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Conservation Assessment for Groundcedar and Stiff Clubmoss in the Black Hills National Forest South Dakota and Wyoming

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Species Assessment
of
Groundcedar and Stiff Clubmoss
in the
Black Hills National Forest,
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EXECUTIVE SUMMARY

Stiff clubmoss (*Lycopodium annotinum* L.) and groundcedar (*Lycopodium complanatum* L.; synonym = *Diphasiastrum complanatum* [L.] Holub.) (Lycopodiaceae) are circumboreal clubmoss species that are widely distributed in North American boreal habitats. In the northern Black Hills of South Dakota and Wyoming, groundcedar and stiff clubmoss occur in disjunct, extremely isolated populations in remnant boreal white spruce and mixed conifer-hardwood forests. To date, only two populations of each species have been located on Black Hills National Forest lands[1]: both species occur in a dense colony in the Upper Sand Creek Botanical Area, Crook County, Wyoming; and smaller, separate populations of each species occur in Lawrence County, South Dakota. The current status of additional occurrences of groundcedar and stiff clubmoss on private lands is not known. Conservation of existing populations is crucial to the persistence of both species in Black Hills National Forest. Although the habitat requirements of these rare species are poorly understood, potentially detrimental management activities are basically precluded on known sites on National Forest lands. The persistence of both species in the Black Hills is at risk due to both the small number and size of their populations, which makes them vulnerable to random stochastic events and invasion by noxious weeds and other invasive plants.

Key words: *Lycopodium*, stiff clubmoss, groundcedar, Black Hills, boreal, white spruce.

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[1] Two additional populations of groundcedar were recently found on Black Hills National Forest lands, one on September 13 and a second on October 18, 2002.

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INTRODUCTION

Three clubmoss species occur in Black Hills National Forest: stiff clubmoss (*Lycopodium annotinum* L.), groundcedar (*Lycopodium complanatum* L.), and tree groundpine or tree-like clubmoss (*Lycopodium dendroideum* Michx.) (Wagner and Beitel 1993; USDA NRCS 2001). Extensive field surveys for tree groundpine (*L. dendroideum*) have revealed that the species is more abundant and widely distributed than previously believed, and therefore it is not considered in this assessment.

Both groundcedar and stiff clubmoss are circumboreal and common across northern latitudes, but disjunct or sparse at the southern limits of their distribution (figs. 1 and 2) (Flora of North America 1993). In the Black Hills, groundcedar and stiff clubmoss species are highly disjunct from the nearest populations in the Rocky Mountains and are restricted to remnant, boreal white spruce habitats on steep, north-facing slopes and streamside benches (USDA Forest Service 2000) (fig. 3). There are two occurrences of each species in the Black Hills National Forest.

The objective of this assessment is to review information on the occurrence and distribution of groundcedar and stiff clubmoss in the Black Hills National Forest and to synthesize information relevant to the management, monitoring and long-term persistence of these species. We relied on general information on the clubmosses, and species-specific literature from the core of the species' ranges and available species information specific to the Black Hills to develop this assessment. Species nomenclature follows the USDA NRCS Plants Database (2001).

CURRENT CONSERVATION SITUATION

The global conservation rank of groundcedar (*Lycopodium complanatum* L.) is secure (G5) (NatureServe 2001). It is nationally unranked (N?) in the United States and Canada and is not under federal protection by the U.S. Fish and Wildlife Service (NatureServe 2001). Groundcedar is currently on the USDA Forest Service Region 2 Sensitive Species List. Groundcedar is widespread throughout the boreal regions of North America from Maine to Alaska; but is ranked as critically imperiled due to extreme rarity (S1) at the southern limits of its range in New York, South Dakota, and Wyoming; and critically imperiled to imperiled in Vermont (S1S2), and imperiled in Oregon (S2) (NatureServe 2001) (table 1).

Stiff clubmoss (*Lycopodium annotinum* L.) also has a global conservation rank of secure (G5) (NatureServe 2001). It is nationally ranked as secure (N5) in the United States and Canada, and it is not under any federal protection by the U.S. Fish and Wildlife Service (NatureServe 2001). Stiff clubmoss is not on the USDA Forest Service Region 2 Sensitive Species List because of its abundance elsewhere in Region 2. However, because of its limited number of occurrences on the Black Hills and it's similarity to ground cedar, the authors chose to include it in this assessment. Stiff clubmoss is generally common and widely distributed in the boreal regions of North America, and in mountainous areas of Arizona, Kentucky and North Carolina (NatureServe 2001; USDA NRCS 2001). Stiff clubmoss is ranked as critically imperiled due to extreme rarity (S1) in South Dakota, New Jersey and Rhode Island; and imperiled (S2) in Wyoming and New Mexico (NatureServe 2001) (table 2). However, it is not tracked as a species of special concern in Wyoming due to numerous occurrences elsewhere in the state (University of Wyoming 1998). In general, the conservation status of both species is less secure towards the southern and western

limits of their ranges where boreal habitats are infrequent or rare. Conservation rankings are not currently available for either species in Eurasia or South America.

Since 2000, known groundcedar and stiff clubmoss occurrences have been revisited, and areas proposed for Forest management activities have been surveyed for both species. A single new occurrence of groundcedar was discovered in 2001. Both clubmoss species have very narrow ecological amplitudes in microhabitats within remnant boreal forest habitats in the northern Black Hills (fig. 2). Because the existence and condition of groundcedar and stiff clubmoss occurrences on private land in the Black Hills are unknown, they are not considered in this assessment.

Several species of clubmoss are widely collected as non-timber, special forest products for use in seasonal decorations and floral displays (Nauertz 1999; Robbins 1999). Tree-like groundpine (*Lycopodium dendroideum*) is among the most heavily harvested *Lycopodium* species (Nauertz 1999) elsewhere in its range, but there is no indication that clubmosses have ever been collected from Black Hills National Forest. In the eastern U.S., collection of running clubmoss (*Lycopodium clavatum* L.) has become a conservation concern (Robbins 1999). In the Pacific Northwest several clubmoss species "have been collected rather ruthlessly for commercial purposes and are becoming rare in areas where they were abundant at one time" (Hitchcock and others 1969). However, there is no indication of current or historic collection of clubmosses in the Black Hills. The isolated occurrences and limited numbers of groundcedar and stiff clubmoss in the Black Hills would likely make collection difficult and unprofitable.

REVIEW OF TECHNICAL KNOWLEDGE

Species Taxonomy

Groundcedar, *Lycopodium complanatum* Linnaeus [Species Plantarum, 1104, 1 May 1753; synonym = *D. complanatum* (Linnaeus) Holub, Preslia 47: 108. 1975] and stiff clubmoss, *Lycopodium annotinum* Linnaeus (Species Plantarum, 1104, 1 May 1753) are both classified as Division Lycopodiophyta (Pteridophyta), Class Lycopodiopsida, Order Lycopodiales, Family Lycopodiaceae (Club-moss Family) (Flora of North America Editorial Committee 1993; Walters and Keil 1996; Duff and Nickrent 1999). The Flora of North America (1993) accepts Holub's (1975) separation of *Diphasiastrum* from *Lycopodium* based on the diameter and shape of the shoots, ranking of the leaves, branching of the peduncles, and the shape of the gametophyte. In North America, there are five species and an additional six fertile hybrid taxa in the genus *Diphasiastrum*, and five species in the genus *Lycopodium* (Øllgaard 1987; Flora of North America Editorial Committee 1993). Under Holub's 1975 classification, *L. complanatum* is included in the genus *Diphasiastrum* while *L. annotinum* remains in the genus *Lycopodium*. The nomenclature used in this assessment follows the USDA NRCS Plants Database (2001), which recognizes *Lycopodium complanatum* L. as the proper binomial for groundcedar. See Appendices A and B for further taxonomic details on groundcedar and stiff clubmoss, respectively.

Species Descriptions

Groundcedar is an evergreen, perennial herb with branched upright stems (Flora of North America Editorial Committee 1993). Groundcedar's flattened sprays and scale-like leaves are distinctive (fig. 4). It most closely resembles deeproot clubmoss (*Lycopodium tristachyum*

Pursh.) and fan clubmoss (*Lycopdium digitatum* Dill. ex A. Braun), but neither of these species occurs in the Black Hills so confusion is unlikely (Lellinger 1985; Flora of North America Editorial Committee 1993).

Stiff clubmoss also arises from horizontal creeping stems that occasionally fork or root at the nodes, but both stem types are more sparsely covered with leaves and erect stems are clustered along horizontal stems (Wagner and Beitel 1993). Stiff clubmoss is distinct from groundcedar and all other *Lycopodium* species in having needle-like leaves, essentially unbranched aerial stems, and sessile strobili (Wagner and Beitel 1993) (fig. 5). The gametophytes of groundcedar are carrot-shaped, while those of stiff clubmoss are flattened, or irregularly button shaped (Bruce 1979; Bruce and Beitel 1979; Flora of North America Editorial Committee 1993).

Tree-like clubmoss, or tree ground pine (*Lycopodium dendroidium* Michx.), is distinguished from groundcedar and stiff clubmoss by its miniature spruce tree-like appearance with needle-like leaves arranged on highly branched aerial stems. Further technical descriptions of groundcedar and stiff clubmoss are given in Appendices A and B, respectively. Refer to the Flora of North America, Volume 2 (Wagner and Beitel 1993) for more detailed species descriptions.

