Selaginella selaginoides (L.) Beauv. ex Mart. & Schrank (club spikemoss): A Technical Conservation Assessment

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Bonnie Heidel and Joy Handley
Wyoming Natural Diversity Database
University of Wyoming
Department 3381, 1000 E. University Avenue
Laramie, WY 82071

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AUTHORS' BIOGRAPHIES

Bonnie Heidel graduated with a Bachelor of Arts degree from Carleton College in Northfield, MN, majoring in Biology, with honors awarded for her senior thesis. She graduated with a Masters degree in Botany from Washington State University in Pullman, WA, working on the rare plants of northern Idaho. She worked on Threatened and Endangered species for the U.S. Fish & Wildlife Service Regional Office in Portland, OR, on plant species status compilation in the Midwest Regional Office of The Nature Conservancy in Minneapolis, MN, on statewide sensitive species survey and related research in natural heritage program positions in Bismarck, ND and in Helena, MT. She is the Botanist of the Wyoming Natural Diversity Database, a research program and information clearinghouse of the University of Wyoming, conducting botanical surveys and research throughout the state.

Joy Handley graduated *cum laude* with a Bachelor of Science degree from the University of Idaho in Moscow, ID, majoring in Range Resources. She worked as a range management specialist with the Salmon National Forest in Leadore, ID and as an assistant vegetation ecologist with the Colville Confederated Tribes in Nespelem, WA. She graduated with a Master of Science degree in Botany from the University of Wyoming, conducting a floristic inventory of the Payette National Forest in Idaho. She is the Assistant Botanist at the Wyoming Natural Diversity Database.

COVER PHOTO CREDIT

*Selaginella selaginoides (*club spikemoss). Photograph by Jennifer Whipple, used with permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *SELAGINELLA SELAGINOIDES*

Status

Selaginella selaginoides (club spikemoss) is a circumboreal species whose distribution reaches its southern extent in the contiguous United States. USDA Forest Service (USFS), Rocky Mountain Region (Region 2) has designated this species as a sensitive species based on published information that indicates that it occurs in Colorado. However, in the course of compiling and corroborating information for this assessment, this information was found to be in error; there are, in fact, no known occurrences of this species in Colorado. Earlier reports of *S. selaginoides* in Colorado (i.e., Britton [1901] and Rydberg [1906]) could not be substantiated. In Wyoming, this species is known from six occurrences, all within the Intermountain Region (Region 4) of the USFS; three of these occurrences are close to boundary units within Region 2. However, there are no surveys or other documentation to prove or disprove that *S. selaginoides* is present in Region 2. There is potential *S. selaginoides* habitat in the Rocky Mountain Region, as later described in this assessment.

NatureServe considers *Selaginella selaginoides* to be globally secure (G5). The Colorado Natural Heritage Program state rank for this species was changed from a rank for species known only from historical records (SH), based on a 1978 report, to a rank for species that are falsely-reported from the state (SRF). The Wyoming Natural Diversity Database ranks this species as critically imperiled (S1) in the Wyoming.

Primary Threats

Selaginella selaginoides is a habitat specialist that requires cool, stable settings and groundwater near the surface during most or all of the growing season. The primary threats to this species on national forests in Region 2 cannot be ascertained without knowing locations, but the general threats to wetland habitat at low- to mid-elevation valley wetlands are habitat loss and degradation associated with water loss, inundation, or successional change. There is evidence to suggest that Wyoming populations may have been or could be impacted by water impoundment, campground development, subdivision development, and road construction. In addition, known populations are potentially affected by water diversions, beaver activity, grazing activities and range developments, crown fires in the surrounding watershed, timber harvest, and exotic species encroachment in the wetland habitat. Finally, the palynological record indicates that *S. selaginoides* is also susceptible to climate warming. As such, it may be a relict species with limited colonizing ability and restoration potential.

Primary Conservation Elements, Management Implications and Considerations

Selaginella selaginoides is a species that requires hydrological stability often associated with discharge zones of springs and seeps. Watershed, riparian corridor, and wetland management practices and policies may affect its conservation at different scales. In addition, the extant Wyoming populations appear to be hydrologically buffered by peat and marl accumulation in or near occupied wetland habitat, so maintaining the integrity and stability of the associated peatland system may be needed to maintain the microhabitat occupied by *S. selaginoides*. This specifically requires maintenance of existing groundwater flows and existing moss mat vegetation at occupied habitat. Baseline surveys for *S. selaginoides* are needed before it is possible to refine and prioritize this picture of conservation elements, management implications, and considerations.

TABLE OF CONTENTS

EDITOR: Richard Vacirca, USDA Forest Service, Rocky Mountain Region

LIST OF TABLES AND FIGURES

Tables:

Figures:

INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project of the USDA Forest Service (USFS), Rocky Mountain Region (Region 2). *Selaginella selaginoides* (club spikemoss) is the focus of an assessment because it is designated as a sensitive species in the Region. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce its distribution. A sensitive species may require special management, so knowledge of its biology and ecology is critical.

Goal

Species conservation assessments are produced as part of the Species Conservation Project to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, and conservation status of the species. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the available ecological background upon which management must be based and examines the consequences of changes in the environment that result from management. This assessment cites management recommendations proposed elsewhere and evaluates the success of those that have been implemented.

Scope

The *Selaginella selaginoides* assessment examines the biology, ecology, and management of this species throughout its range with specific reference to its potential habitat in Region 2 under current environmental conditions. Because the species' known distribution lies outside of Region 2, this assessment incorporates information from the rest of its range (i.e., Wyoming, Montana, the northern Great Lakes region, the northern New England region, and more northerly latitudes) and places it in the ecological context of Region 2. In producing the assessment, refereed literature, herbarium records, and information on the species' status and occurrences compiled by natural heritage programs were reviewed and interpreted. Such data represent the most complete available information for *S. selaginoides* in Region 2.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions for the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference, as described by Platt, suggests that experiments will produce clean results (Hillborn and Mangel 1997), as may be observed in certain physical sciences. The geologist T.C. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (e.g. experiments, modeling, logical inference). Ecological science is, in some ways, more similar to geology than physics because of the difficulty in conducting critical experiments and the reliance on observation, inference, good thinking, and models to guide understanding of the world (Hillborn and Mangel 1997).

This multiple-working-hypothesis approach is enhanced when used in concert with complete species status data to produce a robust analysis. However, previous reports of *Selaginella selaginoides* in the Rocky Mountain Region have not been substantiated, so there is no species status data from the Region. Instead, this assessment draws heavily from information on *S. selaginoides* outside of Region 2 in Wyoming and in Montana to make reasonable inferences. There are no closely-related species in the genus to use as models, nor are there other species in the genus that are restricted to wetland habitats, or have boreal distributions. However, there are other fern allies of wetland habitats and other boreal disjunct species that are cited as possible analogues. The strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

Publication on the World Wide Web

To facilitate their use in the Species Conservation Project, species conservation assessments are being published on the USFS Region 2 World Wide Web site (http://www.fs.fed.us/r2/projects/scp/assessments/index.shtml). Placing the documents on the web makes them available to agency biologists and the public more rapidly than publishing them as reports. More importantly, Web publication facilitates the revision

of assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the web. This assessment of *Selaginella selaginoides* was reviewed through a process administered by the Society for Conservation Biology, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Federal status

Selaginella selaginoides is a widespread species whose distribution reaches its southern extent in the contiguous United States, where it has been reported from Colorado and Wyoming. It is currently listed as a sensitive species within Region 2 of the USFS (**Table 1**; USDA Forest Service 2003a). All known Wyoming populations are in Region 4 of the USFS, where it does not have sensitive species status. Although *S. selaginoides* was reported from a single location on the Routt National Forest, Colorado in Region 2, this report is believed to be in error, and there are no known occurrences in Region 2.

Natural Heritage Program ranks

Selaginella selaginoides is ranked as globally secure (G5; **Table 1**; NatureServe 2005). It is ranked as critically imperiled (S1) in Wyoming (Keinath et al. 2003). It was ranked as known only from historical records (SH) in Colorado based on a 1978 report. Since then, it has been determined that this report is not valid, so it is no longer posted as a species of concern in the state (Colorado Natural Heritage Program 2005), and its rank has changed to indicate that it is falsely-reported in the state (SRF). Outside of Region 2, *S. selaginoides* is ranked as imperiled (S2) in Montana (Montana Natural Heritage Program 2003) and critically imperiled (S1) in Wisconsin, Minnesota, and Maine. Alaska, Idaho, Michigan, Nevada, and New Hampshire do not track *S. selaginoides* and do not rank it. In Canada this species is ranked as imperiled (S2) in Manitoba, New Brunswick, Nova Scotia, and Saskatchewan and vulnerable (S3) in Alberta. All other provinces and territories rank *S. selaginoides* as demonstrably secure, apparently secure, or do not rank it (except for Nunavut where it does not occur).

Table 1. Conservation status and Natural Heritage Program ranks of *Selaginella selaginoides*.

Listing	Status/Rank
U.S. Forest Service Region 2 Sensitive Species List[1]	Sensitive
U.S. Fish and Wildlife Service Endangered Species Act	Not listed
NatureServe Global Ranking[2]	Secure (G5)
Colorado Natural Heritage Program2	Reported for the state based on a false report (SRF)
Wyoming Natural Diversity Database[2]	Critically imperiled (S1)

[1]USDA Forest Service (2003a).

[2]Natural Heritage Program ranks: a standardized ranking system originally developed by The Nature Conservancy and its network of state natural heritage programs (e.g., Colorado Natural Heritage Program, Wyoming Natural Diversity Database) to assess the global and statewide abundance and the probability of extinction of each plant and animal species, subspecies, and variety. The global and state-rank codes are as follows:

G Global rank: rank refers to the rangewide status of a species.

S State rank: rank refers to the status of the taxon in particular state (e.g., Colorado, Wyoming).

Each taxon is ranked on a scale of 1-5 from most vulnerable to extirpation to least.

1 Critically imperiled because of extreme rarity (often known from 5 or fewer extant occurrences or very few remaining individuals) or because some factor of a species' life history makes it vulnerable to extinction.

2 Imperiled because of rarity (often known from 6-20 occurrences) or because of factors demonstrably making a species ulnerable to extinction.

3 Rare or local throughout its range or found locally in a restricted range (usually known from 21-100 occurrences).

4 Apparently secure, although the species may be quite rare in parts of its range, especially at the periphery.

5 Demonstrably secure, although the species may be rare in parts of its range, especially at the periphery.

State protection

Maine designates *Selaginella selaginoides* as Threatened (Maine Department of Conservation 2005) while Minnesota and Wisconsin designate it as Endangered (Minnesota Department of Natural Resources 2005, Wisconsin Department of Natural Resources 2005). There is no state legislation or policy protecting rare plant species in the western states where it occurs, including Montana and Wyoming.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Selaginella selaginoides is a sensitive species in USFS Region 2. Sensitive species designation in the National Forest System signifies it "is a plant species identified by the Regional Forester for which population viability is a concern as evidenced by a significant current or predicted downward trend in population number or density and/or a significant current or predicted downward trend in habitat capability that would reduce a species' existing distribution" (USDA Forest Service 2003a). By USFS mandate, sensitive species must be prevented from becoming designated threatened or endangered by the U.S. Fish and Wildlife Service. *Selaginella selaginoides* has no status under the Endangered Species Act of 1973 (U.S.C. 1531-1536, 1538-1540).

