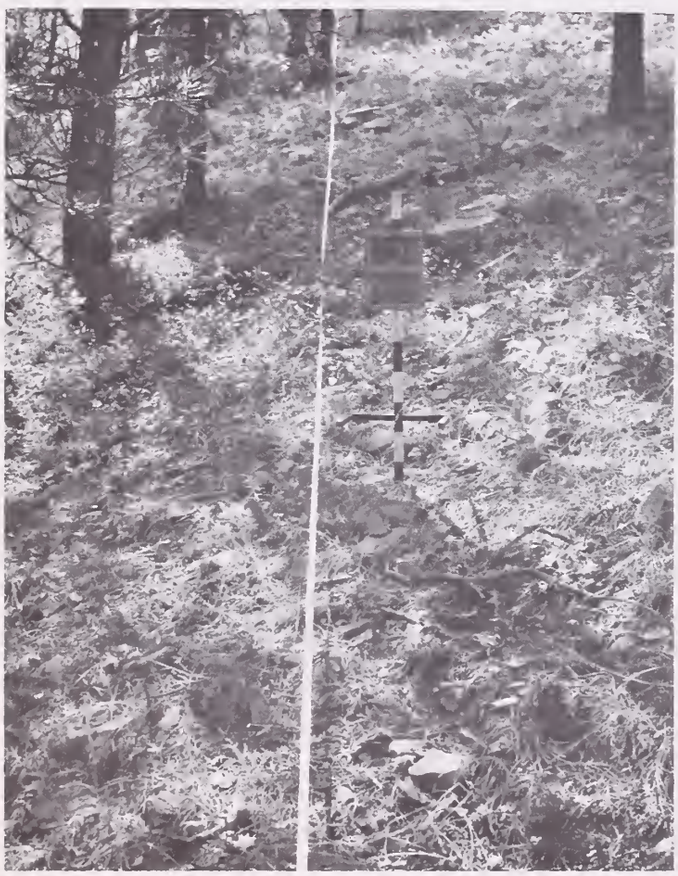


Figure 13.—HU-12: Pinus ponderosa / Prunus virginiana / Andropogon scoparius

HU-13: *Pinus ponderosa/Andropogon scoparius-Bouteloua gracilis* **(fig. 14).**

The single stand representing HU-13 is located in the extreme southeastern Black Hills at an elevation of 4,675 feet. This is the most xeric part of the region, with an annual precipitation between 16 and 18 inches.

Only scattered *Pinus ponderosa* are present in this area. No tree size *Pinus ponderosa* are present on the sample plot and the general appearance of the site is that of an *Andropogon scoparius* grassland. A few *Pinus ponderosa* seedlings are present which indicates the area can support the species.

Figure 14.—HU-13: Pinus ponderosa / Andropogon scoparius-Bouteloua gracilis

The only shrub species present is *Artemisia frigida. Andropogon scoparius, Bouteloua gracilis,* and *B. curtipendula* are the most frequent graminoids. *Stipa comata* and *Andropogon gerardii* are present at low frequency. Several of the forb species occur only in this HU. Among these are *Polygala alba, Echinacea angustifolia, Chrysopsis villosa, Paronychia depressa,* and *Hackelia virginiana.* All are prairie species.

The soil in this HU is derived from limestone and has an A1/AC/C profile. Depth to the top of the C horizon is 22 inches. The A1 horizon is dark colored and high in grass roots. Soil reaction is pH 7.4 or greater throughout the solum.

DISCUSSION

The purpose of habitat classification for wildlife management is to separate a large, heterogeneous habitat into more homogeneous units which are enough alike to be administered, manipulated, or evaluated in groups. Previously, habitats have been grouped almost entirely by subjective methods. While this may be satisfactory for extensive management, or where distinctly different kinds of habitats exist sympatrically, more objective classification methods, particularly those based on quantitative evaluation of actual features or attributes of the area under consideration, are needed for intensive management. This is particularly true for habitats such as the ponderosa pine forest of the Black Hills which cover extensive areas, or have a relatively homogeneous feature such as a closed canopy tree overstory which makes the understory or other habitat variations difficult to distinguish.

The application of computers to the solution of classification problems in plant taxonomy and ecology has received a great deal of attention in recent years. Techniques are available to make ordered and logical arrangements of heterogeneous entities. The method used in this study, cluster analysis, is only one of the many available. It may be defined as an agglomerative (combination of individual entities into a whole) mathematical procedure which groups together entities with the greatest number of shared attributes.

Although HU may be designated at minimum levels of similarity higher than $K \geq 60$, both

the total number of HU and the percentage of HU containing three or less stands increase greatly (table 3).