Species Significance

The isolated, disjunct occurrences of groundcedar and stiff clubmoss in the Black Hills may be evolutionarily important and genetically valuable, as geographic isolation may indicate that the occurrence possesses unique genetic material. These occurrences may also play a role in determining the future biogeography of the species (Huenneke 1991). Boreal disjuncts also are important in the study of phytogeography and paleoecology.

Historically, the Shuswap tribe of the southern interior of British Columbia used stiff clubmoss mixed with clay as building material and fertilizer, and the Woodlands Cree of Saskatchewan used the plant as a cooking tool to separate fish eggs (Moerman 1998). Groundcedar was used by the Blackfeet of Montana, Alberta and Saskatchewan as an antiseptic on wounds, a hemostatic, for treatment of venereal disease, and to set dyes; the Iroquois used a tea made from the plant to induce pregnancy; and the Ojibwa of the upper Midwest and southern Ontario used this species as a stimulant (Moerman 1998). No traditional uses of any clubmoss species were found for the Lakota peoples of the Black Hills region. The spores of some species are used as dry lubricants in surgical gloves and other products, but are used less frequently today as the spores can cause skin reactions (Cunningham and Lowery 1997).

Life History

Clubmosses are among the most primitive groups of vascular land plants (Raven and others 1999). They are morphologically distinct from ferns and flowering plants, and nearly unchanged from the Devonian period 400 million years ago (Levin and Crepet 1973). Like all pteridophytes, *Lycopodium* species produce haploid spores that give rise to tiny gametophytic plants. Each bisexual gametophyte may require from 6 to 15 years to produce haploid eggs and motile sperm for sexual reproduction (Raven and others 1999). Water is required for the sperm to reach the female gametes (Raven and others 1999). Although *Lycopodium* gametophytes are hermaphroditic and are capable of self-fertilization, out-crossing is the predominant mode of fertilization (Raven and others 1999). Soltis and Soltis (1988) found stiff clubmoss to be a predominantly out-crossing species, but no references to groundcedar's dominant reproductive

mechanism was found in the literature. The photosynthetic, evergreen sporophyte, or recognized form of the plant, arises from a diploid embryo housed in the haploid gametophyte (Raven and others 1999).

The spore producing structures, or strobili, are solitary at the end of upright branchlets in stiff clubmoss, and arranged in erect, forked groupings in groundcedar (Wagner and Beitel 1993) (figs. 4, 5). In both species, hundreds of miniscule spores mature and are released late in the fall for dispersal by wind, water, or animals (Nauertz and Zasada 1999). Because clubmosses reproduce by spores, there are no pollinators or specialized dispersal vectors. It is not known if spores can disperse from distant occurrences into the Black Hills, or if all known occurrences are the result of clonal expansion or spore dispersal within the area.

As is common in the Lycopodiaceae, both *Lycopodium* and *Diphasiastrum* spores germinate and form subterranean, non-photosynthetic, gametophytes that require an endomychorrhizal fungal associate to survive (Freeberg 1962; Boullard 1979; Flora of North America Editorial Committee 1993). Endomycorrhizae, or vesicular-arbuscular fungi, are belowground fungal species that supply nutrients to the plant via fibrous hyphae that penetrate the cortical cells of the root, but not the cell membranes (Raven and others 1999). Groundcedar and stiff clubmoss gametophytes are probably associated with different endomycorrhizal species across the range of edaphic conditions and species assemblages in which they occur. The presence or absence of a suitable endomycorrhizal associate could influence *Lycopodium* distributions. However, the species' fungal associates may be common in boreal forest soils or it may be that the clubmoss spore is already infected with the fungal associate when it is released. Endomycorrhizal fungi are not known to occur in Lycopodiaceae sporophytes (Boullard 1979) and apparently are not necessary for their development or persistence. Malloch and Malloch (1982) reported that the roots of the sporophyte of rare clubmoss (*Lycopodium obscurum*) are as fine and dense as fungal hyphae, and therefore do not require a mycorrhizal associate to assist in nutrient acquisition.

Clonal expansion is the dominant form of reproduction in the Lycopodiaceae (Soltis and Soltis 1988). Aerial stems are produced at regular intervals along the rhizome forming clonal groupings. Thus, high-density occurrences of Lycopodium are believed to be the result of clonal growth and not of spore establishment (Nauertz 1999). Accordingly, prevalence of clonal growth may result in a population that consists of only one or a few genetically distinct individuals (Levin and Crepet 1973).

Hybridization is frequent within the genus *Diphasiastrum* (i.e. groundcedar), but is unlikely to occur in the Black Hills where groundcedar is the only member of the genus *Diphasiastrum* and is not genetically compatible with *Lycopodium* species (Flora of North America Editorial Committee 1993). Also, although groundcedar is known to hybridize with fan clubmoss (*L. digitatum*, synonym = *D. digitatum*) and deeproot clubmoss (*L. tristachyum, synonym = D. tristachyum*), both species occur hundreds of miles east of the Black Hills (Hersey and Britton 1981; Flora of North America Editorial Committee 1993; USDA NRCS 2001). Hybridization between stiff clubmoss and other *Lycopodium* species is practically unknown (Flora of North America Editorial Committee 1993). Tree ground pine (*L. dendroidium*) is closely related to stiff clubmoss, but no hybrids are known to occur (Flora of North America Editorial Committee 1993). Given the disjunct nature of stiff clubmoss and groundcedar occurrences in the Black Hills, the establishment of spores from other species becoming established in the Black Hills and producing a hybrid seems unlikely.

Distribution And Local Abundance

Groundcedar occurs in boreal regions of Europe and Asia, and in North America from Alaska to Newfoundland and south to Oregon, Wyoming, Minnesota, Michigan, New Hampshire, and Nova Scotia (Flora of North America Editorial Committee 1993) (fig. 1). Groundcedar is reported in historic records in North Dakota and Saskatchewan (as indicated by Flora of North America 1993, fig. 1), but is not known to exist today (NatureServe 2001). In North America, groundcedar occurs in dry to moist, open coniferous or mixed hardwood forests from sea level to 6,560 ft (2,000 m) elevation (Hitchcock and others 1969; Flora of North America Editorial Committee 1993).

Stiff clubmoss is a circumboreal species that is distributed across North America from Alaska to Newfoundland south in the Rocky Mountains to Arizona and New Mexico, and in the Appalachians south to Kentucky and North Carolina with disjunct occurrences in Saskatchewan and South Dakota (Flora of North America Editorial Committee 1993) (fig. 2). The species is reported from moist woods or thickets in Colorado from 8,000 to 11,000 ft (2,400 to 3,350 m) (Harrington 1954). Stiff clubmoss occupies moist coniferous forest and is occasionally found in drier, open habitats (Hitchcock and others 1969; Gleason and Cronquist 1991; Flora of North America Editorial Committee 1993). Stiff clubmoss also occurs in France; and in Russia, Japan, China and Korea (Missouri Botanical Garden 2001). Stiff clubmoss and groundcedar share similar distributions, but stiff clubmoss is more widespread in boreal habitats in the northern United States, Appalachians, and Rocky Mountains (NatureServe 2001). Groundcedar and stiff clubmoss were first discovered in the Black Hills in Upper Sand Creek in 1982 (Dorn 1983; Great Plains Flora Association 1986; Fertig 2001).

There are five documented occurrences of groundcedar in the Black Hills of Wyoming and South Dakota: two on Black Hills National Forest, one near Custer Crossing in Lawrence County, South Dakota that was located in 2001, and a larger occurrence in extreme eastern Crook County, Wyoming; and three on private lands (South Dakota Natural Heritage Program Records; Fertig 1993; Fertig and Beauvais 1999) (fig. 3).

The larger of the two groundcedar occurrences on Black Hills National Forest is in the Upper Sand Creek Botanical Area at 5,600 ft (1,707 m) elevation on a north-facing slope (Dorn 1983). In 1989, the groundcedar occurrence there was reported as a 98- by 164-ft (30- by 50-m) area (South Dakota Natural Heritage Program Records). Surveys in 2000 and 2001 reported a dense colony of aerial stems of approximately the same size. The site is on a steep slope 20 ft (6 m) above the road and 50 ft (15.2 m) from the creek bed. The occurrence consists of more than 1,000 stems; numerous reproductive strobili were noted in 2000 and 2001. The actual number of individuals cannot be determined due to dense, clonal growth.

The second, smaller occurrence of groundcedar at Custer Crossing in Lawrence County, South Dakota is at an elevation of 5,820 ft (1,774 m) and consists of a dense patch of aboveground stems that covers a 35- by 35-ft area (114 m^2). The site is on a northeast-facing slope just above a mossy drainage bottom. Approximately 3 percent of the stems had mature sporangia in 2001; a similar reproductive effort was noted in 2002. At least three additional occurrences have been documented on private land in the Black Hills, all in Lawrence County. These occurrences are at an elevational range of 5,000 to 5,600 ft (1,524 to 1,707 m), in spruce/birch forests on north-facing slopes (South Dakota Heritage Program Records).

There are only two currently verified occurrences of stiff clubmoss in the Black Hills, both on Black Hills National Forest land. A relatively large occurrence is in the Upper Sand Creek Botanical Area, and a second, smaller occurrence of approximately 50 stems is on Strawberry Creek in Lawrence County, South Dakota (fig. 3). At the Upper Sand Creek site, one of three patches that comprise the occurrence of stiff clubmoss in the Botanical Area consists of a dense patch approximately 22 by 30 ft (7 by 9 m) in the center of the much larger groundcedar occurrence. Although no recent data have been collected at the other two patches of stiff clubmoss in the Sand Creek Botanical Area, in 1989, the estimated total area covered by all patches at that site was approximately 1800 m^2 (19,375 ft^2) (Hall and others 2002). All the patches are close enough in proximity to be considered a single occurrence. The actual number of individuals cannot be determined due to dense, clonal growth, but some vegetative expansion was noted in 2001.

