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Ecology, Silviculture, and Management of Black Hills Ponderosa Pine

Wayne D. Shepperd and Michael A. Battaglia

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Abstract

This paper presents a broad-based synthesis of the general ecology of the ponderosa pine ecosystem in the Black Hills. This synthesis contains information and results of research on ponderosa pine from numerous sources within the Black Hills ecosystem. We discuss the silvical characteristics of ponderosa pine, natural disturbances that govern ecosystem processes, wildlife habitat and management, various silvicultural methods to manage ponderosa pine forests, and watershed management of the Black Hills.

Keywords: Black Hills, silviculture, ecology, ponderosa pine, even-aged management, uneven-aged management, reforestation, wildlife habitat, natural disturbance, snags, insects, disease, fire history

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Ecology, Silviculture, and Management of Black Hills Ponderosa Pine

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USDA Forest Service
Sustaining Alpine and Forest Ecosystems
Under Atmospheric and Terrestrial Disturbances
240 West Prospect Road
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Ecology, Silviculture, and Management of Black Hills Ponderosa Pine

Wayne D. Shepperd and Michael A. Battaglia

Background and Scope

In 1974, Rocky Mountain Station scientists Charles Boldt and James Van Deusen produced Forest Service Research Paper RM-124, which summarized available knowledge about the silviculture and management of ponderosa pine (*Pinus ponderosa*) in the Black Hills of western South Dakota and northeastern Wyoming (Boldt and Van Deusen 1974). The paper, intended as a guide for professional foresters, described the growth environment in the Black Hills, presented the silvical characteristics of ponderosa pine growing there, discussed pests, diseases, and damaging agents affecting growth, and described silviculture techniques that could be used to manage ponderosa pine for wood fiber production.

Our intent in this paper is to build upon the foundation laid by Boldt and Van Deusen. Not only have we updated the discussion to include research published since the earlier report, we have expanded the scope to include a broad-based synthesis of the general ecology of ponderosa pine in the Black Hills. Rather than emphasize management for wood production, as was the focus of the earlier paper, we broadened the discussion of silviculture techniques to include management alternatives for wildlife habitat, esthetics, ecosystem restoration, and biodiversity.

In keeping with current ecosystem-based management philosophy, we synthesized information and results of research on ponderosa pine from numerous sources both within and outside the Black Hills ecosystem. Both even- and uneven-aged silviculture systems are described, and management alternatives are presented that can be used to produce and maintain desired growth and stocking conditions for a variety of natural resource objectives.

Physical Characteristics

Physiography and Geology

The Black Hills is a forested refuge on the Missouri Plateau of the Great Plains Province (Hoffman and Alexander 1987). This refuge spans 125 miles (200 km) from north to south and 60 miles (100 km) from east to west (Fenneman 1931). The total land base is nearly 6,000 square miles (15,540 km^2), with two-thirds of the area in southwest South Dakota and one third in northeast Wyoming (Froiland 1990).

The Black Hills and neighboring Bear Lodge Mountains to the west (hereafter collectively referred to as the Black Hills) were formed by a regional uplift of the Earth's surface during the Laramide mountain-building episodes that produced most of the ranges of the Rocky Mountains several million years ago. Granites pushing up beneath overlying sedimentary formations formed this maturely dissected domal uplift (Orr 1975). The uplift is elliptical in shape, with a crystalline core, which occupies about 20 percent of the Black Hills area. The core is encircled by steeply dipping sedimentary deposits. As a general rule, the closer a formation is to the center of the Black Hills, the older its age (Raventon 1994). These distinct differences in geology across the Black Hills affect vegetation distribution and growth. Consequently, managers must be aware of these differences.

Both the Black Hills and Bear Lodge Mountains are similar in geologic makeup and response to erosion. There are four recognizable geomorphologic features in the Black Hills (fig. 1): (1) Dakota Hogback ridge; (2) Red Valley; (3) Limestone Plateau and Minnelusa Foothills; and (4) Central Crystalline Core (Boldt and Van Deusen 1974; Froiland 1990). Each of the first three geomorphological features encircles the Central Crystalline Core, with the western side of the features wider than the eastern. These features are elevated 1,000 to 4,000 feet (305 to 1,219 m) above the surrounding plains.

The Dakota Hogback ridge rises several hundred feet above the surrounding plains and is on the outer rim of the Black Hills uplift (fig. 1) (Gries 1996). The outer slope of the formation consists of limestone covered by several hundred to a thousand feet of shale (Froiland 1990). The main component of the Hogback ridge is sandstone of the Lakota formation. The eastern edge of the Hogback dips steeply and is narrow, whereas

