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A Century of Change in the Black Hills and Riparian Ecosystems

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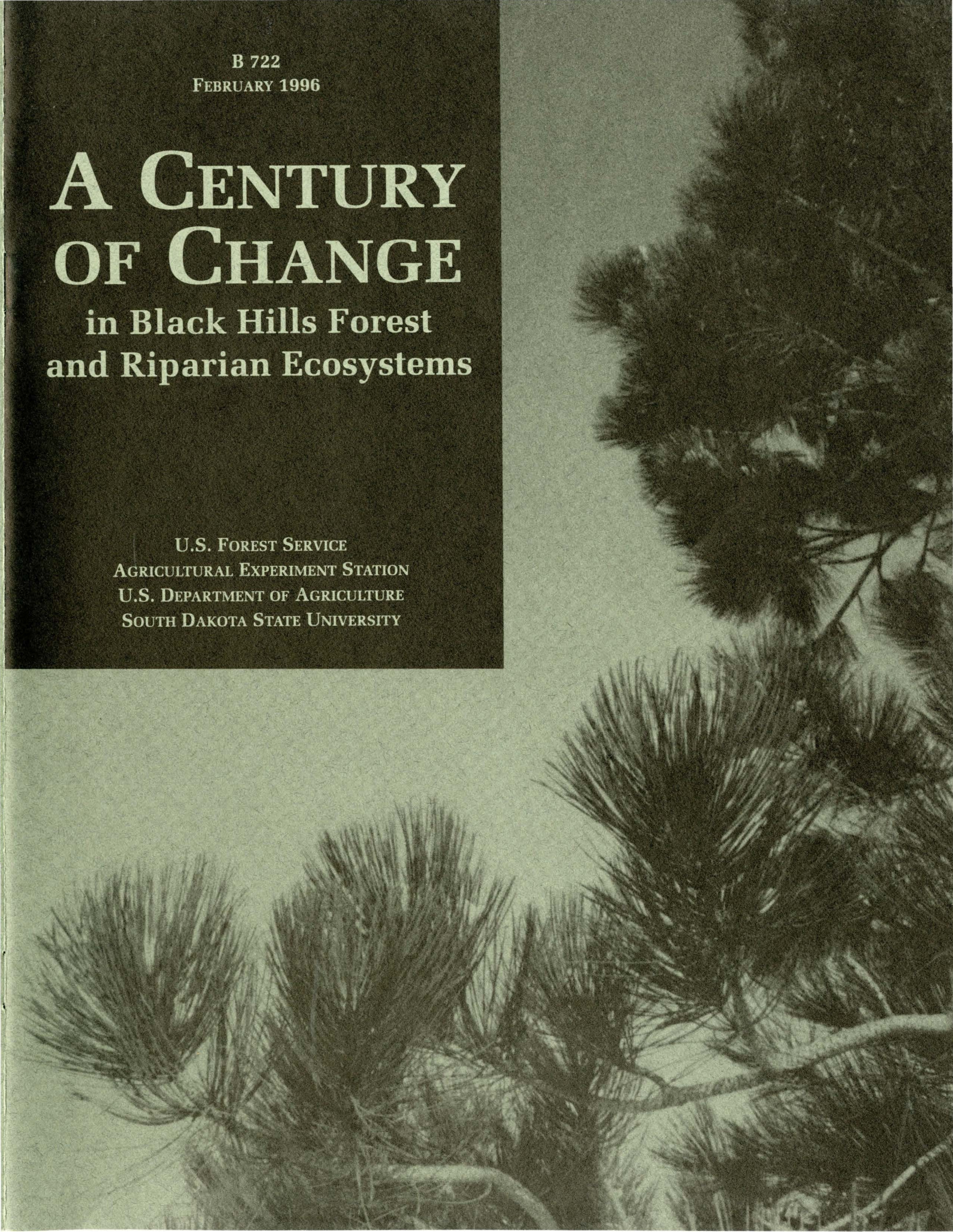
U.S. FOREST SERVICE
AGRICULTURAL EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE
SOUTH DAKOTA STATE UNIVERSITY



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The U.S. Forest Service has recently embraced the type of land management termed "ecosystem management." Goals are set and then met by integrating ecosystem principles into management planning and implementation (Overbay 1992).

Managing ecosystems for the present and future requires that we understand the ecology of the past. An analysis of changes in ecosystems, for example, is the recent work on disturbed forest communities of the Inland West (Covington *et al.* 1994). The ponderosa pine (*Pinus ponderosa*) ecosystem evolved in dynamic equilibrium with recurrent disturbances, especially fire, insects, and short- and long-term climatic cycles.

However, people have not always recognized the importance of these processes.

Early in this century, society viewed forest resources in a utilitarian context and considered "preventable" tree losses to be forfeited economic opportunities. Consequently, an objective of the early U.S. Forest Service was to increase timber productivity in susceptible ecosystems, primarily through fire suppression and silviculture techniques.

This method of forest management achieved its goal of increasing tree survival to merchantable size. Achievement came with a price, however.

Throughout the Inland West, conifer population explosions are commonplace (Covington *et al.* 1994). As a result, forested landscapes are vulnerable to large-scale insect epidemics and conflagrations. The recent insect epidemics in eastern Oregon and Washington forests, the Yellowstone fires of 1988, and the tragic western fires of 1994 are examples.

Thousands of forested acres have succumbed to unnaturally large disruptions. Tree mortality of this magnitude may indicate that management has altered the dynamic equilibrium of these ecosystems.

Managers and scientists now better understand fundamental ecosystem processes. Recognizing the processes and "natural variability" of an ecosystem (Swanson *et al.* 1994) is critical in creating and carrying out a management plan. Recent research has given us a clearer understanding of ecosystem dynamics in the East Slope forests of Oregon and Washington prior to Euro-American settlement (Everett *et al.* 1994). Temperate coniferous forests, grasslands, and riparian communities all evolved under the influence of recurrent physical and biotic disturbances whose frequency and intensity may be predictable if we have enough historical information. Given this information, we may have options to conserve the integrity of an ecosystem and limit undesirable events.