The smaller occurrence of stiff clubmoss at Strawberry Creek Canyon lies just within the FS boundary on a north-northeast facing bench just 4 ft (1.2 m) above the creek bed at 5,000 ft (1,525 m) elevation. Steep rock ledges form the southern border of the 2 m^2 (21.5 ft^2), heavily vegetated site just west of the confluence of Strawberry Creek and an unnamed creek. The occurrence consists of 50 to 60 stems. No strobili were present at the time of the July 2001 survey. Additional stiff clubmoss sites have been documented in the Black Hills on private land but their current status is unknown (South Dakota Natural Heritage Program Records; Fertig and Beauvais 1999).

The closest known occurrences of these species to the Black Hills are an occurrence of groundcedar approximately 450 mi (725 km) to the northwest in Lewis and Clark County, Montana; and an occurrence of stiff clubmoss about 270 mi (435 km) west in Park County, Wyoming (Dorn 1983). Stiff clubmoss is infrequent on the eastern slope of the Colorado Rockies (Weber and Wittmann 1996) and occupies the Medicine Bow and Shoshone National Forests of south central and northwestern Wyoming (University of Wyoming 1998).

Habitat Relationship

In North America, groundcedar and stiff clubmoss are associated with temperate to sub-arctic boreal forest, dry open coniferous forest, mixed sub-alpine and northern forests, thickets and bogs, and sheltered north-facing slopes (Hitchcock and Cronquist 1973; Wofford 1989; Gleason and Cronquist 1991; Wagner and Beitel 1993; Nauertz 1999). In the United States, groundcedar is characterized as an upland species that occasionally occurs in wetland habitats in the north and northeast, and stiff clubmoss is a facultative upland species that may occur in wetlands up to 33 percent of the time (US Fish and Wildlife Service 1996; USDA NRCS 2001). The evergreen nature of *Lycopodium* species enables them to persist in the understory of dense, deciduous forest habitats by taking advantage of increased light availability in the spring and fall (Nauertz 1999). Groundcedar and stiff clubmoss occur in drier, sub-artic or sub-alpine birch forest habitats in Scandinavia and Finland (Lellinger 1985; Headley and others 1988a,b). *Lycopodium* species are widely distributed at subarctic and boreal latitudes (Wagner and Beitel 1993). Stiff clubmoss is one of a few vascular plant species that regularly occurs in white spruce (*Picea glauca*) and balsam fir (*Abies balsamea*) plots across the taiga from Alaska to Newfoundland (LaRoi 1967). In the southern portions of their ranges, both species occupy small-scale patchy habitats in forested communities (Curtis 1959; Nauertz 1999). As a result, the distribution of *Lycopodium* species may appear somewhat random (Curtis 1959).

Both clubmoss species occur in acidic or mixed soil types (Lellinger 1985; Wofford 1989; Ode and Marriott 1991; Gleason and Cronquist 1991). Groundcedar and stiff clubmoss have small root systems, as their rhizomes transport water and nutrients relatively long distances to the actively growing portions of the plant (Headley and others 1988a,b; Komissarova and others 1991). The efficient movement of water and nutrients to distant rhizome and branch tips allows the plant to escape competition and traverse poor habitat conditions to sites where nutrients or light are more available (Headley and others 1988a,b).

Through rhizomatous growth, groundcedar is known to form "fairy rings" when the plant expands from a central location and forms a circle of aerial stems over time (Headley and others 1988a,b; Komissarova and others 1991; Nauertz and Zasada 1999). The soil at the center of a groundcedar fairy ring becomes depleted of humus, calcium and magnesium, and enriched in nitrogen, phosphorous and potassium, which can have negative effects on neighboring species, particularly mosses, grasses, and lichens (Stone and others 1973; Komissarova and others 1991). The fairy ring is thought to be an efficient search strategy for suitable habitats in patchy environments and allows the plant to increase its mass and suppress its competitors until available nutrients are exhausted and the plant begins to die back (Doust 1981; Komissarova and others 1991). This growth pattern has not been noted in Black Hills groundcedar occurrences, but the high density of above ground stems confounds any visible pattern. The groundcedar occurrence at Custer Crossing is expanding vegetatively from the perimeter, but there is no evidence of rhizomatous growth where stems are densely concentrated.

Stiff clubmoss expands vegetatively via creeping rhizomes that allow rapid clonal expansion with minimal resources (Harper 1985; Caraco and Kelly 1991; Nauertz 1999). Groundcedar is reported to be more competitive in late successional habitats, whereas stiff clubmoss is apparently better able to colonize early successional habitats (Headley and others 1988a,b).

Groundcedar is common in pine forests of the upper Midwest and occupies pockets of northern dry-mesic, or northern dry forest communities in Michigan (Nauertz 1999; Nauertz and Zasada 1999). The northern dry-mesic forest communities described in Nauertz (1999) experience greater temperature extremes, and receive slightly more average precipitation than reported for the northern Black Hills climate stations (Appendix C): the Bergland Climate Station (200718; period of record 1961-1990) in Ottawa National Forest receives 37 inches (94 cm) mean rainfall and 173 inches (439 cm) mean snowfall annually (Midwestern Regional Climate Center 2000). Stiff clubmoss is found as a seral species in mature forests elsewhere, where its species associations are consistent with those found in the Black Hills (Cormack 1953; Corns and Annas 1986; Jones and others 1983; Kurmis and others 1986; Matthews 1993) (table 3). In western Montana, stiff clubmoss is common in moist forests of lower creek bottoms in montane and subalpine zones with twinflower (*Linnaea borealis*), bunchberry (*Cornus canadensis*), bride's bonnet (*Clintonia uniflora*), wintergreen (*Pyrola* spp.) and moss species. Groundcedar has a much more limited distribution in moist, lower subalpine forests (Lackschewitz 1991).

In the Black Hills, both groundcedar and stiff clubmoss are associated with high moisture microhabitats within remnant boreal spruce habitats that are disjunct from the main distribution of white spruce to the north. These remnant boreal forests occur primarily in the northern Black Hills on north facing slopes and draws (Marriott and Faber-Langendoen 2000) with paper birch as a common seral or dominant canopy component (Hoffman and Alexander 1987). Environmental site data are currently limited, but the Upper Sand Creek, Strawberry, and Custer

Crossing sites are all characterized as spruce forest intermingled with birch and shrubs; suggesting they are transitional between birch and spruce habitat types (Marriott and Faber-Langendoen 2000). Potential plant community classifications include: white spruce/grouseberry (*Picea glauca*/*Vaccinium scoparium*) forest, which occurs from 5,700 to 6,700 ft (1,737 to 2,042 m) in the northern Black Hills; paper birch/hazel (*Betula papyrifera*/*Corylus cornuta*) forest, which occurs widely from 4,000 to 6,000 ft (1,219 to 1,828 m) elevation; and white spruce alluvial forest, which occupies drainages from 5,000 to 6,300 ft (1,524 to 1,920 m) elevation in the central core and limestone plateau (Black Hills Community Inventory 1999; Marriott and Faber-Langendoen 2000). Groundcedar and stiff clubmoss are restricted to microhabitats within these boreal plant communities in ravines, steep drainages, and on streamside benches from 5,000 to 5,820 ft (1,524 to 1,774 m). Climate summaries of all known sites on Black Hills National Forest are given in Appendix C.

The largest currently known occurrences of both species on the Black Hills National Forest are in the Upper Sand Creek Botanical Area in Crook County, Wyoming, in habitat provisionally classified as white spruce-grouseberry (*Vaccinium scoparium*) or transitional birch-hazelnut (*Corylus cornuta*) forest. A second occurrence of groundcedar is in alluvial white spruce forest at Custer Crossing, Lawrence County, South Dakota; and a second occurrence of stiff clubmoss is in spruce-birch forest along Strawberry Creek, also in Lawrence County. Although these remnant boreal spruce/hardwood forest habitats are relatively widespread in the northern Black Hills, surveys to date indicate that groundcedar and stiff clubmoss occupy a handful of small, isolated microhabitats within them.

In the Black Hills, groundcedar and stiff clubmoss occur on north-facing uplands in shaded microsites (fig. 6). The habitat preferences given for both species elsewhere indicate a broader ecological amplitude than the species' known habitats in the Black Hills (as indicated by Marriott 1991), and underscores our limited understanding of their distributions in Black Hills National Forest. Known occurrences of groundcedar and stiff clubmoss are in moist, somewhat acidic soils (USDA Soil Conservation Service 1983). Both groundcedar and stiff clubmoss occupy sheltered microsites that are cooler and considerably moister than surrounding habitats. The species' microsites occur on steep slopes, in deep narrow drainages, and on streamside benches with high moisture and dense moss cover that may indicate the presence of sub-surface seeps. However, moisture may also be provided by early and late season snow retention due to microtopography and canopy cover at the sites.

At the Upper Sand Creek site, groundcedar and stiff clubmoss co- exist beneath a fairly dense canopy of white spruce, paper birch, and ponderosa pine (*Pinus ponderosa*), with hazelnut, bunchberry (*Cornus canadensis*), grouseberry, thinleaf huckleberry, and dense moss cover in the understory (fig. 6).