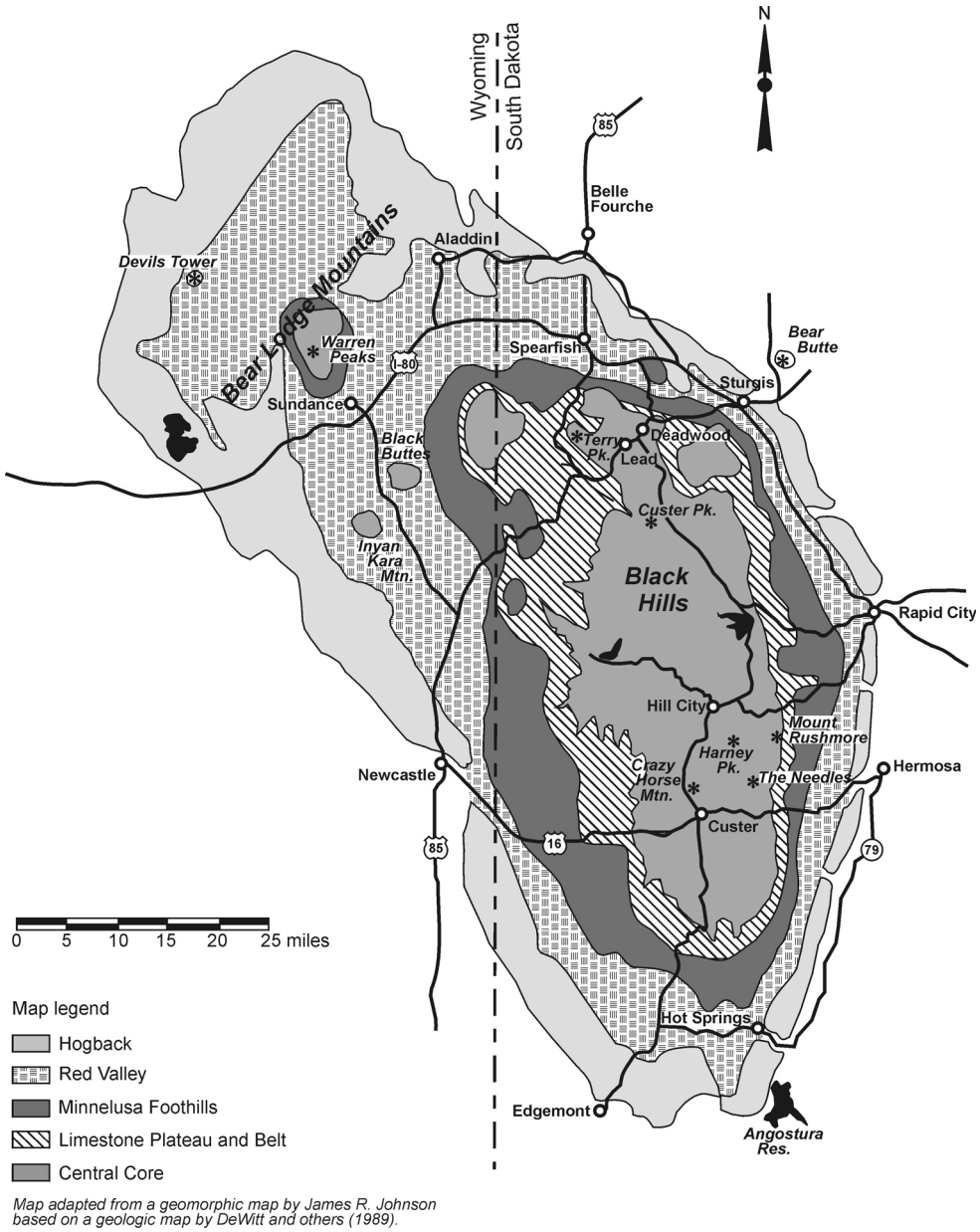


Figure 1: Generalized geologic map of the Black Hills (adapted from Larson and Johnson 1999).

the western edge (side that faces the Red Valley) has a gentle dip that forms a ridge of an outward slope, dissected plateau extending up to 10 miles (16 km) (Fenneman 1931). The ridges are covered with ponderosa pine with intermingled open grassy areas (Radeke and Westin 1963). The potential for mass movement of soil is greatest in this region due to the tilt and thinly bedded sedimentary rocks. Available water capacity is low and permeability is moderate, with a large potential for runoff (Ensz 1990). The stability of the slopes is especially sensitive to roadcuts and excavations (Cattermole 1969). Elevations in this region range from 3,800 feet (1,158 m) in the Rapid City area to 4,900 feet (1,494 m) in the Elk Mountain area of the southwest portion of the Black Hills.

The Red Valley extends entirely around the Black Hills encircling the Limestone Plateau and is in turn surrounded by the Dakota Hogback (fig. 1) (Gries 1996). This geomorpological feature varies in width from 0.5 mile (0.8 km) wide near Rapid City to 5 miles (8 km) wide southwest of Custer. This feature consists of sandstones, sandy clay, and shales of the Sundance and Spearfish formations (Froiland 1990). The Red Valley gets its name from the sedimentary rocks that have oxidized iron particles. The vegetation in this region is typically grass with some clumpy pines and

junipers (Radeke and Westin 1963), most likely a product of the dry conditions and high concentrations of salts in the soil (Froiland 1990). The topography of this region is nearly level to strongly rolling with elevations ranging from 3,300 to 3,500 feet (1,006 to 1,067 m).

Precipitation is lower in both the Dakota Hogback and Red Valley features. Therefore, ponderosa pine in these regions is harder to establish and grows more slowly than elsewhere in the Black Hills.

The Limestone Plateau and Minnelusa Foothills (hereas referred to as the limestone plateau) surrounds the Central Crystalline Core of the Black Hills (fig. 1). The main rock component of the plateau is limestone, but sandstone, shale, siltstone, and dolomite are also present (Gries 1996). On the eastern edge, the plateau is a narrow 2 miles (3.2 km) wide band (Froiland 1990) with an elevation of around 4,000 feet (1,219 m) (Radeke and Westin 1963). This eastern side contains steep escarpments that rise up to 800 feet (244 m) above the Central Crystalline Area (Fenneman 1931). Many large springs that are the headwaters for major streams of the Black Hills arise along the foot of the east-facing escarpments (Gries 1996). On the western part of the Limestone Plateau, elevations range from 6,000 to 7,100 feet (1,829 to 2,164 m), and the area can be as wide as 15 miles (24 km) (Froiland 1990). The summit along the western edge of the plateau is considered the main divide for the Black Hills (USDA Forest Service 1996a). West of this divide, the rocks of the plateau are younger and the slopes are gentle. These slopes are covered with extensive ponderosa pine and white spruce (*Picea glauca*) forests and fertile soils. Precipitation is also higher, which makes the western Limestone Plateau a productive area for tree growth.

The Central Crystalline Core of the Black Hills consists of divided ridges and mountains scattered among large valleys. The valleys have canyons that extend out with a variety of igneous and sedimentary rocks such as silica-rich schists, slates, and quartizites in different stages of metamorphosis. The major topographic feature of the core is the great masses of granite and pegmatites (Froiland 1990). Several eroded outcrops, such as Harney Peak, the Needles, Cathedral Spires, Bear Mountain, and Mt. Rushmore, are found in this area (fig. 1). Elevations in the core range from 4,300 to 6,000 feet (1,311 to 1,829 m), with the tallest, Harney Peak, reaching elevations of 7,242 feet (2,207 m). The granitic region is not susceptible to mass soil movement, although soil slumps do occasionally occur on hillsides if soil water content is high (Ensz 1990). In the metamorphic regions, mass soil movement can occur if steep slopes are disturbed. Throughout the Central Core are many rocky, forested slopes and ridges, intermingled in the western portion with small parklike valleys (USDA Forest Service 1996a). The Central Core is one of the most productive areas for ponderosa pine timber in the Black Hills (Boldt and Van Deusen 1974).