Research for this assessment shows that the presence of *Selaginella selaginoides* in Region 2 cannot be confirmed. The most likely locations of potentially suitable habitat for *S. selaginoides* in Region 2 have been identified and include the Park Range of Routt National Forest in Colorado, the Medicine Bow Mountains and Sierra Madre Range of Medicine Bow National Forest in Wyoming, and the Wind River and Absaroka Ranges and the Beartooth Mountains of Shoshone National Forest, also in Wyoming.

If *Selaginella selaginoides* is found in these areas, then regional and forest management plans would apply. In the Rocky Mountains, *S. selaginoides* is located in riparian corridors, which are addressed as part of the Region 2 Watershed Conservation Practices Handbook (WCPH). Under the WCPH, riparian habitat has a 100 foot buffer as necessary to limit actions in projects to improve watershed health and forest cover and to provide secondary benefits that include protection for associated threatened, endangered, and sensitive species. The Shoshone National Forest Land and Resources Management Plan is in the process of being updated. The current Medicine Bow National Forest Land and Resources Management Plan (USDA Forest Service 2003b) addresses *S. selaginoides* in a Biological Effects evaluation in the Final Environmental Impact Statement as a species that may potentially have habitat in the Medicine Bow National Forest. In addition, this same planning document includes provisions for creating a 300 foot habitat buffer as part of project developments to protect threatened, endangered, and sensitive species that depend on aquatic habitat. While originally developed for fish species, this provision may be applicable to *S. selaginoides*. As part of all these standards, this species has been routinely addressed in biological evaluations in the Medicine Bow and Routt national forests of Region 2 (Proctor personal communication 2005), and an analysis of typical management effects has been developed for *S. selaginoides* in an effects matrix as a regional reference (Proctor 2005).

There are eight collections of *Selaginella selaginoides* that have been made in that portion of Wyoming that falls within Region 4; these are reasonably close to Shoshone National Forest in Region 2 (within approximately 15 to 60 air miles). There are no existing regulatory mechanisms, management plans, or conservation strategies for these occurrences.

Biology and Ecology

Classification and description

Systematics and synonymy

The Selaginellaceae is in the division Lycopodiophyta. The Lycopodiophyta is one of four groups in the pteridophytes, or the ferns and fern allies (vascular cryptogams), which are primitive vascular land plants characterized as having both a well-developed vascular system and independent sporophyte and gametophyte life history stages (Raven et al. 1999). The modern herbaceous Lycopodiophyta appear to be a separate evolutionary line from the giant, tree-like clubmosses that made up the coal flora forests of the Carboniferous (Lellinger 1985). The modern genus *Selaginella* has changed little changed since the Pennsylvanian (Lellinger 1985).

Selaginella is the single genus in the Selaginellaceae (spike-moss family). This genus is comprised of about 700 species, with its center of distribution in tropics and warm climates (Tryon and Tryon 1982). The generic name *Selaginella* was first published by Ambroise Marie François Joseph Palisot

de Beauvois in 1804 and is a diminutive of *Selago*, an ancient name for some species in the closely-related genus of *Lycopodium* (Hitchcock et al. 1969).

The first published scientific name of *Selaginella selaginoides* was *Lycopodium selaginoides* (Linnaeus 1753). The specific epithet *selaginoides* was used by Linnaeus to refer to it as being "like Selago" (Hitchcock et al. 1969). The description of the *Selaginella* genus and the transfer of *S. selaginoides* was published by Ambroise Marie François Joseph Palisot de Beauvois (1829), and the complete scientific name is *S. selaginoides* (L.) P. Beauv. ex Mart. & Schrank. While the original Linnaen description of the genus *Lycopodium* emphasized the leaf-like features of the sporophylls, the revised treatment emphasized spores and sporophyll structure. Members of Selaginellaceae are heterosporous, and the sporangia are borne in modified leaf axils of a loose, open strobilus, whereas members of Lycopodiaceae are homosporous, and their leaves are not modified or else they are modified into a dense, cylindrical strobilus. According to Cronquist et al. (1972), Nevada materials tend to have smoother spores than is usual for the species, but no taxonomic segregation was proposed.

Selaginella selaginoides is in the subgenus *Selaginella*. It is the only species of this subgenus in conterminous North America (Hitchcock et al. 1969). The only close relative and member of the same subgenus is *S. deflexa*, endemic to Hawaii (Valdespino 1993). *Selaginella selaginoides* is generally thought to be a primitive member of the genus even though it has dispersal mechanisms and root development that may be derived characters (Karrfalt 1981, Page 1989, Valdespino 1993). There are species in different subgenera that are cultivated as ornamentals, sold as "resurrection plant" curiosities, and used locally for medicine (Mabberley 2000).

Selaginella selaginoides has the common name of club spikemoss (USDA Natural Resources Conservation Service 2005), in addition to the common names of low spike-moss (Keinath et al. 2003), northern spikemoss (Colorado Natural Heritage Program 2005), mountain spike-moss, and prickly mountain-moss.

History of the species

What we know today as "*Selaginella selaginoides*" was first named by Linnaeus as *Lycopodium selaginoides* (Linnaeus 1754) and described by him in Species Plantarum (Linnaeus 1753). The habitat included in the description was "Europæ *pascuis muscosis*."(European mossy pasture). In the description, Linnaeus mentioned his collection journeys in Lapland (Linnaeus 1737) but he did not designate holotypes for the Lapland specimen. This specimen, now deposited at the Linnaean Herbarium, London was designated as a lectotype by Jonsell and Jarvis (1994). The currently-recognized synonyms include *L. selaginoides* L., *S. spinosa* P. Beauv., and *Lycopodioides selaginoides* Kuntze. All published names are presented in **Table 2**.

The first Wyoming collection of *Selaginella selaginoides* was in 1902 by Edgar Alexander Mearns, an army surgeon and self-taught naturalist stationed at Fort Yellowstone, in Yellowstone National Park (Richmond 1918). This collection was deposited at the Smithsonian Institution and cited in the American Fern Journal by Holmgren (1942).

One of the first printed reports of *Selaginella selaginoides* in Colorado was made by Per Axel Rydberg (1906), noting "exact locality not given." In the introduction to his flora, Rydberg indicated that collections at the Agricultural College at Fort Collins (now Colorado State University) and at the herbaria of the New York Botanical Garden where he worked were

Table 2. Synonyms of *Selaginella selaginoides* (L.) Beauv. Ex Mart. & Schrank.

Scientific name and author	Year	Publication
Bernhardia spinosa Gray	1831	Nat. Arr. 2: 23
Lycopodium bryophyllum Presl	1825	Rel. Haenk., 1: 81
Lycopodium ciliatum Lamarck	1778	Fl. Franc. 1: 32
Lycopodioides selaginoides Kuntze	1891	Revis. Gen. Pl. 2: 824
Lycopodina spinulosa (A. Br.) Bubani	1901	Fl. Pyrenaea, 4: 445
Lycopodium selaginoides L.[basionym]	1753	Sp. Pl.: 1101
Selaginella ciliata Opiz	1823	Böhm. Phan. u. Crypt. Gew., 114
Selaginella spinosa P. Beauv.	1805	Prodr. Aethéogam., 101, 112

his primary sources. He also reviewed specimens from Harvard University and the Smithsonian Institution (GH, US). Finally, he consulted publications, and mentioned five books and the articles of five botanists published in eight journals. Almost all sources cited by Rydberg (1906; **Table 3**) have been searched for information on *S. selaginoides* and its synonyms without being able to find supporting documentation (**Table 3**). However, literature searches documented one earlier report of *S. selaginoides* from Colorado, reported by Britton (1901). Britton based his flora in large part on specimens at New York Botanical Garden, and communications with his colleagues including Rydberg. However, the geographic scope of Britton's flora extended no farther west than Kansas. Britton may have referred to information from Rydberg's work-in-progress.

There are at least three possible explanations for the unverified Rydberg (1906) report of *Selaginella selaginoides* in Colorado. First, it is possible that there was a historical specimen from Colorado at one time. A voucher specimen may have been lost or damaged beyond repair. Subsequent authors incorporated the distribution information in Rydberg (1906) including Robinson and Fernald (1908) and Britton and Brown (1913). Rydberg's report of *S. selaginoides* in Colorado was treated in a group of species considered as doubtful or erroneous in Colorado by Wherry (1938) because there was no known voucher. Harrington (1954) noted that he had never been able to locate a specimen for Colorado.

The second possibility is that, in the introduction to his Colorado flora, Rydberg (1906) alludes to being short-handed in "the more mechanical work of recording the localities" and that the report of *Selaginella selaginoides* in Colorado was in error. Prior to the time that Rydberg was working on the flora of Colorado early in the 20th century, based in New York, two specimens of *S. selaginoides* were collected and subsequently deposited at Colorado State University (Colorado Agricultural College). One was from Canada and the other was from Finland (Mark Simmons personal communication 2005). While it seems unlikely that information about *S. selaginoides* based on these specimens was incorporated by mistake, the omission of *S. selaginoides* from the Rocky Mountain flora subsequently prepared by Coulter and Nelson (1909), in full consideration of the work of Rydberg (1906) is consistent with this interpretation.

The third possibility is that Rydberg (1906) drew from documentation of *Selaginella selaginoides* in Colorado that he did not personally review, and which has been overlooked. The majority of sources described by Rydberg (1906) were reviewed for this assessment without finding documentation of *S. selaginoides* in Colorado (**Table 3**). Specimen information was sought

Table 3. Key references in evaluating whether *Selaginella selaginoides* is documented in Colorado, based primarily on the sources mentioned by Rydberg (1906).

Source type	Source	Check
Specimen	Colorado State University (Colorado Agricultural College)	Yes
Specimen	New York Botanical Garden (NY)	Yes
Specimen	Smithsonian Institution (US)	Yes
Specimen	Gray Herbarium (GH; Harvard University; includes former herbarium at College of Pharmacy - City of New York)	Yes
Book	Synopsis of the Flora of Colorado (Porter and Coulter)	Yes
Book	Manual of Rocky Mountain Botany (Coulter and Nelson)	Yes
Book	Flora of Southwestern Colorado (Brandegee)	Yes
Book	Flora of Denver and Vicinity (Eastwood)	Yes
Book	Report on Long Expedition (Torrey)	Yes
Book	Report on collections of Parry, Hall and Harbour (Gray)	Yes
Journals	Greene in Pittonia, Plantae Baerianae, and Leaflets	Partial
Journals	All other combinations of authors and journals (prior to 1906) listed by Rydberg; as on file in the reprint collection at the Rocky Mountain Herbarium (University of Wyoming, Lararmie, WY)	Partial
Journals	Colorado ferns article (Wherry 1938)	Yes
Book	Manual of the Plants of Colorado (Harrington 1954)	Yes
Book	Ferns and Fern Allies of the US and Canada (Lellinger 1985)	Yes

at the Gray Herbarium (Harvard University; GH), New York Botanical Garden (NY), and the Smithsonian Herbarium (US) but not found. The notes kept by Harrington in preparation of the second Colorado flora (Harrington 1954) were consulted with the assistance of University of Colorado botanists, and they simply cite the reports of the species by Rydberg (1906) and by Britton and Brown (1913). In addition to these primary sources of information, specimen records at regional herbaria were sought without finding additional collections in Colorado, including the University of Idaho (ID), Utah State College (UTC), and Washington State (WS).