The Custer Crossing groundcedar occurrence is in a steep, narrow drainage with a dense understory of moss, lichens, and fungi on shale-derived soils. The canopy is dominated by spruce, and paper birch occurs nearby. The shrub layer is dominated by birch-leaved spiraea (*Spiraea betulifolia*) and bunchberry. A large amount of dead and down trees at the Custer Crossing site suggests historic fire disturbance or a more recent wind-throw event.

At Strawberry Creek, stiff clubmoss occurs on a moist bench under a canopy co-dominated by white spruce and paper birch with young spruce forming a low canopy. Grouseberry dominates the understory, followed by tree-like clubmoss. The three sites that contain all presently known

occurrences of both species in Black Hills National Forest are similar in that they all possess a dense bed of mosses and six plant species that are not common in the Black Hills (identified in table 3); these plant species are common to boreal forests elsewhere (Curtis 1959; Hamilton and Yearsley 1988).

The patchy distribution of both species in the Black Hills may be, in part, due to frost pockets on north-facing slopes and in other sheltered sites that results in snow retention and significantly great soil moisture throughout the year. Shaded sites retain snow pack much later in the spring and after early snows in late autumn. This may create unusual, high moisture microhabitat conditions that do not extend more that a few feet away from the snow-covered site.

Although the species is adapted to forage for nutrients (Headley and others 1988a,b) and canopy openings (Nauertz 1999), in the Black Hills, both species may be restricted to shaded habitats that retain sufficient moisture for the plants to persist. Both species may be vulnerable to small shifts in their microhabitat conditions, such as increased light exposure or reduced moisture. For this reason, surrounding habitat structure may exert a strong influence on microhabitat conditions, particularly shade and moisture. Although habitat conservation is integral to plant species conservation, the micro-scale distribution of both species in the Black Hills is not well understood. It may be that cold, moist microclimatic conditions, canopy associations, fungal associations, or a combination of these factors define extant habitats. In addition, these factors may be limited to certain seral stages in successional development.

Disturbance Ecology

The habitat needs and disturbance ecology of groundcedar and stiff clubmoss are not well understood. The two occurrences of each species in the Black Hills National Forest are small and occupy boreal habitats, but do not share identical species associates (table 3). However, the currently known occurrences are on unusually moist soils and both species may therefore have moisture requirements that would limit them to rare habitats in the Black Hills. The spores of both species could require disturbance of the mineral soil in order to germinate and *Lycopodium* gametophytes are reported to need disturbance to mature (Nauertz 1999; Nauertz and Zasada 1999). Moderate soil disturbances may create favorable microhabitats for *Lycopodium* spore germination and clonal expansion (Nauertz 1999). However, there is no evidence of recent or historic soil disturbance at any of the known occurrences of either species in Black Hills National Forest. Groundcedar occurs on soils derived from schists or shale parent material at both Upper Sand Creek and Custer Crossing, and the mineral rich soils in the northern Black Hills may also be a habitat requirement for both species. All known occurrences are strictly associated with a thick bed of moss, and are confined within the limits of existing high soil moisture conditions. It is likely that surrounding trees provide shade and a climatic buffer around the occurrences.

There is evidence that fire negatively influences both species by killing aboveground portions of the plant; however, fire is necessary for the maintenance of well distributed seral stages in forested habitats. Groundcedar and stiff clubmoss regenerate following fire by sprouting from surviving surface rhizomes (Soltis and Soltis 1988; Nauertz 1999). Stiff clubmoss is killed by intense fire, but it may regenerate from surface rhizomes following fast-moving fires of low intensity (Matthews 1993), and the rhizomes of a groundcedar subspecies (*L. complanatum* spp. *chamaecyparissus*) can survive fire belowground and resprout (Kukkonen 1967). Higher elevations and north-facing slopes tend to have less frequent, but more intense fires, than lower

elevations and southern aspects (Brown and Sieg 1996, 1999). However, on a microscale, there are often mesic areas that would not burn, whether they occur at low or high elevation (Sieg and Wright 1996; Severson and Boldt 1989). Because *Lycopodium* spores can survive for several years without germinating, and the gametophytes may live underground for decades, it is possible that both species are well adapted to regenerate following a catastrophic disturbance.

It is not known how either species responds to fire in their habitats in the Black Hills, but elsewhere they apparently respond differently in different plant community types (Matthews 1993). However, there is no evidence to suggest that either species depends upon fire or other disturbances for its establishment or persistence.

In Michigan, stiff clubmoss was most abundant in unmanaged old growth and managed even-aged forests, possibly due to the amount of time between disturbances in these deciduous forest types (Nauertz 1999). Nauertz (1999) also indicated that although higher cover values for stiff clubmoss were more common in unmanaged old growth and managed even-age stands, this could be due to its tolerance of a range of moisture conditions and frequency in rocky, acidic soils rather than the method of forest management. Nauertz (1999) suggests that a minimum of 80 years after disturbance is required for *Lycopodium* species to show substantial increases in cover and frequency. This is in part due to the long period of time (up to 20 years) it takes for the species to mature from spore to gametophyte to sporophyte (Nauertz and Zasada 1999).

Key Risk Factors

The greatest risk to both species in the Black Hills is the small number and limited size of occurrences on Forest Service administered lands. There are no apparent ongoing risks to either species, but all known locations are small enough that random events, such as drought or fire, could eradicate an occurrence entirely. As boreal remnants, climatic changes since the last glacial period may be the primary controlling factor for the frequency and persistence of these species and habitats that would support them. It should be considered that remnant occurrences of northern boreal species simply may not be able to persist, or the species may not be able to colonize other sites, under current or future climatic conditions in the Black Hills.

Groundcedar occurrences in the Black Hills National Forest are unlikely to be impacted by timber harvesting or other management activities. National Environmental Policy Act (NEPA) of 1969 [42 U.S.C. 4321 (note)] analyses for proposed management include an assessment of known locations of designated sensitive species. Known sites are avoided to the extent possible unless activities are designed to enhance conditions at known occurrences. Surface mining activities in or near known sites could impact the species and their habitats (USDA Forest Service 2001). The Lead, Deadwood and Galena areas in the northern Black Hills have been at the center of both recent and historic gold mining activity (USDA Forest Service 1996). These mining areas encompass all known occurrences of groundcedar and stiff clubmoss in the Black Hills National Forest. Future mining activity is likely to occur in the area (USDA Forest Service 1996). The Upper Sand Creek Botanical Area is withdrawn from mineral entry.

Although dense spruce cover may enhance shade and snowfield retention at the sites, the continuity of highly flammable, dense pine stands adjacent to the Upper Sand Creek occurrences is of concern. Similar conditions exist near other known groundcedar and stiff clubmoss occurrences. Large tracts of dense conifers may lead to widespread, high severity wildfires that could negatively affect clubmoss sites. Prescribed fire or fuels reduction activities are subject to

NEPA analysis. Wildfire and fire containment measures are a potential risk to both species.

The Upper Sand Creek site is in an active cattle-grazing allotment, but the *Lycopodium* occurrences are on a steep (40 to 50 percent) slope that prevents cattle access. The site is also within a 20-acre (8-ha) placer mining claim, but there is no foreseeable risk to the species since the site is within the designated Upper Sand Creek Botanical Area and is therefore withdrawn from mineral entry. The Upper Sand Creek site is adjacent to private property and is accessible by road. Privately owned roads and land adjacent to the site may preclude heavy use of the area by the public, but Forest system roads border the site ca. 50 ft (15 m) below the site on two sides and there is evidence of off-road vehicle use in the area, particularly along Sand Creek north of the site. Tree cover at the site may provide shelter from vehicle or management activity along the roads or in the creek bottom. Changes from the current use of private lands adjacent to known sites or an increase in public use of these areas could negatively affect the species and their habitats (USDA Forest Service 1996). No immediate risks to either species were observed at the site in 2000 or 2001.

The Strawberry Creek and Custer Crossing sites in Lawrence County are in active grazing allotments, but are either too steep (>30 percent slope) or are protected by dense thickets that exclude cattle. A mining company and private individual own the property immediately adjacent to the Strawberry Creek Canyon stiff clubmoss occurrence (Ode 1989). There is a complex land-ownership pattern along Strawberry Creek that could present a risk to colonies of stiff clubmoss that are along the creek just within the forest boundary. The Gilt Edge mine is approximately 1 mile (1.6 km) upstream from the site and presents some degree of risk to the stiff clubmoss colonies from siltation and erosion along the streambed. Erosion was noted along Strawberry Creek in 1989 (Ode 1989); however silt traps of hay bales and steel posts were in place at that time. No erosion or other disturbance to the stream bank was noted at the time of the 2001 survey.

Although exotic, invasive plants are not currently an immediate risk to either species, there is potential for invasion. Invasive plant species occur in the vicinity of all known groundcedar and stiff clubmoss locations on Black Hills National Forest administered lands. Because these clubmoss species become established on disturbed soil, competition from colonizing weeds could inhibit their establishment. Nodding thistle (*Carduus nutans* L.), houndstongue (*Cynoglossum officinale*), St. John's wort (*Hypericum perforatum*), and tansy (*Tanacetum vulgare*) occur along Sand Creek, but do not currently occupy the groundcedar and stiff clubmoss site. Canada thistle (*Cirsium arvense*) and yellow toadflax (*Linaria vulgaris*) occur near the Strawberry Creek stiff clubmoss location. Canada thistle (*Cirsium arvense*) and houndstongue occur in the vicinity of the Custer Crossing groundcedar location. Although exotic, invasive plants occur in close proximity to the Upper Sand Creek site, they are not found within it. In this case, these invasive species may be excluded by conditions within the site such as shade or soil conditions. Site visits may need to be limited in order to prevent the introduction of noxious and other invasive plant species into the habitat.

