Sullivantia hapemanii (Coult. & Fisher) Coult. var. *hapemanii* (Hapeman's coolwort): A Technical Conservation Assessment

Prepared for the USDA Forest Service,
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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, and on statewide sensitive species survey and related research in natural heritage program positions in Bismarck, ND and in Helena, MT. She is currently Botanist of the Wyoming Natural Diversity Database, a research program of the University of Wyoming, conducting botanical surveys and research throughout the state, and providing technical information services.

COVER PHOTO CREDIT

Sullivantia hapemanii var. *hapemanii* (Hapeman's coolwort). Photograph by B. Heidel.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *SULLIVANTIA HAPEMANII* VAR. *HAPEMANII*

Status

Sullivantia hapemanii var. *hapemanii* (Hapeman's coolwort) is a regional endemic of the Big Horn Mountains (Wyoming) and the contiguous Bighorn Canyon (Montana), as well as of disjunct populations in the Middle Fork of the Snake River Canyon (Idaho). It was previously designated a sensitive species by the Rocky Mountain Region, USDA Forest Service but is not currently designated sensitive on the list signed by the Regional Forester in 2003. It is not designated sensitive by the Bureau of Land Management in Wyoming. The NatureServe Global rank for this variety and the species overall is vulnerable (G3T3). *Sullivantia hapemanii* var. *hapemanii* is ranked as vulnerable (S3) in Wyoming by the Wyoming Natural Diversity Database, and imperiled (S2) by both the Montana Natural Heritage Program and the Idaho Conservation Data Center. Of the 47 extant occurrences rangewide, 32 are in Wyoming, and of these, 16 are on the Bighorn National Forest. The Rocky Mountain Region populations represent 50 percent of the total number of occurrences in Wyoming, and over 80 percent of the known numbers of this taxon in the state.

Primary Threats

Sullivantia hapemanii var. *hapemanii* is potentially affected by streamflow alterations, including impoundments and diversions that may desiccate or inundate habitat. Dam construction activities are likely to have impacted the taxon in the past outside of national forest boundaries. This species is also potentially threatened by trampling, where the plant grows at recreation sites or at water sources for livestock. The known potential threats are localized, and there is no direct evidence that it is affected by large-scale land use practices and disturbances higher in the watershed (e.g., fire and logging).

Primary Conservation Elements, Management Implications and Considerations

Sullivantia hapemanii var. *hapemanii* is a riparian species that has narrow ecological amplitude and occupies fragile habitat, specifically coldwater spring, seep, and streamside settings at low- and mid-montane elevations generally associated with limestone outcrops. *Sullivantia hapemanii* var. *hapemanii* appears to be a glacial relict. Despite this intrinsic vulnerability, it generally occurs in settings with high-gradient streams and/or steep slopes, often in remote settings and habitat of limited access, which serve to lower vulnerability concerns.

All national forest populations of *Sullivantia hapemanii* var. *hapemanii* are located on lands managed for multiple uses, with the exception of Shell Creek Research Natural Area, which was established to maintain rare species and supporting hydrology. Of the populations occurring on national forest managed for multiple uses, six are located on potential Research Natural Areas. Until an area is formally proposed and designated, the area is part of prior land management units. Current information suggests that the many Wyoming populations, including the majority of the national forest populations, are relatively secure because of their remote location and inaccessible habitat. Maintaining *S. h.* var. *hapemanii* in the long term may require maintaining and buffering its riparian habitat and supporting hydrological conditions to ensure long-term viability.

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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). *Sullivantia hapemanii* var. *hapemanii* (Hapeman's coolwort; also referred to as Hapeman's sullivantia) is the focus of an assessment because it is a regional endemic that has its highest known numbers throughout its range on National Forest System land in Region 2.

This assessment addresses the biology of *Sullivantia hapemanii* var. *hapemanii* throughout its entire range. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. 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 but to provide the ecological background upon which management must be based. While the assessment does not provide management recommendations, it does present the available information on the consequences of changes in the environment that result from management, and cites management recommendations proposed for a closely-related taxon. It provides a reference to promote species conservation on Forest Service lands (Blankenship et al. 2001).

Scope

The *Sullivantia hapemanii* var. *hapemanii* assessment examines the biology, ecology, conservation status, and management of this taxon throughout its range, with specific reference to the geographic and ecological characteristics of the Rocky Mountain Region (Region 2) under current environmental conditions. The evolutionary history of this taxon and its environment are considered in conducting this synthesis but placed in a current context. The range of this taxon lies primarily within Region 2, where it occurs on lands administered as part of the USFS Rocky Mountain Region in the Bighorn National Forest, Wyoming. This assessment also incorporates information from the rest of its range in Idaho and Montana, placing it in the ecological context of Region 2.

The taxonomic scope of this report covers only the type variety, *Sullivantia hapemanii* var. *hapemanii*. Throughout the text of this report, *S. h.* var. *hapemanii* is referred to by its full scientific name. It is one of two varieties of the species. The other variety, *S. h.* var. *purpusii* (Purpus' sullivantia or hanging garden sullivantia) is endemic to Colorado, known from Garfield, Gunnison, Montrose, Pitkin and Rio Blanco counties (Spackman et al. 1999). The latter was previously treated as a separate species, *S. purpusii* Brandegee until the revisionary monographic work of Soltis (1991). These are the only two *Sullivantia* taxa in Region 2.

In producing the assessment, refereed literature, non-refereed literature, herbarium documentation, and information resources compiled natural heritage programs were reviewed. For Region 2 in particular, the data represent robust documentation of *Sullivantia hapemanii* var. *hapemanii* that draws from over 20 years of information compiled on it as a Wyoming plant species of concern and a taxon that has attracted the attention of collectors whenever it is encountered, beginning with Frederick Hayden in 1859. In addition, existing distribution data and Geographic Information Systems base layers have been used to assess potential distribution and adequacy of existing survey information. A summary of the potential distribution model results are incorporated in the body of this report.

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, it is difficult to conduct critical experiments in the ecological sciences, and often observations, inference, good thinking, and models must be relied on to guide the understanding of ecological relations. In this assessment the strength of evidence for

particular ideas is noted, and alternative explanations are described when appropriate. While well-executed experiments represent a sound approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are also accepted approaches to understanding the features of biology. These scientific tools are to be used in concert with the most complete species status data to produce a robust analysis. The data and analyses presented in this document are based on published and unpublished literature and systematic surveys throughout the range of *Sullivantia hapemanii* var. *hapemanii* in Wyoming, in addition to that from contiguous habitat in Montana and status information in Idaho. The technical information provides a robust framework for interpreting the status, distribution and habitat requirements of *S. h.* var. *hapemanii*.

Publication on the World Wide Web

To facilitate use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site. Placing the documents on the web makes them available to agency biologists and the public more rapidly than publishing them as reports. More importantly, it facilitates revision of the 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 release on the web. This assessment of *Sullivantia hapemanii* var. *hapemanii* was reviewed through a process administered by the Center for Plant Conservation, 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

In a lengthy report that was accepted as a petition under the Endangered Species Act in 1975, *Sullivantia hapemanii* was identified by the Smithsonian Institution as a species that may become threatened (USDI Fish and Wildlife Service 1975). This report was published with updates and revisions as a working list of Endangered and Threatened plants of the United States (Ayensu and DeFilipps 1978). In the ensuing review process, *S. hapemanii* was downlisted as a 3C taxon (USDI Fish and Wildlife Service 1985). It was later reinstated as a Category 2 candidate (USDI Fish and Wildlife Service 1993), along with *S. purpusii* (synonym: S. *hapemanii* var. *purpusii*). *Sullivantia hapemanii* was subsequently recommended for down-listing (Wyoming Natural Diversity Database 1995), but this recommendation was not implemented. In 1996, the USDI Fish and Wildlife Service discontinued the use of Category 2 designation (USDI Fish and Wildlife Service 1996), so both taxa have no status under the Endangered Species Act. There are no efforts underway to list either taxon.

Both varieties of *Sullivantia hapemanii* were designated sensitive in the USFS Rocky Mountain Region (USDA Forest Service 1993), but neither variety was designated as sensitive in the updated Rocky Mountain Region list signed in 2003 (USDA Forest Service 2003b). *Sullivantia hapemanii* var. *hapemanii* does not have USFS sensitive status in Region 4, where it occurs on Salmon National Forest in Idaho, and it does not occur on national forests of Region 1 in Montana. The NatureServe global rank for the species overall and for *S. h.* var. *hapemanii* is vulnerable (G3T3; NatureServe 2002). It is ranked vulnerable (S3) by the Wyoming Natural Diversity Database, and imperiled (S2) by both the Idaho Conservation Data Center and the Montana Natural Heritage Program (Keinath et al. 2003, Idaho Data Conservation Data Center 2002, Heidel 2002, respectively.)

Sullivantia hapemanii var. *hapemanii* was on the first Wyoming rare plant species list that accompanied the flora published by Dorn (1977). It was only recently removed from tracking on the Wyoming plant species of special concern list in 2002 based on the number of occurrences and the low degree of threat (Fertig and Heidel 2002), but it remains on the list of endemic species that are of potential concern (watch list; Keinath et al 2003). There is no legislation or management policy in Wyoming that accompanies this ranking and tracking status.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

In Region 2, *Sullivantia hapemanii* var. *hapemanii* occurs on National Forest System land (Bighorn National Forest), land managed by the Bureau of Land Management, state land, and private land. Of the 47 extant occurrences rangewide, 32 are located in Wyoming and 16 are located in part or in full on the Bighorn National Forest.

All 16 populations of *Sullivantia hapemanii* var. *hapemanii* on the Bighorn National Forest are on lands currently managed for multiple-use with exception of Shell Canyon Research Natural Area (RNA). Six populations are found within potential RNAs, the Crazy Woman Creek, Tensleep Canyon, Dry Fork, Tongue River, Elephant Head, and Mann Creek potential RNAs. One other population is found in the Trapper Canyon Wilderness Study Area. The Mann Creek potential RNA includes the largest known population complex in Region 2 and rangewide (Jones and Fertig 1998). It harbors at least half of all known individuals in Wyoming and spans over seven miles of riparian corridor habitat. The set of potential RNA sites encompasses several of the largest canyons on the Bighorn National Forest.

Outside of the Bighorn National Forest, *Sullivantia hapemanii* var. *hapemanii* occurs on other public lands administered by the BLM Buffalo, Cody, and Worland field offices. Two populations occur at least in part within the Five Springs and Spanish Karst Areas of Critical Environmental Concern (ACECs). Seven more populations are protected within Nature Conservancy conservation easements on private lands and in the Conservancy's Tensleep Preserve. One population is located in the Amsden Creek Wildlife Habitat Management Area.

Outside of Region 2, there are 10 occurrences in Montana (Heidel and Fertig 2000, 2001) that are all on Bighorn Canyon National Recreation Area, and there are 5 occurrences in Idaho (Moseley personal communication 1996) that are all in the River of No Return Wilderness in the Salmon National Forest.

There are no laws, regulations, management plans, or conservation plans that directly address *Sullivantia hapemanii* var. *hapemanii* in any portion of its range. In Region 2, potential impacts to populations were not identified when evaluating project proposals and management plans when the taxon was previously recognized as sensitive (Bornong personal communication 2002).

Biology and Ecology

Classification and description

The full scientific name is *Sullivantia hapemanii* (Coulter & Fisher) Coulter var. *hapemanii*. All previous taxonomic treatments and synonymy involving this species are listed below and described in the following section that presents a brief history.

Heuchera hapemanii Coulter & Fisher, Bot. Gaz. 17:348. 1892.

Sullivantia hapemanii (Coulter & Fisher) Coulter, Bot. Gaz. 17:421. 1892.

Sullivantia oregana var. *hapemanii* (Coulter & Fisher) C.O. Rosend., Bot. Jahrb. 27, Biebl. 83: 60. TYPE: U.S.A. Wyoming: "Big Horn Mountains," *Hapeman 907* (HOLOTYPE: GH!) Hapeman s.n. (ISOTYPES: F!, US!).