Separate from the Rydberg (1906) report, there is a recent report of *Selaginella selaginoides* in Colorado, cited in Weber et al. (1979) and Weber and Wittmann (2001). It is based on a collection made by Dr. Dieter Wilkin in 1978 along Bear Creek in Jackson County on the Routt National Forest. The latter authors describe the circumstances around its discovery in the narrative for the Selaginaceae of eastern Colorado:

> "*Selaginella selaginoides* is one for which we have a sight record only. Dr. Dieter Wilken collected some mosses from a canyon in the eastern Park Range of North Park a few years ago, and having placed them in a terrarium for class use, he discovered that he had found the *Selaginella* for the first time in Colorado. However, by some strange accident, a specimen was not preserved, and we have not been able to locate it in the field again. Here is a challenge for someone."

This account has been corrected by Dr. Dieter Wilken who reported that the *Selaginella selaginoides* material was added to the terrarium by other botanists and was not collected with other plants from the Colorado canyon collection site (Wilken personal communication 2005). Wilken learned of this contamination only after *S. selaginoides* was published as an addition to the Colorado flora. It has subsequently been reported for Colorado by Lellinger (1985), Valdespino (1993) and Weber and Wittmann (2001) but the species has been removed from the Colorado checklist (Hartman and Nelson 2001) based on clarification made by Wilken.

In 1986, *Selaginella selaginoides* was reported from Colorado in a publication of ferns and fern allies in the United States (Lellinger 1985). Dr. Lellinger was consulted on reporting the species for Colorado. While there are no remaining records that he developed for this project, he cited four categories of information (Lellinger personal communication 2005). Lellinger depended on specimens at US, and there are no specimens of *S. selaginoides* from Colorado. He used published monographs, including that of Tryon (1955) which reports *S. selaginoides* in Colorado, presumably based on Rydberg (1906). He used reports of individual species as published by Weber et al. (1979). He also used published floras, but *S. selaginoides* was not included by Harrington (1954) or Wherry (1938). Whatever the validity or error of reports for *S. selaginoides* in Colorado, it is perpetuated in the *Flora of North America* (Valdespino 1993).

Non-technical description

Selaginella selaginoides is a moss-like, glabrous, perennial herb with slender, prostrate, dichotomously-branched vegetative stems and ascending, unbranched fertile stems arising 3 to 10 cm above the ground (**Figure 1**, **Figure 2**). The vegetative stems form loose clusters or clumps. The thin, flat, narrowly scale-like leaves are 1 to 3 mm long, spirally arranged on the stem in six ranks, deciduous, and have bristles on the margin though not on the tip. The upper leaves of fertile stems (sporophylls) are larger than lower stem leaves, forming a loose, open cylindrical cone-like structure (strobilus), with spore-bearing receptacles at the leaf bases. Orange-yellow sporangia are in the upper leaf axils. The megasporangia contain no more than four yellow-white megaspores, and the microsporangia contain hundreds of very minute spores (Holmgren 1942, Hitchcock et al. 1969, Dorn and Dorn 1972, Lellinger 1985, Cody 1989, Valdespino 1993, Weber and Wittmann 2001).

Six other species of *Selaginella* occur in the five states that comprise the Rocky Mountain Region besides *S. selaginoides*. These include *S. densa*, *S. mutica*, *S. rupestris*, *S. underwoodii*, *S. watsonii*, and *S. weatherbiana*. They differ from *S. selaginoides* in having a distinct bristle at the leaf apex, leaves with dorsal grooves, and 4-angled strobili. Unlike *S. selaginoides*, they are all terrestrial species and occur on rock outcrops or other dry upland settings rather than being restricted to wetlands. None of the six have a boreal center of distribution. *Selaginella rupestris* is the most widespread species in North America, disjunct at its western limits in the Black Hills (Valdespino 1993). *Selaginella densa* is a Great Plains species that occurs throughout basins and plains of Region 2 (Great Plains Flora Association 1986). *Selaginella weatherbiana* is endemic to the southern Rocky Mountains of Colorado and New Mexico (Valdespino 1993). *Selaginella mutica* and *S. underwoodii* occur in Southern Rocky Mountain

Figure 1. *Selaginella selaginoides*. Photograph by Jennifer Whipple, reprinted with permission.

and Great Basin States, the latter extending into Mexico. *Selaginella underwoodii* occurs in eight western states from Idaho and Montana to Arizona and California.

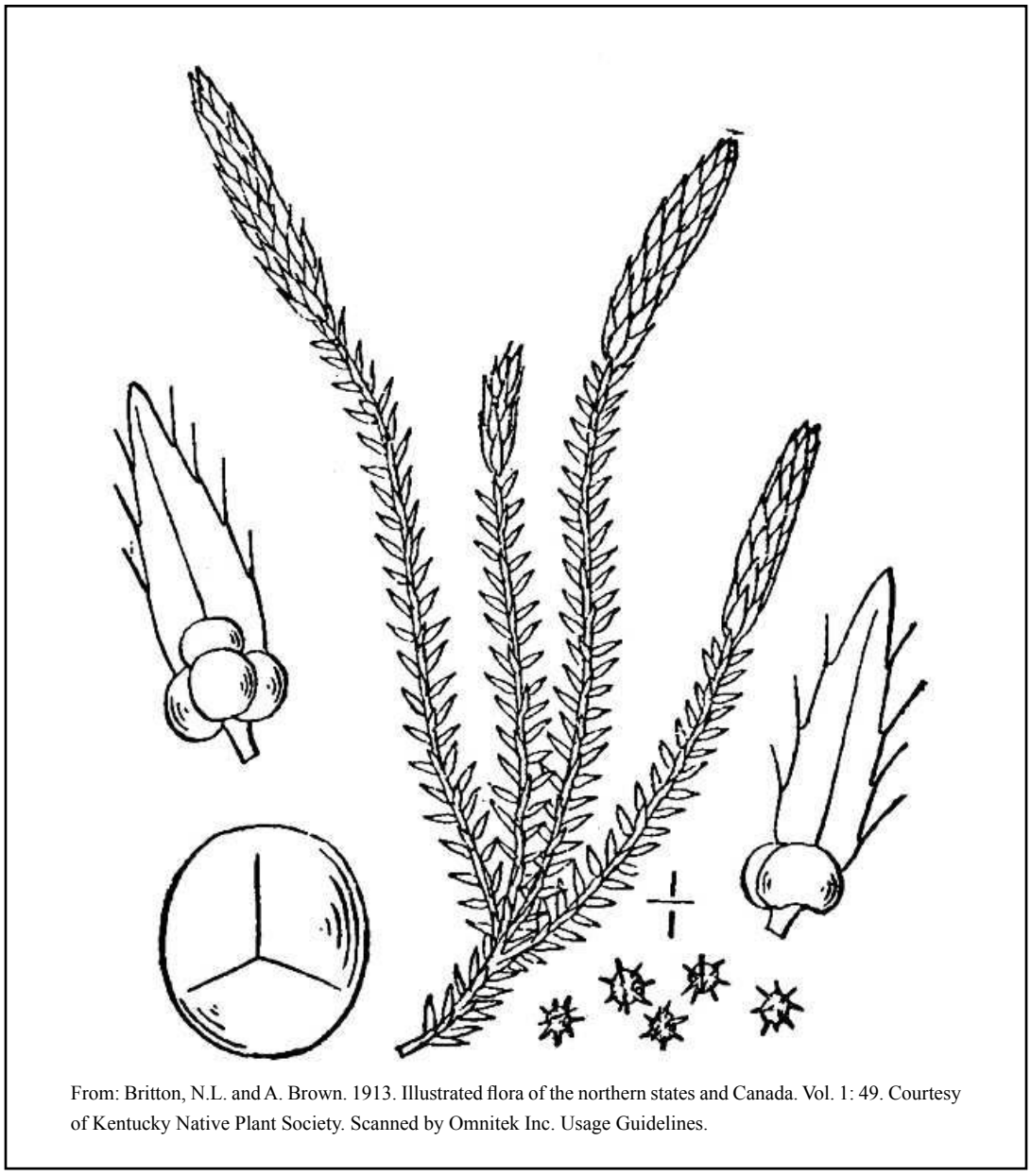
There are instances of incomplete information in this assessment. Incorporation of information on other species of *Selaginella* was considered but rejected because the other six species of *Selaginella* in Region 2 are terrestrial. Three of the other *Selaginella* species are tracked as Wyoming plant species of concern (Keinath et al. 2003), but none are boreal. One other species of *Selaginella* is also distributed at high latitudes, *S. sibirica*, but it is restricted to high latitudes and occupies terrestrial habitat, in Alaska, British Columbia, Northwest Territories, and the Yukon, as well as Japan and the former Soviet Republics (Valdespino 1993). Instead, analogues are sought among boreal disjunct species including other members of the Lycopodiophyta, the ferns, and the flowering vascular plants.

Despite the superficial similarity of *Selaginella selaginoides* to mosses, which are nonvascular plants, it can be differentiated by its dimorphic leaves on the upright fertile stems, absence of a capsule, and stature that is generally taller than most mosses. In addition, it has true roots and vascular tissue. It is important to be able to distinguish *S. selaginoides* from mosses because it often grows among mosses (Evert personal communication 2005, Whipple personal communication 2005, Heidel personal observation), and its mats are sometimes threaded through mosses or muskeg (Cody 1989).

The chromosome number of *Selaginella selaginoides* is 2n = 18 (Hitchcock et al. 1969, Cronquist et al. 1972, Löve and Löve 1975). This is a uniform number for temperate species of *Selaginella* (Tryon and Tryon 1982). The *Selaginella* genus has the smallest chromosome numbers among ferns and fern allies.

Distribution and abundance

Selaginella selaginoides is a circumboreal species, extending sporadically across Eurasia from Finland to Japan, and south to Spain and Italy; it also occurs in Iceland. Its three largest centers of distribution are in northeastern and northwestern North America in Canada, and in western Eurasia (Hulten 1968). It is known to be present in all provinces and territories of Canada (except Nunavut) and in Greenland (Cody



From: Britton, N.L. and A. Brown. 1913. Illustrated flora of the northern states and Canada. Vol. 1: 49. Courtesy of Kentucky Native Plant Society. Scanned by Omnitek Inc. Usage Guidelines.

Figure 2. Illustration of *Selaginella selaginoides*. (Center: sporophyte. To left: megaporangia and megaspore. To right: microsporangia and microspores.)
From: Britton, N.L., and A. Brown. 1913. Illustrated flora of the northern states and Canada. Vol. 1: 49. Courtesy of Kentucky Native Plant Society. Scanned by Omnitek Inc. Usage Guidelines.

1989, NatureServe 2005). In the contiguous United States, *S. selaginoides* reaches the southern limit of its North American range, and its southernmost populations are in mountains of Nevada (Holmgren 1942, Valdespino 1993).

In the western states, *Selaginella selaginoides* is disjunct and at its southern limits. It is found at multiple collection stations in the Ruby Range of Elko County, Nevada. In southwestern Montana, it is known from seven occurrences (Montana Natural Heritage Program 2003, 2005; Evert personal communication 2005). It is widely scattered in Idaho, and in northwest Wyoming it is known from six occurrences, all of which are outside of Region 2. Although *S. selaginoides* is known in Wyoming (**Figure 3**) and is reported for Colorado in at least two independent sources (i.e., Rydberg [1906], Weber et al. [1979]), there are no known vouchers of the species from Region 2.