Clubmosses are generally considered unpalatable due to alkaloids that are toxic to many animals (Ayer 1983; Markham and others 1983; Williams 1990). However, there is evidence of occasional moose *(Alces alces)* feeding on stiff clubmoss in Alaska (Foote 1983; Williams 1990). Moose do not occur in the Black Hills and monitoring in 2000 and 2001 did not reveal any impacts from wildlife browsing. No evidence of livestock use has been noted to date at the

Upper Sand Creek, Strawberry Creek or Custer Crossing occurrences. All three sites are either too steep (>30 percent slope) for livestock to access, or are protected by dense shrub thickets. For this reason, cattle do not currently pose any risk to any of the occurrences (USDA Forest Service 2000, 2001). However, the complete absence of plants or rhizomes from the small game trail that passes through the Custer Crossing groundcedar occurrence is evidence that the species does not tolerate trampling. There is no evidence of insect predation; it is uncommon on clubmosses (Lycopodiaceae), and fern allies in general (Lellinger 1985).

Management for mature spruce habitats in the Black Hills would likely conserve existing clubmoss habitats in the short term, but in the long term may reduce or eliminate seral boreal hardwood forest that both groundcedar and stiff clubmoss appear to require. The primary conservation concern for both species is small occurrence size and apparently narrow ecological amplitude of their habitats (Marriott and others 1990). The low number of sites makes both species particularly vulnerable to random events, such as floods or fires – either of which could eliminate an entire occurrence.

CONSERVATION PRACTICES

Management Practices

Because only two, small occurrences of each species are found on Black Hills National Forest administered lands, a conservative management approach is warranted. Livestock use, timber harvest and road building are precluded at known sites, or the occurrences are in topographic positions that provide natural barriers to these activities. Currently, exotic, invasive plant infestations have not been detected in or adjacent to the known occurrences; however, the maintenance of weed-free conditions at the sites is critical.

The Upper Sand Creek drainage and its surrounding uplands were given administrative designation as a botanical area in 1997 (USDA Forest Service 1996). Under this direction, the botanical area is to be managed in such a way that the drainage and the botanical features for which it was established are not impaired (USDA Forest Service 1996). Designated botanical areas are withdrawn from mineral entry, protected from off-road motorized use and travel is restricted to designated roads and trails, and timber harvest and firewood gathering are also restricted (USDA Forest Service 1996). Fire suppression and the use of prescribed fire may be allowed in botanical areas, but must protect the values for which the botanical area was set aside (USDA Forest Service 1996).

There is an active, 20-acre (8-ha) placer mining claim adjacent to, and possibly including, the Upper Sand Creek groundcedar and stiff clubmoss site. However, no permits to operate have been issued to date; both species occur 47 feet (14.3 m) above Sand Creek where panning or dredging would theoretically occur; and Sand Creek is a Class 1 stream where mining disturbance, such as digging and dredging, is not permitted by the State of Wyoming (Timm, personal communication).

The Brohm Mining Corporation of Deadwood, South Dakota owns property immediately adjacent to the Strawberry Creek occurrence (Ode 1989). The Gilt Edge mine is approximately 1 mile (1.6 km) upstream from the site. Silt traps of hay bales and steel posts to control erosion along Strawberry Creek have been in place since at least 1989 (Ode 1989). Test wells, monitoring stations, and a well with an electrical transformer cage have been installed along the

road and upstream from the site (Ode 1989). A single colony of groundcedar occurs nearby on private land on a north-facing slope (Ode 1989).

There is also a concern that intense wildfires could extirpate known occurrences of these two species. Where currently known occurrences are bordered by continuous, dense conifer stands, cutting firebreaks and other fuel reduction activities should be considered as mechanisms to allow crown fires to drop to the ground before fires burn into known sites. This fuel reduction approach could also provide a range of seral stages for later colonization, which might benefit the species' persistence in the long term. Tree removal in surrounding uplands could have the added benefit of providing increased moisture to the sites. However, given that both of these species are considered "boreal remnants," it is possible that there are few, if any, other sites on the Black Hills National Forest that are suitable for colonization by groundcedar or stiff clubmoss.

Conservation Measures

The Upper Sand Creek Botanical Area was established to conserve a suite of rare and sensitive species, which includes the larger occurrences of both groundcedar and stiff club moss and their habitats. In addition, The Nature Conservancy has targeted all known occurrences of both species in the Black Hills for conservation (Hall and others 2002). Groundcedar has been ranked as a high priority primary plant conservation target and stiff clubmoss is ranked as a secondary plant target, with currently known locations recommended for conservation attention (Hall and others 2002). Acquisition of all known sites may potentially be achieved through TNC easements or long-term Forest Service/TNC acquisition, but this is dependent upon funding, land availability, and landowner willingness to participate. In the event that additional potential habitats are identified, the conservation or acquisition of these sites for the potential introduction of both clubmoss species could be considered. Spores could be collected from known occurrences of both species and stored in a local repository to provide local genetic material for potential propagation and reintroduction efforts in the event that existing occurrences are lost or likely habitats for reintroduction are discovered elsewhere.

Survey, Inventory And Monitoring Approach

The occurrence of groundcedar and stiff clubmoss in the Black Hills is limited to two currently known sites of each species on National Forest land. The status of other sites on private land is unknown and the odds of finding additional occurrences in the Black Hills are low because of the rarity of moist boreal microhabitats and because a large amount of potential habitat has been surveyed. Both species are target species for plant surveys being completed on the Black Hills National Forest. Surveys of even marginally suitable habitats will continue in areas where projects are proposed, and in additional areas, as funding becomes available.

The persistence of both these species in the Black Hills is contingent on conserving the two known occurrences of each species on public land. Therefore, the current monitoring protocol is designed to detect and respond in a timely manner to changes in the extent and condition of the species and their habitat at known sites. Both species are evergreen and can be monitored at any time during the growing season, but are best observed in the spring or fall when overstory or other understory vegetative cover is low. Although it is feasible to count or estimate the number of aerial stems, it is not possible to distinguish individual plants without destructive techniques or time-consuming and costly genetic analysis. Because of the steep conditions at the Upper

Sand Creek site, there is concern that clubmoss plants and their habitat might be damaged during attempts to monitor them; and weeds can be introduced by monitoring staff. Efforts in 2000 and 2001 to spatially define the Sand Creek groundcedar occurrence using a Global Positioning System were not sufficiently accurate to reflect changes in the occurrences from year to year. Techniques that have less risk of impact to occurrences have been designed for future monitoring. Further, site visits may need to be limited to reduce the risk of introducing noxious weeds or other invasive plants to the sites.

The current monitoring protocol for groundcedar for 2002 is to determine whether or not each of the currently known patches is present, and to estimate the percent area occupied by the species in each of four quadrants for the Sand Creek occurrence. The current design includes permanently marking quadrants by placing pvc pipe in each of the four cardinal directions outside the perimeter of the occurrence, and using the pvc pipe to define a north-south and an east-west transect bisecting the patch. Plans are to review the monitoring data periodically to determine if changes in the protocol are warranted. In particular, if the extent of the Sand Creek groundcedar occurrence declines by more than 10 percent, plans are to consult scientists and biometricians familiar with the species on more rigorous sampling techniques.

The current monitoring protocol for stiff clubmoss consists of determining whether or not each of the currently known sites is present. Because one of three known patches of stiff clubmoss in the Sand Creek Botanical Area is in the middle of the groundcedar occurrence, baseline data have been gathered for that patch, and the quadrant monitoring method currently designed for groundcedar could be used for any future monitoring of stiff clubmoss. The presence of invasive or noxious plant species or any disturbance to the sites is to be recorded.

CONCLUSIONS AND INFORMATION NEEDS

Literature on the ecology of groundcedar and stiff clubmoss in the Black Hills is almost non-existent and the applicability of the small amount of information from elsewhere is limited. With only two small occurrences each of groundcedar and stiff clubmoss on Forest Service lands, and status uncertain on most private land occurrences, the long-term persistence of both of these species in the Black Hills is questionable. Until recently, one occurrence of groundcedar was known from Black Hills National Forest lands and was included in a recently designated botanical area. One of the stiff clubmoss occurrences is also found within the same botanical area. Conservation of known occurrences of stiff clubmoss on lands of mixed ownership is a priority of The Nature Conservancy (Hall and others 2002).

Recognizing the importance of conserving the limited occurrences of groundcedar on Forest Service land, a rigorous monitoring protocol was put in place beginning in 2000 for the (then) one known location at Upper Sand Creek. The monitoring protocol has been redesigned (2002) to include the new occurrence site at Custer Crossing. The hope is to detect, and respond in a timely manner, to changes in the status of groundcedar or its habitat from exotic or noxious plant invasion, disturbance to the site, or stochastic events such as drought. Because of similarities in growth characteristics revealed by baseline data collection, stiff clubmoss could likely be monitored using the same protocols. As data become available, the monitoring plan may be revised and augmented, as needed. In addition, new information may be valuable in designing conservation measures for the species.

Both species are targets for plant surveys being completed on the Black Hills National Forest. A predictive habitat mapping effort was conducted in the Northern Black Hills in 2002 that identified potential rare plant locations, based upon the distribution of sheltered north-facing aspects (Zacharkevics and Silvey 2002, unpublished data). This approach was effective in identifying boreal remnant habitats, particularly those dominated by birch (Zacharkevics and Silvey 2002, unpublished data). Similar mapping efforts could be used to identify potential occurrences of groundcedar and stiff clubmoss.