Sullivantia halmicola A. Nelson ex Small, N. Amer. Fl. 22:122. 1905. Type: U.S.A. Wyoming: "Hat Six Creek, Casper Mountain," 7 Aug 1898, *E. Nelson* 5032 (HOLOTYPE: NY!; ISOTYPES: ILL!, MO!, MR!, US!).

Sullivantia hapemanii var. *hapemanii* is a delicate perennial herb with a glandular-pubescent stem 5 to 60 cm tall arising from fibrous roots. Basal leaves are long-petioled and have rounded or kidney-shaped blades 1 to 11 cm wide. The margins of the blades are palmately divided into 5 to 13 shallowly wedge-shaped or toothed segments. Stem leaves have shorter petioles and progressively reduced blades. Foliage is glandular-pubescent. The inflorescence is an open, glandular panicle. Flowers have five white, spoon-shaped petals, 1.2 to 5 mm long, and five short stamens, and a glandular calyx. The ovary is 1/2 to 3/4 inferior, 2-celled, and develops into a narrowly cylindric-ovate capsule at maturity (Soltis 1991, Girard 1992, Fertig et al. 1994, Fertig 2000a, Dorn 2001). The species' illustration is presented in **Figure 1**, and species' photographs are presented in **Figure 2** and **Figure 3**. The inflorescence branches are not always radially distributed but may be concentrated on one side, and the erect flowering stalk may lean in overhang settings. Note the differences in the lobes and teeth of the leaf outline in the illustration and two photos (**Figure 1**, **Figure 2**, and **Figure 3**).

The *Sullivantia* genus occurs only in the United States and is technically differentiated from other genera of the Saxifrage family by the 2-celled ovary with five stamens, calyx adnate to the base of the pistil, and petals 1.5 to 2.5 mm long. Members of the *Sullivantia* genus are readily distinguished from species in the *Saxifraga* genus by having five stamens rather than 10. The two genera are otherwise similar in that they each have an open inflorescence with spreading branches. *Sullivantia hapemanii* var. *hapemanii* superficially resembles *Saxifraga odontoloma* (streambank saxifrage), but the latter also has toothed, unlobed leaves and 10 stamens per flower. It superficially resembles *Heuchera*

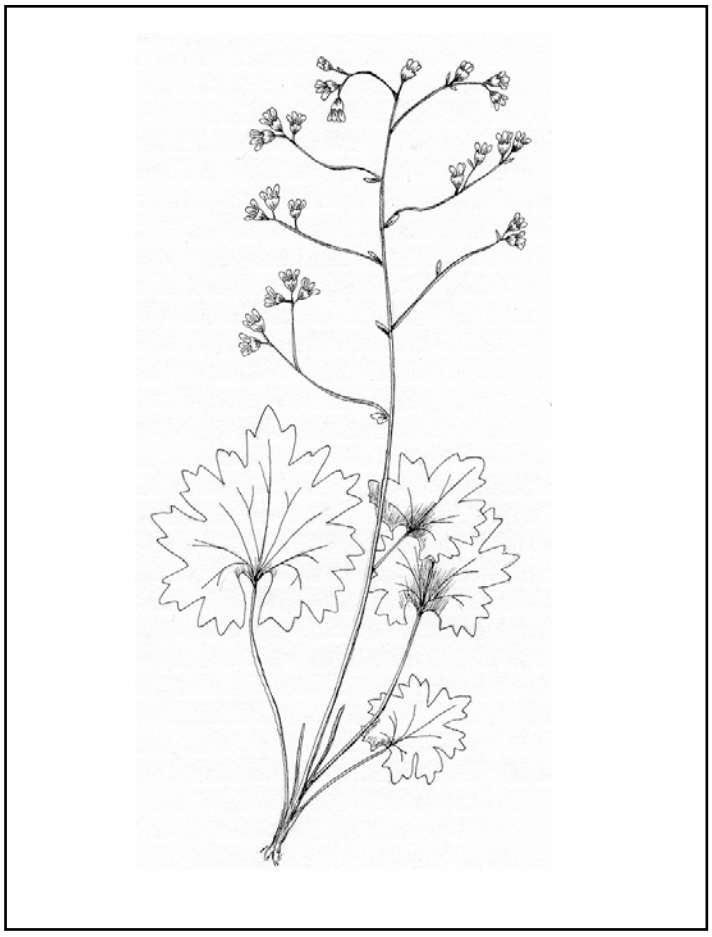


Figure 1. Illustration of *Sullivantia harpemanii* var. *hapemanii*, by Walter Fertig (from Fertig et al. 1994).

parvifolia (little-leaf alumroot) and *Conimitella willliamsii* (Williams' miterwort), but *H. parvifolia* has a congested inflorescence, round-lobed basal leaves, and a 1-celled ovary. *Conimitella williamsii* also has a raceme, round-lobed, leathery, ciliate-margined basal leaves, and a 1-celled ovary (Soltis 1991, Fertig et al. 1994, Spackman et al. 1999).

History of the taxon

Members of the *Sullivantia* genus were first described by Torrey and Gray (1840) under the name *Saxifraga*(?) *sullivantii* in honor of William S. Sullivant, a bryologist who collected the first specimen in Highland County, Ohio. After review of fruiting capsules, this species was elevated to a separate genus and described as *Sullivantia sullivantii* (Gray 1842).

In 1859, Frederick Hayden collected the first specimen of a *Sullivantia* in Wyoming from the Big Horn Mountains (Hayden s.n. MO). The next collection was made prior to 1892 by Dr. H. Hapeman also in the Big Horn Mountains (Hapeman 907 GH; Hapeman s.n. F, US). It was described as *Heuchera hapemanii* by Coulter and Fisher (1892) and reassigned to the *Sullivantia* genus the same year (Coulter 1892) based on the Hapeman specimen, which did not have a year and date on the specimen label. It was later collected in 1896 by Aven Nelson from Wolf Creek Canyon, also in the Big Horn Mountains (*A. Nelson 5032*).

In 1898, Elias Nelson collected a *Sullivantia* species from Hat Six Falls at Casper Mountain, Wyoming. It was described as a new species, *Sullivantia halmicola* (Small and Rydberg 1905) and attributed to A. Nelson but based on the collection of E. Nelson. This species was distinguished from S. *hapemanii* chiefly on leaf size differences (Soltis 1991). It was later reduced to synonymy with S. *hapemanii* (Coulter and Nelson 1909). However, it was retained as a separate species by Rosendahl (1927). The most current research into the taxonomy of the genus, including morphological analyses, greenhouse breeding trials, and flavonoid chemistry characteristics, has shown that there is no evidence to retain *S. halmicola,* and it has been reduced to synonymy (Soltis 1991).

Figure 2. Photograph of *Sullivantia hapemanii* var. *hapemanii* showing plants in shade, by Bonnie Heidel.

Figure 3. Photograph of *Sullivantia hapemanii* var. *hapemanii* showing plants in partial light, by Bonnie Heidel.

The treatment of *Sullivantia* material from other states was in flux at the same time. Material from Colorado previously referred to as *Boykinia purpusii* was reduced to a synonym of *S. hapemanii* (Brandegee 1899), as were collections of *S. sullivantii* from Minnesota and Wisconsin (Small and Rydberg 1905). Each of these was elevated to three separate species of *Sullivantia* by Rosendahl (1927), who also treated *S. halmicola* as separate from *S. hapemanii*.

Soltis revised the taxonomic treatment of the *Sullivantia* genus in 1991 and recognized the Colorado and Wyoming material as two distinct varieties of the same species, *S. hapemanii* (Coulter & Fisher) Coulter var. *hapemanii* and *S. h.* var. *purpusii* (Brandegee) Soltis. The current treatment of this species, both varieties, and other species in the genus are presented in the monograph by D.E. Soltis (1991). The two varieties differ primarily in that *S. h.* var. *hapemanii* has the ovary about as long as broad at anthesis and less than 2.5 times longer than broad as maturity, while *S. h.* var. *purpusii* has the ovary about 2 times as long as broad at anthesis and at least 2.5 times longer than broad at maturity. *Sullivantia hapemanii* is one of four species of *Sullivantia* in the continental United States.

Surveys have been conducted for *Sullivantia hapemanii* var. *hapemanii* in Wyoming since it was proposed as Threatened in 1975. It was collected in 1977 by Robert Dorn and placed on the first list to be compiled of Wyoming rare and endangered plant species (Dorn 1977). The following years brought concerted collecting by Dorn and Robert Lichvar, mainly on Bighorn National Forest. The increase in the number of known occurrences since this time is thought to correspond with new survey efforts rather than with overall differences between current and historic regional distribution and abundance. There were also concerted surveys on BLM lands (Fertig 1993) and on potential RNAs of Bighorn National Forest in 1998 (Jones and Fertig 1992, Jones and Fertig 1998, Welp et al. 1998a-f). The historic Casper Mountain population has been relocated, but no other survey has been conducted in the northern Laramie Mountains on surrounding Medicine Bow National Forest. Two new records were added in 2002 by Kate VinZant on BLM-administered lands and by Bonnie Heidel along Federal Highway 20 in the Wind River Canyon. The largest set of voucher specimens is maintained at Rocky Mountain Herbarium (RM; University of Wyoming).

Distribution and abundance

Sullivantia hapemanii var. *hapemanii* is a regional endemic of north-central Wyoming, adjoining south-central Montana, and central Idaho (Fertig et al. 1994, Fertig 2000a, b, Croft et al. 1997, Lichvar et al. 1984, Lichvar et al. 1985, Heidel and Fertig 2000, NatureServe 2002). The three-state distribution spans a distance of over 200 miles, but Idaho populations are disjunct. The species' range in Montana is contiguous with its range in Wyoming. Species and populations in the *Sullivantia* genus in general are notable for their disjunct patterns of distribution and occurrence at Pleistocene glacial margins (Soltis 1991; **Figure 4**). Many *Sullivantia hapemanii* var. *hapemanii* populations from the Big Horn Mountains occur between 1200 and 1700 m at elevations that probably escaped glaciation (Soltis 1991, Karow personal communication 2002).

Sullivantia hapemanii var. *hapemanii* occurs in six counties of Wyoming, the complete extent of its distribution in Region 2. It is known from the Big Horn Mountains in Big Horn, Johnson, Sheridan, and Washakie counties, and from two outlying populations in the Wind River Canyon in Hot Springs County, in addition to one outlying population in the northern Laramie Range in Natrona County (Neighbours and Marriott 1991, Fertig 1993, Fertig et al. 1994, Harman and Nelson 1998, Fertig 1999, Beauvais et al. 2000, Fertig 2000 a, b, Welp et al. 2000, Dorn 2001). In south-central Montana the taxon occurs in the Bighorn Canyon, contiguous with the Big Horn Mountains of Wyoming. In central Idaho it occurs on the Middle Fork of the Salmon River. Of the 47 extant occurrences rangewide, 32 are in Wyoming, and of these, 16 are on the Bighorn National Forest (Region 2; Wyoming Natural Diversity Database 2003).

Sullivantia hapemanii var. *hapemanii* is also known from two historical records in Wyoming (**Figure 5**). The original Hayden collection site ("Big Horn Mountains") is unmappable. Twenty-seven of the 32 extant populations have been discovered or relocated since 1988 (most recently, two populations were discovered in 2002). A total of 16 populations are located in part or in full within the boundaries of Bighorn National Forest (**Table 1**). The distribution of this taxon is also posted electronically on the Atlas of the Vascular Plants of Wyoming (Hartman and Nelson 1988).

A model of potential distribution of *Sullivantia hapemanii* var. *hapemanii* was prepared to identify areas of high, medium, and low probability based on classification tree methods. All available distribution data for the taxon in the state were used and correlated with sets of environmental attributes in Geographic Information System (GIS) layers (Fertig and Thurston 2002). In addition, "negative data" were used where the species is not known to occur. The high probability areas of *S. h.* var. *hapemanii* are primarily in the Big Horn Mountains, though areas with similar geology were identified as high probability potential habitat in the Absaroka Range along the Clarks Fork and the South Fork of the Shoshone River. All areas of high probability are in the Big Horn Mountains (**Figure 6**). Areas of at least low probability are in small portions of the Medicine Bow and Shoshone national forests. The data sources include all specimen vouchers over one mile apart. The GIS data layers and analysis methods are presented in a report on the potential distribution of BLM sensitive species in Wyoming (Fertig and Thurston 2003 (http://uwadmnweb.uwyo.edu/WYNDD/Reports/pdf_fertig/FinalReport_03BLMmodeling.pdf), though this report does not address *S. h.* var. *hapemanii*.