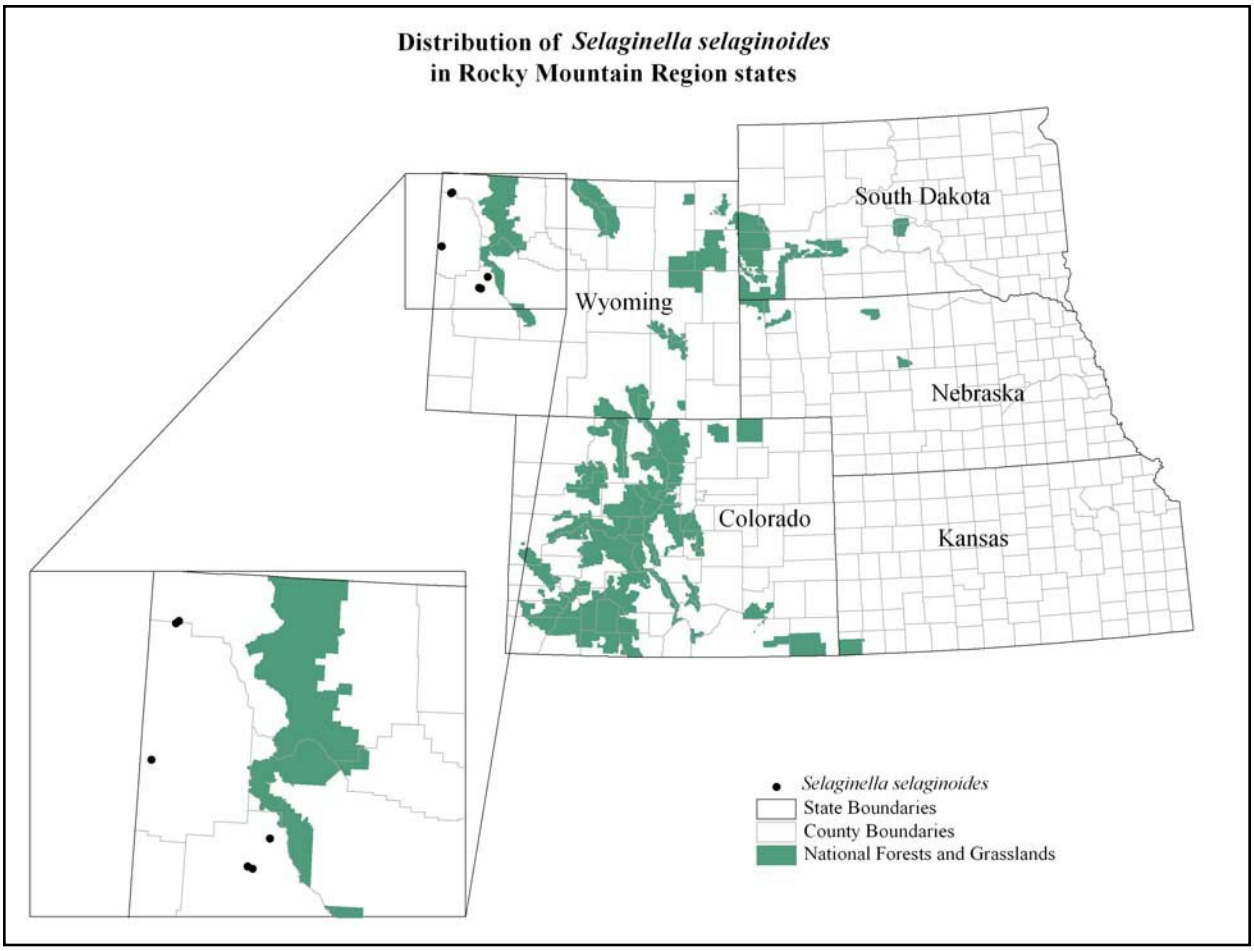


Figure 3. Distribution of *Selaginella selaginoides* in USDA Forest Service Region 2 states.

In 1979, *Selaginella selaginoides* was reported from the Parks Ranger District of the Routt National Forest on the east side of the Park Range in Jackson County, Colorado (Weber et al. 1979). This report was based on plant materials collected for a terrarium in 1978 along Bear Creek and the Ute Pass-Bear Creek Trail (Colorado Natural Heritage Program 2005). Efforts to relocate the site were reported as unsuccessful in the most recent flora (Weber and Wittmann 2001). However, this report is erroneous according to Dr. Dieter Wilken because the *S. selaginoides* material was added to the terrarium by other botanists and not from a Colorado collection site, a contamination and source of misinterpretation that did not come to light until after the publication (Wilken personal communication 2005).

In addition, *Selaginella selaginoides* has been collected eight times in at least six locales of northwestern Wyoming in Park, Sublette, and Teton counties (Dorn 2001, Hartman and Nelson 2005, Whipple personal communication 2005, Wyoming Natural Diversity Database 2005). These collections represent six discrete occurrences (**Figure 3**, **Table 4**), including one historic occurrence on the Targhee National Forest (#001 as represented by *Anderson 614 RM, UTC, US*), two historical occurrences on the Bridger-Teton National Forest (#002, #003 as represented by three collections *Payson and Payson 4596 RM, US, Payson and Payson 4403 RM, GH, US* and *Ownbey 1136 RM, WS*), one extant occurrence on the Pinedale Field Office of the Bureau of Land Management (BLM; #005 by *Fertig 15397 RM*), two extant occurrences on Yellowstone National Park (#006, #007 by *Evert 4028 RM* and by *Whipple 4325 YELLO*), and one historical collection from an unspecified location in Yellowstone National Park (*Mearns 3704 US*). The latter collection location is essentially unmappable and does not represent an occurrence. Three of the six occurrences are located close to the northwestern boundary of Region 2. They include the historical and extant occurrences on the west side of the Wind River Range whose divide separates the USFS regions. The others are on the Teton Range and Yellowstone Plateau. Wyoming records are

Table 4. Descriptions of *Selaginella selaginoides* occurrences in USDA Forest Service Region 2 states.

Occurrence number	County (State)	Site name	Ownership	Date of observations	Estimated abundance and extent	Elevation	General habitat description	Associated plant species
1	Teton (WY)	Treasure Lake of Teton Range	USDA Forest Service (USFS) Region 4 Targhee National Forest	Aug 2, 1956	Frequent among mosses	2,085	Wet soil in *Salix*, *Betula* and *Cornus* community	Includes *Cornus sericea*, either *Betula glandulosa* or *B. occidentalis*, and *Salix* spp.
2	Sublette (WY)	New Fork River	USFS Region 4 Bridger-Teton National Forest	July 21, 1925	No data	2,350	Mossy rocks in wet meadow	*Parnassia parviflora*
3	Sublette (WY)	Lower Green River Lake	USFS Region 4 Bridger-Teton National Forest	Aug 1925, Sept 7, 1936	No data	2,440	Mossy banks in forest	No data
5	Sublette (WY)	Marsh Creek	Bureau of Land Management Pinedale Field Office	Aug 16, 1994	Locally common in small area	2,350	Hummocky wet meadow on banks of creek adjacent to willow thickets. Soil marly	*Juncus balticus*, *Parnassia palustris*, *Potentilla fruticosa*, *Salix brachycarpa*, *Thalictrum alpinum*, *Gentianopsis detonsa*, *Senecio cymbalarioides*, *Muhlenbergia* spp.
6	Park (WY)	Gibbon River	Yellowstone National Park	July 14-15, 1994	Four subpopulations, two likely in decline or extirpated since 1994, and two estimated at total less than 150 in 1994	2,110	Open fens on marl, in cooled habitats previously associated with geothermal activity, concentrated in mossy microhabitats	Variable. Includes *Eleocharis quinqueflora*, *Carex interior*, *C. capillaris*, *C. aquatilis*, *Botrychium multifidum*, *Drosera anglica*, *Gentianopsis detonsa*, *Parnassia parviflora*, *Pedicularis groenlandica*, *Rhamnus purshii*, *Lonicera caerulea*, and *Triglochin maritime*
7	Park (WY)	Secret Valley	Yellowstone National Park	July 10, 2003	No data	2,210	Open fen on marl, concentrated in mossy microhabitats	*Pedicularis groenlandica*, *Eriophorum viridicarinatum*, and *Triglochin maritime*

included in the description of the species' distribution in Region 2 because of their proximity and likely similarity to potential habitat.

The nearest potential habitats to known occurrences for *Selaginella selaginoides* in Region 2 are on the Shoshone National Forest. No surveys have been conducted for this species on the Shoshone National Forest. There may be potential habitat on the east side of the Wind River Range in the Lander and Wind River ranger districts of the Shoshone National Forest similar to the west side of the Wind River Range (Pinedale Ranger District of the Bridger-Teton National Forest, and the BLM Pinedale Field Office). There is also peatland habitat in the Clarks Fork District of the Shoshone National Forest that may be similar to some habitats for *S. selaginoides* found in Yellowstone and Grand Teton national parks.

There have been no other systematic surveys of *Selaginella selaginoides* habitat in Colorado or Wyoming, or modeling to test the potential distribution for the species. The east side of the Park Range in Colorado, where it was reported in 1979, is among the most likely areas of potential habitat in Colorado. There may also be suitable habitat in the Sierra Madre Range of Wyoming (confluent with the Park Range) and the Medicine Bow Range. Concerted species surveys for this species in the Medicine Bow Range have been limited to project surveys to date. In addition, a segment of its suitable habitat across the east side of the Medicine Bow Range was surveyed for sensitive species and both vascular and nonvascular flora in systematic peatland surveys with no results for *S. selaginoides* (Heidel and Thurston 2004, Heidel and Jones in progress).

The species was characterized as locally common in places at two of the three extant Wyoming occurrences (# 005 in the Upper Green River Basin and #007 in Yellowstone National Park) and described as frequent at a historical occurrence (#001 in Grand Teton National Park) (**Table 4**). These descriptions may actually represent a low number of individuals because the prostrate stems can connect fertile stems under duff or moss cover, and the species can form small mats. Therefore, even though it is feasible to count or estimate the number of fertile stems, it is not possible to distinguish individual plants without destructive techniques or time-consuming and costly genetic analysis. The population extent has not been mentioned except at one site where total extent was estimated as 1 acre (# 005 in the Upper Green River Basin).

Selaginella selaginoides has infrequently been collected south of the Canadian border (Hitchcock et al. 1969). There are at least three possible explanations for this apparent rarity in the United States. The full explanation is likely to be some combination of the three. First, the species is not easy to find due to its low stature and similarity to mosses, with which it is associated. Support for this explanation is provided by a Canadian author (Cody 1989) who remarked:

> "This widespread circumpolar species, which occurs northward nearly to the limits of trees, is often partly buried in mosses or muskeg, and thus is easily overlooked."

Second, *Selaginella selaginoides* occupies a narrowly-restricted habitat zone in the southern limits of its range that is intrinsically rare and may be difficult to locate. Intrinsic habitat rarity at southern limits of the species' range is reported in Maine (Maine Department of Conservation 2004). It is a wetland species, but only portions of wetland basins may support the species in discrete zones or patches. For example, in a Montana habitat photograph (**Figure 4**), *S. selaginoides* is restricted to moss-lined rivulets along less than a 10 m margin of a large wetland basin.

Finally, *Selaginella selaginoides* appears to be intrinsically rare in the number of places it occurs at the margins of its distribution. The only New England state with extant populations of *S. selaginoides* is Maine, with six known populations (four recent, two historical; Maine Department of Conservation 2004). It is also present in the northern Great Lakes states, including Michigan, Minnesota, and Wisconsin.