Conversion of an ecosystem back to natural or historical conditions may not be a societal objective. But managing within the constraints of an ecosystem can be crucial to long-term sustained health. Several forest scientists, including Covington and Moore (1994), Covington *et al.* (1994), and Bonnicksen (1993) have championed a process of forest restoration ecology. These researchers realize that many forest ecosystems may require corrective actions to

retain desirable characteristics such as late succession, commercial productivity, and forest, prairie, or savanna landscapes. In the absence of management, large-scale disturbance may be inevitable.

This paper summarizes changes in forests, riparian areas, and wildlife of the Black Hills since Euro-American settlement in the 1870s. Specific objectives were to:

1) Document conditions of forests, riparian ecosystems, and associated wildlife prior to Euro-American settlement in the 1870s through historical references; and,

2) Compare historical and current conditions to ascertain ecosystem shifts incurred during the past 120 years.

Hopefully, this work will provide land managers with an ecological perspective for resource management activities and will spur research to more completely quantify natural ecological conditions.

FINDINGS

Reports from early expeditions to the Black Hills such as Warren (Hayden 1862), Custer (Ludlow 1875), and Dodge (1965) were the principal sources for historical resource information.

These sources tend to be impressionistic and subjective. However, their descriptions of the Black Hills prior to significant modification by Euro-Americans were relatively consistent.

FOREST ECOSYSTEMS

PONDEROSA PINES

The Black Hills are an isolated montane region in western South Dakota and northeastern Wyoming surrounded by prairie ecosystems (Fig 1). The Lakota Nation referred to the area as "paha sapa," meaning literally "hills that are black." The conifer forests appear dark when viewed from almost any direction on the adjacent plains (Froiland 1990).

Economic potential was the focus of forest resource descriptions by early visitors to the Black Hills. They described a landscape dominated by extensive ponderosa pine forest. Other tree species were minor in comparison (Donaldson 1914, Dodge 1965, McLaird and Turchen 1974).

Generally, they referred to the ponderosa pine forests in glowing terms; although most authors qualified these impressions by noting recurrent signs of widespread forest fires, small tree size, and unrealized commercial possibilities (Donaldson 1914; Dodge 1965). All of these documents provide a general view that the ponderosa pine forests were widespread but that disturbances, especially from fire, limited the number and extent of coniferous trees across the landscape.

The first extensive quantification of forest resources was a report to Congress entitled "Black Hills Forest Reserve, South Dakota and Wyoming" (Graves 1899). This report not only described forest conditions at the end of the nineteenth century but also provided insight for the period leading up to initial Euro-American settlement in 1874. Attached to the report were landscape-level maps of merchantable ponderosa pine volumes. According to Graves, "14 inches in the stump is about the minimum limit of merchantable timber ...." These maps display merchantable timber volumes existing between 1874 and 1894 for most of the Black Hills. They also appear to delineate the extensive timber harvests on the eastern portion of the Black Hills that took place between 1874 and the mid 1890s as an overlay of pre Euro-American conditions.

Graves (1899) described the ponderosa pine forest as being composed of all age classes. Large, old ponderosa pines, 250 to 300 years old, were grouped into three classes of "old trees" or "original forest" with different developmental and structural characteristics.

Fig 1. Black Hills vicinity.

Black Hills National Forest

Stands of the first class were on productive soils that, in Graves' opinion, had been nearly devoid of fires, insects, diseases, and other mortality (Graves 1899). These stands undoubtedly experienced disturbance but were still able to develop relatively high volumes. The trees averaged 20 inches in diameter and 80 feet in height. Graves estimated average density, which we interpret to be canopy cover based on his description, to be 80%. He referred to trees of this class as crowded stands of timber and, based on location descriptions, depicted them on the accompanying maps as the category 5,000-10,000 board measure (board feet) per acre.

The two largest stands, about 15,000 to 20,000 acres, were west of Spearfish Canyon. The remaining patches, primarily in the northwestern and eastern portions of the Black Hills, ranged from about 80 to 10,000 acres in size, averaging approximately 1,000 acres. In total, these stands comprised about 59,000 acres of the land base in the South Dakota portion of the Hills and made up the smallest amount of the "original forest" in terms of areal extent.

The second class was the most abundant type of "original forest" ranging over most of the Black Hills (Graves 1899). Diameters were similar to the first class, but the trees averaged 65 to 70 feet in height. These areas were not as dense as the first class due to the influences of fire and other mortality. Average density (canopy cover) was 50%.

The third class was restricted to ridges and steep slopes. Trees in these stands were shorter (average of 60 feet) and smaller (14 to 17 inches in diameter) than the previous classes, possibly due to poorer site conditions.

Graves' (1899) "original forest" discussion probably was designed to give Congress a sense of the commercial timber potential. But we can interpret this same information to develop a concept of late-succession landscapes in the Black Hills.

The second and third classes had low densities of old trees typical of other ponderosa pine ecosystems (Weaver 1961, Arno 1988, Covington and Moore 1994, Covington *et al.* 1994, Everett *et al.* 1994). If we use southwestern ponderosa pine as a model (Covington and Moore 1994), second and third classes may have consisted of individuals or groups of old trees intermixed with pine of all ages. Spacing between tree clumps was likely variable with a wide array of stand sizes. Although the pine population structure was diverse, synchronous reproduction may have produced clumps across the landscape with similar age-class distributions.

The lowest volume levels (less than 2,000 board measure feet per acre) depicted on the Graves (1899) maps comprised about 75% of the Black Hills landscape. These volume estimates lend insight into stand densities. His 2,000 board feet per acre volume equates to about five 20-inch dbh (diameter at breast height) trees per acre. In contrast, 11 20-inch dbh trees contain about 5,000 board feet per acre, the highest volumes mapped.

Graves (1899) also noted that the forest appeared "irregular and broken." From this description it appears that the natural pattern of ponderosa pine across much of the forest compares favorably with other conspecific ecosystems (Covington and Moore 1994, Covington *et al.* 1994).