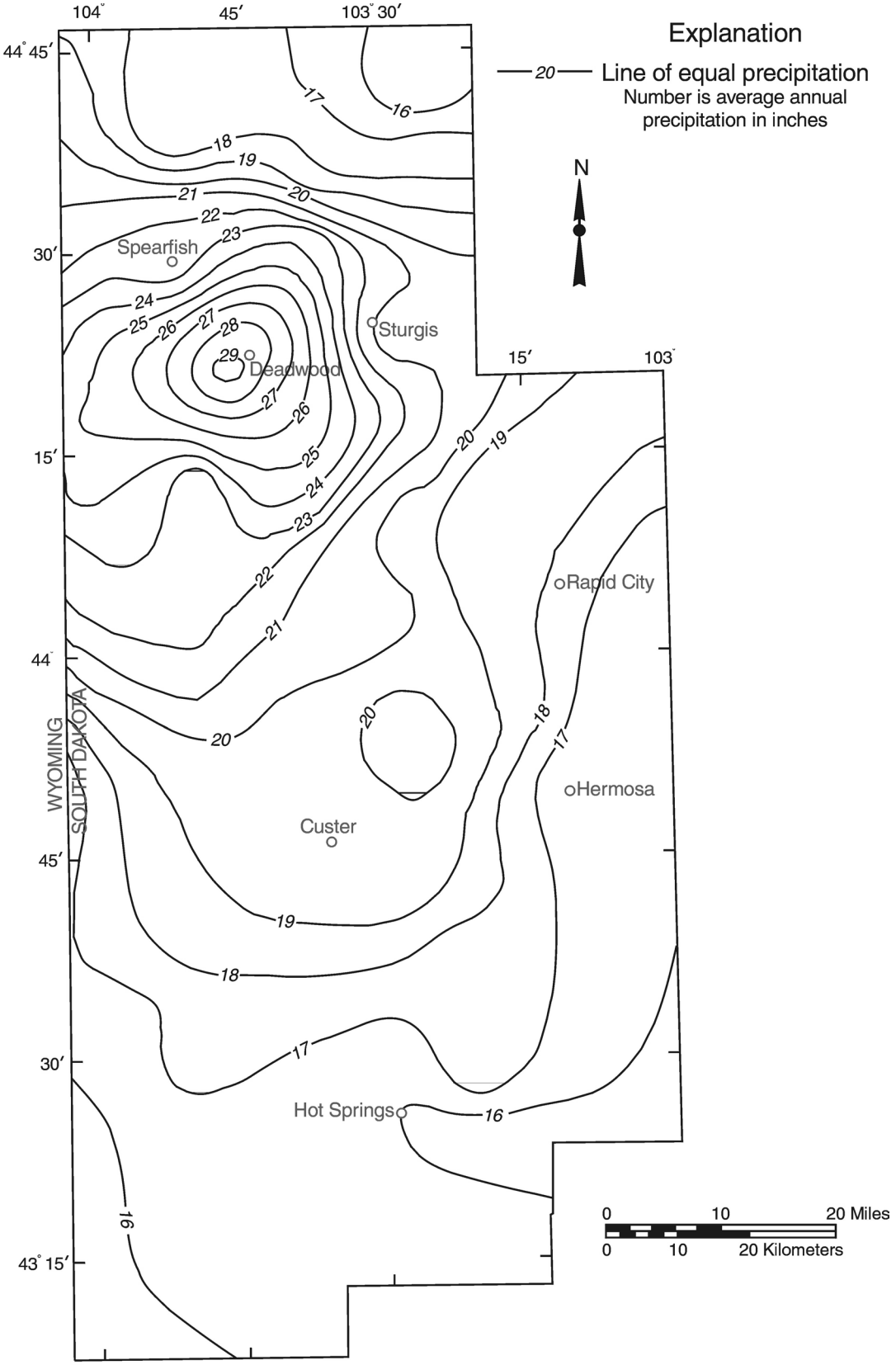
Scattered throughout the northern part of the Black Hills are Tertiary igneous intrusive areas and volcanic features known collectively as the Laccolith Mountains (Fenneman 1931). These intrusive magmas were formed during the uplift of the Black Hills region. The Laccolith Mountains range in diameter from less than a mile to as much as 10 miles (16 km), with the Missouri Butte as the most western intrusion and Bear Butte as the most eastern intrusion. Other prominent intrusions include: Devils Tower, Inyan Kara Mountain, Sundance Mountain, and Terry Peak (fig. 1). Terry Peak is the highest of the intrusions with an elevation of 7,071 feet (2,155 m), while the majority of the other intrusions range between 5,000 to 6,500 feet (1,525 to 1,981 m).

Climate

The climate of the Black Hills differs from the surrounding plains due to the influence of the regional uplift. The Black Hills microclimate is a Continental type, cold in winter and hot in summer (Johnson 1949). The increased elevation results in an orographically induced microclimate that increases precipitation and decreases temperatures at the higher elevations (Driscoll and others 2000). The uplift also moderates the variations in air temperature and lowers the wind velocities compared to the surrounding Great Plains (Froiland 1990).

The precipitation patterns in the Black Hills differ along elevational and latitudal gradients (fig. 2). In general, northern locations and higher elevations receive more precipitation than southern locations and lower elevations. Precipitation patterns are influenced by such factors as wind direction, topography, season, and storm type. In areas upslope of the wind direction, precipitation occurs more frequently (Hjelmfelt and others 1994). The uplift of air due to topography can enhance convective showers and thunderstorms, increasing precipitation at higher elevations at the expense of lower precipitation at lower elevations (Trimarchi 1997).

Average annual precipitation ranges from approximately 29 inches (74 cm) in the northern Black Hills near Lead and Deadwood to about 16 inches (41 cm) in the southern Black Hills near Hot Springs toward the Plains (fig. 2) (Driscoll and others 2000). Within the Black Hills, precipitation averages over 20 inches (51 cm) at the higher elevations.



Base modified from U.S. Geological Survey digital data, 1:100,000 and City Engineer's map, Rapid City, 1991

Figure 2: Isohyetal map of the distribution of average annual precipitation in the South Dakota Black Hills region for water years 1961 to 1990 (map adapted from Driscoll and others 2000).

November through February are the least likely months for precipitation with an average of 12.4 percent of annual precipitation (Driscoll and others 2000). Precipitation is higher in places where upslope flow from the northwest and north enhance precipitation, such as in Lawrence County where 17 percent of the annual precipitation occurs during these months (Driscoll and others 2000). On average, there are two to three snowstorms every year with blizzards occurring on average every 2 to 3 years (Trimarchi 1997).