Population trend

Trend data are lacking for *Selaginella selaginoides*. Some historical collection sites near the New Fork Lakes in the upper Green River Basin of Wyoming may have been destroyed during dam and campground construction in the 1930's (e.g., #002; Markow and Fertig 2001). Decline has been inferred at the Gibbon River population of *S. selaginoides* in Yellowstone National Park (#006); this population may have declined in two of three colonies due to habitat changes that accompanied highway construction (Whipple personal communication 2005). It is possible that *S. selaginoides* declined after 1988 crown fires burned across much of the watershed around the Secret Valley population in Yellowstone National Park (#007), but this population was not discovered until 2003.

Figure 4. *Selaginella selaginoides* habitat in the Tobacco Root Mountains, Montana. It occurs in a small segment of the margin with wetland seeps (in foreground). Photograph by Bonnie Heidel.

Many ferns have great capacity for long-distance dispersal due to the ease of spore movement (Barrington 1993). Many fern allies would be expected to have similar capacities. However, as a species of relict habitats, *Selaginella selaginoides* would have limited suitable habitat conditions in the Rocky Mountains. Its megasporangia are ejected only short distances. As a rare species, it has limited potential for colonization or recolonization. The combined scenario suggests that populations may be vulnerable to decline unless habitat conditions are stable, including microclimate conditions.

Habitat

Selaginella selaginoides occupies moist, montane habitats in the western United States, which are variously characterized as wet places, mossy stream banks, lakeshores, fens, and wet talus slopes, usually at low- to mid-elevations (below timberline), in neutral to alkaline soil (Hitchcock et al. 1969, Cronquist et al. 1972). It requires substrates that are wet for at least part of the growing season because it requires water for reproduction and has an extremely shallow root system. It is characterized as a facultative wetland species in western Wyoming (USDI Fish and Wildlife Service 1996). This means that it usually (66 to 99 percent of the time) occurs in wetland habitat, but it is occasionally found in non-wetland habitat.

From the information at hand, the technical classification of this species' habitat in Wyoming is that of a palustrine system, either on saturated soils or with emergent (herbaceous) vegetation (USDI Fish and Wildlife Service 1998). Habitat descriptions for all six occurrences of *Selaginella selaginoides* in Wyoming are presented in **Table 4**, and a profile of habitat requirements and malentities are represented in an envirogram (**Figure 5**). Information on the groundwater conditions, moss cover, pH, conductivity, canopy and herbaceous structure, associated bryophyte flora, water erosion features (if any), water and soil temperatures, and substrate water-holding capacity are not available in Montana and Wyoming. Details of the rooting medium usually emphasize mosses, but the moss mat might be part of duff, peat, or marl, in any case having moist or saturated aerobic conditions that draw from a shallow groundwater table.

The three extant occurrences in Wyoming provide the most detailed habitat information, and the species appears to be associated with the cool water temperatures of discharge zones at springs and seeps. The settings are open, mossy banks and moss-covered zones in wet meadows, at 2,085 to 2,440 m (6,760 to 8,000 ft.; **Table 4**; Markow and Fertig 2001). In the upper Green River Basin, the habitat was described as hummocky wet meadow on stream banks adjacent to willow thickets, with marly soil (#005; *Fertig 15397*

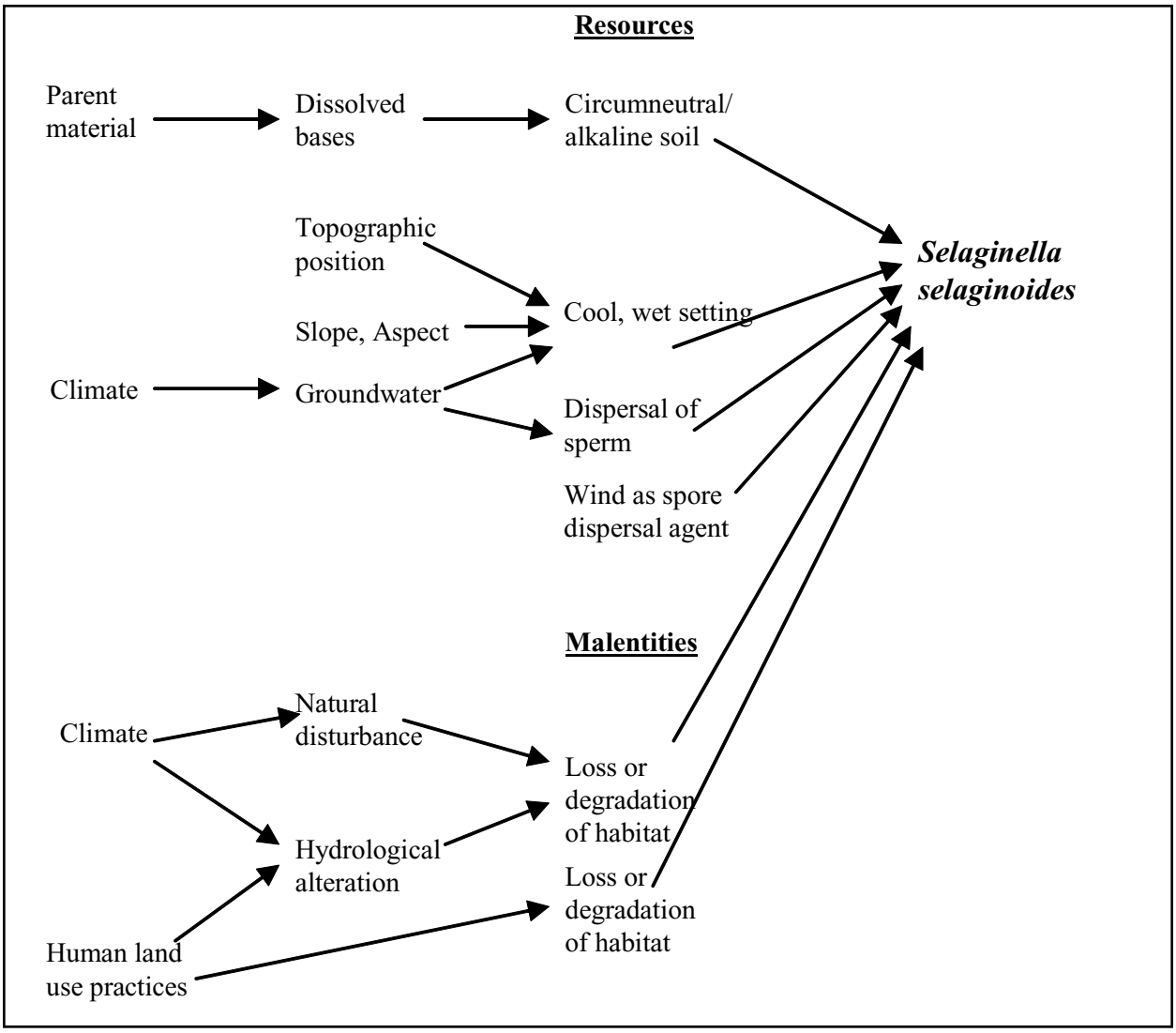


Figure 5. Envirogram of key resources for *Selaginella selaginoides* in the USDA Forest Service Region 2 states.

RM). Marl is a saturated calcium carbonate precipitate. In the Yellowstone Plateau, the habitat of *Selaginella selaginoides* is part of cooled portions of a geothermal tuffaceous landscape on the Gibbon River (#006; Whipple personal communication 2005), and along Secret Creek its habitat is open fen (#007; Evert personal communication 2005). It appears that all three settings have cool surface temperatures maintained by low groundwater temperatures discharging into its habitat, and by the moss mat that acts like an insulation layer as well as a water wick. The Wyoming populations are growing in full or partial sun, and their cool conditions do not appear to be linked to aspect or shade conferred by woody and herbaceous vegetation. Four of the seven Montana occurrences are in settings described as seeps or streams (*Lackschewitz 7710*, *7494 MONTU*, *Lesica 5885 MONTU*, *Heidel 1317 MONTU*).

There is often peat in proximity to occupied habitat if not directly overlapping with *Selaginella selaginoides* distribution in its valley settings. Peat and marl have water retention capacity in excess of any minerotrophic soils, and they may be indirect if not direct factors in habitat stability. Erwin Evert characterized the habitat at his three collection sites of *S. selaginoides* in the three-state Greater Yellowstone Area as saturated during parts of the growing season although they may be dry at the time of collecting (Evert personal communication 2005). He further described the sites as moss-dominated habitats at relatively low elevations from 1,830 to 2,440 m (6,000 to 6,760 ft.). It is not possible to say that *S. selaginoides* is restricted to peat or at least flowing water settings where it occurs in the Rocky Mountains, although it is associated with stable microhabitats.

The erroneous report of *Selaginella selaginoides* in Colorado was said to be from a "moist stream bank" at 9,500 ft. (Colorado Natural Heritage Program 2005). Weber and Wittmann (2001) elaborated from information provided by Dr. Dieter Wilken, the collector, in describing the setting as "marshy places by beaver ponds in wet spruce forests." This one Colorado report that was made in error from the northern Park Range poses a conundrum because the wet spruce habitat where it was thought to have been collected fits the habitat profile for *S. selaginoides* elsewhere in its distribution, and the northern Park Range has the highest concentration of species with northern biogeographic affinities in Colorado, representing some of the most suitable of potential habitat in the state.

Elsewhere in its range, *Selaginella selaginoides* is found in wet places, among mossy stream banks, lakeshores, bogs, and wet talus slopes, in neutral to alkaline soil, between 600 and 2,900 ft. (Scoggan 1978, Cody 1989, Valdespino 1993). This species has its widest range of ecological amplitude in its boreal centers of distribution, where it extends from coastal to alpine elevations and across a range of seral to climax habitats ranging from gravel bars to peatlands (Cody 1989). It has a narrow range of habitats at southern distribution limits, but they may differ across its southern limits. In Montana, as mentioned previously, it is known from seep zones of upper montane meadows (**Figure 4**), talus slopes, and fens (Montana Natural Heritage Program 2005). In the Great Lakes states, *S. selaginoides* is found on streambanks and lakeshores, on cool, mossy talus slopes, in conifer bogs and swamps, and in moist dunes (Chadde 1998). In Wisconsin, its habitat was once characterized as northern sedge meadows with histosol substrate (Curtis 1959), but it is currently only known from stabilized beach dunes (Wisconsin Department of Natural Resources 2005). In northern Maine, *S. selaginoides* is found exclusively in circumneutral fens (Maine Department of Conservation 2004), representing lowland settings and narrow edaphic conditions (Miller 1990).

There is one important caveat to add in characterizing *Selaginella selaginoides* habitat. The habitat requirements of the short-lived gametophyte life history stage and the microspore sperm may be much narrower than that of the sporophyte life history stage. Information is lacking on habitat requirements at these stages of the life cycle. In any case, *S. selaginoides* gametophytes would be expected to complete their life cycle in the vicinity of the sporophyte. The available information suggests that *S. selaginoides* is a wetland habitat specialist that requires cool, stable settings at the southern limits of its range.