Graves (1899) also described the abundance and distribution of age classes not ready for harvest. Trees that were 150 to 160 years old were scattered throughout the forest. Considerable numbers of young poles, 40 to 50 years old, occurred in the northern and southern Hills. Trees in the 100-year-old age class apparently were abundant. A "great belt," composed almost entirely of these "second growth" trees, covered an area from the mouth of Bear Butte Canyon west to Spearfish Canyon and down the western Limestone Plateau (Fig 1) to the headwaters of Hell and Gillette canyons. Much of the northeastern portion of this belt had been harvested by 1899, but the western Limestone Plateau remained essentially untouched.

Progulske (1974) provided photographic evidence supporting the premise that Black Hills forests

have undergone considerable change. In his study, sites photographed during the Custer Expedition of 1874 were relocated and photographed in 1974. Throughout the pictorial series, the 1974 ponderosa pine forest appears to be much denser and cover more of the landscape (Figs 2 and 3). The author attributed these shifts to a century of fire suppression. Similar trends in fire-dominated ecosystems have been photo-documented elsewhere in the West (Gruell 1983, USDA Forest Service 1993).

Ponderosa pine mortality in the pre-Euro-American forest (Figs 2 and 3) was conspicuous and noteworthy (Ludlow 1875, Graves 1899, Donaldson 1914, Dodge 1965). The most common causes of mortality appear to have been fire and mountain pine beetles (*Dendroctonus ponderosae*). Early explorers frequently noted evidence of forest fires such as burned trees and treeless meadows with residual stumps (Ludlow 1875, Dodge 1965).

Graves (1899) reported fire scar dates. Although dating techniques were primitive, he discussed evidence for a number of fires prior to 1875. On the basis of his estimates, a fire or series of fires burned much of the Black Hills between 1730 and 1740. Fires of that magnitude burned again between 1790 and 1800. He also identified smaller-scale fires in 1842 and 1852.

It appears, from the historical information, that widespread, stand-replacing fires may have swept parts of the Black Hills periodically, although the frequency is unknown. Cooper (1960) and Weaver (1961) regarded these fires as rare or nonexistent in southwestern and northwestern ponderosa pine. Although they were uncommon, Weaver (1951) described conditions that could lead to intense fires in ponderosa pine.

Low-intensity ground fires also were important in the Black Hills. However, discussions by explorers are scanty because these fires left behind little obvious evidence. Instead of leaving charred tree remains, these fires actually stimulated growth or regeneration in many deciduous trees, shrubs, and herbaceous plants.

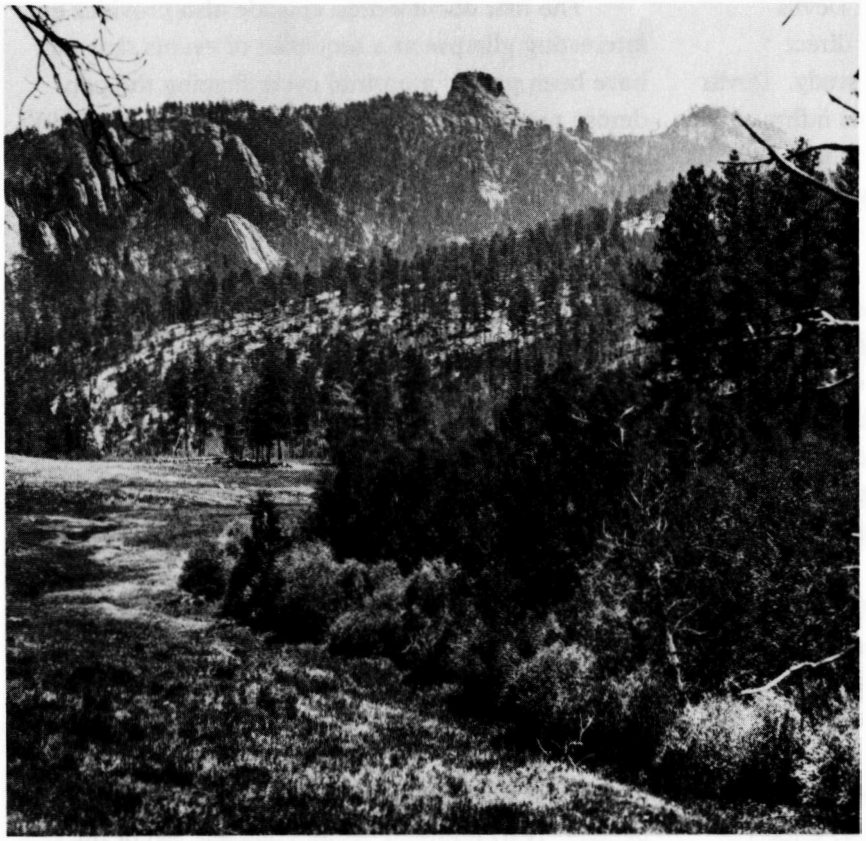
Graves (1899) seems to be the first author to recognize that fires of different intensities burned in the Hills. Large, hot burns were thought to be relatively rare. In contrast, cooler surface fires had a natural thinning effect on seedlings and saplings. Graves felt that the greatest damage to the forest from fires was the destruction of young pines. These interpretations coincide with later analyses of the Black Hills (Gartner and Thompson 1973, Progulske 1974) and descriptions of low-intensity fires in other ponderosa pine ecosystems (Weaver 1955, Cooper 1960, Covington and Moore 1994, Covington *et al.* 1994).

The only quantitative information available for low-intensity fires in the region comes from research at Devils Tower National Monument, Wyoming, west of the Bearlodge District. In this study, Fisher *et al.* (1987) found, for the years before 1770, a 27-year mean period between regional fires that were hot enough to scar many mature trees without inflicting mortality. After 1770 and continuing until 1900, fire return intervals decreased to 14 years.

This change corresponded with the move of the Lakota into the Black Hills area from the outlying plains. The authors theorized that the Lakota may have driven game into rivers or over breaks with fire. Assuming no significant change in lightning patterns, Fisher *et al.* (1987) concluded that increased fire frequencies corresponded with Lakota settlement.