The number of HU approximately doubles for each 5 percent increase in K, while the percentage of HU containing three or less stands increases from 39 percent at $K \geq 60$, to 57 percent at $K \geq 65$, and to 91 percent at $K \geq 70$. Increasing the minimum level of similarity higher than $K \geq 60$ apparently defeats the purpose of classification, which is to obtain groups of relatively similar stands.

At $K \geq 84$, all HU consist of a single stand, and an ordination of stands is obtained. For some purposes, ordination may be a useful technique of analysis, especially where strong environmental gradients are present. It should be noted that there is an element of ordination in the arrangement of the dendrogram (fig. 1): there is a general decrease in precipitation, elevation, etc., from top to bottom. However, there are also abrupt changes in other environmental features of the Black Hills such as geological formation, and these are reflected in abrupt changes in species composition and other attributes. Therefore, classification of stands appears to be a more appropriate technique of analysis.

In assessing the validity of the classification of the ponderosa pine forest ecosystem, several points must be emphasized. First, as with any classification, only the things being classified—in this instance, the sample stands—are real in the sense that they actually occur in nature. Each stand has a set of measurable (or at least recordable) attributes of vegetation, soil, and site which characterize it. These attributes are the result of a sequence of environmental events, the majority of which are usually unknown. Furthermore, the combination of attributes which characterize a stand exist only at the specific time at which they were recorded due to succession, disturbance, and chance. Because of their dynamic nature, no two stands can be expected to be exactly alike.

Second, any classification unit, such as an HU, is an abstraction based on the modal characteristics of a number of sample stands which usually are widely separated geographically. The range of attribute characteristics of a unit depends on the attribute variability of the included stands, and the level of homogeneity at which it has been defined. This level of homogeneity, in turn, depends upon the purpose for which the classification has been made. For some purposes, very high levels of homogeneity may be desirable; for other purposes, lower levels may be adequate, or even necessary. Because of the interdependence of homogeneity and purpose, there does not ap-

Table 3.--Number of habitat units (HU) with one, two, three, or more included stands for levels of similarity of $K \geq 60$, $K \geq 65$, and $K \geq 70$

Number of included stands	HU at $K \geq 60$		HU at $K \geq 65$		HU at $K \geq 70$	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
1	4	31	5	19	29	57
2	--	--	5	19	13	26
3	1	8	5	19	4	8
4+	8	61	11	43	5	9
Total	13	100	26	100	51	100

pear to be an intrinsic level of homogeneity at which classification units must, or should, be defined.

Third, synecological classification units such as HU are best defined on a multi-attribute basis, although they often may be recognized and described by relatively few important or "indicator" attributes. A stand which is said to "belong" to a given HU need not possess all of the attributes which define the HU. Furthermore, since the HU are defined on this multi-attribute basis, the effect of the presence or absence of a single attribute is minimal. This minimal effect is enhanced, of course, when attributes are unweighted and/or standardized.

Finally, there is the question: What constitutes a "good" classification? For synecological purposes, units in a good classification show close relationship with what occurs in nature. The classification must provide a logical separation of the landscape into units, examples (stands) of which may be easily recognized in the field, and which may be related to the environmental regime.

The 13 HU defined at $K \geq 60$ appear to constitute a realistic classification of the ponderosa pine forest of the Black Hills. There is a reasonable number of units, examples (stands) of which can be easily recognized in the field by the presence and prevalence of certain attributes, particularly plant species.

The major (multistand) HU show a good relationship with environmental features of the Black Hills, especially geological formation and precipitation regime, neither of which were directly used in the calculation of the similarity matrix. The general regions of the Black Hills where a given HU can be expected to predominate can be mapped (map 4).

The major multistand HU, HU-1 (*Pinus ponderosa/Juniperus communis/Symphoricarpos albus/Berberis repens)* and HU-5 *(Pinus ponderosa/Symphoricarpos albus/Arctostaphylos uva-ursi)* are the most extensive subdivisions of the ponderosa pine forest. In general, they occupy separate geographic regions of the Black Hills and, although many plant species are common to both, there are distinct differences in both overstory and understory characteristics and in environment which make them distinguishable in the field.