Population sizes of *Sullivantia hapemanii* var. *hapemanii* are highly variable, ranging in magnitude from less than 10 plants to 10,000+ plants (**Table 1**; Fertig 1993, Marriott and Jones 1993, Jones and Fertig 1998, Welp et al. 1998a-f, Fertig 2000a, b, Birkholz personal communication 2002). Population size estimates are not available for over 25 percent of the Wyoming occurrences, but a tally of existing estimates indicates total species numbers of 89,563 to 146,172 individuals in the state. Of these, over 80 percent are on Bighorn National Forest. There is one Bighorn National Forest population at Mann Creek that may surpass all other known populations rangewide. Population numbers at Mann Creek are estimated between 60,000 and 80,000 individuals. Three other national forest populations with population numbers greater than 10,000 plants include Dry Creek, Taffner Creek, and West Pass. All four of these populations are on the east side of the Big Horn Mountains. There is at least one population on the west side with numbers that approach this size; Tensleep and Leigh canyons have a population size estimated between 4,000 and 7,000 plants. By comparison, only two occurrences in Montana have population numbers greater than 10,000 plants. Population size estimates are not available in Idaho.

Estimates of population size of *Sullivantia hapemanii* var. *hapemanii* are preliminary for all but small populations. *Sullivantia hapemanii* var. *hapemanii* produces one flowering stem per individual. It is often present in high density, growing in clumps or mats where it appears to be locally abundant (**Figure 2**, **Figure 3**), but it is restricted to small areas. It is at least as common to find high-density clumps of plants as it is to find few, isolated stems. In high-density patches, it is difficult to distinguish flowering stems from one another at a glance, and it is not possible to distinguish the basal leaves of non-flowering individuals from flowering individuals, except by sorting basal shoots at close inspection. These density counts have not been made. A 1-m^2 patch with continuous cover of individuals may represent a few dozen individuals or hundreds, depending on density and vigor. Furthermore, many patches are not accessible for close inspection, such as those on vertical outcrops or waterfall margins.

Population aerial extent of *Sullivantia hapemanii* var. *hapemanii* ranges from less than 1 to 67 ha (**Table 1**), but the area values mask the distances involved. Populations may occupy a single small spring, waterfall spray zone, or boulder less than 5 m^2, or they may span several miles of discontinuous or semi-continuous streamside habitat. Aerial extent was determined by digitizing boundaries that were mapped in the field. There were only 12 populations of *S. h.* var. *hapemanii* extensive enough with documented boundaries to allow mapping as polygons onto 1:24,000 maps. Most of these extensive populations are on the Bighorn National Forest. The population numbers and aerial extent are summarized in **Table 1**; those populations with rough estimates of areas covered are asterisked. Most of the mapped population boundaries follow elongate habitats, i.e., riparian corridors. A few have multiple polygons, e.g., seven discrete sub-populations at Mann Creek. Population area estimates are not available for over 25 percent of the occurrences, but a tally of existing estimates indicates total statewide (regionwide) population extent at 245.9 ha (607.6 acres). Over half of all area occupied by the species is found at two occurrences, at Mann Creek (Bighorn National Forest) and Trapper Creek (BLM Worland Field Office).

Population trend

Sullivantia hapemanii var. *hapemanii* trend data are lacking in Wyoming except for permanent photopoint monitoring at Tensleep Preserve that shows overall population stability (Davis personal communication 2003). The only other trend information is based on informal observations made during repeat visits. From these limited observations, *S. h.* var. *hapemanii* populations in Wyoming appear to be highly

Figure 4. Rangewide distribution of *Sullivantia hapemanii* var. *hapemanii* and all other *Sullivantia* species compared to the extent of the Wisconsin glaciation (Soltis 1991). **Note:** The map does not show complete distribution of *Sullivantia hapemanii* var. *hapemanii* present in central Idaho and the Wind River Canyon.

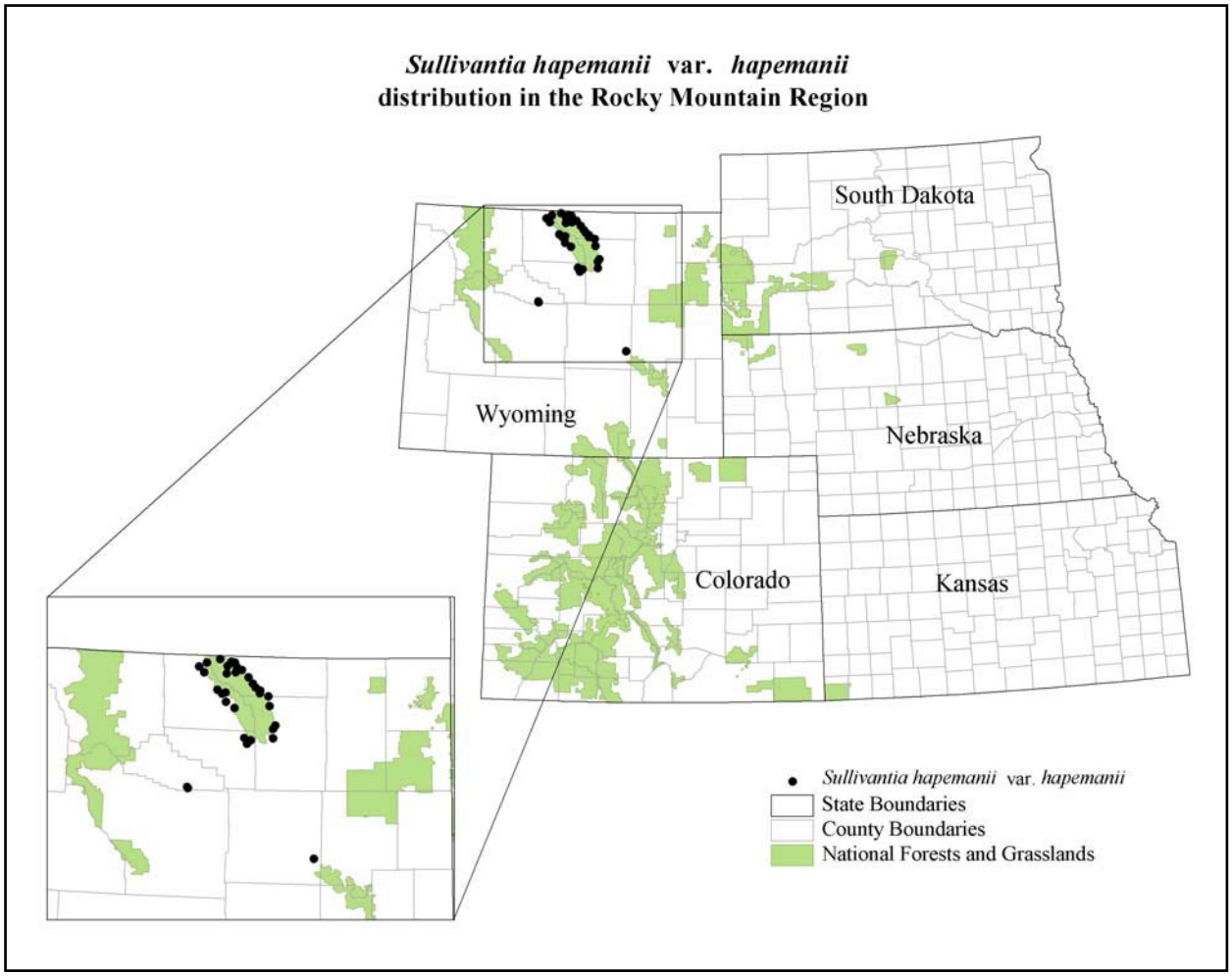


Figure 5. Wyoming distribution of *Sullivantia hapemanii* var. *hapemanii*.

Table 1. Populations of *Sullivantia hapemanii* var. *hapemanii* in Wyoming. Place names that are bold-faced are on the Bighorn National Forest. Places that are data-sensitive do not include a place name and are left blank. Population extent values that are asterisked are based on rough estimates in the field rather than field mapping and digitizing.

Occurrence number	Place	Setting	Occurrence rank[1]	Estimated population number	Population extent (ha)
001	**Tensleep and Leigh Canyons**	West slope of Big Horn Mountains	AB	4,000 to 7,000	11
002	**Shell Canyon**	West slope of Big Horn Mountains	E	Not available (NA)	Not available (NA)
003	Five Springs Falls	West slope of Big Horn Mountains	E	Several 100's	2.0*
004	**Lion's Den on Little Goose Creek**	East slope of Big Horn Mountains	H	NA	NA
006	**Wolf Creek Canyon**	East slope of Big Horn Mountains	E	NA	NA
007	**Freezeout Point**	East slope of Big Horn Mountains	E	NA	NA
008		North end of Laramie Range	E	NA	11.5
009	**North Fork Crazy Woman Creek**	East slope of Big Horn Mountains	C	10 to 15	0.1*
010	**Tongue River**	East slope of Big Horn Mountains	B	1,000 to 1,500	1.6
011	Spanish Point	West slope of Big Horn Mountains	B	2,500+ in larger of two subpopulations	33
012	Trapper Creek	West slope of Big Horn Mountains	A	NA	61.9
013	Tensleep Preserve	West slope of Big Horn Mountains	AB	100's	NA
014		East slope of Big Horn Mountains	B	500 to1,000+	5.7
015	**West Pass**	East slope of Big Horn Mountains	A	2,000 to 20,000	14.6
017	**Taffner Creek**	East slope of Big Horn Mountains	B	1,000 to 10,000	19.3
019		East slope of Big Horn Mountains	BC	Few	NA
020		Wind River Canyon area	E	NA	NA
021	Tensleep Preserve	West slope of Big Horn Mountains	A	Low 1,000's	3.6*
022	Poison Creek Canyon	East slope of Big Horn Mountains	A	2,600+	9.1*
023		East slope of Big Horn Mountains	B	400 to 500	0.6*
024		East slope of Big Horn Mountains	B	500 to 800	0.2*

Table 1 (concluded).

Occurrence number	Place	Setting	Occurrence rank[1]	Estimated population number	Population extent (ha)
026	**Mann Creek**	East slope of Big Horn Mountains	A	60,000 to 80,000	67.1
027	**Dry Fork**	East slope of Big Horn Mountains	E	10,000+	NA
028	**Shell Falls**	West slope of Big Horn Mountains	B	100 to 250; possibly more subpopulations	0.5
029	**Upper Devils Canyon**	East slope of Big Horn Mountains	AB	1,700 to 2,100	3
030	**Near Fool Creek**	West slope of Big Horn Mountains	C	1,500 to 2,000	0.2*
031	**Tongue River**	East slope of Big Horn Mountains	B	250 to 500	0.2*
032	**North and South. Forks of Piney Creek**	East slope of Big Horn Mountains	E	NA	NA
033	Windy Point	Wind River Canyon area	C	500+	NA
034		East slope of Big Horn Mountains	D	100	0.2
035	Cottonwood Canyon	West slope of Big Horn Mountains	E	NA	NA
036	Dry Fork Horse Creek	West slope of Big Horn Mountains	E	NA	NA
037		East slope of Big Horn Mountains	E	NA	NA
038	"Big Horn Mountains"	?	H	100+	1
TOTAL: 34 records (32 extant)				90,163+ to 146,772+	245.9

[1]Element occurrence rank definitions have been assigned for all records as follows:

H = Historical record; collected prior to 1971 and with no basis for interpreting whether it persists

E = Extant record; collected since 1970 but with no detailed information to evaluate viability

A = Outstanding contribution to viability

B = Good contribution to viability

C = Fair contribution to viability

D = Poor contribution to viability

stable in their cover and extent under current conditions (Fertig 2000a). The Idaho populations are likely to be stable and secure within the River of No Return Wilderness Area (Moseley personal communication 1996). It is significant to note that the three discrete springs and waterfalls where this taxon was first collected in the 1800's still support populations of the species, and all five historic collection records made in the 1930's have been relocated. Only one 1904 record has not been relocated, and the place name is unknown ("Lion's Den" on Little Goose Creek). The original 1854 collection location is vaguely described as the "Big Horn Mountains" and is unmappable. In keeping with the glacial relict hypothesis, there is no evidence to suggest that this species is adapted for colonization but is relatively static and requiring stable conditions.