Reproductive biology and autecology

Reproduction

Like ferns and other fern allies, *Selaginella selaginoides* has a diploid (sporophyte) stage and independent male and female haploid (gametophyte) life history stages (**Figure 6**). The sporophyte of *S. selaginoides* is the long-lived life history stage. Each year, the sporophyte produces new fertile shoots that give rise to spores, which undergo meiosis. The sporophyte produces two types of sporangia and spores within the sporophylls of the strobilus, or cone. The mother cells inside the megasporangia and microsporangia undergo meiosis, producing the haploid megaspores and microspores (**Figure 2**), respectively. The megaspores are catapulted from the sporophyte in a unique dispersal adaptation (Page 1989). Upon landing in suitable habitat, a megaspore germinates to form a female gametophyte. Archegonia form on the exposed, upper surface of the female gametophyte, with each archegonium bearing a single egg. The microsporangia rupture and passively release the minute microspores, which are readily dispersed by air currents. Microspores germinate to become male gametophytes, which develop the sperm-producing antheridia. The sperm swim through a film of water in response to a sex attractant secreted by the mature archegonium to fertilize the egg and form the diploid zygote. The zygote develops into a sporophyte, growing out of the archegonium of the female gametophyte (**Figure 6**). The phenology of the *S. selaginoides* life cycle is not documented in the literature.

Cross-fertilization is reported to be high in the closely-related *Lycopodium* genus (Soltis and Soltis 1988), but dispersal of both the megasporangia and the microspores of *Selaginella selaginoides* may affect the probability of cross-fertilization.

Hybridization

There is hybridization in other subgenera of *Selaginella*, including *S. ludoviciana* and *S. apoda* in the southeastern United States (Somers and Buck 1975) and *S. firmula* and *S. laxa* in Fiji (Gardner 1997), but not within the *Selaginella* subgenus that contains *S. selaginoides*.

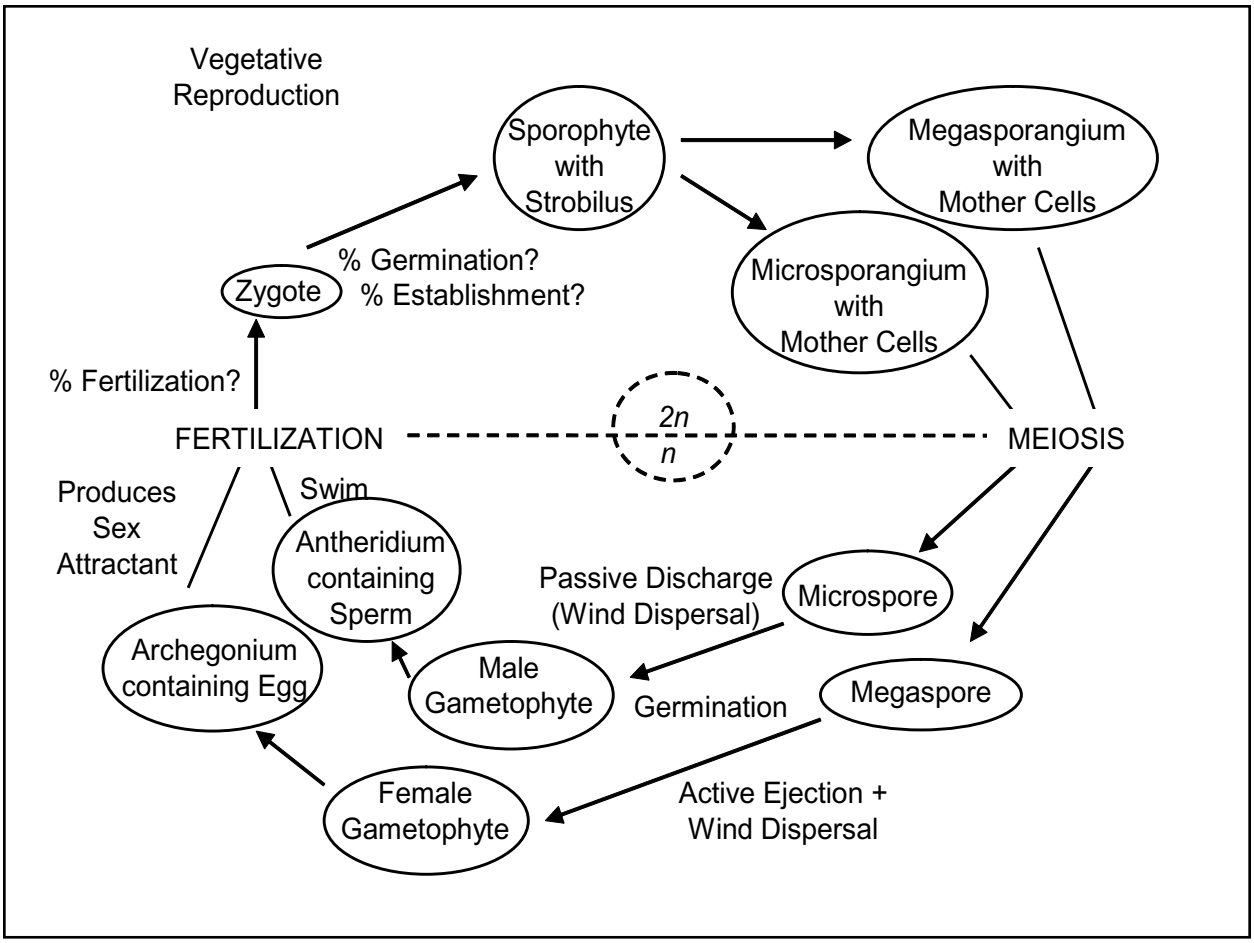


Figure 6. Schematic illustration of the life cycle of *Selaginella selaginoides*.

Phenotypic plasticity

The megasporangia of *Selaginella selaginoides* are typically on the lower leaves of the strobilus, and the microsporangia are on the upper leaves (Horner and Arnott 1963 as cited by Valdespino 1993, Hulten 1968). However, some individuals have megasporangia at the tip of the strobili (Valdespino 1993). In addition, Nevada specimens tend to have smoother megaspores than is usual for the species (Cronquist et al. 1972). The nature and significance of these morphological variations in reproductive characters are not known.

Demography

Demographic studies of *Selaginella selaginoides* are lacking, and basic parameters circumscribing life history characteristics are unknown. There is a framework for demographic research in the literature on the developmental biology of *S. selaginoides* (Bruchmann 1887 as cited by Karrfalt 1981). The finite branching of *S. selaginoides* in particular gives it a tight growth form in comparison with other species in the genus, resulting in a compact plant body (Karrfalt 1981). Longevity of the sporophyte is not known. The gametophytes are described only as short-lived.

In the laboratory, the *Selaginella* genus is most often propagated by dividing mature clumps and replanting the divisions, but it can also be propagated by spores (Carolina Biological Supply 1998). The growth medium must retain moisture yet be porous enough to allow air to reach the roots. Commercial sources were not found for *S. selaginoides*, but the more common of *Selaginella* species in the United States, *S. rupestris*, is available from scientific supply companies.

Selaginella selaginoides is the only species in the genus with a mechanism for dispersing the megasporangia (Page 1989), but it is among many species of the genus that passively release the microsporangia (Koller and Scheckler 1986). It would

appear that the ejection of megasporangia increases the likelihood that progeny establish beyond the small area occupied by the parent plant, and the profuse production of microsporangia increases the likelihood of fertilization and outcrossing. The dispersal ability of the female gametophyte is enhanced by its autonomy as indicated by the capacity to become photosynthetic and produce its own nourishment (Cronquist et al. 1972).

No population viability analysis has been done for *Selaginella selaginoides*.

Community ecology

Selaginella selaginoides is a habitat specialist that fits the pattern of a disjunct glacial relict as it occurs in Region 2 because it occurs in cool, moist, and stable habitat, and is many hundreds of miles from its arctic-boreal center of distribution. It has no known colonizing propensity or positive response to disturbance. The key resources for this species appear to be its microclimate conditions, including moist substrate and cool, stable setting. The key malentities for this species appear to be climate-related landscape disturbances that change the microclimate conditions. As such, *S. selaginoides* may be adapted to conditions that are reduced in availability within Region 2. This would make the species a poor competitor, and as a southern disjunct its habitat is more vulnerable to change than at the core of its distribution. The schematic representation of climate as both an overarching requirement and a malentity for species' viability is presented in the conceptual envirogram (**Figure 5**).

Community ecology information from the nearest occurrences of *Selaginella selaginoides* (i.e., those in western Wyoming and neighboring states) refine and reinforce the habitat descriptions. The three extant occurrences of *S. selaginoides* in Wyoming and the closest Greater Yellowstone collections of Erwin Evert (*23360, 40388 RM*) and Heidel (*1317 MONT*) are comprised of native facultative and obligate wetland species. In the upper Green River Basin, it was associated with *Juncus balticus* (Baltic rush), *Parnassia palustris* (marsh grass of Parnassus), *Pentaphylloides floribunda* (shrubby cinquefoil), *Salix brachycarpa* (shortfruit willow), *Thalictrum alpinum* (alpine meadowrue), *Gentianopsis detonsa* (windmill fringed gentian), *Senecio cymbalarioides* (Rocky Mountain groundsel), and *Muhlenbergia* spp. (muhly grass; *Fertig 15397* RM). In the Greater Yellowstone area at the Driggs Fen in Idaho and a Tobacco Root Mountains fen in Montana, *Selaginella selaginoides* was associated with *Carex gynocrates* (northern bog sedge), a species that is often in turf habitats and wetland margins (Evert personal communication 2005). Evert also indicated that the vegetation at the latter had a high cover of mosses and heath shrubs (*Phyllodoce* spp.). In the Yellowstone Plateau along the Gibbon River, *S. selaginoides* occurred where *Eleocharis quinqueflora* (few-flower spikerush) was abundant; it was also associated with *C. interior* (inland sedge), *Botrychium multifidum* (leathery grapefern), *G. detonsa*, and *C. capillaris* (hairlike sedge) (Whipple personal communication 2005). It was associated with *Pedicularis groenlandica* (elephanthead lousewort), *Eriophorum viridicarinatum* (thinleaf cottonsedge), and *Triglochin maritimum* (seaside arrowgrass) in Secret Valley above the Gibbon River (*Evert 40281 RM*). Several of the species associated with or in the immediate area of the Yellowstone National Park populations are rare boreal species, some of which are also disjunct, including *B. multifidum*, *Drosera anglica* (English sundew), *Eleocharis elliptica* (elliptic spikerush), *C. buxbaumii* (Buxbaum's sedge), *C. livida* (livid sedge), and *Eriophorum viridicarinatum* (Evert personal communication 2005, Whipple personal communication 2005). Information on the associated bryophyte flora in *S. selaginoides* habitat is lacking and may provide further insights into its habitat specificity and stability. Moss cover may provide the moist, stable habitat conditions that are represented in terms of other habitat characteristics in the envirogram (**Figure 5**).

The microspores of *Selaginella selaginoides* are among the limited number of plant fossils identifiable at the species level, and therefore, palynological records provide community ecology insights over geological time. Presence of *S. selaginoides* microspores has been determined to correspond to climatic cooling episodes and shifts from forested landscapes to open boreal-alpine environments in both North America (Heusser and Peteet 1988, Baker et al. 1989, Garry et al. 1990) and Eurasia (Ambrosiani and Robertsson 1992, Demske et al. 2002). It has been documented as a glacial relict (Plio-Pleistocene relict) in the Western Pacific region of North America and Asia, and it is used to study range history and migration from glacial refugia during the late Quaternary (Heusser and Igarashi 1994). At its southern limits in midwestern states, its presence in the palynological record was also interpreted to represent a rich fen habitat with calcareous conditions (Garry et al. 1990). It was present without interruption in pollen profiles from the state of Washington from 47,000 b.p. to about 10,000 b.p., but it is not known from the state of Washington at present. Its documented range contraction and pattern of small, isolated, persisting

populations elsewhere fits the definition of a glacial relict (Heusser and Igarashi 1994) and applies to the Rocky Mountains.