After 1900, fire return intervals at Devils Tower extended to 42 years (Fisher *et al.* 1987) due to fire suppression. This was an era of dynamic change for Black Hills ecosystems. Although natural fire-ignition frequencies probably did not change from the pre-Euro-American period, successful suppression reduced ponderosa pine mortality. Instead of young pine regeneration undergoing natural thinning by fire, as documented in other ponderosa pine ecosystems (Weaver 1955, Covington *et al.* 1994), dense pine thickets developed. As suppression became more sophisticated, fewer fires escaped containment. The result has been a population explosion of ponderosa pine in the Black Hills that appears to be common throughout other coniferous communities in the West (Covington *et al.* 1994).

Figure 2. Duplicate photographs of Castle Creek (1874 and 1974). The 1874 photograph (top) shows sparse forest uplands in foreground, extensive quaking aspen across Castle Creek, and an extensive willow community along the drainage. By 1974 (bottom) the ponderosa pine forest in the foreground is more dense and extensive, the white spruce has encroached into the historic aspen, and the riparian area is drier as evidenced by the road and lack of willows and spruce on the bottom.



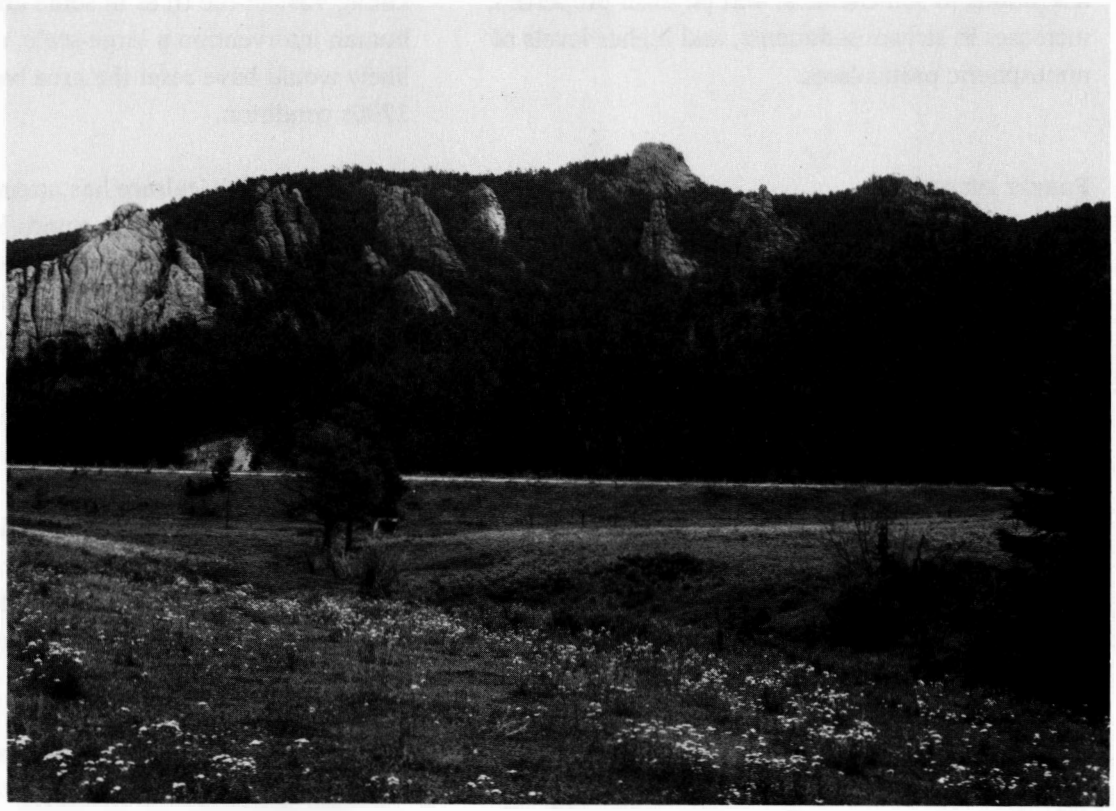


Figure 3. Duplicate photographs of Tenderfoot Creek (1874 and 1974). The 1874 picture (top) shows a sparse ponderosa pine forest on the hills in the background and a deciduous shrub community along the creek in the foreground. In 1974 the ponderosa pine community is denser and the historic willow community has been replaced by herbaceous plants and coniferous trees indicating drier site conditions.

Significant differences between the Devils Tower area and the Black Hills preclude direct extrapolation of the Fisher *et al.* (1987) study. Devils Tower did not experience the tremendous influx of settlers that came to the Black Hills in the late 1800s. These new residents undoubtedly influenced fire regimes, although no data are currently available.

The Black Hills also shows considerable ecological diversity due to variations in temperature, moisture, and evaporation/transpiration gradients. Intuitively, fires should have been less frequent and more intense in the cooler and more mesic northern Hills, the Harney Peak range, and on north-facing slopes, although no comparative data are available.

Reduced fire frequencies achieved the objective of more merchantable timber but altered forest structure and natural ecosystem processes. Ultimately, increased fuel loads due to reduced fire frequencies can result in more intense fires (Covington and Moore 1994) that influence the ecosystem differently than low-intensity fires. The more obvious effects of intense burns include a reduction in forested areas, alterations to soil chemical and physical properties, increases in stream sediments, and higher levels of atmospheric particulates.

Forest insects

Endemic insects and diseases are a common cause of tree mortality and increase the likelihood of fire (Weaver 1955). Mountain pine beetles are probably the most significant biotic mortality agent on Black Hills pine. These native beetles have coexisted with pine for millions of years (Knight 1994). Under normal conditions, individual beetles survive in weakened or recently fallen trees (as reviewed by Knight 1994), creating small infection loci. The duration and intensity of infestations is a function of the number of trees in the stand between 7.1 and 13.0 inches dbh (Lessard 1986). Widespread epidemics are limited to landscapes dominated by these conditions.

The history of mountain pine beetles in the Black Hills is basically a chronicling of epidemics. The first documented episode also provides an interesting glimpse at a sequence of events that may have been part of a natural cycle shaping the ponderosa pine forest. Graves (1899), Murdoch (1910), and Dodge (1965) provided information used to synthesize this scenario.