Past population declines have been inferred for *Sullivantia hapemanii* var. *hapemanii* in Montana, where the species is known only from the Bighorn Canyon National Recreation Area (NRA.) There was likely to have been decline and loss among some Bighorn Canyon populations due to inundation, grazing and water developments, or alterations prior

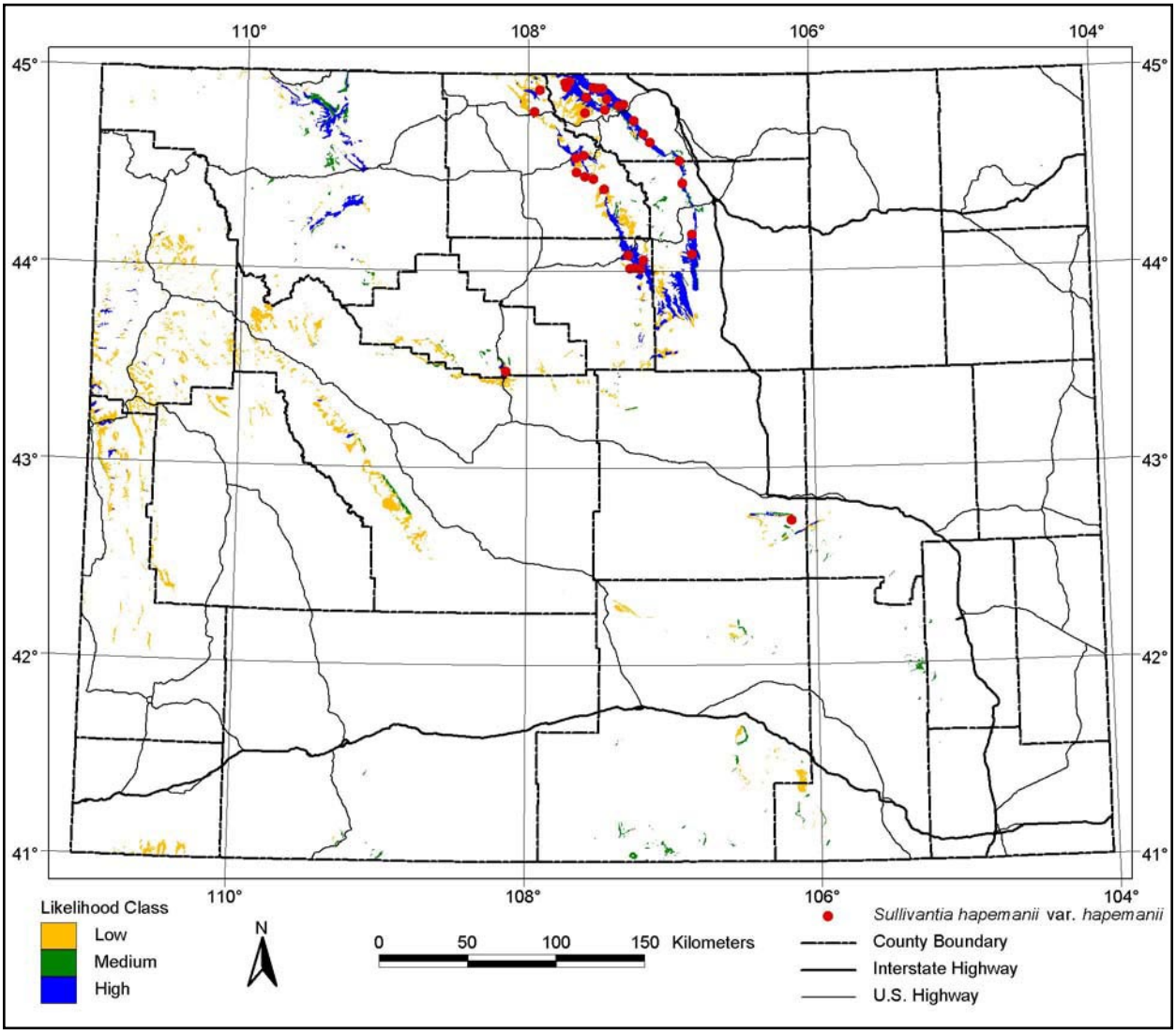


Figure 6. Potential distribution map of *Sullivantia hapemanii* var. *hapemanii* (Fertig, W. and R. Thurston. 2003. Modeling the Potential Distribution of BLM sensitive and USFWS Threatened and Endangered Plant Species in Wyoming (http://uwadmnweb.uwyo.edu/WYNDD/Reports/pdf_fertig/FinalReport_03BLMmodeling.pdf). Report prepared for the BLM – Wyoming State Office by WYNDD – University of Wyoming, Laramie, WY).

to NRA establishment. There may also have been subsequent declines. For example, an area described as an "amphitheater" filled with *Sullivantia* above the Yellowtail Reservoir in 1983 (Lichvar et al. 1984) was half-filled with rubble from slumping and had a population that numbered only in the 100's in 1999, apparently as a result of habitat destabilization from highwater conditions on the reservoir (Heidel and Fertig 2000). In addition, repeated observations between 1998 and 2001 indicate that the species may decline in certain small spring and seep habitats under drought conditions that reduce the duration and volume of groundwater discharge (Heidel personal observation). The capacity of *S. h.* var. *hapemanii* for recolonization and rebounding to high densities is not known.

Habitat

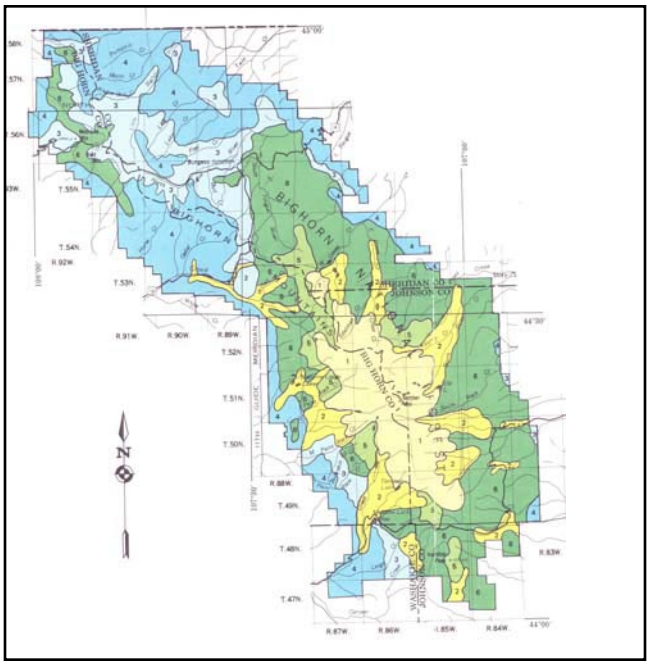
Sullivantia hapemanii var. *hapemanii* is a riparian species that grows in cool, seasonally- or permanently-saturated microhabitats. These microhabitats are found around springs or seeps, in and along coldwater streams and rivulets, and in the zone of waterfall spray. The potential habitat model for *S. h.* var. *hapemanii* identified surficial geology and elevation as primary factors (Fertig and Thurston 2002), occurring in association with limestone or dolomite outcrops, including the Madison Formation limestone (Mississipian Age) and the Bighorn Formation dolomite (Ordovician Age). The springs, seeps, and coldwater streams where *S. h.* var. *hapemanii* occurs are sometimes associated with contact zones between limestone or dolomite and underlying impervious layers, or groundwater discharge along fracture lines. On the general soils map of the Bighorn National Forest, the distribution of *S. h.* var. *hapemanii* matches closely with that of limestone and dolomite parent material map units, including the Owen Creek – Tongue River – Gateway unit (No. 3), and the Cloud Peak – Starley – Rock outcrop unit (No. 4) (**Figure 7**). **Table 2** provides a summary of habitat information by occurrence.

Sullivantia hapemanii var. *hapemanii* occurs at foothills and montane zones from 4,600 ft to 8,200 ft in elevation. Populations in Montana occur as low as 3,200 ft in elevation. The surface geology map indicates that suitable bedrock does not extend appreciably above 7,200 ft elevations. The Bighorn and Madison formations encircle the Big Horn Mountains, with central peaks comprised of older uplifted igneous and metamorphic bedrock. During Laramide mountain-building events, the younger formations were elevated along the flanks, rotated and downcut, resulting in extensive cliffs, canyons, and incised valleys (Lageson and Spearing 1988). Steep topography and high gradients are associated with these riparian settings, having deeply incised stream channels, low sinuosity, limited soil development, and limited alluvial deposition (Girard et al. 1997). Riparian vegetation is often restricted to narrow canyons that are long and linear. The most extensive streambank riparian communities are often dominated by *Populus angusftolia* (narrowleaf cottonwood), and sometimes *Pinus ponderosa* (ponderosa pine) and *Pseudotsuga menziesii* (Douglas-fir). The settings are often on north-facing slopes, in the shade of rock overhangs, in shaded canyons, or under tree and shrub canopy, but settings may also be in partial or full sun (**Figure 8**, **Figure 9**, and **Figure 10**).

Sullivantia hapemanii var. *hapemanii* is absent from the national list of wetland indicator species (USDI Fish and Wildlife Service 2002), but it is a wetland-obligate. *Sullivantia hapemanii* var. *hapemanii* variously grows as an emergent in running water with the base of its stem submerged, or more often with its entire aboveground material out of water. The rooting zone is typically saturated for most or all of the year. These settings are all fed directly or indirectly by groundwater discharge, water percolation, or surface flow that saturates the soil at least early in the growing season. The rooting material may include loose gravel, as well as fractured bedrock or a vegetation mat over rock outcrops. Sometimes mosses dominate the vegetation mats, and sometimes *S. h.* var. *hapemanii* alone forms dense mats with intertwining roots.

The closely-related variety, *Sullivantia hapemanii* var. *purpusii*, is found in similar habitats of Colorado, including dripping cliffs and overhangs, permanently wet cracks and crevices, always in shade on limy soils. It grows from 6,500 to 10,500 ft (Nyborg 1979). The habitat similarities between these two varieties and with other species in the genus are consistent with the glacial relict hypothesis of Soltis (1991).

The groundwater of limestone regions, heavily enriched with carbon dioxide of terrestrial origin from decomposition, can release much carbon dioxide into the atmosphere when it flows to the surface, with resulting precipitation of calcium bicarbonate. When such bicarbonate-rich spring water surfaces, it covers all substrates with a dense encrustation of calcium bicarbonate. This encrustation is evident at most sites of *Sullivantia hapemanii* var. *hapemanii* at springs and seeps and sometimes along streams. Calcium carbonate deposits have been observed on leaves in some populations of *Sullivantia* species (Soltis 1991)



LEGEND:

The "blue" map units in the map to left contain limestone or dolomite parent material.

The light blue (3) is the Owen Creek – Tongue River – Gateway unit, of moderately deep, well drained soils that formed in material derived from interbedded shale, sandstone, and limestone on mountain slopes and landslide deposits.

The dark blue (4) is the Cloud Peak – Starley – Rock outcrop unit, with moderately deep and shallow, well drained soils that formed in material derived from limestone on mountain slopes and ridges.

Figure 7. General soil map of Bighorn National Forest, Wyoming (from USDA Forest Service and Natural Resource Conservation Service 1985).

and on leaves of *S. h.* var. *hapemanii* in particular (Heidel personal observation). Soltis (1991) noted that this genus has veins that converge at the tips of teeth to produce a glandular structure, the "hydathode." Hydathodes sometimes secrete a solution of calcium carbonate that occasionally forms solid deposits on the leaf surface. This structure is shared in common with other genera in the Saxifrage Family (Metcalfe and Chalk 1950; Taylor 1965; as cited in Soltis 1991). This ability to deposit calcium carbonate is also shared with aquatic nonvascular plants through different structures (*Chara* spp. and select mosses). A list of associated moss and liverwort species is not available. It is possible that *S. h.* var. *hapemanii* augments calcium carbonate precipitation.