The Black Hills is subjected to three storm types: Northern Pacific, Rocky Mountain, and the Colorado type. Each storm type influences the amount of moisture received by the area. Northern Pacific storm types bring cold and blustery conditions with small amounts of precipitation. Rocky Mountain storm types also bring cold and blustery conditions with small amounts of precipitation, but move quickly over the area. Colorado type storms are strong systems that move slowly east and northeasterly out of the Rockies and bring heavy amounts of precipitation (Johnson 1949).

The months from April to July have the highest probability of precipitation due to the warmer, moister air from the south combining with the colder, drier air of the north. On average, May and June are the wettest months of the year, with an average of 33 percent of total annual precipitation (Driscoll and others 2000). June and July are prime times for convective thunderstorms, which usually occur in the afternoon and evenings, especially in the central portion of the Black Hills, and typically move eastward (Trimarchi 1997). These storms can be severe with strong, gusty winds, heavy rain, and hail. For example, on July 5 and 6, 1996, a hailstorm carved a 75-mile (120-km) path of destruction in Meade and Butte Counties; hail was baseball sized and winds were reported as high as 111 mph (50 m/s) (Klimowski 1997). Flash floods are also common during these months (Trimarchi 1997). The convective activity diminishes by August, and precipitation from August to November decreases substantially (Driscoll and others 2000).

Mean annual temperature is also influenced by latitude and elevation. Stations in the northern Black Hills are generally cooler than those at similar elevations in the southern Black Hills (Froiland 1990). Mean annual temperatures range from 48.1 ˚F (9 ˚C) at Hot Springs to 37.2 ˚F (2.9 ˚C) at Deerfield. Mean annual high temperatures range from 63 ˚F (17.2 ˚C) at Hot Springs to 52.5 ˚F (11.4 ˚C) at Deerfield (Trimarchi 1997). Mean annual low temperatures range from 35.8 ˚F to 21.9 ˚F (2.1 ˚C to –5.6 ˚C), although the 35.8 value may be biased due to the location of the sensor on a rocky surface (Trimarchi 1997).

Temperatures in the winter are less severe than the typical temperatures found in the surrounding plains due to temperature inversions (Trimarchi 1997). These inversions occur because of shallow, arctic air masses that stretch across the Northern Great Plains and downslope warming of air at night. November through March are the coldest months, with the lowest temperatures occurring in areas where the temperature inversions reach the ground less frequently, or in the highest elevations when inversions are lacking and snow is present (Trimarchi 1997). Mean high temperatures in January range from 29.3 ˚F (–1 to 2 ˚C) in the northern Black Hills to the upper 30s (˚F) (2 to 4 ˚C) in the southern Black Hills. Mean low temperatures in January range from single digits ˚F (–16 to –12 ˚C) in most of the higher locations to the lower teens ˚F at lower elevations (Trimarchi 1997).

Temperatures in the summer are generally cooler as the elevation increases. July is the warmest month in the Black Hills. Mean high temperatures range from the upper 70s (˚F) (24 to 26 ˚C) in the higher elevations to the upper 80s (˚F) (29 to 32 ˚C) on the surrounding plains (Trimarchi 1997). Mean low temperatures range from the upper 40s (˚F) (7 to 10 ˚C) in the higher elevations to the upper 50s (˚F) (13 to 15 ˚C) on the plains.

The growing season in the Black Hills ranges from 154 days at Rapid City to a minimum of 100 days in the higher northern locations (Orr 1975). The average last spring freeze occurs in early to mid May along the perimeter of the Hills and late May to early June in the higher elevations (Trimarchi 1997). The first fall freeze typically occurs in September and is variable due to the elevation.

Wind velocities in the Black Hills are much lower than those found in the surrounding plains. The prevailing wind direction in most of the Black Hills is from the northwest. However, on the southeastern side of the Black Hills, near Hermosa, the prevailing winds are from the north, and on the northwestern side of the Black Hills, near Sundance, the winds are from the southwest (Johnson 1949). Furthermore, the velocity of winds in the foothill areas are more variable than those found in the interior of the Black Hills.

Chinooks commonly occur in the Black Hills. These warm, dry, downslope winds cause rapid warming of the lower elevations in the colder months of the year (Trimarchi 1997). When winds are strong, temperatures can increase 10 to 20 ˚F (6 to 11 ˚C) and then drop when the winds cease. Chinooks are commonly found on the east, northeast, and northern slopes (Johnson 1949).

Soils

The Black Hills National Forest encompasses five counties in South Dakota (Custer, Falls, Lawrence, Meade, and Pennington) and two in Wyoming (Crook and Weston). Soil inventories for each county have been completed by the National Resources Conservation Service (NRCS, previously SCS) over the past 25 years. Unfortunately, the soil associations are not consistently named with the same name across county borders. Furthermore, there are 107 soil series within the seven counties. To describe each of the associations and soil series is beyond the scope of this publication. In general, soils in the Central Crystalline Core are Alfisols with the major soils consisting of Stovho, Trebor, Virkula, Mocmont, rock outcrops, Pactola, and Buska (Bryce and others 1998). Soils found in the Limestone Plateau and Minnelusa Foothills are Alfisols, Mollisols, and Inceptisols. Common soil series in this region include Citadel, Vanocker, Grizzly Buska, Mocmont, Pactola, and Paunsaugunt. The Red Valley and Hogback regions consist of Entisols and Mollisols. Common soil series in these regions include Butche, Canon, Enning, Nevee, Spearfish, Grummit, Tilford, Vale, and Rekop (Bryce and others 1998). Detailed information for each soil series can be found in the NRCS soil survey, and we suggest that the manager utilize the survey specific to the site where the management activity will occur. These surveys have maps at the 1:24000 scale, with soil series boundaries delineated.