In the 1890s, an extensive and relatively dense second growth of ponderosa pine grew on the western Limestone Plateau. Graves (1899) attributed this second growth to the aftermath of a large fire or series of fires during the 1790s. Following the fire(s), prolific seed crops were produced by the surviving trees under good germinating conditions, a relatively common situation in most of the Black Hills.

For unknown reasons this large area escaped significant mortality and developed into a relatively dense forested landscape. Trees reached the 10- to 14-inch diameter class in the 1890s and, due to their high densities, became susceptible to mountain pine beetles. A widespread beetle epidemic swept the western Limestone Plateau from about 1895 to 1906, killing 90% of the trees in some areas. Without human intervention a large-scale, cataclysmic fire likely would have reset the area back to the initial 1790s condition.

Modern silviculture has attempted to reduce beetle impacts by thinning stands below vulnerable densities. However, there have been a number of beetle episodes during the twentieth century. The last outbreak occurred in the Bear Mountain area during the early 1990s. Following a beetle outbreak, affected areas have typically been salvage-harvested to reduce fire potential and limit outbreak extent.

There has been no research designed to evaluate mountain pine beetle epidemics in the pre-Euro-American forests or how these outbreaks may have affected fire regimes. Nor is the beetle/fire history of the past 120 years clear.

It is reasonable to deduce that where stand densities were high, outbreaks were a natural event and were commonly followed by fire. However,

because most of the Black Hills now is available for timber harvest, contemporary epidemics may be less extensive and ensuing fires less common.

Forest understory

Changes in Black Hills forest communities have also had a significant impact on understory vegetation.

Research indicates that understory plant biomass and species diversity are both inversely related to pine canopy density (Pase 1958, Uresk and Severson 1989, Wrage and Gartner 1993). Early explorers remarked about the prodigious herbaceous vegetation throughout the Hills and the excellent potential for livestock grazing (Newton and Jenney 1880, Dodge 1965).

Frequent recurring disturbances, characteristic of the Black Hills (as reviewed by Sieg 1992), maintained a generally open, mature forest canopy with a productive and diverse understory over much of the forest. Exceptions, with depauperate understories, may have included the first class of timber (described earlier) and the dense second growth of the northern Hills and western Limestone Plateau.

Following a century of fire suppression and forest management, ponderosa pine is more dense and more extensive. This leads to diminished understory productivity, reduced interior prairies and meadows, and a simplification of community diversity (Pase 1958, Gartner and Thompson 1973, Progulske 1974, Uresk and Severson 1989, Wrage and Gartner 1993). This pattern appears to be consistent with other ponderosa pine ecosystems (Weaver 1955, Covington and Moore 1994).

At the turn of the century the combination of widespread pine mortality on the western Limestone Plateau due to mountain pine beetles and the intensive logging on the eastern half of the forest reduced mature, overstory pine and increased potential understory productivity and diversity. Quite likely, the understory potential during this period was high, although large numbers of domestic livestock probably limited standing crops and diversity.

Introductions of exotic plants, beginning in the late 1800s, had a substantial impact on understory vegetation. Aggressive, strongly competitive plants such as Canada thistle (*Cirsium arvense*) became established, especially where there was soil disturbance or changes in site conditions.

Undesirable weeds continue to be a problem on the Forest; at least 29,000 acres were affected in 1994 (unpublished data, Black Hills National Forest). Control programs such as chemical spraying and biological agents are effective but labor intensive and costly. Many weed species are now common components of the Black Hills flora, adversely affecting the abundance and diversity of native species.

Other forest trees

Although ponderosa pine is the dominant forest community in the Black Hills, other tree species are worth mentioning. Quantitative historical information is limited for noncommercial species, but some general trends during the past century are apparent.

White spruce (*Picea glauca*), dominant at high elevations and in cool canyon bottoms (Hoffman and Alexander 1987) has probably increased in range since 1874. Spruce, typically with limbs at ground level and a thin bark, is more susceptible to fire than ponderosa pine. This species is also more shade tolerant than pine. Fewer fires have reduced spruce mortality and produced favorable conditions, such as increased ground shading, for regeneration. The result has been an expansion in spruce populations, leading to more dense and extensive stands at higher elevations and on north-facing slopes.

Quaking aspen (*Populus tremuloides*) is the most abundant deciduous tree in the Black Hills. Aspen is generally seral to conifers but in rare situations can be a potential natural community (Severson and Thilenius 1976). Aspen abundance is historically a function of fire that stimulates reproduction by root suckers (Mueggler 1988, Jones and DeByle 1985a) and creates conditions suitable for seed germination. Seed production, however, appears to have been very rare (McDonough 1985, Kay 1993).

The reduced influence of fire affects aspen stands in two ways. First, stands not harvested or burned have aged and become more susceptible to insects and disease. Second, without treatments to retard succession, later seral stage conifers have encroached into aspen stands and will eventually replace them (Fig 2).

Herbivore grazing patterns have also influenced aspen communities. Aspen shoots and associated understory vegetation provide palatable forage for livestock and wildlife. Continued overuse of regenerating shoots until the existing clone dies has converted some aspen stands to a grassland type dominated by Kentucky bluegrass (*Poa pratensis*) (Severson and Thilenius 1976).

Since existing aspen clones may be 8,000 to 10,000 years old (Jones and DeByle 1985b) and successful reproduction by seed is rare (McDonough 1985, Kay 1993), loss of individual clones during the past century may have reduced this species' genetic diversity in the Black Hills.

Paper birch (*Betula papyrifera*) and bur oak (*Quercus macrocarpa*) also tend to be seral to conifers in the Hills, and the same general successional relationships pertain to them. It is reasonable to conclude that the acreage of the upland deciduous forest was greater prior to 1874 than it is today, although no data are available.

Riparian Ecosystems

Early settlers in the Black Hills cared mainly about the ability of riparian ecosystems to support placer mining, farming, and grazing (Rydberg 1896). Limited information from early authors such as Hayden (1862), Grinnell (included in Ludlow 1875), Donaldson (1914), and Dodge (1965) provide a general historical background of riparian areas.

Over the thousands of years before Euro-American settlement, erosional and depositional periods combined to form channel configurations and valley profiles (White and Hannus 1985) in the Hills.