The herbaceous plant species that are associated with *Sullivantia hapemanii* var. *hapemanii* vary greatly by locale. A summary of herbaceous plant species associated with *S. h.* var. *hapemanii* in Wyoming is presented in **Table 3**. Mat-forming and submerged mosses may be common or dominant and vascular species absent. Sometimes *S. h.* var. *hapemanii* is the only vascular plant present, growing in rock fractures or on sheer cliffs. In its best-developed spring-and-seep habitats, *S. h.* var. *hapemanii* can form a mat of 100 percent cover or an interrupted mat with it as the only vascular plant species present. Some of the most distinct settings are "hanging gardens" on sheer wet cliffs, and "amphitheaters" that are grotto-like erosion features set back into cliffs where *Sullivantia* covers damp, cavernous walls. Such habitats were called "*Sullivantia* seeps" by Lichvar et al. (1985), a rare habitat dominated by a rare plant. In the very largest populations, it is present in multiple settings and different stream gradients.

Habitats of *Sullivantia hapemanii* var. *hapemanii* are stable in most environmental characteristics, with little or no meandering. Downcutting, scouring, and siltation are limited or absent. Water temperatures generally remain cool throughout the growing season. Soils are saturated throughout at least the early part of the growing season. Localized calcium carbonate accretion

Table 2. Habitat of *Sullivantia hapemanii* var. *hapemanii* in Wyoming. Place names that are bold-faced are on Bighorn National Forest. Places that are data-sensitive do not include a place name and are left blank.

Occurrence number	Site name	County	Elevation range (ft)	General habitat description	Associated species
001	**Tensleep and Leigh Canyons**	Washakie	5,600 to 6,000	Occurs in three main habitats: (1) Cool, moist, shady limestone cliff walls along the stream and on north-facing alcoves and slopes above the riparian corridor within a forest community dominated by *Picea engelmannii*. (2) Mossy limestone boulders and rocks within the stream channel under the shade of *Picea engelmannii*. Often located within the spray of waterfalls. (3) In full sun on limestone boulders within the spray zone of creek. Site is seasonally flooded.	*Picea engelmannii*, *Erigeron acris*, *Adoxa moschatellina*, *Boykinia heucheriformis*, *Asplenium trichomanes-ramosum*, *Campanula rotundifolia*, *Cystopteris* spp., *Pellaea* spp.
002	**Shell Canyon**	Bighorn	4,840 to 7,000	Rocky shelves and wet seeps near waterfalls, seeps on north-facing limestone cliffs, and moist boulders of limestone or dolomite in creek beds.	*Carex hassei (C. aurea)*, *Betula occidentalis*
003	Five Springs Falls	Bighorn	6,680 to 7,400	Moist ledges near waterfall.	*Heuchera* spp., *Telesonix* spp., *Acer glabrum*, *Pseudotsuga menziesii*
004	**Lion's Den on Little Goose Creek**	Sheridan	6,000	Moist, shady creek bank and rocks at base of waterfall.	Not reported
006	**Wolf Creek Canyon**	Sheridan	5,000	Mossy rocks in stream.	Not reported
007	**Freezeout Point**	Sheridan	8,000 to 8,300	North-facing limestone outcrops.	*Telesonix* spp., *Musineon* spp.
008		Natrona	6,300	Wet soil on limestone around pool and beneath overhang at base of falls.	*Cardamine oligosperma*
009	**North Fork Crazy Woman Creek**	Johnson	6,320	Whitish-tan calcareous boulders in partial sunlight in the creek channel and on wet cliffs at the edge of creek.	*Heuchera parvifolia*, *Cystopteris fragilis*, *Pellaea breweri*, *Erigeron compositus*, *Festuca saximontana*, *Telesonix heucheriformis*
010	**Tongue River**	Sheridan	4,200 to 4,600	Weathered, sparsely vegetated, shaded limestone boulders along and within creek. Riparian vegetation.	*Populus angustifolia*, *Pseudotsuga menziesii*, *Poa interior*, *Leucopoa kingii*, *Apocynum androsaemifolium*, *Salix bebbiana*, *Rosa woodsii*, *Equisetum hyemale*, *Aster mollis* x *A. occidentalis* hybrid, varied shrubs, mosses, liverworts
011	Spanish Point	Big Horn	8,200 to 8,600	Moist, shady calcareous cliff.	Not reported
012	Trapper Creek	Big Horn	5,200 to 7,400	Moist to wet calcareous cliffs and calcareous boulders and outcrops along streams. Often on north-facing, shady sites.	Not reported
013	Tensleep Preserve	Washakie	5,160 to 6,000	Moist Madison Limestone cliffs and boulders along streambed on north-facing slopes under shady cover.	*Acer negundo*, *Galium triflorum*, *Pseudotsuga menziesii*, *Pinus ponderosa*, *Saxifraga occidentalis*, *Heuchera parvifolia*

Table 2 (cont.).

Occurrence number	Site name	County	Elevation range (ft)	General habitat description	Associated species
014		Johnson	5,600 to 5,700	On mossy rocks and limestone outcrops along shaded creek in riparian community. Found in shady, saturated to mesic creek bottoms.	*Populus angustifolia*, *Cornus sericea*, *Parnassia* spp., *Habenaria* spp., *Equisetum* spp., *Betula occidentalis occidentalis*, *Physocarpus monogynus*, *Salix bebbiana*, *Clematis ligusticifolia*, *Erigeron subtrinervis* var. *conspicuus*, *Equisetum laevigaetum*
015	**West Pass**	Sheridan	5,575 to 5,600	Wet limestone bedrock and alluvium in shady riparian. Part of one colony extends into the mouth of a limestone cave.	*Pseudotsuga menziesii*, *Betula occidentalis*, *Salix* spp., *Acer glabrum*
017	**Taffner Creek**	Sheridan	5,600	Partial shade on wet limestone bedrock and alluvium in stream channel within narrow riparian zone.	*Betula occidentalis*, *Salix* spp., *Mertensia ciliata*, *Saxifraga odontoloma*, *Mimulus* spp., *Glyceria* spp., *Parnassia* spp.
019		Sheridan	5,200	Saturated limestone alluvium beneath patchy shrub overstory.	Not reported
020		Hot Springs	4,640 to 5,800	Wet spring areas on west-facing slopes.	Not reported
021	Tensleep Preserve	Washakie	7,200 to 7,440	Semi-open or shady moist limestone cliffs and cave entrances in shady forest and on shady ledges and wet boulders along creek in forest.	*Picea engelmannii*, *Ribes lacustre*, *Pseudotsuga menziesii*, *Arnica cordifolia*, *Spiraea betulifolia*, *Adoxa moschatellina*, *Cystopteris fragilis*, *Arenaria rubella*, *Erigeron acris*, *Heuchera parvifolia*, *Heuchera* spp., *Petrophyton* spp., mosses
022	Poison Creek Canyon	Johnson	6,400 to 6,800	Narrow limestone canyon with steep cliff faces and large boulders in stream channel. Shady canopy.	*Picea engelmannii*, *Acer* spp.
023		Sheridan	6,000	Wet mossy rocks or cracks in limestone cliff face in shady stream channel in wet riparian forest.	*Picea engelmannii*, *Acer glabrum*, *Saxifraga odontoloma*, *Heuchera parvifolia*, *Mimulus glabratus*, *Ribes lacustre*, *Equisetum hyemale*, *Epilobium ciliatum*, *Mertensia ciliata*, *Telesonix heucheriformis*
024		Sheridan	4,800	Rocky streambanks in shade or on cliff faces below seep spring in full sun. Restricted to calcareous substrates.	*Campanula rotundifolia*, *Veronica* spp., *Juncus* spp., *Urtica* spp., *Clematis ligusticifolia*, *Populus* spp., *Cornus* spp., *Acer* spp., *Betula* spp.
026	**Mann Creek**	Sheridan	5,440 to 7,800	Below series of seep springs. Along moist, steep, shady banks of streams below seep springs on north-facing slopes. Soil damp, often mossy, limestone-gravel. By springs below calcium carbonate-rich cliffs in burned area in full sun. On mossy limestone rocks and boulders along large streams in valley bottoms. Semi-shady to densely shaded. Shady cracks and crevices in whitish dolomite or limestone boulders in drier tributary channels off main creeks. Hanging gardens lining the walls of wet, calcareous grottos below seep springs. Surrounded by forests.	*Picea engelmannii*, *Pseudotsuga menziesii*, *Ribes lacustre*, *Carex* spp., *Bromus inermis*, *Populus balsamifera*, *Silene menziesii*, *Epilobium* spp., *Frageria virginiana*, *Galium boreale*, *Aster foliaceus*, *Saxifraga odontoloma*, *Ribes oxyacanthoides*, *Arnica lonchophylla*, *Cryptogramma stelleri*, *Saxifraga* spp., moss
027	**Dry Fork**	Sheridan	6,200 to 6,400	Moist limestone near canyon floor.	Not reported

Table 2 (concluded).

Occurrence number	Site name	County	Elevation range (ft)	General habitat description	Associated species
028	**Shell Falls**	Big Horn	6,400	Granite cliffs in canyon immediately adjacent to falls within shady woods. Cliffs in spray zone of waterfall (and possibly below seep springs).	*Picea engelmannii*, *Physocarpus monogynus*
029	**Upper Devils Canyon**	Big Horn	8,000	Moist, shaded limestone outcrop above a stream. Plants grow midslope on steep NNE and SSW-facing slopes, where it is moist to saturated from seepage above the outcrop. Some plants were found growing on the soil just beneath the limestone rocks.	*Pseudotsuga menziesii*, *Picea engelmannii*, mosses
030	**Near Fool Creek**	Sheridan	8,280	Occurs on the shady and moist west-facing and south-facing sides of a sedimentary rock outcrop in a Spruce-Fir stand. Restricted to moist microclimates in the rock outcrop such as cracks, crevices, and shaded ledges.	*Picea engelmannii*, *Viola nephrophylla*, *Fragaria virginiana*, *Allium acuminatum*, *Ribes* spp., moss
031	**Tongue River**	Sheridan	7,100	On the ground and lower edge of the north side of a large boulder flanked by a river and a mixed conifer stand. Soil is muddy and dark, while the boulder is composed of white, porous, sedimentary rock. Within a cool, moist microclimate on the north side of a boulder.	*Arnica cordifolia*, *Picea engelmannii*, *Pseudotsuga menziesii*, *Telesonix heucheriformis*, *Ribes* spp., moss
032	**North and South Forks of Piney Creek**	Johnson/ Sheridan	5,600 to 5,700	On wet, limestone cobbles and gravels, east-facing, 1% slope in partial shade to full shade.	*Mertensia ciliata*, *Equisetum arvense*, *Picea engelmannii*, *Pseudotsuga menziesii*, *Sorbus* spp., *Acer glabrum*, *Cornus* spp.
033	Windy Point	Hot Springs	4,560 to 4,570	Spring-fed, vertical, 15 ft. seep and trickle, probably emanating from Bighorn Formation above, moss cover as the only vegetation on the sheer, moist slopes. A bench lies above and a small rubble pile lies below.	*Cornus stolonifera*, *Salix exigua*, *Sambucus* spp., *Solidago* spp., moss
034		Johnson	6,000	On limestone rock in man-made pond along creek. Surrounded by woodland.	*Pseudotsuga menziesii*, *Pinus ponderosa*
035	Cottonwood Canyon	Big Horn	5,300 to 7,000	On north-facing, shady slopes with saturated limestone talus and limestone gravel/loam substrates.	*Acer glabrum*, *Betula* spp., *Salix* spp., grasses
036	Dry Fork Horse Creek	Big Horn	5,825	Riparian habitat on west-facing slope with no cover and saturated, limestone gravel/loam substrate. In rock crevices.	Not reported
037		Sheridan	5,240 to 5,400	Riparian habitat on wet, limestone boulders, cobbles and gravel on east-facing, 1% slope, in partial shade.	*Marchantia* spp., *Agrostis stolonifera*, *Betula occidentalis*, *Cornus sericea*, moss
038	"Big Horn Mountains"	Not reported	Not reported	Not reported	Not reported
TOTAL: 34 records (32 extant)					

Figure 8. Photograph of *Sullivantia hapemanii* var. *hapemanii* streamside plants on vertical rock outcrops, by Walter Fertig.