Descriptions and variables associated with soil productivity within the Central Crystalline Core and Limestone Plateau were developed by Myers and Van Deusen (1960). Equations for estimating ponderosa pine site index in these areas were based on (1) soil depth to top of the C horizon, (2) slope position (distance up the slope as a percentage of total slope length), (3) slope percent, and (4) aspect. In the Central Crystalline Core area where soil is derived from metamorphic or igneous rocks, all four variables are required. The equation for the Central Crystalline Core is: $Y = 1.64660 - 0.10315*X_1 - 0.01895*X_2 - 0.09042*X_3 + 0.13330*X_4$; ($r^2 = 0.83$). In the Limestone Plateau area where soils are derived from mostly limestone, only soil depth and slope position are needed. The equation for the Limestone Plateau is: $Y = 1.54200 - 0.11819*X_3 + 0.20821*X_4$; ($r^2 = 0.78$). For each equation, Y = Logarithm of site index, X_1 = Grade or percent of slope, as a decimal, X_2 = Aspect as the sine of the azimuth clockwise from southeast, plus one, X_3 = Distance of plot center up the slope as a percentage of total slope length, expressed as a decimal, and X_4 = Logarithm of soil depth in inches to top of C horizon (Myers and Van Deusen 1960).

Vegetation

The Black Hills is a refuge for plant species that occur in four of the North American biomes: Cordilleran Forest, Grassland, Eastern Deciduous Forest, and Northern Coniferous Forest (Marriott and others 1999). This mixture of vegetation is a result of the varied topography, geology, and climates found within the Black Hills.

There have been several surveys of Black Hills vegetation since Europeans first visited the region. Each survey described the vegetation with different classification schemes. Graves (1899) inventoried timber resources and forest conditions, and classified stands by age class. McIntosh (1930, 1931) described vegetation types based on successional status, and listed plant species for various habitats. Thilenius (1972) surveyed vegetation that occurred in deer habitats and classified them into habitat units using cluster analysis. Hoffman and Alexander (1987) performed one of the most extensive classifications of habitat types for the Black Hills, in which habitat types were defined based upon quantitative data and Daubenmire methodology[1]. Habitat type refers to the potential climax natural vegetation. Johnston (1987) reported plant associations for the Rocky Mountain Region (Region 2), which includes the Black Hills National Forest. Within this survey, Johnston relates classifications from other surveys (for example, Thilenius habitat units and Hoffman and Alexander habitat types) to his plant associations. Recently, The Nature Conservancy completed the Black Hills Community Inventory report, which classified and described vegetation within the region using the U.S. National Vegetation Classification System (Marriott and others 1999).

Relationships for the information of the three most recent vegetative descriptions of ponderosa pine habitats (Hoffman and Alexander 1987; Johnston 1987; Marriott and others 1999) are shown in table 1. Hoffman and Alexander listed only eight ponderosa

[1] Plant association is a kind of plant community represented by stands occurring in places where environments are so closely similar that there is a high degree of floristic uniformity in all layers (Daubenmire 1968). Not only is vegetational uniformity important in the classification, but also the abiotic (landform and soils) components must be similar (Johnston 1987). A habitat type is a collective term for all parts of the land surface supporting or capable of supporting the same kind of climax plant association (Daubenmire 1968). Plant association should be used for the climax plant community (the taxonomic unit), and habitat type should be used for the land unit (map unit) to which each plant association corresponds (Johnston 1987).

Table 1: Cross-reference of different habitat vegetative surveys of ponderosa pine habitats in the Black Hills.

Habitat type Hoffman and Alexander (1987)	Plant association code Johnston (1987)	U.S. National Vegetation Classification System (USNVC)[a] Marriott and others (1999)
Pinus ponderosa/Arctostaphylos uva-ursi	Pipo/Arad	Pinus ponderosa/Arctostaphylos uva-ursi Woodland (CEGL000844)
Pinus ponderosa/Carex heliophila	Pipo/Cahel	Pinus ponderosa/ Carex inops spp.heliophila Woodland (CEGL000849)
Pinus ponderosa/Juniperus scopulorum	Pipo/Bocu	Pinus ponderosa/Juniperus scopulorum Woodland (CEGL000861)
Pinus ponderosa/Juniperus communis	Pipo/Juco; Pipo/Juco-Syal	Pinus ponderosa/Juniperus communis Woodland (CEGL000859)
Pinus ponderosa/ Symphoricarpos albus	Pipo/Syal	Pinus ponderosa/ Symphoricarpos albus Forest (CEGL000203)
Pinus ponderosa/ Symphoricarpos albus Phase: Balsamorhiza sagittata	Pipo/Spbe	N/A
Pinus ponderosa/ Symphoricarpos albus Phase: Oryzopsis asperifolia	Pipo/Syal phase 2	Pinus ponderosa/Oryzopsis asperifolia Woodland (CEGL002123)
Pinus ponderosa/Physocarpus monogynus	Pipo/Phmo	Pinus ponderosa/Physocarpus monogynus Forest (CEGL000190)
Pinus ponderosa/Prunus virginiana	Pipo/Pavi	Pinus ponderosa/Prunus virginiana Forest (CEGL000192)
Pinus ponderosa/Quercus macrocarpa	Pipo/Quma	Pinus ponderosa/Quercus macrocarpa Woodland (CEGL000873)
Not discussed	Pipo/Rosp	Pinus ponderosa/ Pseudoroegneria spicata [b] Woodland (CEGL000865)
Not discussed	Pipo/Scsc-Elsm	Pinus ponderosa/Schizachyrium scoparium Woodland (CEGL000201)
		Pinus ponderosa/Pascopyrum smithii [c] Woodland (CEGL000188)
Not discussed	Pipo/Pavi phase 4	Pinus ponderosa/Mahonia repens [d] Forest (CEGL000187)
Not discussed	Not discussed	Pinus ponderosa Limestone Cliff Sparse Vegetation (CEGL002055)
Not discussed	Not discussed	Pinus ponderosa Scree Woodland (CEGLK000878)

[a] Global code used in the Biological and Conservation Database maintained by The Nature Conservancy and its Natural Heritage Program Partners.
[b] Also known as Agropyron spicatum.
[c] Also known as Agropyron smithii.
[d] Also known as Berberis repens.

pine habitat types, while Marriott and others listed 15 different ponderosa pine community types. Some of these 15 community types corresponded to Johnston's plant association descriptions. Recently, the Black Hills National Forest adopted the use of the U.S. National Vegetation Classification System used by The Nature Conservancy (Marriott and others 1999). Our descriptions in the following section will refer to the Hoffman and Alexander (1987) classification unless otherwise noted.

Ponderosa pine (*Pinus ponderosa*) series

Ponderosa pine is the most dominant tree in the Black Hills. It occurs at all elevations, on all soil types, and on all aspects. Ponderosa pine is considered to be the climax species over much of the Black Hills due to fire disturbance and insect outbreaks.