In the period leading up to Euro-American settlement, 1500 to 1874, the climate was relatively stable, producing stream flows generally within the capacities of the drainage systems. Floods that realigned stream channels certainly occurred but were not documented by early explorers. Prior to 1874, stream systems were probably in dynamic equilibrium as defined by Heede and Rinne (1990).

The historical range of riparian plant communities probably was a function of elevation and, more specifically, of moisture and light gradients (Thoreson 1988), geology, soil, valley bottom width, and slope gradient. Lower elevation riparian zones probably supported deciduous hardwoods such as green ash (*Fraxinus pennsylvanica*), boxelder (*Acer negundo*), and American elm (*Ulmus americana*), while white spruce was characteristic of the higher Hills. Riparian communities typically supported abundant shrubs (Figs 2 and 3) such as willows (*Salix* spp.), birches (*Betula* spp.), and red-osier dogwood (*Cornus stolonifera*) (Froiland 1990). These shrubs are characteristic of the wet meadow conditions described by explorers (Ludlow 1875, Dodge 1965).

Influence of beavers

Beavers (*Castor canadensis*) may have been the most important biological influence on the Black Hills riparian ecosystems, particularly in low-gradient drainages that supported abundant deciduous woody species. Olson and Hubert (1994) arrived at the same conclusion for montane streams in Wyoming.

Early authors commented on the abundance of beavers (Ludlow 1875, Donaldson 1914, Dodge 1965). This furbearer was especially noteworthy at the time because pelts were a valuable commodity.

Beavers primarily used low-gradient riparian areas (Munther 1981) with ample forage and dam building materials such as willow and aspen. Impounded, water-saturated soils increased the width of riparian zones (Munther 1981) and created habitat for plants adapted to wet soils. Suspended

sediments were trapped behind dams and filtered out of solution by the riparian vegetation. Thus, valley bottom alluvial volume probably increased in the presence of beaver dam complexes (Munther 1981, Olson and Hubert 1994).

Beavers not only influenced riparian vegetation composition. They also changed stream flows.

In streams without beaver colonies, much of the runoff came as a pulse during spring snow melt and warm-season precipitation. A complex of beaver dams with associated wet meadow soils and vegetation functioned like a sponge, discharging lower volumes in the spring and, especially in small streams, extending flows to later in the summer. Consequently, beaver could convert intermittent drainages to perennial flows.

Beavers were not permanent fixtures in a stream reach (as reviewed by Olson and Hubert 1994). Overuse of woody forage would trigger a move to a different stream reach. The untended dams eventually breached during high flows, and the stream downcut into the accumulated sediments. As the water table lowered, especially at the periphery of a meadow, plants that were adapted to drier soils increased in abundance.

Intermittent streams that the beavers had changed to perennial flows by slow release from beaver dam complexes reverted back to seasonal drainages with runoff occurring only during snow melt and rain storms.

Recovery of overused woody plants was typically rapid because plants such as willow resprout following browsing. The bare, fertile sediments exposed behind breached dams made ideal sites for seed germination of woody species.

Beavers eventually recolonized a stream reach once the woody species recovered. This cycle was probably typical for small, low-gradient streams.

In the Black Hills, beavers were heavily exploited during the latter part of the 1800s. They were valued for their pelts and were abundant and easily trapped. In a short time, unregulated harvest caused a drastic population reduction. Bailey (as reviewed by Turner 1974) noted that by 1888 beaver numbers were low and restricted to remote portions of the Hills. Riparian ecosystem degradation following beaver removal was probably rapid (Munther 1981), so eradication from a drainage could have had substantial long-lasting effects.

During the 1930s, in an effort to increase the Black Hills beaver population, the state of South Dakota imposed harvest regulations and supplemented the population with transplants from the eastern part of the state. Populations have fluctuated during the past 60 years but have not attained their original numbers due to the reduction in suitable habitat.

Land managers now recognize the significant ecological role of beavers. Currently, a beaver harvest moratorium on the South Dakota portion of the Black Hills National Forest is designed to increase population levels in areas with ample habitat. As beaver numbers rise they should become a key ingredient in riparian restoration.

Influence of humans

Human alterations of riparian ecosystems coincided with the discovery of gold.

Recent paleoenvironmental evidence indicates that fires burned through riparian vegetation (unpublished data, Dr. Jeff Saunders, Illinois State Museum), although their frequency and intensity are unknown. Fire in mesic riparian areas must have been an infrequent event but undoubtedly was an important ecosystem process. Riparian vegetation, like the upland forest, probably was more susceptible to fire during droughts. Fire has a rejuvenating effect on riparian plants such as willow. Fire suppression this century has reduced frequencies, although there are no data available on extent or consequences of the reduction.

The first prospectors were placer miners. Placer mining required excavation of the stream bot-

tom and floodplain substrate, disrupting riparian vegetation. The intensity of mining was severe in some areas (Parker 1981), but it was not the sole human impact on riparian areas.

Early settlers also established communities and transportation routes along streams. Many residents owned livestock which tended to graze in riparian areas because of the palatable forage and proximity to water. Effluent from mining, milling, and domestic sources was dumped directly into streams. Water was diverted from streams for milling, domestic use, or to drain meadows for cultivation.

Cumulatively, these impacts took a toll on riparian ecosystems.

Stream meander configurations were altered, especially in those channelized for mining or farming. Higher water velocities downcut into the alluvium, causing water tables to drop. Riparian vegetation eventually converted to drier-site plants, resulting in less diverse communities. Kentucky bluegrass and smooth brome (*Bromus inermis*), both drier-site constituents, replaced diverse, native, wet-meadow complexes. Western snowberry (*Symphoricarpos occidentalis*) probably also increased under these circumstances.

Most of these impacts have moderated during the twentieth century under improved management.

Localized impacts from grazing, mining, and effluent discharges still occur but are less significant than in the late 1800s. However, the legacy of that earlier period still exists in the form of drier sites, altered plant communities, modified stream courses, and toxic leachates.

Two influences more in evidence this century are road developments and water yields.