There are many aspects of the genetic makeup and life history attributes of groundcedar and stiff clubmoss that are unknown. It is not known if the Black Hills occurrences are subspecies or ecotypes of occurrences in the main portion of the species' ranges. It is also unknown to what degree individual plants are related within occurrences, or how the Black Hills occurrences are related to each other. These genetic attributes are potentially highly relevant in developing plans to store spores and exploring both *ex situ* and in situ propagation techniques for these rare boreal species.

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APPENDICES

Appendix A. Technical description of groundcedar, *Lycopodium complanatum*.

Alternative taxonomic treatments for groundcedar, *Lycopodium complanatum*, include: *Diphasiastrum complanatum* (L.) Holub.; *Diphasium anceps* (Wallr.) A. & D. Lőve; *Diphasium complanatum* (L.) Rothm.; *Diphasium complanatum* (L.) Rothm. ssp. *montellii* Kukkonen; *Diphasium wallrothii* H.P. Fuchs; *Lycopodium anceps* Wallr.; *Lycopodium complanatum* L. ssp. *anceps* (Wallr.) Aschers; and *Lycopodium* complanatum L. var. *canadense* Victorin. (Flora of North America Editorial Committee 2000; Missouri Botanical Garden 2001; USDA NRCS 2001). *Lycopodium complanatum* L. var. *flabelliforme* Fernald is now recognized as a separate species (Flora of North America Editorial Committee 2000).

Groundcedar is an evergreen, perennial herb with branched upright stems 4 to 12 inches (10 to 30 cm) arising from horizontal, shallow growing or creeping stems; leaves are scale-like, ~1/16th inch (1 to 2 mm) long with acute tips and are spirally arranged in three rows on the upper and lower surfaces of the branchlets; branchlets are flattened in cross section, green and faintly shiny on the upper side and dull, pale and flat on the underside, and have a saw-toothed appearance due to the spreading tips of the marginal leaves; the spore-bearing cones (strobili) are ½ to 1 ½ inches (1 to 3 cm) long, solitary or in candelabra-like arrangements of two to five, and are borne on sparsely scaly stalks 1 ½ to 3 inches (3 to 6 cm) long; the sporophylls are broadly triangular to heart-shaped, 1/16th to 1/8th inches (2 to 3 mm) by ~1/8th inches (2 to 2.4 mm) with an abruptly tapered tip (fig. 4) (Hitchcock and others 1969; Lellinger 1985; Fertig 1993; Flora of North America Editorial Committee 2000).

Appendix B. Technical description of stiff clubmoss, *Lycopodium annotinum*.

Alternative taxonomic treatments for *Lycopodium annotinum* include: *Lycopodium dubium* Zoega (USDA NRCS Plants Database 2001); and *Lepidotis annotina* (L.) P. Beauv. (Missouri Botanical Garden 2001). In addition, these subtaxa may represent environmentally induced forms: *L. annotinum* (L.) var. *pungens* (La Pylaie) Desv.; *L. annotinum* (L.) var. *annotinum*; *L. annotinum* (L.) var. *alpestre* C. Hartman (Flora of North America 1993); *L. annotinum* (L.) ssp. *pungens* (La Pylaie) Hultén; *L. annotinum* (L.) var. *acrifolium* Fern.; and *L. annotinum* (L.) ssp. *alpestre* (Hartman) A. & D. Löve (USDA NRCS Plants Database 2001). The Flora of North America (2001) does not currently recognize the subspecies and varieties of *Lycopodium annotinum* as distinct taxa. The varieties *L. annotinum* var. *annotinum*, *L. annotinum* var. *acrifolium* Fern., *L. annotinum* var. *pungens* (LaPyle) Desv., and *L. annotinum* var. *alpestre* Hartman are recognized elsewhere based upon ecological and morphological characteristics (Fernald 1950; Matthews 1993).

Stiff clubmoss arises from horizontal creeping stems that occasionally fork or root at the nodes; both the horizontal and erect stems are sparsely covered with leaves; erect stems are clustered along horizontal stems, 2.5 to 12 inches (6 to 30 cm) long, and are mostly entire with occasional lateral branches; the leaves are 1/8th to ½ inches (3 to 11 mm) long, narrow with a sharply pointed tip, and the leaf margin varies from virtually no teeth to a few obvious large teeth; the leaves are spreading to reflexed along the stem; the cones or strobili are ¼ to 2 inches (0.6 to 4.5 cm.) long, borne singly at the end of the branchlets; sporophylls are 1/16th to 1/8th in (1.5 to 3.5 mm) by 1/32nd to 1/16th inches (0.7 to 2 mm) and abruptly narrowed to a pointed tip (fig. 5) (Hitchcock and others 1969; Lellinger 1985; Fertig 1993, 2001; Flora of North America Editorial Committee 2000).

Appendix C. Climate summaries for groundcedar, *Lycopodium complanatum*, and stiff clubmoss, *Lycopodium annotinum*, on Black Hills National Forest.

Upper Sand Creek (Lead, SD Climate Station):
The closest weather stations to the Upper Sand Creek groundcedar and stiff clubmoss populations are the Spearfish, South Dakota Climate Station, approximately 15 miles (24.1 km) to the northeast, and the Sundance, Wyoming Climate Station, 15 miles (24.1 km) to the west. Although the Spearfish and Sundance Climate Stations are geographically closer to the Upper Sand Creek site, they are lower in elevation than the Sand Creek population. For this reason, climate data from the Lead Climate Station are likely the best representation of climatic conditions at Sand Creek. Precipitation at the Lead Climate Station is concentrated in April, May and June and snowfall is concentrated in March and April (High Plains Regional Climate Center 2001).

Custer Crossing (Buskala Ranch, Deerfield and Lead, South Dakota Climate Stations)
The Lead Climate Station is approximately 10 miles (16.1 km) north of the Custer Crossing groundcedar population. The Buskala Ranch station is approximately 3 miles (4.8 km) to the west-southwest of the Custer Crossing groundcedar population. There is insufficient temperature data for Buskala Ranch. Precipitation is concentrated in May, June and July, and snowfall is concentrated in January, February and March (High Plains Regional Climate Center 2001). Climatic conditions at the Deerfield 5 NW Climate Station, 15 miles (24.1 km) to the south of the Custer Crossing site, are very similar to monthly and annual precipitation and snowfall at the Buskala Ranch station, and may roughly reflect annual temperatures maximums and minimums at Custer Crossing.

Strawberry Creek (Lead, South Dakota Climate Stations)
The Lead Climate Station (period of record 1948 through 2000), approximately 5 miles (8.1 km) northwest of the Strawberry Creek Canyon stiff clubmoss population. Very similar climate data are reported for the Deadwood Climate Station (period of record 1948 through 2000), also 5 miles (8.1 km) to the northwest of the site.

Climate summary for groundcedar and stiff clubmoss populations in the Black Hills National Forest (High Plains Regional Climate Center 2001).

Climate Station	Period of record	Average min. temp. (January)	Average max. temp. (July)	Total annual precip.	Average total snowfall
Buskala Ranch	1948-1997	Insufficient data	Insufficient data	23.4 inches (59.4 cm)	145.1 inches (368.6 cm)
Deerfield	1948-1980	0.8° F (-17.4° C)	77.1° F (25.0° C)	22.95 inches (58.3 cm)	155.7 inches (395.5 cm)
Lead	1948-2000	14.0º F (-10º C)	79.5º F (26.4º C)	29.0 inches (73.7 cm)	169.3 inches (430.0 cm)

FIGURES

Figure 1. North American distribution of groundcedar (*Lycopodium complanatum*; syn. *Diphasiastrum complanatum*) (Flora of North America Editorial Committee 1993, 2002 – online).

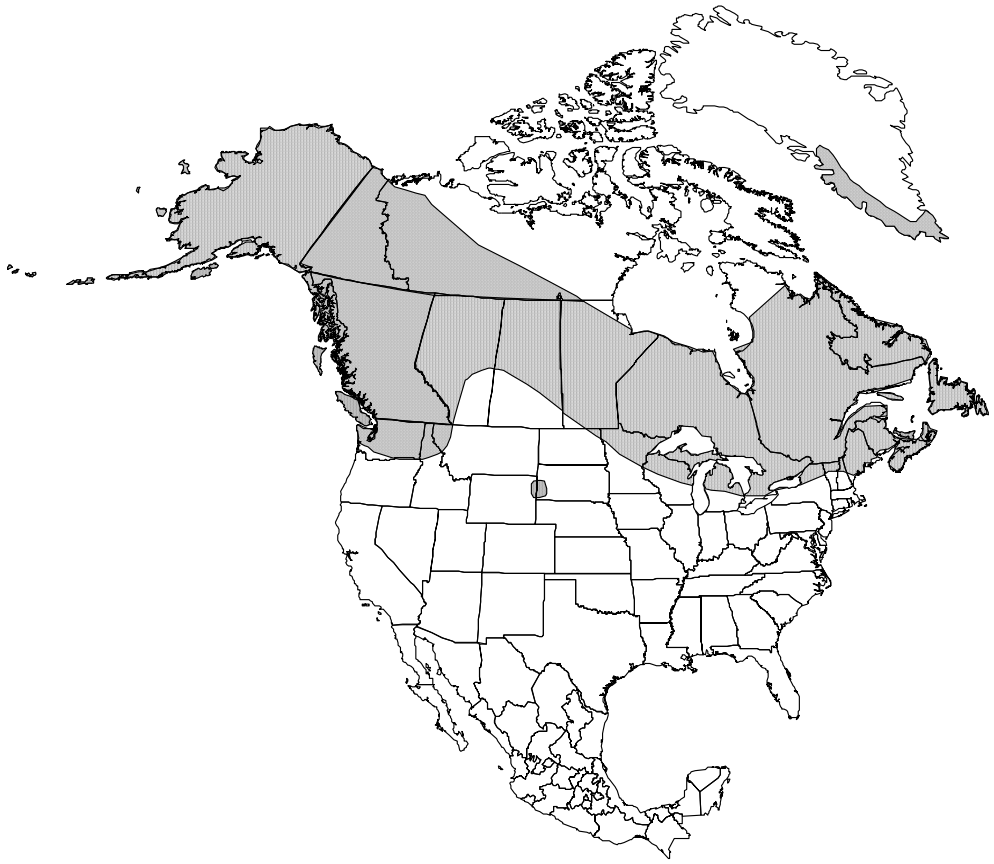

Figure 2. North American distribution of stiff clubmoss (*Lycopodium annotinum*) (Flora of North America Editorial Committee 1993, 2002 – online).