It is noteworthy that microspores of *Selaginella selaginoides* were found so consistently and in such abundance in the palynological records of peat cores and lake sediments that they could be used to indicate climate change (Heusser and Peteet 1987). Comparison of past records with the "pollen rain" of currently occupied habitats at the same sites may help to compare current *S. selaginoides* habitats with Quaternary habitats, when the species was most abundant.

The community ecology and distribution of other disjunct boreal species in the Rocky Mountains may shed light on that of *Selaginella selaginoides*, much like its rich palynological record has been used to document glacial refugia elsewhere in its distribution over geological time.

Mycorrhizal relationships

Members of the Selaginellaceae do not form mycorrhizal relationships (Miller personal communication 2005). Exposed portions of the female gametophyte often become photosynthetic and are therefore able to produce their own nourishment (Cronquist et al. 1972).

Competition

Selaginella selaginoides grows in areas with high cover of mosses (Evert personal communication 2005, Whipple personal communication 2005, Heidel personal observation), which tolerate nutrient-poor conditions. It is possible, but not documented, that the high cover of mosses are suitable or necessary substrates for development and fertilization of the female gametophyte, rather than representing competition.

The diminutive plants of *Selaginella selaginoides* with their shallow root systems are vulnerable to vegetation succession if not direct competition with other vascular plants. These morphological traits and its restriction to a narrow range of conditions suggest that it is a poor competitor. The establishment and increase of phreatophytes or other vascular plants that contributed to a lowering of the water table and drying of *S. selaginoides* habitat may lead to its extirpation just as quickly as direct competition. This would include, but is not limited to, invasive exotic species.

Herbivory

There are no reports of herbivory on *Selaginella selaginoides* or evidence of browse on herbarium specimens. It is possible, but not proven, that *Selaginella* species contain alkaloids that deter herbivory as *Lycopodium* species do (Ayers 1983 as cited by Hornbeck et al. 2003).

Selaginella selaginoides is a small plant with low forage value. If there is browsing or grazing, such herbivory is likely to be accidental and limited. Secondary effects of livestock grazing are likely to be more important than actual herbivory. Grazing may affect the species' through damage to the moss mat vegetation. The other effects of grazing may include trampling, eutrophication, and increases in hummock microtopography that contribute to desiccation. There may also be similar effects of pack animal use and of wildlife use on *S. selaginoides* habitat.

CONSERVATION

Threats

Selaginella selaginoides is a wetland habitat specialist that requires cool, stable conditions. The primary threats to this species on National Forest System land in Region 2 cannot be ascertained without knowing its location, but the general threats to low- to mid-elevation valley wetlands are habitat loss and degradation associated with water loss, inundation, or successional change. Potential threats can exert their influence by affecting the landscape water budget and water regime for the system. They can also influence the hydrological buffering or suitability of the microhabitat. For a species like *S. selaginoides*, the habitat and associated threats may be defined in terms of meters rather than kilometers. Furthermore, as a species of small, isolated populations, *S. selaginoides* may also be vulnerable to inbreeding depression. There has been little evidence for inbreeding depression documented among disjunct populations of ferns (Barrington 1993), which are also spore-dispersed. However, Barrington (1993) did not address boreal disjunct populations of ferns in particular.

Each of the existing and potential threats to *Selaginella selaginoides* that have been identified in Wyoming is reviewed against these considerations. The threats to *S. selaginoides* include both natural threats and threats associated with land uses. Both may impact

the hydrological conditions or result in either loss or degradation of habitat, as represented in the envirogram (**Figure 5**).

Water impoundments may impact *Selaginella selaginoides* habitat because it is associated with groundwater discharge zones so often flooded by any impairment of water flow and does not survive submerged conditions. Historical collection sites near the New Fork Lakes in the upper Green River Basin of Wyoming (#002, #003) may have been destroyed during dam and campground construction in the 1930's (Markow and Fertig 2001). The construction of impoundments may also curtail downstream flow, fostering downstream channelization that lowers the groundwater. Beaver activity potentially affects *S. selaginoides* habitat in the same way as man-made impoundments, but generally on a smaller scale.

Upstream water diversions potentially diminish groundwater flow to *Selaginella selaginoides* habitat by dewatering the system and lowering water tables. If the water diversions adjoin occupied habitat, canal seepage may actually increase groundwater flow into *S. selaginoides* habitat and lead to inundation.

Likewise, road construction potentially inundates or desiccates *Selaginella selaginoides* habitat as it interferes with surface and groundwater flows. The Gibbon River Valley population in Yellowstone National Park (#006) is dissected by a road, and reconstruction of the road in 1994 appears to have altered the habitat for at least two of three colonies (Whipple personal communication 2005). The wetland habitat of *S. selaginoides* does not always have standing water in the immediate vicinity, and it may or may not qualify as a jurisdictional wetland with filling of such wetlands regulated by U.S. Army Corps under Section 404 of the Clean Water Act. Road construction through occupied habitat may also lead to impacts from right-of-way management practices including run-off, herbicide treatment, and highway maintenance vehicles or others driving the right-of-way corridors.

Selaginella selaginoides has small stature and no apparent sign of palatability, so the effects of grazing would most likely depend on whether its habitat has frequent livestock use associated with water or forage. Its habitat is seasonally grazed by livestock at Marsh Creek (#005), and grazing may be the cause of hummocks reported at this site. Trampling potentially causes hummocks that sometimes desiccate habitat and damages the protective moss mat at least in the hummock troughs. Livestock grazing may also dramatically increase the nutrient load or favor robust, upland species. Pack animal use may have effects similar to livestock grazing if the *S. selaginoides* habitat is at a heavily-used watering spot. Wildlife use might also have similar effects. *Selaginella selaginoides* is in areas of Yellowstone National Park that are grazed by bison in the Gibbon River Valley (#006), and although hummocks are formed, the presence of bison does not otherwise appear to have had an effect on this species (Whipple personal communication 2005).

Recreation developments and trails often take advantage of cool settings with springs and seeps, corresponding with *Selaginella selaginoides* habitat. Historical collection sites near the New Fork Lakes in the upper Green River Basin of Wyoming (#002, #003) may have been destroyed during dam and campground construction in the 1930's (Markow and Fertig 2001). Related fishing access developments and hiking trail developments may also potentially impact *S. selaginoides* habitat.

Fire is not likely to burn habitat of *Selaginella selaginoides*, but it may pose a threat where that habitat is at forest margins. It is reasonable to expect that *S. selaginoides* would potentially also be impacted by crownfires that burn in the surrounding watershed, as these may lead to habitat changes such as high spring run-offs, greater fluctuations in water levels, reduced groundwater flows, desiccation of buffering peat in the area reducing local water retention, elevated nutrient levels, and accompanying vegetation changes. *Selaginella selaginoides* has a very shallow root system, sometimes rooted in no more than duff, so its habitat may burn under prolonged drought. *Selaginella selaginoides* was recently discovered in Secret Valley (#007) in Yellowstone National Park, 15 years after crown fires burned throughout the surrounding watershed. Its presence at Secret Valley is evidence that it can survive the effects of fire in the landscape.

Logging is not a direct factor in the herbaceous habitats of extant *Selaginella selaginoides* habitat in Wyoming. But like fire, logging may indirectly impact *S. selaginoides* habitat by fostering high spring run-offs, causing greater fluctuations in water levels, reducing groundwater flows, elevating nutrient levels, causing decay and decompose the buffering peat so that local water retention is reduced, and fostering vegetation changes.

Land development and agricultural developments that include clearing and filling of natural habitat, fragmentation of natural habitat, and installation of new

wells are all potential threats at Marsh Creek (#005). These threats are greatest at low elevations, and they would be most severe in coastal zones and at the lowest elevations outside of the Rocky Mountains.

There are no exotic species reported in association with *Selaginella selaginoides* in Montana or Wyoming. Any of the previously-mentioned threats may precipitate degradation or loss of the associated vegetation. Generalist noxious weeds (e.g., Canada thistle [*Cirsium arvense*]) may invade springs and seeps. More likely to pose a threat are non-native grasses transported for hay like smooth brome (*Bromus inermis*) or timothy (*Phleum pratense*, and possibly other non-native grasses like reed canarygrass (*Phalaris arundinacea*) and Kentucky bluegrass (*Poa pratensis*). Encroachment of native clonal wetland species like *Salix* spp. (willows) and *Typha* spp. (cattails) may also be a threat precipitated by disturbance.

Climate warming is a long-term threat that has been touted for many plant species of conservation concern. The palynological record for *Selaginella selaginoides* is particularly rich and indicates that this species is an indicator of cool conditions. As such, it represents a relict species of past cool conditions in the western United States and may have limited colonizing ability and restoration potential in general. This means that it may also have reduced capacity to respond to other threats under increased temperatures. Disjunct and peripheral populations of *S. selaginoides*, like those found in the western United States, may be particularly susceptible to rising temperatures compared to those in the core of its distribution. Even without a global warming scenario, there are possibilities that boreal, relict species may not be able to persist indefinitely, as postulated in the conservation assessment for two other species in the Lycopodiophyta (Hornbeck et al. 2003).

Conservation Status of Selaginella selaginoides in Region 2

The status of *Selaginella selaginoides* as a sensitive species in USFS Region 2 hinges on its presence there, and this remains to be documented. Updating of the sensitive species list occurs biannually, and the information in this assessment will be considered in the 2006 update. *Selaginella selaginoides* has no other status in the states of Region 2. Preliminary inferences on the biological and ecological status of *S. selaginoides* are presented in this section rather than in-depth discussion because the levels of information for extant occurrences in Montana and Wyoming are limited, and their applicability to Region 2 is unproven.

Management of Selaginella selaginoides in Region 2

Implications and potential conservation elements

Selaginella selaginoides is a habitat specialist that has been characterized as a glacial relict at the southern limits of its distribution and is restricted to a cool, moist, stable habitat. It is vulnerable to habitat loss and degradation, both directly and indirectly. As a relict species, it is possible that habitat losses are irreversible for most practical purposes, and habitat declines are difficult to address. As for most species that require specialized wetland habitat, management actions are often directed toward buffering existing habitat rather than mitigating habitat or conducting management intervention after there is decline. In some cases, Region 2 national forests with boreal remnant species have been designated as special botanical areas or research natural areas (e.g., Hornbeck et al. 2003) in order to place habitat maintenance for these species among management priorities. The applicability of this model for *S. selaginoides* in Region 2 remains to be determined.

The primary elements necessary to maintain viable populations of *Selaginella selaginoides* are managing for cool, moist, stable wetland habitats. Maintenance of existing groundwater flows and existing moss mat vegetation at occupied habitat is necessary but may not be sufficient. Its habitat is potentially affected by overall management of a given watershed, the riparian corridor, and the wetland site. The primary conservation consideration identified for the species in Maine is the maintenance of the hydrological integrity of its open fen habitat (Maine Department of Conservation 2004), linked to groundwater flow. Along these lines, a Rocky Mountain Region "effects matrix" has been developed for the species (Proctor 2005). In addition, watershed, riparian, and wetland conservation practices are incorporated during project level planning and implementation, assessing site-specific risks and strategies (USDA Forest Service 2001). Wetlands are also addressed under Section 404 of the Clean Water Act. There is also a draft white paper on fens in Region 2 (Austin 2005) that pertains to potential habitat for *S. selaginoides* in the Region.