Many of the ponderosa pine vegetation habitat types at lower elevations can be classified as Dry Coniferous Forest and Woodlands (Marriott and others 1999). The ponderosa pine/bearberry (*Pinus ponderosa/Arctostaphylos uva-ursi*) habitat type (fig. 3) is widespread in the Central Core region (fig. 1) in areas of granite outcrops and calcareous soils (Hoffman and Alexander 1987; Marriott and others 1999). This habitat type occurs at elevations from 5,080 to 6,700 feet (1,548 to 2,042 m) but is restricted to the more xeric sites at higher elevations (Marriott and others 1999). Soil textures range from sandy loam to clay loam (Hoffman and Alexander 1987), and soil depth is moderately deep to lithic and well drained (Johnston 1987). Soil pH ranges from 4.7 to 6.7, with organic matter ranging from 2 to 10.3 percent (Hoffman and Alexander 1987). Understory species associated with this habitat type include: prickly rose (*Rosa acicularis*), white coralberry (*Symphoricarpos albus*), rough-leaved ricegrass (*Oryzopsis asperifolia*), yarrow (*Achillea millefolium*), wild strawberry (*Fragaria virginiana*), cream peavine (*Lathyrus ochroleucus*), and wild spirea (*Spiraea betulifolia*) (Hoffman and Alexander 1987; Johnston 1987).

The ponderosa pine/sun sedge (*Pinus ponderosa/Carex heliophila*) habitat type (fig. 4) is most dominant at lower elevations along the foothills on borders and hogback ridges (fig. 1) in the plains (Johnston 1987; Marriott and others 1999), although it can be found at higher elevations (Marriott and others 1999). This habitat type occurs at elevations from 4,500 to 5,170 feet (1,372 to 1,576 m) (Hoffman and Alexander 1987; Johnston 1987). Soil texture ranges from sandy loam to loam with organic matter ranging from 1.5 to 4.7 percent (Hoffman and Alexander 1987). Reported values for pH differ, ranging from 4.8 to 5.8 (Hoffman and Alexander 1987) or 5.8 to 6.9 (Johnston 1987). Graminoids comprise 67 to 90 percent of the total

Figure 3: Ponderosa pine/bearberry (*Pinus ponderosa/Arctostaphylos uva-ursi*) habitat type on the Black Hills Experimental Forest. Note the complete development of the understory.

Figure 4: Ponderosa pine/sun sedge (*Pinus ponderosa/ Carex heliophila*) habitat type in the southwestern Black Hills. Note the abundance of graminoids covering the forest floor.

undergrowth coverage, with the most important being sun sedge, poverty oatgrass (*Danthonia spicata*), and Kentucky bluegrass (*Poa pratensis*) (Hoffman and Alexander 1987). In some areas, bur oak (*Quercus macrocarpa*) can be found in the understory.

Although not discussed by Hoffman and Alexander (1987), the ponderosa pine/little bluestem (*Pinus ponderosa/Andropogon scopanis*) and ponderosa pine/ western wheatgrass (*Pinus ponderosa/Agropyron smithii*) habitat types have been described by Johnston (1987), Marriott and others (1999), and Thilenius (1972). These habitat types dominate the lower elevations of the foothills and Hogback Rim in the southwestern part of the Black Hills (fig. 1). Elevations range from 4,800 to 5,500 feet (1,463 to 1,676 m) (Johnston 1987; Thilenius 1972). Soils are often deep and derived from limestone, with pH ranging from 7.2 to 8.0 (Johnston 1987; Thilenius 1972). Common understory species include: Rocky Mountain juniper (*Juniperus scopulorum*), woods rose (*Rosa woodsii*), and white coralberry (Thilenius 1972). Herbaceous species such as star lily (*Leucocrinum montanum*) and leafy phlox (*Phlox alyssifolia*) indicate the affinity to the prairie herb stratum (Thilenius 1972).

Located in the outer Hogback Rim and Red Valley on the dry southern parts of the Black Hills (fig. 1) is the ponderosa pine/Rocky Mountain juniper (*Pinus ponderosa/Juniperus scopulorum*) habitat type (fig. 5) (Hoffman and Alexander 1987; Marriott and others 1999). This habitat type is usually found on steep, rocky slopes on sandy loam soils at an elevation of about 3,900 feet (1,200 m) (Hoffman and Alexander 1987; Johnston 1987). Soil pH is around 7.3 with organic matter content approximately 6.9 percent (Hoffman and Alexander 1987). Understory growth is poorly defined and unevenly dispersed, and includes species such as sideoats grama (*Bouteloua curtipendula*), littleseed ricegrass (*Oryzopsis micrantha*), pasqueflower (*Anemone patens*), fringed sagewort (*Artemisia frigida*), and bluebell (*Campanula rotundifolia*) (Hoffman and Alexander 1987).

Many of the ponderosa pine vegetation habitat types at higher elevations and mesic sites at lower elevations can be classified as Mesic Coniferous Forest and Woodlands (Marriott and others 1999). The ponderosa pine/ common juniper (*Pinus ponderosa/Juniperus communis*) habitat type (fig. 6) is widely distributed on the Limestone Plateau in the northwestern and western part of the Black Hills (fig.1) at higher elevations on cool, moist sites (Hoffman and Alexander 1987; Johnston 1987; Thilenius 1972). Elevations range from 5,670 to 6,780 feet (1,384 to 1,989 m). Soils are typically derived from limestone, but the habitat type has also been found on soils derived from igneous rock

Figure 5: Ponderosa pine/Rocky Mountain juniper (*Pinus ponderosa/Juniperus scopulorum*) habitat type in the southern Black Hills.

Figure 6: Ponderosa pine/common juniper (*Pinus ponderosa/Juniperus communis*) habitat type.

(Hoffman and Alexander 1987). Soil texture has been characterized as sandy loam to clay loam with pH ranging from 5.1 to 6.5 and organic matter ranging from 4.6 to 9.7 percent (Hoffman and Alexander 1987). Vegetation in this habitat type is diverse and even includes an occasional paper birch (*Betula papyrifera*) or white spruce in the overstory. Vegetation in the understory includes various shrubs and herbaceous species. The shrub layer is the most important undergrowth lifeform in this habitat type (Hoffman and Alexander 1987), with common juniper (*Juniperus communis*) as the most prevalent shrub reaching heights up to 3 feet (0.9 m) (Thilenius 1972). Other shrubs in the understory include bearberry, Oregon grape (*Berberis repens*), prickly rose, wild spirea, and white coralberry. Herbaceous species include smooth brome (*Bromus inermis*), yarrow, wild strawberry, and silvery lupine (*Lupinus argenteus*) (Hoffman and Alexander 1987). This habitat type has an understory similar to ponderosa pine/bearberry but is distinguished by the presence of common juniper, Oregon grape, and silvery lupine and the absence of cream peavine and rough-leaved ricegrass.