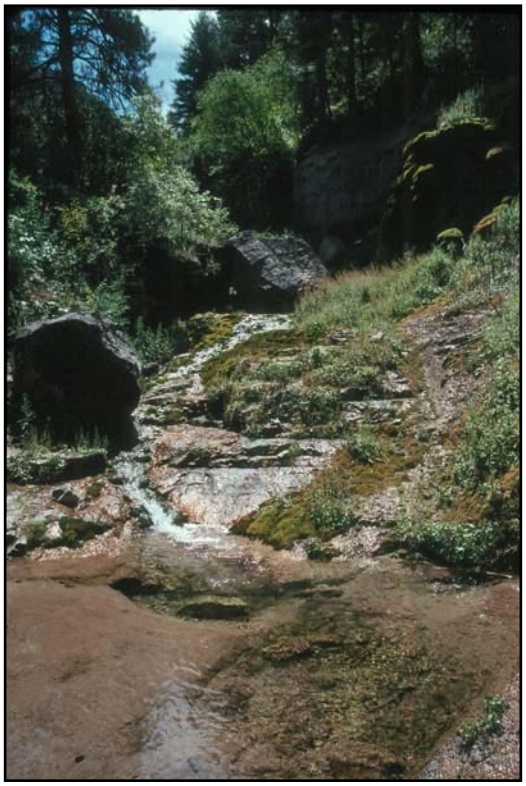


Figure 9. Photograph of *Sullivantia hapemanii* var. *hapemanii* streamside habitat (Montana). *Sullivantia hapemanii* var. *hapemanii* is rooted in moss mats overlying bedrock (bright green to the right of stream), by Bonnie Heidel.

enhances the uniformity and stability of the microhabitat. Nevertheless, these habitats are occasionally unstable under natural conditions because of waterflow surges, debris jams, or the movement of gravels, cobbles, and boulders along springs, creeks, and at waterfalls, all of which can uproot plants. Most riparian settings for *S. h.* var. *hapemanii* are in high gradient reaches that are generally too small for ice jams and major flooding events. There is also occasional natural slumping and sliding of steep unconsolidated substrates under the overlying vegetation mat. The persistence of this species on sheer cliffs and unconsolidated cobble is possible because of its network of intertwining roots that penetrates fractures and fissures.

Figure 10. Photograph of *Sullivantia hapemanii* var. *hapemanii* streamside habitat (Montana). *Sullivantia hapemanii* var. *hapemanii* is rooted in mats directly on rock outcrop and unconsolidated gravel below (bright green in right half), by Bonnie Heidel.

Table 3. Herbaceous species most often associated with *Sullivantia hapemanii* var. *hapemanii* in Wyoming.

Scientific name	Common name	Scientific name	Common name
Acer glabrum	Mountain maple	*Habenaria hyperborea*	Green bog-orchid
Adoxa moschatellina	Moschatel	*Heuchera parvifolia*	Little-leaf alumroot
Aster foliaceus	Alpine leafy-head American-aster	*Mertensia ciliata*	Tall-fringed bluebells
Betula occidentalis	Western birch	*Mimulus glabratus*	Round-leaf monkeyflower
Boykinia heucheriformis	False saxifrage	*Parnassia fimbriata*	Fringed grass-of-Parnassus
Campanula rotundifolia	Harebell	*Physocarpus monogynous*	Mountain ninebark
Cardamine oligosperma	Little western bittercress	*Poa interior*	Forest bluegrass
Carex aurea	Golden-fruit sedge	*Populus angustifolia*	Narrowleaf cottonwood
Catabrosa aquatica	Brookgrass	*Ribes lacustre*	Bristly black gooseberry
Cornus sericea	Red osier dogwood	*Rosa woodsii*	Wood's rose
Cystopteris fragilis	Brittle bladderfern	*Salix bebbiana*	Bebb's willow
Epilobium ciliatum	Fringed willow-herb	*Saxifraga occidentalis*	Mountain saxifrage
Equisetum hyemale	Tall scouring rush	*Saxifraga odontoloma*	Streambank saxifrage
Equisetum laevigatum	Smooth scouring rush	*Senecio pseudoaureus*	Streambank groundsel
Festuca saximontana	Rocky Mountain fescue	*Senecio streptanthifolius*	Rocky Mountain groundsel
Galium boreale	Northern bedstraw	*Smilacina stellata*	False starry Solomon's-seal
Glyceria striata	Fowl mannagrass		

Reproductive biology and autecology

Sullivantia hapemanii var. *hapemanii* is a sexually-reproducing herbaceous perennial that produces numerous small seeds per capsule. Reports of stoloniferous reproduction are in error; vegetative reproduction is known only in *S. oregana* (Soltis 1991). The taxon flowers for a few weeks between late June and August. The timing differs between locales depending on such factors as elevation, moisture regime, and exposure. Flowers are regular, complete, slightly protandrous, pedicelled, and odorless (Soltis 1991). It is likely, but not confirmed, that the species is iteroparous. Nectar is visible at the base of the styles and along the lower wall of the hypanthium (Soltis 1991). In *S. h.* var. *hapemanii*, as with both other western taxa (*S. h.* var. *purpusii* and *S. oregana*), the inflorescence is erect with branches that are perpendicular to the central axis when fruits mature (Soltis 1991). In the *Sullivantia* genus, the flowers are visited by a variety of flies (Diptera) and small bees (Hymenoptera; Soltis 1980). However, Soltis reported that "One notable feature of the pollination biology of *Sullivantia* is the apparent scarcity of insect visitors." Soltis (1981) conducted artificial pollination

studies to determine that all *Sullivantia* species are self-compatible. For *S. h.* var. *hapemanii*, flowers frequently set fruit by self-fertilization, a process that is facilitated by the positioning of stigmas that are at or just below the level of the anthers when they are receptive to pollen.

The proportion of flowering to non-flowering individuals of *Sullivantia hapemanii* var. *hapemanii* appears to vary by population (Soltis 1991). It may also vary by environmental conditions, though it does not appear to vary by light levels (from full sunlight to complete shade) so much as by water conditions (Heidel personal observation).

Seeds of *Sullivantia hapemanii* var. *hapemanii* are linear-fusiform, winged, and have the greatest range in seed length among *Sullivantia* taxa, from 0.9 to 1.6 mm (mean: 1.21 mm; Soltis 1991). The capsule dehisces from the apex and releases its seeds. Seed dispersal by water is likely but has not been addressed in the literature. Dispersal distance probably depends on slope and proximity to water. The stems of *S. h.* var. *hapemanii* often lean over the water where it grows along streamsides, facilitating water-dispersal (**Figure 8**). It is otherwise most likely to become established in the vicinity of parent plants, augmenting population density. The fertility, viability, and success rate of seedling establishment are not known.

There is low phenotypic plasticity within populations and high variation between populations of *Sullivantia hapemanii* var. *hapemanii*. As evidence, several of the morphological characteristics used by Rosendahl (1927) to distinguish species of *Sullivantia* have been re-evaluated and determined to represent phenotypic plasticity within this variety. The plant height and other size differences used by Rosendahl to distinguish *S. hapemanii* from *S. halmicola* were characterized as partially due to the degree of exposure to direct sun (Soltis 1991). Likewise, the characteristics of leaf lobes and teeth that were considered diagnostic traits by Rosendahl (1927) to distinguish *S. hapemanii* from other species were rejected by Soltis in common garden experiments (1991).

In the field, individuals at a given locale appear to be strikingly uniform as to height, inflorescence branching patterns, phenology, vegetative characteristics, and all manner of growth form. The remarkable uniformity resembles that sought by horticulturalists, and may be part of the reason that *Sullivantia* populations are sometimes described as "garden-like." There is no evidence of hybridization. Many populations in the *Sullivantia* genus appear to be fixed for certain morphological characteristics according to Soltis (1991). These characteristics may explain the apparent uniformity of individuals in the field, and correspond with electrophoretic fixation between populations that he documented, representing genetic traits. Soltis (1982) mentioned two examples among populations of *Sullivantia hapemanii* var. *hapemanii* in which unusual flower structure (inward-pointed calyx lobes and short petals) and unusually leafy flowering stems were noted throughout a Montana population, and in which unusually wingless seeds were noted throughout a Wyoming population. He interpreted these observations as indication of the prevalence of founder effect and inbreeding in the genus (Soltis 1991).

Chromosome data are not available for any species or varieties of *Sullivantia*, and this may help elucidate phyletic relations within the genus.

Demography

The basic life history stages of *Sullivantia hapemanii* var. *hapemanii* include seed, seedling, and mature plant (vegetative and flowering phases). A simple life cycle model is diagramed in **Figure 11**. No demographic studies have been undertaken, and transition probabilities between the different steps are unknown. There may also be an intermediate immature plant stage represented by few small basal leaves and limited root development. Examples of what may be the immature plant stage (or just a vegetative stage) are mounted with mature plants on a few herbarium sheets (RM). It is not known whether the seeds germinate in the fall or spring. There are no reports of seedlings on specimen labels or in the literature. Possible explanations include 1) the timing of germination relative to flowering, when most observations are made, 2) the inconspicuous nature of the seedling, 3) the rarity of seedlings, or 4) the low frequency of seedlings germinating distant from the obscuring canopy cover of mature plants. Seedlings and small, presumably newly-established plants are reported from field surveys of the closely-related variety, *S. h.* var. *purpusii* (Keammerer and Keammerer 1978). Any record of greenhouse techniques used in taxonomic research may elucidate life history patterns. More information is needed to define which life history stages have the greatest effect on population persistence.

It is possible that plants of *Sullivantia hapemanii* var. *hapemanii* grow from seedlings to flowering plants in two growing seasons as short-lived perennials. This is based largely on the observed lack of old leaf bases or root masses at the base of the flowering stems to