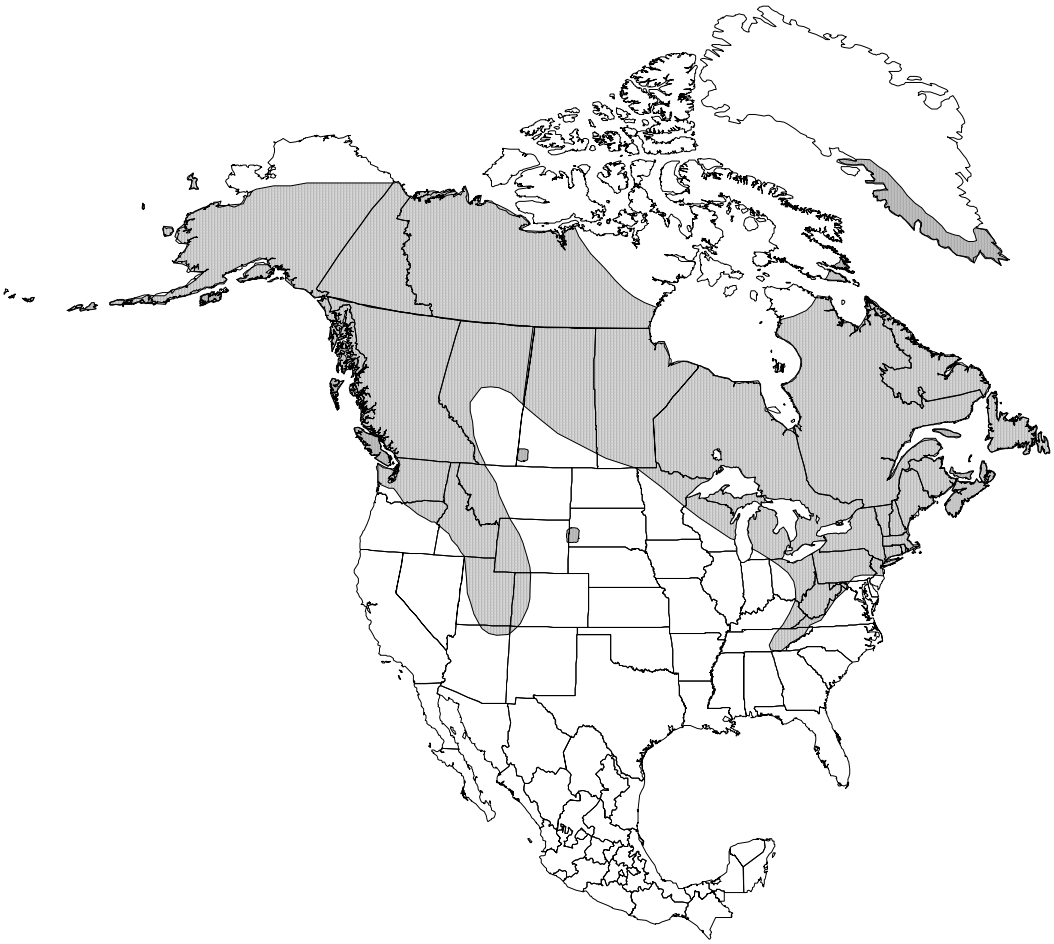

Figure 3. Black Hills distribution of groundcedar (*Lycopodium complanatum*) (LYCO) and stiff club moss (*Lycopodium annotinum*) (LYAN).

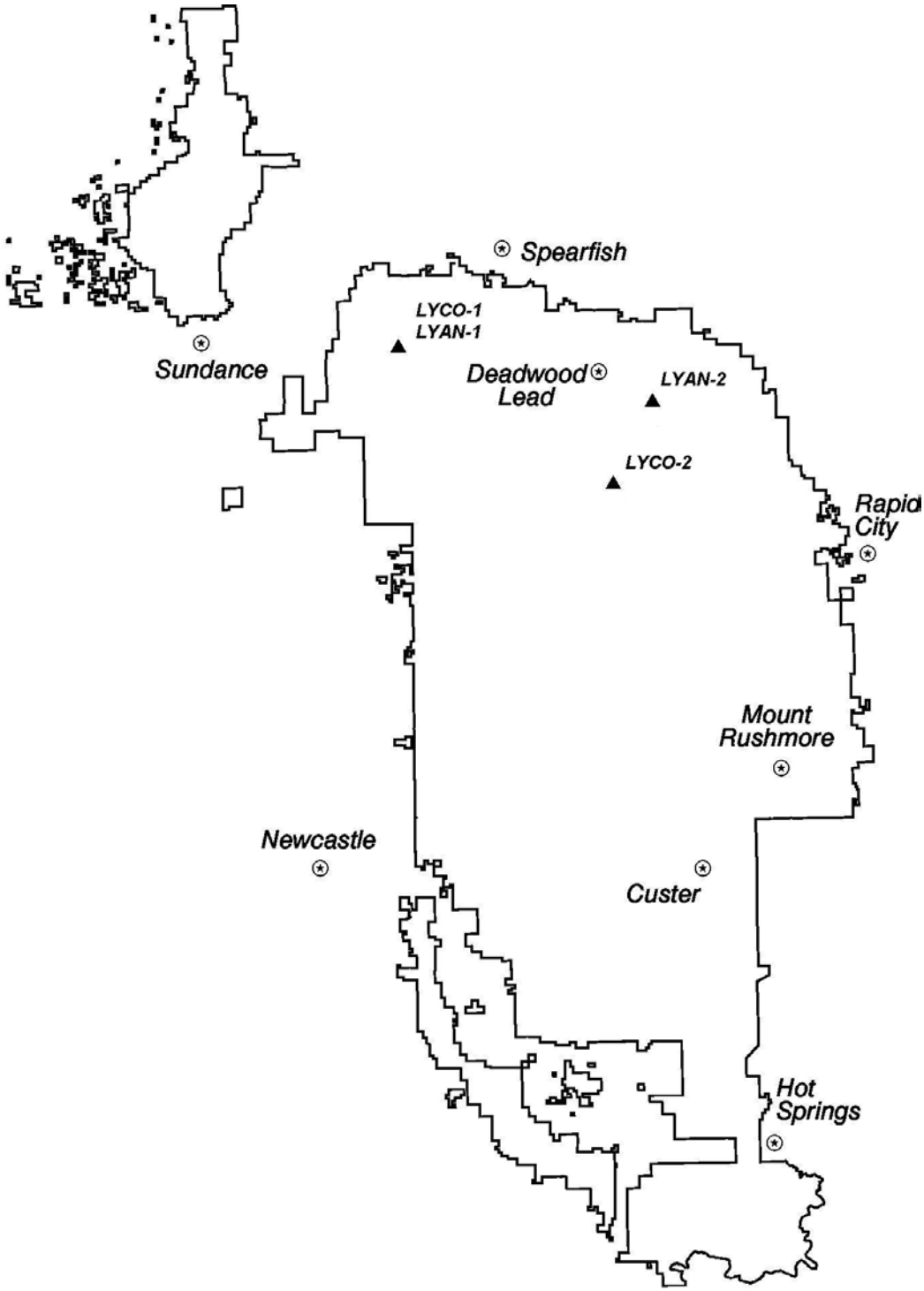

Figure 4. Color illustration of groundcedar (*Lycopodium complanatum* L.) (C.A.M. Lindman: Bilder ur Nordens Flora 1901-1905).

Figure 5. Stiff clubmoss (*Lycopodium annotinum* L.) color illustration (C.A.M. Lindman: Bilder ur Nordens Flora 1901-1905).