The most common ponderosa pine dominated habitat type in the Black Hills is ponderosa pine/white coralberry (*Pinus ponderosa/Symphoricarpos albus*)

(fig. 7) (Hoffman and Alexander 1987; Johnston 1987; Thilenius 1972). This habitat type is typically found on moderately steep slopes on southern aspects in the northern Black Hills, on northern aspects in the southern Black Hills, and along stream bottoms throughout the area (USDA Forest Service and others 1982). Elevations range from approximately 3,700 to 6,100 feet (1,127 to 1,860 m) on sandy loam to silty loam soils. Soil pH ranges from 5.1 to 7.0 with organic matter content 3.5 to 16.6 percent (Hoffman and Alexander 1987). Aspen (*Populus tremuloides*), paper birch, and bur oak are occasional components of the overstory (Thilenius 1972). The understory is dominated by the open growing low shrub, white coralberry, but other important shrubs include western serviceberry (*Amelanchier alnifolia*), Woods rose, common juniper, and russet buffaloberry (*Shepherdia canadensis*) (Hoffman and Alexander 1987; Thilenius 1972). The herbaceous layer is highly diverse with ricegrass (*Oryzopsis* spp.), yarrow, pasqueflower, pussytoes (*Antennaria* spp.), arrowleaf balsamroot (*Balsamorhiza sagittata*), bluebell, timber oatgrass (*Danthonia intermedia*), low northern sedge (*Carex concinna*), and bearberry. This habitat type is quite easily identified where past management activities have left a variety of size classes and gaps in the overstory, which favors understory development of these species. The habitat type ponderosa pine/white coralberry has two recognized phases in the Black Hills. The arrowleaf balsamroot phase is restricted to the western edge of the Black Hills and is separated based on its codominance with white coralberry in the understory (Hoffman and Alexander 1987). The rough-leaved ricegrass phase is usually found in the Central Core region on more acidic, sandy loam soils (Hoffman and Alexander 1987; Johnston 1987). Rough-leaved ricegrass is prominent along with white coralberry and bearberry.

The habitat type ponderosa pine/ninebark (*Pinus ponderosa/Physocarpus monogynus*) (fig. 8) is found scattered throughout the central and southern Black Hills on north to northwest facing slopes at elevations ranging from 5,140 to 5,700 feet (1,567 to 1,737 m) (Hoffman and Alexander 1987; Marriott and others 1999). Soil texture is typically loamy with pH ranging from 6.5 to 7.1 and organic matter content 4.5 to 11.3 percent (Hoffman and Alexander 1987). Vegetation in the understory consists of several species including ninebark (*Physocarpus monogynus*), chokecherry (*Prunus virginiana*), prickly rose, white coralberry, slender wheatgrass (*Agropyron caninum*), pasqueflower (*Anemone patens*), northern bedstraw (*Galium boreale*), and mosses and lichens. Some stands are ecotonal between ponderosa pine dominated forests and true mountain mahogany (*Cercocarpus montanus*) dominated shrub-steppe. If a fire occurs in these stands, a stage of true mountain mahogany will occur and will

Figure 7: Ponderosa pine/white coralberry (*Pinus ponderosa/ Symphoricarpos albus*) habitat type. This habitat type is the most common ponderosa pine dominated habitat in the Black Hills.

Figure 8: Ponderosa pine/ninebark (*Pinus ponderosa/Physocarpus monogynus*) habitat type in the southern and southwestern Black Hills.

be eventually shaded out by ponderosa pine (Hoffman and Alexander 1987).

Although only discussed briefly by Hoffman and Alexander (1987), the ponderosa pine/chokecherry (*Pinus ponderosa/Prunus virginiana*) habitat type has been described by Johnston (1987), Marriott and others (1999) and Thilenius (1972). This habitat type is scattered throughout the central and southern Black Hills, but limited to a few locations in the northern Black Hills. Elevations range from 5,125 to 5,440 feet (1,562 to 1,658 m). The habitat type is found on calcareous or noncalcareous gravelly silt loam to silty soil with pH ranging from 6.0 to 9.0 (Johnston 1987). The understory vegetation includes chokecherry and western serviceberry (Hoffman and Alexander 1987). Other important understory plants include Oregon grape, wild spirea, and spreading dogbane (*Apocynum androsaemifolium*). This habitat type might be another phase of the ponderosa pine/white coralberry habitat type (Hoffman and Alexander 1987).

The ponderosa pine/bur oak (*Pinus ponderosa/Quercus macrocarpa*) habitat type (fig. 9) is found in the northern Black Hills, but is most common in the Bear Lodge Mountain area (fig. 1) (Hoffman and Alexander 1987). It is found at elevations ranging from 4,120 to 5,300 feet (1,256 to 1,615 m) on calcareous soils and soils derived from igneous rocks. Soil texture is sandy loam to clay loam with pH ranging from 5.3 to 6.9 and organic matter of 4.6 to 9.5 percent. The most important shrub in this habitat is bur oak, but other shrubs observed include western serviceberry, Oregon grape, chokecherry, and wild spirea (Hoffman and Alexander 1987). Both graminoids such as dryspike sedge (*Carex foenea*) and rough-leaved ricegrass, as well as the forbs Lindley's aster (*Aster ciliolatus*), northern bedstraw, silvery lupine, and starry false Solomon's seal (*Smilacina stellata*) are found in the understory (Hoffman and Alexander 1987).

Aspen (*Populus tremuloides*) series

Severson and Thilenius (1976) analyzed aspen in the Black Hills using a synecological classification approach, which produced nine different aspen vegetation associations. Marriott and other (1999) listed four different aspen community types. Hoffman and Alexander (1987) characterized aspen habitats based on quantitative data and Daubenmire methodology, and classified only one aspen habitat type, with two phases. Hoffman and Alexander's associations are included here for consistency with the ponderosa pine habitat types already reported.