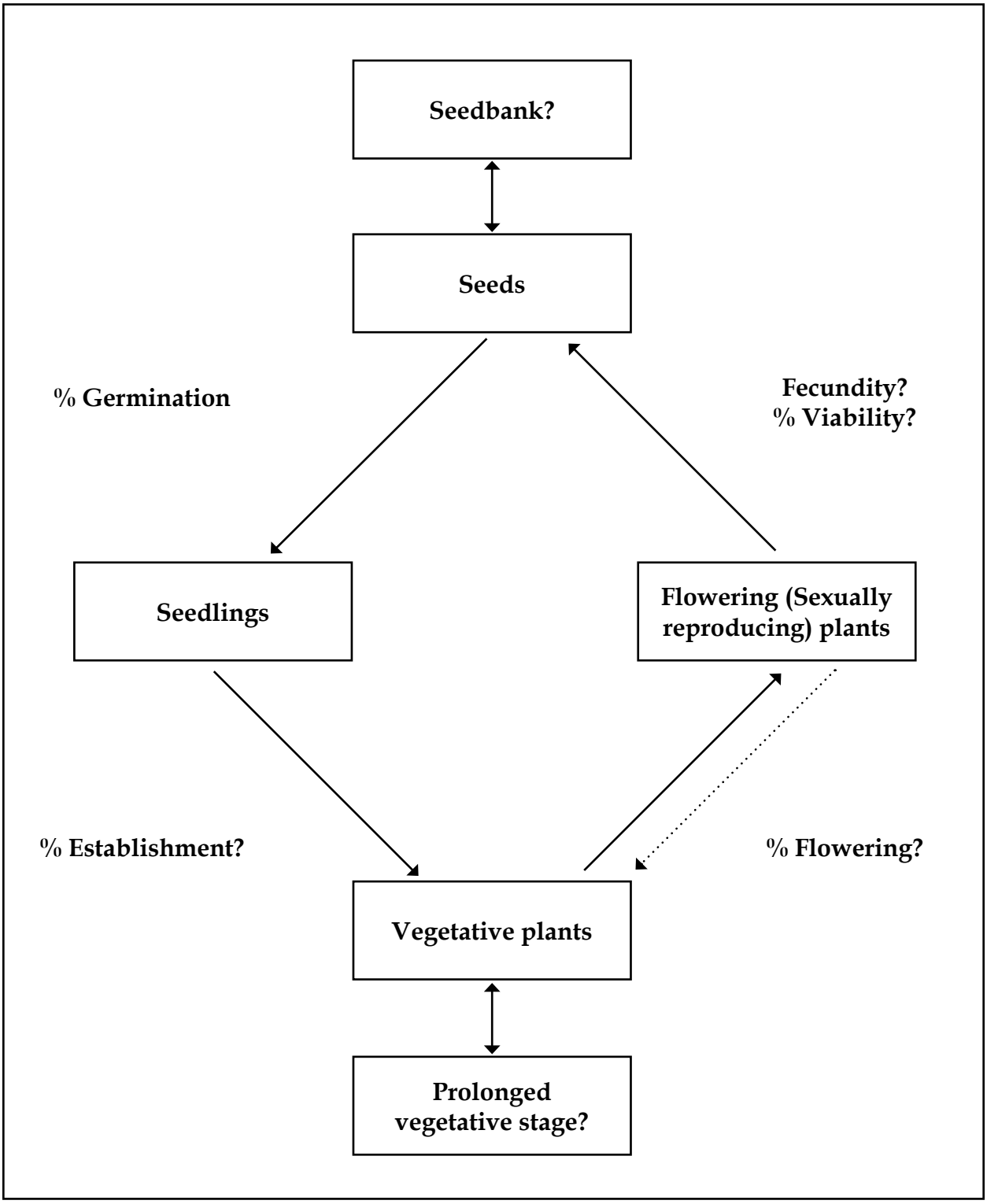


Figure 11. Life cycle diagram for *Sullivantia hapemanii* var. *hapemanii*.

indicate several year's growth, and inference from the delicate growth form and habitat conditions. Flowering stems are elongate and visible in early spring (Fertig personal communication 2002).

Watersheds may provide a basis for re-examining occurrences in a metapopulation framework for *Sullivantia hapemanii* var. *hapemanii* if seed dispersal and genetic exchange is concentrated within watershed boundaries. The 16 occurrences on the Bighorn National Forest are on at least 14 separate river systems. There are nine other occurrences in the Big Horn Mountains that lie downstream of national forest boundaries, many on the same streams. There are 184 discrete watersheds on Bighorn National Forest (USDA Forest Service 1985), so it is present in less than 12.5 percent of the watersheds in the Big Horn Mountains and in discrete stream reaches of these.

Community ecology

There are no observations or reports of herbivory on *Sullivantia hapemanii* var. *hapemanii* by wildlife, livestock, or insects. The glandular pubescence may deter browsing and grazing. The leaves and stem are "sticky" and have the smell of allspice when fresh (*Johnston 1300*).

Competition and encroachment of *Sullivantia hapemanii* var. *hapemanii* habitat by native and non-native species may occur in riparian corridor settings depending on water erosion patterns, bank or channel substrate and shape, valley shape, hydrology, and seed sources. Successional changes and exotic species invasions are generally deterred by the seasonally-saturated, cold, aquatic, nutrient-poor conditions. Non-native species and ruderal native species that appear to displace *S. h.* var. *hapemanii* along riparian corridors or else encroach at springs or seeps include *Arctium minus* (burdock), *Cirsium arvense* (Canada thistle), *Festuca arundinacea* (tall fescue), *Solanum dulcamara* (enchanter's nightshade), and *Phalaris arundinacea* (reed canarygrass). The incidence of encroachment appears to be low in the Big Horn Mountains, including settings where encroachment is highly unlikely if not impossible. Some wetland plants have mycorrhizal relations, but there are no references in the literature for *S. h.* var. *hapemanii*.

A rust is present at low frequency and density on leaves of *Sullivantia hapemanii* var. *hapemanii* in the wild and on herbarium specimens (Heidel personal observation). There are no known symbiotic or mutualistic interactions. It is possible that the glandular pubescence of some plant species, as found on stems and leaves of *S. h.* var. *hapemanii*, may "augment" the nutrient supply by helping trap and digest small insects, though this form of carnivorous adaptation among plants has not been well-documented or extensively researched.

The habitat of *Sullivantia hapemanii* var. *hapemanii* is highly restricted in extent, so habitat availability directly limits species' extent. This species shows no sign of limits to population density, and some populations may grow by increases in density.

Envirograms for *Sullivantia hapemanii* var. *hapemanii* are shown in **Figure 12**. An envirogram is a graphic representation of the resources and deterrents (malentities) that influence the species' viability, as put forward by Andrewartha and Birch (1984). Those components that are known to influence *S. h.* var. *hapemanii* are in solid lines, and hypothesized influences are in dashed lines. Direct resource needs include a permanently or seasonally-saturated rhizosphere, calcium carbonate-rich soil conditions, and mesic microhabitat. Direct deterrents include substrate destabilization and desiccation or inundation outside of the range of hydrological variability.

CONSERVATION

Threats

Among the primary threats to *Sullivantia hapemanii* var. *hapemanii* are changes to hydrology from dams or water diversions for irrigation (Fertig 1993). There are no documented instances of impacts in Region 2. One recently proposed project, expansion of the Tensleep Fish Hatchery on Bighorn National Forest, was confined to previously disturbed habitat and located downstream from the nearest known population (USDA Forest Service 2003a).

Timber harvesting and livestock grazing potentially affect habitat suitability for *Sullivantia hapemanii* var. *hapemanii* in terms of the surface and groundwater flows it requires, the cool microhabitat conditions, and the low competition from exotics. The majority of Bighorn National Forest populations fall within active range allotments. However, the steep slopes and limited access of most of its habitat makes it secondary range for most livestock use, except where it grows at water sources for stock and is then potentially impacted by trampling, habitat destabilization, or vegetation degradation. Logging is not feasible or economical in much of the taxon's steep-sloped habitat

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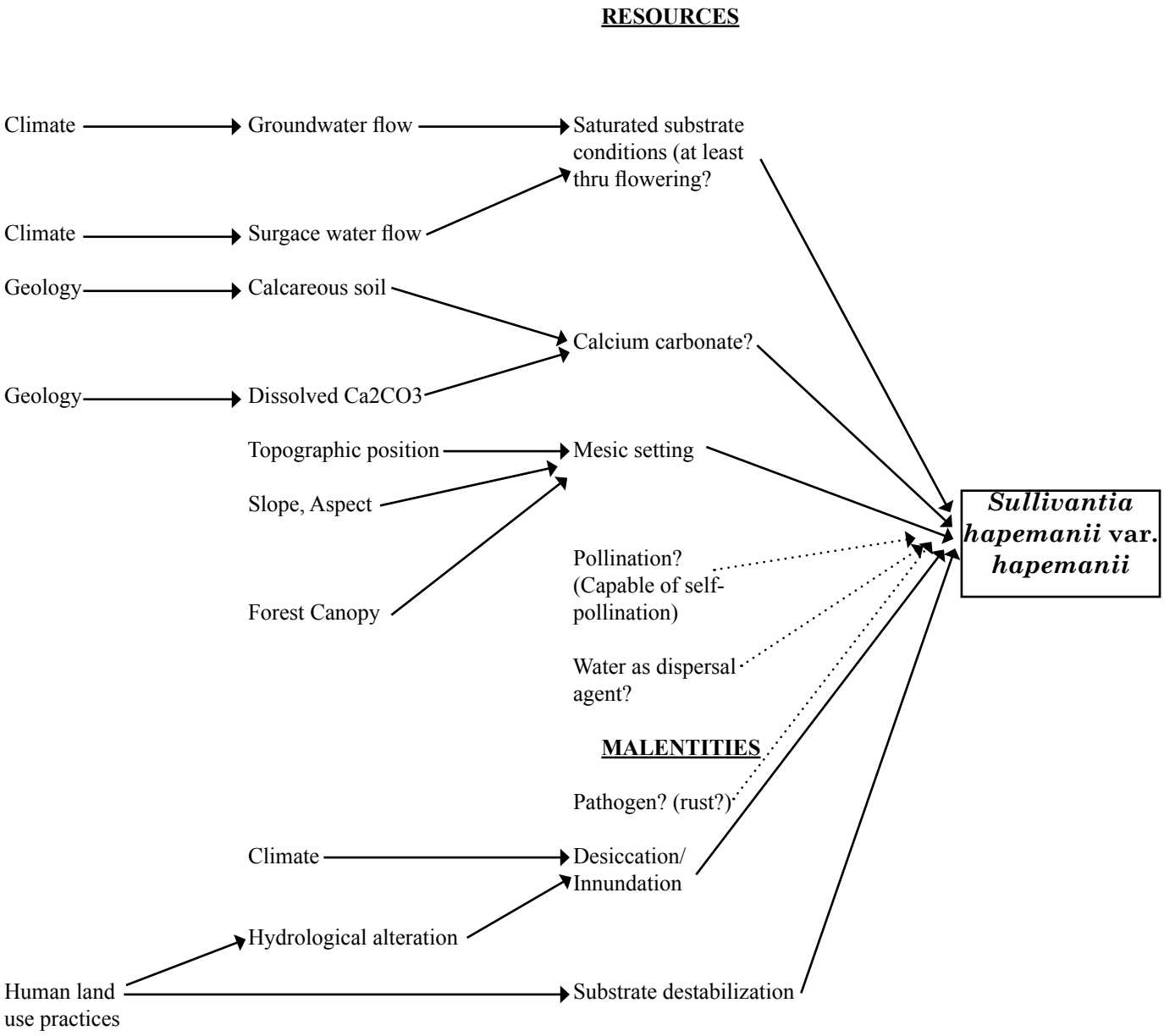

Figure 12. Envirogram of key resources and malentities for *Sullivantia hapemanii* var. *hapemanii*.

and is not permitted at the margins of permanent streams. Potential adverse affects can be minimized or ameliorated by buffering the species' local habitat. *Sullivantia hapemanii* var. *hapemanii* is not known to be affected by large-scale changes higher up in the watershed (Bornong personal communication 2002).

Potential recreation impacts are limited in *Sullivantia hapemanii* var. *hapemanii* habitat and may take the form of trampling, destabilization, or weed introduction. There is at least one Bighorn National Forest population that may be affected by heavy use by fishermen and hikers on the Tongue River. While some populations are at heavily visited sites, including caves and waterfalls, most populations occupy inaccessible habitat in them. Recreation may have indirect effects in fostering introduction and spread of exotic species, or by changing run-off and increasing sedimentation.

There are few exotic species known to be encroaching into the habitat of *Sullivantia hapemanii* var. *hapemanii* in the absence of disturbance. *Cirsium arvense* is present at two sites in the Big Horn Mountains, including one on the Bighorn National Forest. Non-native grasses were planted for hay or spread from water diversions and are present in some Bighorn Canyon populations of Montana, including *Phalaris arundinacea* and *Festuca altaica*. Most Wyoming populations occupy habitat that has little or no exotic species present in the river corridor.

Data from past Bighorn National Forest water quality monitoring programs indicate that surface water quality in the Big Horn Mountains is very high, with water temperatures that are low and dissolved oxygen values that are high (USDA Forest Service 1985). The number of impoundments is also limited. Of the 21 reservoirs in the Big Horn Mountains that hold more than 10 acre feet, only two are on the Bighorn National Forest; of these, only Meadowlark Reservoir lies upstream of *Sullivantia hapemanii* var. *hapemanii* populations on Tensleep Creek. Additional reservoirs were being proposed for development by private groups in 1984 on the national forest, and such development pressures are even greater for populations below Bighorn National Forest boundaries. Irrigation is an important use for water resources of Bighorn National Forest. Potential impacts to *S. h.* var. *hapemanii* may be appropriate to address for any proposed impoundments or diversions, or in watershed planning initiatives for the drainages it occupies. The only places where *S. h.* var. *hapemanii* is reported from disturbed habitat are places where it adjoins natural habitat occupied by the species, including a rock-face fed from seepage below a drainage ditch in Wyoming (Occurrence 024), and on the closest segment of a small diversion ditch below a large streamside population in natural habitat in Montana. These two small "artificial" habitats have not necessarily provided additional habitat, and creation of them may have eliminated natural habitat.