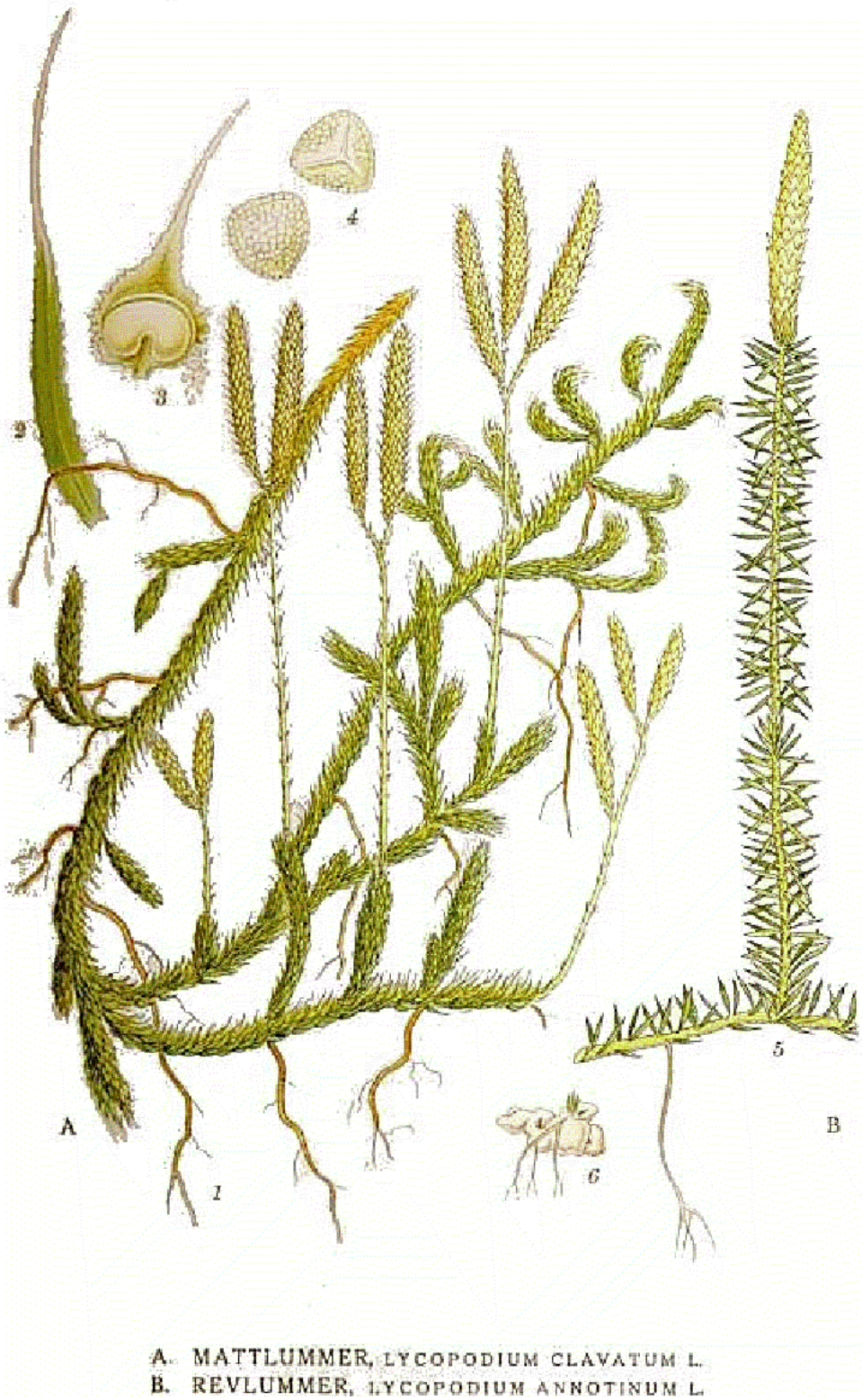

Figure 6. Groundcedar and stiff clubmoss habitat in the Black Hills.

TABLES

Table 1. Conservation status of *Lycopodium complanatum* L. in North America (NatureServe 2001).

State or Province	Rank	Definition
New York	S1	Critically imperiled due to extreme rarity.
South Dakota	S1	Critically imperiled due to extreme rarity.
Wyoming	S1	Critically imperiled due to extreme rarity.
Vermont	S1S2	Imperiled to critically imperiled due to rarity.
Oregon	S2	Imperiled due to rarity.
Nova Scotia	S3?	Vulnerable?
Prince Edward Island	S3?	Vulnerable?
Michigan	S4	Apparently secure.
Labrador (Newfoundland)	S4S5	Apparently secure to secure.
Newfoundland Isl.	S4S5	Apparently secure to secure.
Alberta	S5	Demonstrably widespread, abundant, and secure.
Manitoba	S5	Demonstrably widespread, abundant, and secure.
Ontario	S5	Demonstrably widespread, abundant, and secure.
Alaska	SR	Reported.
Idaho	SR	Reported.
Maine	SR	Reported.
Minnesota	SR	Reported.
Montana	SR	Reported.
New Brunswick	SR	Reported.
New Hampshire	SR	Reported.
Northwest Territories	SR	Reported.
Nunavut	SR	Reported.
Quebec	SR	Reported.
Washington	SR	Reported.
Wisconsin	SR	Reported.
Yukon Territory	SR	Reported.
British Columbia	S?	Rank not determined.
Saskatchewan	S?	Rank not determined.

Table 2. Conservation status of *Lycopodium annotinum* L. in North America (NatureServe 2001).

State or Province	Rank	Definition
New Jersey	S1	Critically imperiled due to extreme rarity.
Rhode Island	S1	Critically imperiled due to extreme rarity.
South Dakota	S1	Critically imperiled due to extreme rarity.
New Mexico	S2	Imperiled due to rarity.
Wyoming	S2	Imperiled due to rarity.
Oregon	S3	Vulnerable.
Connecticut	S3S4	Vulnerable to extirpation or extinction to apparently secure
Colorado	S4	Apparently secure.
Labrador (Newfoundland)	S4S5	Apparently secure to demonstrably secure.
Maryland	S4S5	Apparently secure to demonstrably secure.
Newfoundland Is.	S4S5	Apparently secure to demonstrably secure.
Alberta	S5	Demonstrably widespread, abundant, and secure.
Manitoba	S5	Demonstrably widespread, abundant, and secure.
Nova Scotia	S5	Demonstrably widespread, abundant, and secure.
Ontario	S5	Demonstrably widespread, abundant, and secure.
Prince Edward Island	S5	Demonstrably widespread, abundant, and secure.
Alaska	SR	Reported.
Arizona	SR	Reported.
Idaho	SR	Reported.
Kentucky	SR	Reported.
Maine	SR	Reported.
Massachusetts	SR	Reported.
Minnesota	SR	Reported.
Montana	SR	Reported.
New Brunswick	SR	Reported.
New Hampshire	SR	Reported.

State or Province	Rank	Definition
New York	SR	Reported.
North Carolina	SR	Reported.
Northwest Territories	SR	Reported.
Nunavut	SR	Reported.
Ohio	SR	Reported.
Quebec	SR	Reported.
Utah	SR	Reported.
Vermont	SR	Reported.
Washington	SR	Reported.
Wisconsin	SR	Reported.
Yukon Territory	SR	Reported.
Tennessee	SH	Known only from historic records-may still exist.
British Columbia	S?	Rank not determined.
Michigan	S?	Rank not determined.
Pennsylvania	S?	Rank not determined.
Saskatchewan	S?	Rank not determined.
West Virginia	S?	Rank not determined.

Table 3. Groundcedar (*Lycopodium complanatum*) and stiff clubmoss (*L. annotinum*) species associates. Compiled from three known sites in 2000 on the Black Hills National Forest.

Scientific Name	**Common Name**	**Family**
Anaphalis margaritacea	Pearly everlasting	Asteraceae
Aralia nudicaulis	Wild sarsaparilla	Araliaceae
Arnica cordifolia	Heart leaved arnica	Asteraceae
Aster spp.	Asters	Asteraceae
Betula papyrifera*	Paper birch	Betulaceae
Cornus canadensis*	Bunchberry	Cornaceae
Corylus cornuta	Beaked hazelnut	Betulaceae
Crepis runcinata	Fiddleleaf hawksbeard	Asteraceae
Disporum trachycarpum	Fairybells	Liliaceae
Fragaria virginiana	Wild strawberry	Rosaceae
Galium sp.	Bedstraw	Rubiaceae
Goodyera oblongifolia	Rattlesnake plantain	Orchidaceae
Juniperus communis	Common juniper	Cupressaceae
Lathyrus sp.	Wild pea	Fabaceae
Linnaea borealis*	Twinflower	Caprifoliaceae
Lycopodium dendroideum	Treelike clubmoss	Lycopodiaceae
Mahonia repens	Creeping barberry	Berberidaceae
Maianthemum canadense	Canada mayflower	Liliaceae
Orthilia secunda (syn. *Pyrola secunda*)	Sidebells wintergreen	Pyrolaceae
Oryzopsis asperifolia*	Roughleaf ricegrass	Poaceae
Scientific Name	**Common Name**	**Family**
Picea glauca*	White spruce	Pinaceae
Pinus ponderosa	Ponderosa pine	Pinaceae
Populus tremuloides	Quaking aspen	Salicaceae
Prunus virginiana	Chokecherry	Rosaceae
Pteridium aquilinum	Western bracken fern	Dennstaedtiaceae

Scientific Name	**Common Name**	**Family**
Ribes sp.	Currant	Grossulariaceae
Rosa sp.	Rose	Rosaceae
Rubus sp.	Blackberry	Rosaceae
Spiraea betulifolia	Birch-leaved spiraea	Rosaceae
Symphoricarpus albus	White snowberry	Rosaceae
Taraxacum officinalis	Dandelion	Asteraceae
Vaccinium membranaceum	Thinleaf huckleberry	Ericaceae
Vaccinium scoparium*	Grouseberry	Ericaceae
Vicia sp.	Vetch	Fabaceae
Viola sp.	Violet	Violaceae
unknown	**Mosses***	
unknown	Lichens	

* Species found at all three sites