HU-2 *(Pinus ponderosa/Shepherdia canadensis/Symphoricarpos albus/Arctostaphylos uva-ursi)* is in many attributes intermediate between HU-1 and HU-5. It might be described as a mesic phase of HU-5. It also has close relationship to HU-1; the major differentiating attributes are the absence of *Berberis repens* and the occurrence on noncalcareous geological materials. These, of course, are interrelated, since *Berberis repens* is apparently confined to calcareous soils in the Black Hills. Although it occurs in the same general geographic area and at similar elevations, HU-4 *(Pinus ponderosa/Symphoricarpos occidentalis/Rosa fendleri/Poa pratensis)* is easily distinguished from the above three HU by the dominance of *Symphoricarpos occidentalis* in the tall-shrub stratum and the very open overstory of *Pinus ponderosa.*

Except for HU-10 *(Pinus ponderosa-Juniperus scopulorum/Cercocarpus montanus/Symphoricarpos albus/Andropogon scoparius)* which is distinct due to the dominance of *Cercocarpus montanus* in the understory, the remaining multistand HU are less easy to define. In general, they represent the transition zone between ponderosa pine forest and the Northern Great Plains. HU-9 *(Pinus ponderosa/Poa pratensis-Danthonia intermedia)* occupies the most mesic sites in this more xeric region of the Black Hills. HU-12 *(Pinus ponderosa/Prunus virginiana/Andropogon scoparius)* occurs on exposed locations in the more mesic northern and eastern foothills, and shows relationships in a few attributes to HU-6 *(Pinus ponderosa-Quercus macrocarpa/Prunus virginiana/Symphoricarpos albus/Berberis repens)* and HU-7 *(Pinus ponderosa-Quercus macrocarpa/Prunus virginiana/Symphoricarpos albus/Schizachne purpurascens-Carex foenea)* particularly in the presence of *Quercus macrocarpus* at low frequency in some of the stands. HU-11 *(Pinus ponderosa/Andropogon scoparius)* occupies the most xeric sites with a *Pinus ponderosa* overstory. The general appearance of most of the stands is that of a ponderosa pine savanna.

The four single-stand HU defined at $K \geq 60$ are distinct in many attributes. Two of them, HU-3 *(Pinus ponderosa/Potentilla fruticosa/Symphoricarpos albus/Fragaria vesca)* and HU-8 *(Pinus ponderosa/Prunus virginiana/Amelanchier alnifolia/Galium biflorum)* occur in mesic environments, the former in a high elevation, high precipitation zone and the latter on a shaded river bench in a deep canyon. The third, HU-7 *(Pinus ponderosa-Quercus macrocarpus/Prunus virginiana/Schizachne purpurascens)* has close similarities with HU-6 *(Pinus ponderosa/Quercus macrocarpus/Prunus virginiana/Berberis repens)* and at $K \geq 59$ these would be combined. There are distinct differences in understory species composition and soil attributes, however, which distinguish HU-6

from HU-7. The final single-stand unit, HU-13 *(Pinus ponderosa/Andropogon scoparius-Bouteloua gracilis)* is more representative of the Northern Great Plains than the ponderosa pine forest. It was the final stand to be incorporated into the cluster analysis, which emphasizes its lack of similarity with the other 99 stands.

The disturbed condition of all 100 stands makes any discussion of the successional status of the HU rather tentative. There is a degree of floristic similarity between all stands, and if the HU had been defined only on floristics, this possibility of successional stages might be difficult to resolve. However, soil-site attributes were also utilized in the classification of the stands into HU, and these less easily altered attributes also show a considerable degree of within-HU similarity, it is believed the HU represent distinct climax types (in the sense of Tansley 1949, not Clements 1936), although in a disclimax stage mainly due to man-caused disturbances.

As with any classification scheme, the classification of the ponderosa pine forest presented here should and will be modified as knowledge of the subject increases. However, in its present form it provides a framework for studies of practices to improve forage production, utilization, nutrition, and habitat carrying capacity. As such, it can be a useful tool for deer habitat management in the Black Hills.

HABITAT EVALUATION

Long-term data on pellet group densities collected by the South Dakota Game, Fish, and Parks Department on segments of the 1,000-foot transect within the 60 x 100-foot macroplot were used to evaluate the degree of deer use of the HU defined at $K \geq 60$. No attempt has been made to convert pellet group densities to animal numbers; they were used directly, and only as an index of the comparative use of the habitat units by deer as suggested by Riney (1957).

Differences in mean pellet group densities (table 4) between HU were analyzed by analysis of variance—one-way classification, with unequal sample sizes (Li 1957). The results of this analysis indicated there was a significant difference ($p = .05$) in the mean pellet group densities.

To test the significance of differences between means, the multiple range test (Duncan 1955) was applied. The results of this test are shown in table 4 by the underscored lines.