Other management provisions and buffers may apply to the potential habitat of *Selaginella selaginoides* as well as other sensitive wetland species on national forests of Region 2. The watershed conservation practices of Region 2, cited in the most current Routt

National Forest planning document (USDA Forest Service 1998), provide a policy framework that sets a 300 ft. buffer in watersheds containing aquatic, wetland, or riparian-dependent species that are Threatened, Endangered or sensitive. This document specifies the allowable activities and uses within that buffer. In addition, the Routt National Forest Land and Resource Management Plan states that camping is not allowed 100 ft. from wet areas, pack stock are not to be tethered or hobbled within 100 ft. of wet areas, and weed-free hay requirements are in place (USDA Forest Service 1998, John Proctor relaying personal communication of Tina Lanier 2005). The Medicine Bow National Forest Land and Resource Management Plan has similar provisions (USDA Forest Service 2003). The Shoshone National Forest Land and Resource Management Plan is currently being revised. Timber harvest and livestock grazing guidelines vary among management units.

Tools and practices

Species inventory

Systematic species inventory of *Selaginella selaginoides* is warranted in areas of Region 2 with potential habitat, including the northern Park Range (Routt National Forest), Medicine Bow and Sierra Madre ranges (Medicine Bow National Forest), and the Beartooth Mountains, east slope of the Wind River Range and southern Absaroka Range (Shoshone National Forest). Systematic surveys are usually conducted by visiting the known population sites, visiting as many similar settings as possible across areas of potential habitat, using aerial photography and topographic maps, and consulting with people who know the landscape. Low elevation springs, as mapped on topographic maps, are a meaningful but extremely large set of inventory targets for *S. selaginoides* inventory.

Habitat inventory

Selaginella selaginoides is not an obligate peatland species, but in western Wyoming it appears to occur at spring and seep zones in or near fens. There has been a systematic survey for fen habitat in over 10 percent of the Medicine Bow Range (Heidel and Thurston 2004), and fen survey is in progress in the Beartooth and contiguous northern Absaroka Range (Heidel 2005). These studies included rare species objectives with the habitat inventory objectives. Outside of Region 2, there has also been fen inventory on the west slope of the Wind River Range (Cooper and Andrus 1994).

Population monitoring

The topic of monitoring *Selaginella selaginoides* in Region 2 is not relevant unless it is documented there. In general, there are no published protocols for monitoring *S. selaginoides*. As clonal species with prostrate stems that sometimes forms mats, it is not possible to distinguish genetically-unique individuals in the field when clumps overlap, in which case canopy cover is a more appropriate gauge of trend. Trends in cover have been used for monitoring populations of other vascular and nonvascular mat-forming species using a frame or plexiglass grid overlain in a permanent plot or monitoring belt transect, with or without photo documentation (e.g., Lesica and Achuff 1991).

Habitat monitoring

Monitoring of *Selaginella selaginoides* habitat is warranted if there are signs of mortality in the population, if natural disturbances or management activities transpire that could have a major impact, or if observations otherwise indicate an increase in associated plant stature or a decrease in water flow. Habitat monitoring is intended to evaluate the nature and implications of habitat change. Techniques need to be developed that address the site circumstances and might include photo points to record gross vegetation structure, a set of piezometers to record groundwater flow and levels, or grids to measure moss mat vegetation cover in occupied habitat.

Population or habitat management approaches

Selaginella selaginoides is a species that requires stable habitat. The management guidelines for wetland species that require stable habitats often involve buffering the habitat rather than directly managing it. The small extent of occupied habitat signifies that small-scale threats can eradicate entire populations, and in turn, that small-scale avoidance and buffering measures can circumvent threats. Maintenance of both existing groundwater flows and existing moss mat vegetation at occupied habitat are necessary but may not be sufficient standards. As mentioned previously, the scale of *S. selaginoides* management may range from watersheds to microhabitats.

Information Needs

Baseline surveys for *Selaginella selaginoides* in Region 2 supercede all other information needs.

Locating the species may require familiarity with its morphological characteristics and habitat requirements. It remains to be determined whether known sites of *S. selaginoides* closest to Region 2 all represent peatland habitat and histosol soil orders, which would narrow the search for suitable habitat. The one Colorado occurrence that was reported in error from the northern Park Range poses a conundrum because the habitat described fits the species' habitat profile, and the northern Park Range has the highest concentration in Colorado of species with northern biogeographic affinities (Weber and Wittmann 2001). Systematic surveys of wetlands in Jackson County, Colorado that include the northern Park Range are slated to take place in 2006 (Culver personal communication 2005). This provides an opportunity to survey for *S. selaginoides* and other rare species found in wetland habitat.

In general, *Selaginella selaginoides* might be made a survey target in the Medicine Bow Range as well as the Sierra Madre, Absaroka and Wind River ranges of the Routt, Medicine Bow, and Shoshone national forests. Systematic floristic documentation of the Wind River Range flora on the east side (Shoshone National Forest) is being conducted through the Rocky Mountain Herbarium, as an opportunity for filling floristic gaps. This is the last major area of national forest in the Wyoming portion of Region 2 that has not had floristic inventory to date (Chumley 2005), and *S. selaginoides* might be sought in this area. Systematic peatland documentation in the Beartooth Unit of Shoshone National Forest is being conducted through the Wyoming Natural Diversity Database, and the species may also be sought in this study area. In addition, *S. selaginoides* is being made a survey target in appropriate biological evaluations conducted in the Park Range and in the Sierra Madre Range.

From the information at hand, it seems appropriate to focus survey efforts around vegetation that forms on marl, including but not limited to *Eleocharis quinqueflora* emergent vegetation (few-flowered spikerush herbaceous vegetation), as known in Colorado (Carsey et al. 2003) and in Wyoming (Heidel and Laursen 2003). Spruce swamp vegetation may also be appropriate habitat as found in Colorado with *Picea pungens/Equisetum arvense* woodland (Blue spruce/Field horsetail woodland; Carsey et al. 2003), and in Wyoming with *Picea glauca/Equisetum arvense* vegetation (White spruce/Field horsetail woodland; Heidel and Laursen 2003).

Potential distribution models for other peatland-sensitive plant species in Region 2 have been developed (Beauvais and Smith 2005), but not for *Selaginella selaginoides*. The species model that most closely relates to known and potential distribution and habitat of *S. selaginoides* at montane elevations is that for *Carex diandra* (lesser panicled sedge). The distribution of this peatland species overlaps with that of *S. selaginoides* in Wyoming. *Carex diandra* is also present in the northern Park Range of Colorado and in the Beartooth/northern Absaroka ranges of Wyoming.

An alternative approach to pursuing surveys of *Selaginella selaginoides* involves bryophyte surveys. Few vascular plant surveys and studies have addressed moss species, much less focused on them, but any such projects that focused on moss-dominated wetland habitats may be effective in locating associated species, like *S. selaginoides*.

In any form of survey for *Selaginella selaginoides*, or resurvey outside Region 2, it would be useful to collect more detailed information on vegetation structure, bryophyte flora, water erosion features (if any), water and soil temperature and pH values, and substrate water-holding capacity.

Information on the trends of *Selaginella selaginoides* in Yellowstone National Park may help to determine the nature and severity of widespread potential threats and provide insights into habitat stability. The documentation of the Secret Valley population in 2003, surrounded as it is by areas completely burned in 1988 crown fires, is encouraging (Evert personal communication 2005). Expanded evaluation of wetland characteristics and aerial photograph changes may help to evaluate the severity of wildfire threats. The Gibbon River population has not been intensively surveyed since road construction in 1994. Repeat surveys with note of wetland characteristics and aerial photograph changes may help to evaluate the nature and severity of the road construction effects.

Little information could be found in the literature on the habitat and life history phenology of *Selaginella selaginoides* in its gametophyte stage. Further consultation with researchers who specialize in fern allies and their propagation may be warranted.

In closing, it bears reiteration that concerted baseline surveys for *Selaginella selaginoides* in areas of potential habitat are needed above all other investigations to determine whether it is appropriate to recognize *S. selaginoides* as a sensitive species in Region 2.

DEFINITIONS

Alkaloid – A nitrogenous organic compound produced especially by vascular plants, many with pronounced physiological activity in animals and including those that deter herbivory.

Antheridium – Sperm-bearing structure on the male gametophyte.

Archegonium – Egg-bearing structure on the female gametophyte.

Calcareous – Containing calcium carbonate.

Capsule – In mosses, the spore-bearing structure, borne on an elevated stalk.

Circumboreal – Distributed in the New and Old World across high northern latitudes.

Dichotomous – Divided into two (symmetrical not sure it has to be symmetrical) parts, as with a two-forked branching pattern.

Dimorphic – Fertile and sterile leaves that are morphologically differentiated.

Diploid – Having a double set of homologous chromosomes, typical of many organisms derived from fertilized egg cells.

Disjunct – Distinctly separate, in the case of a discontinuous range in which one or more populations are separated from other potentially interbreeding populations by sufficient distance to preclude gene flow between them. In Wyoming, this term is usually reserved for populations separated over 300 miles from their core distribution.

Dorsal – Located on the back side.

Fen – A type of peatland that receives significant inputs of water and dissolved solids from a mineral source, such as runoff from mineral soil or groundwater discharge.

Gametophyte – The haploid gamete-producing plant, an autonomous life-cycle stage.

Glacial relict – A species that has survived from a Pleistocene fauna or flora, typically in a restricted location or habitat.

Haploid – Having a single set of homologous chromosomes.

Heterosporous – Having two discrete forms of spores.

Holotype – The single specimen when no type was specified but only one specimen was taken.

Lectotype – The type specimen selected from the syntype series by a subsequent author in the absence of a holotype.

Meiosis – Two special cell divisions that occur once in the life cycle of every sexually reproducing plant and animal, halving the chromosome number and effecting a segregation of genetic determiners.

Megasporangium – Sporangium that bears megaspores.

Megaspore – The large spore that gives rise to the female gametophyte.

Microsporangium – Sporangium that bears microspores.

Microspore – The small spore that gives rise to the male gametophyte.

Mycorrhizae – The association between a fungus and the root system of a vascular plant.

Outcrossing – Mating or crossing of individuals that are less closely related than average pairs in the population.

Palynological – The study of pollen and spores, both living and fossil.

Peat – An accumulation of unconsolidated, partially decomposed plant material found in more or less waterlogged habitats of fen or bog.

Peatland – Any waterlogged area containing an accumulation of peat 30 cm or more thick.

Perennial – Persisting more than two years.

Phreatophytes – A plant that absorbs water from the permanent water table, generally having high transpiration water loss.

Plasticity – The capacity of an organism to vary morphologically or physiologically as a result of environmental influence.

Rank – NatureServe and the Natural Heritage Program use a ranking system (Internet site: http://www.natureserve.org/explorer/granks.htm). A rank of "G5" indicates that *Selaginella selaginoides* is "demonstrably secure globally" though it may be very rare and local in parts of its range. A rank of "S1" indicates that it is critically imperiled at the state (subnation) level because it is very rare or local, or because of some other factor(s) making it very prone to extirpation from the state.

Sporophyll – A spore-bearing leaf.

Sporophyte – The diploid plant lifecycle stage in which meiosis occurs.

Strobilus – Modified leaves or ovule-bearing scales grouped together on an axis.

Zygote – Diploid cell resulting from the fusion of two gametes.

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