Sullivantia hapemanii var. *hapemanii* shows every sign of having stable populations on a relatively stable habitat. Population viability cannot be assessed without defining life history stages in greenhouse studies and devising a non-disruptive monitoring scheme of individuals. This is especially challenging under high-density distribution patterns. All available information and observations indicate that the majority of *S. h.* var. *hapemanii* subpopulations, not including those that are growing in streambeds, are very static under natural conditions.

There are no known consumptive uses of *Sullivantia hapemanii* var. *hapemanii* for commercial, recreational, scientific, or educational purposes, though other members of the genus are cultivated.

Conservation Status in Region 2

Sullivantia hapemanii var. *hapemanii* often occurs in remote settings that are extremely rugged, have few direct threats, and are protected by natural barriers that make access difficult. There is no hard evidence that it has declined in the Big Horn Mountains, in the center of its range. *Sullivantia hapemanii* var. *hapemanii* was a sensitive species from 1993 to 2003 on the Bighorn National Forest. Of all projects subject to National Environmental Policy Act documentation that have been developed on the Bighorn National Forest during this time period, there were no determinations that the proposed management actions may adversely affect the viability of *S. h.* var. *hapemanii* (Bornong personal communication 2002). Nevertheless, it has narrow ecological amplitude, and populations may be confined to areas of several square meters that are subject to chance small-scale disturbance events. *Sullivantia hapemanii* var. *hapemanii* is thought to be a glacial relict (Soltis 1991), and such taxa are usually restricted to sheltered, stable habitat. While there are no trend data documenting decline, the fragile nature of the habitat and the unknown capacity of the taxon for recolonization or rebound places a premium on maintaining and buffering existing habitat and hydrological conditions.

With a possibly high degree of self-fertilization in *Sullivantia hapemanii* var. *hapemanii*, and no likely dispersal vector aside from water, a premium is placed

on maintaining large population complexes to provide for genome exchange, and on maintaining populations in more than one watershed. There are no data to support metapopulation models or interactions and dynamics. If springs and seeps represent single establishment events, then they are likely to have low genome diversity. Springs and seeps may act as "sources" for the riparian corridor "sink" because of their relative stability and higher topographic position than the streamsides. If this is correct, then the riparian corridor is more likely to have higher genome diversity than springs and seeps. Landscapes with both population components would thus have the highest population viability.

The big population numbers of *Sullivantia hapemanii* var. *hapemanii* are countered by their limited aerial extent. The most extensive population on Mann Creek (Bighorn National Forest) is estimated to cover about 67 ha (Occurrence 026), but most populations are magnitudes smaller. For conservation planning purposes, the limited number of discrete locations may be more important than the number of individuals, and the number of stream segments may be more important than the total number of miles they span.

Potential Management in Region 2

Considering the small aerial extent, high habitat specificity, and potential rangewide implications of Region 2 status, RNA designation may be warranted as safeguard and long-term protection to ensure that *Sullivantia hapemanii* var. *hapemanii* does not require sensitive species designation in the future. Almost half of its known populations on Bighorn National Forest are in potential RNAs, including the largest known population. Designation status of potential RNAs hinges on the Bighorn National Forest Plan that is in progress. Population estimates are lacking for 25 percent of all known Wyoming populations, but the available numbers for the majority of populations indicate a skewed distribution. Among Wyoming populations with size estimates, at least 50 percent, and possibly as many as 75 percent, of all *S. h.* var. *hapemanii* individuals (60,000 of approximately 76,000) are part of the Mann Creek population. It is highly likely that this population is essential to the viability of *S. h.* var. *hapemanii*. A special designation for this site of the largest population is warranted. It lies on the east side of the Big Horn Mountains. Tensleep - Leigh Canyons with the largest population on the west side also warrants consideration. This does not diminish the values of the four other potential RNAs and their collective attributes.

Prescriptive management actions are inappropriate for *Sullivantia hapemanii* var. *hapemanii*, except as they might minimize existing environmental concerns, e.g., mechanical treatment of encroaching *Cirsium arvense*, installation of fences or boulder barriers at recreation sites and livestock watering holes to check trampling and erosion, or water bars to reduce run-off from trail and road construction.

Techniques have not been developed for quantitatively monitoring *Sullivantia hapemanii* var. *hapemanii*. The only population monitoring in place has been photopoint monitoring conducted every three years at Tensleep Preserve (The Nature Conservancy) at two subpopulations, initiated by Ann Humphrey. There has been no perceptible change since the monitoring was started (Davis personal communication 2003). This action is especially appropriate for small, accessible populations. In the absence of threats, photopoint monitoring confirms the species' presence and static population boundaries. This species is not subject to oscillations, so photopoint monitoring is an efficient way to spot-check stability. While changes would not be quantifiable, change of any sort might trigger a refined monitoring or management intervention. For more quantifiable information, it may be possible to accurately estimate population size if not census the populations, or to devise a photopoint close-up photograph that can be gridded and quantified (Elzinga et al. 1998.) Demographic monitoring techniques have not been worked out, and background life history information obtained through greenhouse studies would help set the framework. In general, sloping *Sullivantia* spring and seep habitats are too fragile for an investigator to traverse without destabilizing them, while riparian habitats are feasible to monitor to the extent that they are accessible.

Seeds of *Sullivantia hapemanii* var. *hapemanii* are not archived in any botanical gardens, and any occurrence that is at risk throughout a drainage in the future is appropriate to target for seed collection and storage.

The six-point management plan developed for the other variety, *Sullivantia hapemanii* var. *purpusii* (Nyborg 1979) is reprinted below as a model for *S. h.* var. *hapemanii*:

1. Because of widely scattered populations, management will be geared to protection on existing sites rather than propagation.

2. Inventory of other possible locations will be ongoing, utilizing both inservice and outservice available expertise.

3. All mining, road construction, and ground disturbing activities will be closely evaluated prior to plan approval to prevent conflicts.

4. Although the species is well protected by its inaccessible habitat, periodic examinations will be made of known locations to determine any use by livestock or recreationists and needed adjustments will be made.

5. Livestock management systems will be designed to preclude entry into known localities.

6. Water quality and quantity will be protected.

Information and Research Needs

More complete information on numbers, aerial extent, and precise location is needed at eight of the 16 occurrences of *Sullivantia hapemanii* var. *hapemanii* on the Bighorn National Forest. They are represented only by single points corresponding with the original collection stations.

New surveys of *Sullivantia hapemanii* var. *hapemanii* should be added as clearance tasks in project reviews that occur in settings of suitable geology and hydrology. The highest probabilities for finding new populations would be in unsurveyed canyons in the Big Horn Mountains, identified by overlaying the current and potential distribution map with stream coverages and topography at 7.5' or 15' scale.

A genetics study is needed to determine if selfing is common in *Sullivantia hapemanii* var. *hapemanii* and whether subcolonies in spring-seep settings and in riparian settings are genetically homogeneous or heterogeneous. This is fundamental for characterizing population structure and viability.

Greenhouse studies of *Sullivantia hapemanii* var. *hapemanii* are needed for documenting the life cycle, which would provide the framework for defining population stability and the background for any demographic monitoring. Along these lines, the germination requirements and colonizing ability of *S. h.* var. *hapemanii* might be tested in a combination of lab or field experiments on varying substrates to help understand the nature of streamside populations and develop management guidelines. A more detailed microhabitat characterization that includes the associated mosses and liverworts would also help characterize stability and possible colonization or succession. Depending on the outcomes of genetics studies and greenhouse studies, follow-up research on the pollination biology and dispersal biology of *S. h.* var. *hapemanii* may also warrant consideration.

DEFINITIONS

Adnate – Union of unlike parts.

Anthesis – Time of flower opening.

Calyx – Outermost series of flower parts, often but not always green; the sepals collectively.

Capsule – Dry dehiscent fruit with more than one carpel.

Ciliate – Fringed with hairs.

Dehisce – Splitting open of the capsule along regular lines.

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.

Electrophoresis – A technique for separating mixtures of organic molecules based on their different mobilities in response to an electric field.

Exotic – Not native; a species that has been introduced into an area.

Flavonoid – A class of secondary glycosides in plants thought to represent chemical defense, often associated with yellow pigmentation.

Founder effect – That only a small fraction of the genetic variation of a parent population or species is present in the small number of founder members of a new colony or population.

Fusiform – Widest at middle, tapering gradually to both ends, and round in cross-section.

Genet – A genetically homogeneous entity, whether represented by a single above-ground shoot or multiple shoots connecting belowground.

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

Herbivory – Feeding of animals on plants.

Holotype – The single specimen designated or indicated as the type specimen of a nominal species by the original author at the time of publication, or the single specimen when no type was specified but only one specimen was present.

Hydathode – Glandular structure in the Saxifragaceae associated with convergence of veins at leaf tips, with capacity to secrete calcium carbonate.

Hypanthium – Tube or cup extending from the base or tip of ovary to the point of attachment of sepals, petals, and stamens.

Inbreeding depression – Reduction of fitness and vigor by increased homozygosity as a result of inbreeding in a normally outbreeding population.

Inflorescence – Flowering part of plant.

Isotype – A duplicate of a holotype from the single collection that contained the holotype.

Iteroparous – Repeated reproductive cycles, i.e., flowering more than once.

Metapopulation – Subpopulations of natural populations that are partially isolated from one another and are connected by pathways of immigration and emigration.

Mutualism – A symbiosis in which both organisms benefit, frequently a relationship of complete dependence.

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

Ovary – Part of pistil containing ovules.

Palmate – With leaves, lobes, or veins arising from the same point at tip of petiole.

Panicle – An inflorescence with more than 1 flower on each stalk that arises from each node of the main axis; the central and terminal flowers are the youngest.

Pedicilled – Inflorescence in which each flower surmounts a stalk.

Petal – One member of the corolla, usually, but not always, colored and showy.

Petiole – Stalk of a leaf.

Phenotype – The sum total of observable structural and functional properties of an organism produced as the interaction between the genotype and the environment.

Pistil – Female organ of flower containing ovules, consisting of ovary, style and stigma.

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

Protandrous – With the male parts of a flower (stamens) maturing before the female (pistil).

Raceme – An indeterminate inflorescence with single flowers on pedicels arranged along the rachis.

Rank – NatureServe and the Natural Heritage Program use a ranking system (Internet site: http://www.natureserve.org/explorer/granks.htm). A rank of "G3T3" indicates that *Sullivantia hapemanii* var. *hapemanii* is "vulnerable globally" at both the species and variety levels "either because it is very rare and local throughout its range, found only in a restricted range (even if it is abundant at some locations, or because of other factors making it vulnerable to extinction or elimination." A rank of "S3" indicates analogous vulnerability at the state (subnation) level. A rank of "S2" indicates it is "imperiled in the state because of rarity or because of some factor(s) making it prone to extirpation from the state.

Regional endemic – Distribution is restricted to a limited geographic region that straddles state lines but spans an area that is smaller than the state of Wyoming.

Regular flowers – Radially symmetrical flowers, divisible into two equal halves in more than one plane.

Riparian – Pertaining to the banks of rivers and streams.

Ruderal – A plant inhabiting disturbed sites.

Source-sink model – The hypothesis that species diversity builds up when restricted localities favorable to certain species allow them to produce a surplus of emigrants, hence to be a source of new individuals dispersing to less favorable sites nearby, the sinks.

Stamen – Male organ of flower containing pollen and consisting of filament and anther.

Stigma – Tip of pistil, receives the pollen and is usually sticky.

Stolon – Stem which grows along ground and roots at the nodes.

Symbiosis – The beneficial relationship between two interacting species.

Synonymy – The list of names considered by an author to apply to a given taxon.

Viability – Capacity for long-term persistence of a species or population under a given set of intrinsic and extrinsic conditions.

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