The following explanation of the variable deer use of the HU is based on studies by the South Dakota Game, Fish, and Parks Department, the Wildlife Habitat Research Unit of the Rocky Mountain Forest and Range Experiment Station, and personal experience of the author in the Black Hills. In assessing the validity of the explanation, some points should be kept in mind. First, although ponderosa pine forest is the most widespread habitat

Table 4.--Mean pellet group densities[1] (1960-68) for the 13 Habitat Units (HU) defined at $K \geq 60$

Item	Habitat Unit												
	6	4	7	8	10	2	9	1	12	5	11	3	13
Number of stands	4	6	1	1	3	9	7	24	9	25	9	1	1
Mean pellet group density	10.0	9.7	6.6	5.7	4.9	4.8	4.4	4.2	4.0	3.0	2.6	0.6	0.1
	NSD[2] a = .05												
			NSD a = .05										
										NSD a = .05			

[1] Density recorded on a 6- by 100-foot plot.
[2] Nonsignificant difference.

available to deer in the Black Hills, other habitats such as quaking aspen *(Populus tremuloides)* woodland, old forest fire burns, and mountain meadows, not included in this classification are also important deer habitats. Second, the juxtaposition of the ponderosa pine forest with these other habitats influences use by deer. Third, the white-tailed deer in the Black Hills are noticeably more migratory than is usually expected for this species, and tend to move considerable distances and occupy distinct winter, spring, and summer-fall ranges.

HU-6, HU-4, and HU-7 had the highest mean pellet group densities (10.0 to 6.6). HU-6 occurs only in the northern foothills of the Black Hills, and is an area where deer concentrate during the winter. Low elevation and relatively little snow, plus the presence of several palatable species of browse, combine to make this HU attractive to deer during the winter. HU-4 represents important spring deer range in the Black Hills. During April and May this HU and adjacent meadows are favored feeding areas for deer. Their diet during this period consists mostly of *Poa pratensis* [4] which is the dominant herb species in HU-4. HU-7 is also a low-elevation winter range, and is similar to HU-6 in many attributes.

The six HU with moderate pellet group densities (5.7 to 4.0) range from mesic, high-elevation forest (1, 2, 8) to xeric, low-elevation forested shrubland (9, 10) and forested grassland (12). Three (8, 10, 12) are winter range in various parts of the Black Hills, one (9) is spring range, and the remaining two (10, 2) are important summer-fall deer range.

Of the four remaining HU, with low pellet group densities (3.0 to 0.1), HU-5 is the most widely distributed, and, because of its location at moderate elevations, is probably both year-long and transition range. While it has only relatively low deer use, because of its wide distribution it is still important deer habitat. HU-11 is located mainly in the southwestern Black Hills at low elevation and is winter range. The remaining two HU (3, 13) represent extremes in the ponderosa pine forest, and are each represented by a single stand. The former is located at almost the maximum elevation possible in the Black Hills, and has an understory dominated by a dense stand of the unpalatable shrub, *Potentilla fruticosa;* the latter is an open grassland in the most xeric portion of the Black Hills and provides little in the way of forage or cover for deer.

[4] *Dietz, Donald R. Personal communication.*

SUMMARY

Cluster analysis of a similarity matrix derived from the ecological attributes (vegetation, soil, and site characteristics) of 100 stands located throughout the ponderosa pine forest of the Black Hills produced a classification of the forest into 13 Habitat Units (HU) with a minimum internal similarity of 60 percent.

The coefficient of similarity, $K = 2c/a + b$, was used to construct the initial matrix, and the weighted-pair group method of cluster analysis was used to separate this matrix into the Habitat Units (groups of similar stands).

The indicator species of the overstory, shrub, and herb strata and the number of stands included in each HU are:

HU-1: *Pinus ponderosa/Juniperus communis/Symphoricarpos albus/Berberis repens* (24 stands)

HU-2: *Pinus ponderosa/Shepherdia canadensis/Symphoricarpos albus/Arctostaphylos uva-ursi* (9 stands)

HU-3: *Pinus ponderosa/Potentilla fruticosa/Symphoricarpos albus/Fragaria vesca* (1 stand)

HU-4: *Pinus ponderosa/Symphoricarpos occidentalis/Rosa fendleri/Poa pratensis* (6 stands)

HU-5: *Pinus ponderosa/Symphoricarpos albus/Arctostaphylos uva-ursi* (25 stands)

HU-6: *Pinus ponderosa-Quercus macrocarpa/Prunus virginiana/Symphoricarpos albus/Berberis repens* (4 stands)

HU-7: *Pinus ponderosa-Quercus macrocarpa/Prunus virginiana/Symphoricarpos albus/Schizachne purpurascens-Carex foenea* (1 stand)