The aspen/beaked hazelnut (*Populus tremuloides/Corylus cornuta*) habitat type (fig. 10) is typically found at higher elevations in the Bear Lodge Mountains and in the northern limestone plateau of the Black Hills (fig. 1) (Hoffman and Alexander 1987). This habitat type occurs at elevations from 4,000 to 6,240 feet (1,219 to 1902 m) (Hoffman and Alexander 1987). Soil textures range from sandy loam to silty loam with soil pH ranging from 5.5 to 6.2. Organic matter ranges from 2.2 to 8.7 percent. Both beaked hazelnut and paper birch are tree species found in the understory as undergrowth. Stands in the central Black Hills will frequently have bur oak in the understory as well. This

Figure 9: Ponderosa pine/bur oak (*Pinus ponderosa/Quercus macrocarpa*) habitat type found in the northern Black Hills and the Bear Lodge Mountains.

Figure 10: Aspen/beaked hazelnut (*Populus tremuloides/ Corylus cornuta*) habitat type.

species rich habitat type has several shrubs and herbaceous species. Frequent shrubs found in the understory include: western serviceberry, Oregon grape, wild honeysuckle (*Lonicera dioica*), chokecherry, pink shinleaf (*Pyrola asarifolia*), prickly rose, red raspberry (*Rubus idaeus*), wild spirea, and white coralberry. Frequent herbaceous species found in the understory include: baneberry (*Actaea rubra*), wild sarsaparilla (*Aralia nudicaulis*), Lindley's aster, wild strawberry, sweet-scented bedstraw (*Galium triflorum*), cream peavine, wild lily-of-the-valley (*Maianthemum canadense*), sweetroot (*Osmorhiza* spp.), bracken fern (*Pteridium aquilinum*), Maryland sanicle (*Sanicula marilandica*), starry false Solomon's seal, purple meadowrue (*Thalictrum dasycarpum*), Canada violet (*Viola canadensis*), and rough-leaved ricegrass. The

habitat type aspen/beaked hazelnut has two recognized phases in the Black Hills: bracken fern and wild sarsaparilla.

The bracken fern phase (fig. 11) is distinguished by several features. First, the abundance of bracken fern under the beaked hazelnut is at least 23 to 33 percent coverage and the frequency is greater than 50 percent. Second, some stands of aspen/bracken fern are over 100 years old, with the bracken fern still growing vigorously and remaining dominant. Third, the soils in this phase are distinct from those of the parent habitat type as well as the wild sarsaparilla phase; more exchangeable Ca and Mg are found in the upper 4 inches (10 cm) of the soil, indicating a higher cation-exchange capacity and more organic matter (Hoffman and Alexander 1987).

The wild sarsaparilla phase is distinguished by the dominance of wild sarsaparilla in the understory. Other prominent understory species include: Lindley's aster, spurred gentian (*Halenia deflexa*), Maryland sanicle, and poison ivy (*Toxicodendron rydbergii*). Grasses, such as Kentucky bluegrass and timothy (*Phleum pratense*), are also abundant in the understory, and tend to increase with grazing pressure (Hoffman and Alexander 1987).

Bur oak (*Quercus macrocarpa*) series

Bur oak communites occupy the upland areas of the Black Hills. Marriott and others (1999) recognized three bur oak community types, while Hoffman and Alexander (1987) reported only two. Hoffman and Alexander's associations are included here for consistency with the ponderosa pine habitat types already reported.

The bur oak/ironwood (*Quercus macrocarpa*/*Ostrya virginiana*) habitat type is typically found in the drier and lower elevations of the northern Black Hills (Hoffman and Alexander 1987). Stands can be found around elevations ranging from 3,500 to 4,200 feet (1067 to 1280 m). Soil textures range from sandy loam to clay loam with soil pH ranging from 5.6 to 7.4. Organic matter ranges from 3.6 to 8.5 percent. Vegetation in this habitat type is distinguished with abundant ironwood (*Ostrya virginiana*) in the shrub layer. Other tree species such as green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), paper birch, and ponderosa pine occur in the understory; however, only ponderosa pine persists beyond the seedling stage. Other understory species include: Oregon grape, chokecherry, currant (*Ribes* spp.), western snowberry (*Symphoricarpos occidentalis*), dryspike sedge, fairybells (*Disporum trachycarpum*), starry false Solomon's seal, and mountain cliff fern (*Woodsia scopulina*).

The bur oak/western snowberry (*Quercus macrocarpa/Symphoricarpos occidentalis*) habitat type (fig. 12) occurs along the northern periphery of the

Figure 11: Aspen/beaked hazelnut (*Populus tremuloides/Corylus cornuta*) habitat type bracken fern (*Pteridium aquilinum*) phase found in the Bear Lodge Mountains. Bracken ferns are abundant in the understory.

Figure 12: Bur oak/western snowberry (*Quercus macrocarpa/ Symphoricarpos occidentalis*) habitat type with chokecherry (*Prunus virginiana*) in understory.

Black Hills with the best-developed stands occurring in the foothills between Sundance, WY, and Whitewood, SD (fig. 1) (Hoffman and Alexander 1987). This habitat type is typically drier than the bur oak/ironwood habitat type. Most of these stands are heavily grazed, but Hoffman and Alexander (1987) did report on one intact stand located around 4,200 feet (1,280 m) in elevation. Soil texture was loamy and pH was 6.0 with 7.2 percent organic matter. Vegetation in this habitat type is distinguished with abundant western snowberry in the understory. Other shrubs found in this habitat type include: western snowberry, Oregon grape, chokecherry, red raspberry, and poison ivy. Important herbaceous species include dryspike sedge, Kentucky bluegrass, and bedstraw (*Gallium* spp.).

White spruce (*Picea glauca*) series

The Black Hills is home to the furthest western white spruce (*Picea glauca*) population in the United States. White spruce forests constitute the high-elevation coniferous forests of the Black Hills (fig.13) where temperatures are cooler and precipitation is greatest (fig. 2). These forests grow on soils derived from both igneous and limestone parent material. The common seral species in these forests include: ponderosa pine, aspen, and paper birch (Hoffman and Alexander 1987). Marriott and others (1999) recognized three white spruce community types, while Hoffman and Alexander (1987) reported only two. Hoffman and Alexander's associations are included here for consistency with the ponderosa pine habitat types already reported.

Figure 13: White spruce (*Picea glauca*) forest in the northern Black Hills.