Road densities have increased substantially, giving access to timber harvests, private lands, grazing allotments, recreational areas, etc. As was the case with initial road and rail sitings, riparian areas were commonly selected for modern construction. Transportation corridors in riparian zones replace riparian habitat, relocate channels, increase sediment loads, and reduce channel meander potential.

Reduction in water yields and perennial stream mileage during this century has generated substantial concern. Monitoring by the U.S. Geological Survey (Driscoll and Zogorski 1990) and historical fish stocking records (Stewart and Thilenius 1964) both indicate that there are fewer miles of perennial stream flow than earlier in the century.

The most commonly cited reason for declines in water yields and stream mileage has been a higher evapo-transpiration rate associated with larger ponderosa pine populations (Stewart and Thilenius 1964). Other factors include the reduction in active beaver dam complexes that regulated water flow throughout the year, plus increases in consumption for domestic, industrial, and agricultural purposes. Combined, all these factors have reduced perennial stream flows and decreased the extent of true riparian habitats.

WILDLIFE

Resident wildlife at the time of Euro-American exploration primarily reflected the plant communities that had reached the Black Hills and survived the fluctuating climate since the last glacial period.

Presettlement plant communities and associated wildlife included northern boreal forests [northern flying squirrel (*Glaucomys sabrinus*) and three-toed woodpecker (*Picoides tridactylus*)], eastern deciduous forests [ovenbird (*Seiurus aurocapillus*) and ruffed grouse (*Bonasa umbellus*)], western coniferous forests [mule deer (*Odocoileus hemionus*) and pygmy nuthatch (*Sitta pygmaea*)], and the Great Plains [sharp-tailed grouse (*Tympanuchus phasianellus*) and bison (*Bison bison*)].

Early accounts of the Black Hills noted native wildlife, although much of the focus was on large conspicuous species, especially those hunted and trapped (e.g., Dodge 1965, Donaldson 1914). More

extensive lists for the Black Hills and adjacent prairies came from the observations and collections of naturalists Ferdinand V. Hayden (1862) and George B. Grinnell (included in Ludlow 1875).

Euro-Americans influenced wildlife in the Black Hills in four ways:

(1) Some species were harvested for food or fur or killed because they were perceived to be a threat to settlers and their livestock.

These included bison, Manitoban elk (*Cervus elaphus manitobensis*), Audubon bighorn sheep (*Ovis canadensis auduboni*), wolf (*Canis lupus*), grizzly bear (*Ursus arctos horribilis*), and blue grouse (*Dendragapus obscurus*) (Over and Churchill 1941, Thomson 1968, Turner 1974, South Dakota Ornithologists' Union 1991). All of these species were extirpated from the Black Hills as a direct result of overharvesting.

Others such as the beaver, black bear (*Ursus americanus*), and white-tailed (*Odocoileus virginianus*) and mule deer were nearly eliminated by the early 1900s.

Regulated harvests restored the deer populations, and transplants successfully reestablished elk (*Cervus elaphus canadensis*), bighorn sheep (*Ovis canadensis canadensis*), and beaver, although the first two are different subspecies than the original populations (Turner 1974). There have been unsuccessful attempts to reintroduce blue grouse (South Dakota Ornithologists' Union 1991).

(2) Other species, including nearly all of the current wildlife, were influenced by habitat modifications.

Fire suppression and logging changed the ponderosa pine communities. These landscapes, once dominated by relatively sparse stands of multi-aged trees with diverse productive understories, are now broad, contiguous expanses of higher density, medium-aged trees 70 to 120 years old with abundant pine regeneration and relatively depauperate understories. These shifts may have increased habitat for species that prefer dense mid-aged forests while decreasing habitat for open forest wildlife.

The abundance of deciduous forest wildlife has probably declined as preferred habitat was lost. In particular, wildlife species associated with aspen such as ruffed grouse and red-naped sapsuckers (*Sphyrapicus nuchalis*) have declined as a result of succession to conifers.

On the other side of the spectrum, there may be more abundant habitat for species that utilize late-succession white spruce such as golden-crowned kinglets (*Regulus satrapa*), three-toed woodpeckers, and northern flying squirrels.

The impact of fire, mountain pine beetles, and other mortality factors in the pre-Euro-American forest may have produced relatively high dead tree (snag) densities. Newton and Jenney (1880), Donaldson (1914), and Dodge (1965) commented on the large number of fire-killed trees but did not provide estimates. Graves (1899) published the first quantification of snag densities based on 69 plots (one-half and one acre in size) distributed across the Forest Reserve. Snag densities, based on this data, averaged 273 per 100 acres, and diameters ranged from 9 to 19 inches in the sampled area.

Again, it is important to realize that the objective of the Graves (1899) report was to justify inclusion of the Black Hills in the Forest Reserve System based on forest productive potential. The plots selected may have represented good timber areas. It may be logical to assume that areas with high snag densities and open, park-like situations with low snag densities were omitted from his report. Graves (1899) stated that in some areas up to 50% of the timber was defective and 3 to 4% was dead throughout the original forest.

Snags are probably fewer in number in the 1990s.

Silvicultural management reduced the abundance of "defective" trees that could eventually

become snags and reduced forest vulnerability to mountain pine beetle epidemics. Fire suppression efforts limited tree mortality from fires. Salvage harvesting operations following burns and epidemics typically removed a considerable proportion of dead trees. Fuelwood collection, primarily near communities and along forest roads, may have reduced snag densities.

In these situations, potential nest sites for snag-dependent species such as woodpeckers have undoubtedly declined. Remote portions of the Hills not intensively harvested and areas with limited access may have densities more like those reported by Graves (1899).

Habitat modification also occurred in riparian areas. The loss of beaver dam complexes and declines in perennial stream mileage converted riparian ecosystems to drier communities (as previously mentioned). These modifications reduced available habitat for species such as beaver, waterfowl, amphibians, and fish. Shifts in habitat also may have eliminated some aquatic invertebrates; however, since early naturalists did not survey these animals, no comparative information is available.

Developments also influenced available habitats. Reservoirs behind dams added lacustrine habitats, naturally absent from the Black Hills. Recently, ospreys (*Pandion haliaetus*) successfully nested in the Black Hills for the first time in recorded history near Pactola Reservoir (South Dakota Ornithologists' Union 1991). Without reservoirs there would be little suitable habitat for this bird.