HU-8: *Pinus ponderosa/Prunus virginiana/Amelanchier alnifolia/Galium biflorum* (1 stand)

HU-9: *Pinus ponderosa/Poa pratensis-Danthonia intermedia* (7 stands)

HU-10: *Pinus ponderosa-Juniperus scopulorum/Cercocarpus montanus/Symphoricarpos albus/Andropogon scoparius* (3 stands)

HU-11: *Pinus ponderosa/Andropogon scoparius* (9 stands)

HU-12: *Pinus ponderosa/Prunus virginiana/Andropogon scoparius* (9 stands)

HU-13: *Pinus ponderosa/Andropogon scoparius-Bouteloua gracilis* (1 stand)

Data on pellet group density collected in the sample stands over a 9-year period were analyzed to evaluate the comparative use of the different HU by deer. The results of this analysis indicated HU-6, -4, and -7 received

significantly higher deer use (mean pellet group densities 10.0 to 6.6) than the other HU; HU-8, -10, -2, -9, -1, and -12 received moderate deer use (mean pellet group densities 5.7 to 4.0) and HU-5, -11, -3, and -13 received only light deer use (mean pellet group densities 3.0 to 0.1).

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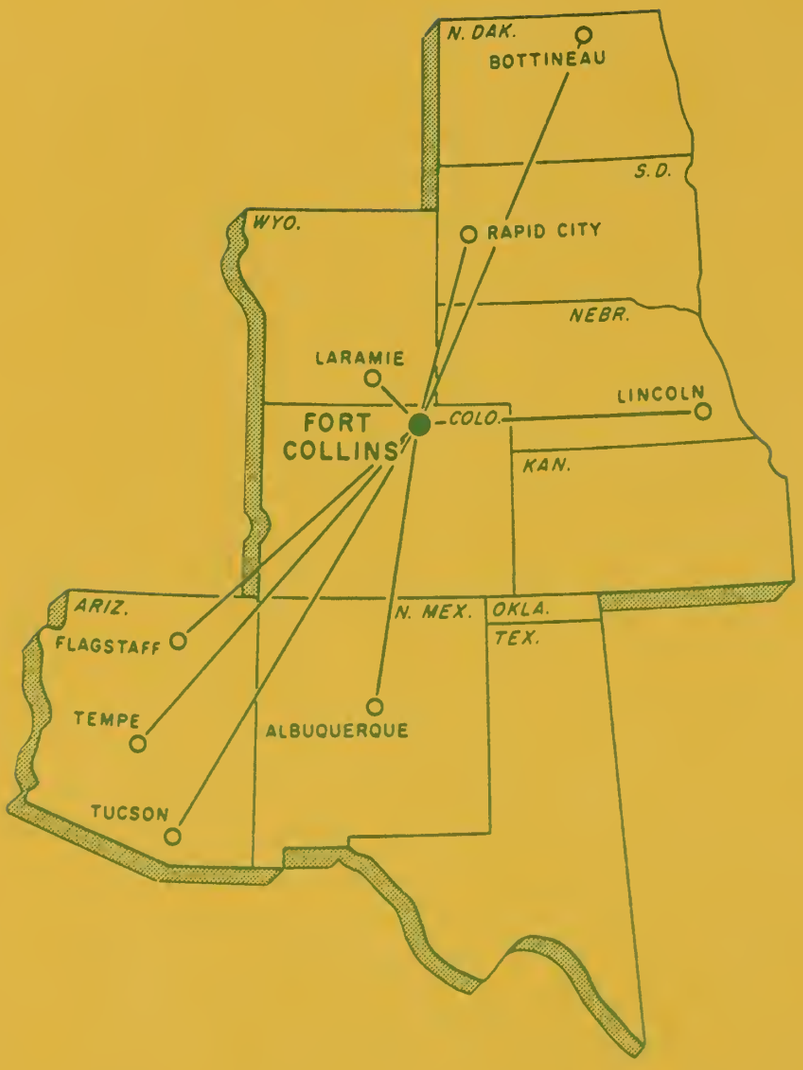
The ponderosa pine forest was classified into 13 habitat units by cluster analysis of a similarity matrix based on the vegetation, soil, and site attributes of 100 randomly located sample stands. Habitat units were defined at a minimum similarity of 60 percent. The comparative use of the habitats by deer was evaluated by analysis of variance of long-term (9 years) data on deer pellet group densities in the sample stands.

Keywords: Wildlife management, forest-wildlife relations, synecology, *Pinus ponderosa*.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