Extensive mining during the past century has left numerous abandoned mine shafts and adits. These have supplemented the historical habitat for cave dwelling species, such as bats, originally limited to natural caves found primarily in the limestone formations.

Community and rural housing developments have supplanted many acres of prime winter range for elevational migrants such as deer and sharp-tailed grouse. In the aggregate, these low-elevation plant community conversions may limit winter habitat availability during critical periods of the year for some wildlife species.

The extensive road network in the Black Hills area has had multiple effects upon habitat. The first is direct conversion of habitat to roads. Historically, road construction in riparian areas and meadows was common. Second is collisions with vehicles (up to 1,400 deer per year in the 1990s), which have become an important mortality factor for some species. Third is increases in vehicular traffic which reduces habitat quality for some wildlife. Elk are a good example because they tend to avoid areas near roads with traffic (Lyon and Ward 1982).

(3) The third impact of Euro-Americans on native wildlife has been the introduction of other species into the Black Hills. The Merriam's turkey (*Meleagris gallopavo merriami*), mountain goat (*Oreamnos americanus*), and all existing game fish were successfully introduced to enhance recreation.

Another group of introductions includes the house sparrow (*Passer domesticus*), European starling (*Sturnus vulgaris*), common pigeon (*Columba livia*), Norway rat (*Rattus norvegicus*), feral dogs (*Canis familiaris*), and cats (*Felis catus*) which accompanied or followed settlement during the past century.

Each of these species successfully occupied a niche and may have altered the composition of native fauna. For example, starlings are aggressive secondary cavity nesters that can displace other cavity-dependent species. Feral dogs and cats inevitably become predators on a wide variety of native wildlife.

There is, however, no clear understanding of the direct and cumulative impacts of exotics on the native fauna.

(4) The fourth category of impacts of Euro-Americans on wildlife in the Black Hills consists of species documented in the Black Hills but, for a variety of reasons other than hunting, are no longer part of the fauna. These include the peregrine falcon

(*Falco peregrinus*), raven (*Corvus corax*), and purple martin (*Progne subis*).

The peregrine falcon probably disappeared from the Hills during world-wide declines induced by exposure to chlorinated hydrocarbons (USDI, Fish and Wildlife Service 1984). Only one attempt was made to reintroduce this bird, and it was unsuccessful (Sharps and O'Brien 1984). Ravens, once common throughout South Dakota, were associated with large bison herds (South Dakota Ornithologists' Union 1991). The extirpation of these herds also led to the disappearance of ravens. Purple martins historically inhabited the Black Hills (Ludlow 1875) but today are essentially absent in the western third of South Dakota (South Dakota Ornithologists' Union 1991). No reason for this change in distribution was found, although it may be related to isolation of the Black Hills caused by reductions in prairie floodplain forests and snag abundance throughout the western portion of the state.

Summary and Conclusions

Forest Ecosystems

Black Hills forest ecosystems prior to Euro-American influence appear to have been similar to other forest ecosystems in the Inland West (Covington *et al.* 1994). Recurrent disturbances from fires, insects, and storms governed ponderosa pine structural attributes, densities, age class distribution, and population size. As a result, much of the Black Hills was probably a patchy forest mosaic composed of fire resistant older ponderosa pine over multiple age classes. Frequent low-intensity fires thinned out dense stands of seedlings and saplings.

Historical accounts appear to indicate that the Black Hills did not fit the description of a "typical" presettlement ponderosa pine forest ecosystem in every way.

First, limited numbers of large-scale (80 to 10,000 acre) patches of relatively dense late-succession ponderosa pine (250 to 300 years old) may have been present in 1874. Dense stands that were this large have not been documented in other ponderosa pine ecosystems.

This information about the Black Hills should be viewed cautiously because there were insufficient data to accurately determine stand densities. The influence of external factors such as soil, landform, elevation, aspect, and precipitation on stand location and development also was unclear.

Second, dense second growth pine was documented across a large, contiguous area of the northern Hills and western Limestone Plateau. Such second growth was rare in other regions of the West because of high mortality incidence.

This situation was recorded only once in the Black Hills, and it was of a limited duration (about 100 years). There was no information available to determine how often an area this large might escape significant disturbance, and it did not tell us if a 100-year gap in landscape level mortality was normal.

Third, early explorers recorded an abundance of charred logs and snags, attributing these to intense stand-replacing fires. However, based on other ponderosa pine ecosystems (Covington *et al.* 1994), the conclusions of early Black Hills explorers that crown fires were common is suspect.

These three situations would represent rare phenomena in ponderosa pine ecosystems, and further analyses are warranted.

One factor that may play a role in making the Black Hills distinct from other ponderosa pine ecosystems is the timing of precipitation. Precipitation comes at a favorable time for seed germination, making ponderosa pine regeneration in the Black Hills extremely successful.

Other tree species have responded to changes in ways based, to a large extent, on their successional position. White spruce, a late successional species, has probably increased in abundance and extent

under a century of management. In contrast, early successional deciduous trees, such as quaking aspen, may have become less abundant due to conifer encroachment.

Riparian Ecosystems

Changes in Black Hills riparian ecosystems are similar to those noted for other western montane regions.

Historically, beaver dam complexes and wet meadow conditions were abundant on low-gradient streams. Livestock grazing, reduced water yields, farming, road construction, and placer mining have all contributed to the conversion of historical wet meadows to drier sites.

These changes in site conditions have converted many diverse riparian bottoms to areas composed primarily of Kentucky bluegrass and smooth brome with substantially reduced shrub communities and transitional deciduous trees.

Wildlife

Compositional changes in wildlife during the past century were primarily due to overharvesting, reductions in habitat, and introductions of exotic species.

Generally speaking, most vertebrates encountered by early naturalists still inhabit the Black Hills. The documented wildlife extirpations were usually linked to overharvest or habitat loss. Less information was available for invertebrate populations.

The extensive habitat modifications in deciduous hardwoods, forest understory communities, and riparian ecosystems logically may have resulted in species extinctions in the Black Hills; however, little historical data for invertebrates is available.

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