Gilia sedifolia Brandeg. (stonecrop gilia): A Technical Conservation Assessment

Prepared for the USDA Forest Service, Rocky Mountain Region, Species Conservation Project

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Author's Biography

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Cover Photo Credit

Gilia sedifolia (stonecrop gilia). Photograph by Susan Komarek.

Then whisper, blossom, in thy sleep
  How I may upward climb
The Alpine path, so hard, so steep,
  That leads to heights sublime;
How I may reach that far-off goal
  Of true and honoured fame,
And write upon its shining scroll
  A woman's humble name.

— From "The Fringed Gentian" (Anonymous)

Summary of Key Components for Conservation of *Gilia sedifolia*

Status

Gilia sedifolia (stonecrop gilia) is a narrow endemic known from two occurrences in the San Juan Mountains of southwestern Colorado. The type locality ("Sheep Mountain") was last seen in 1892, and its location is uncertain. The other occurrence, known from Half Peak in Hinsdale County, Colorado, consists of two stands and approximately 1,100 individuals. It was last seen in 2003. The Half Peak occurrence is on the Gunnison National Forest, and the type locality may be on the San Juan National Forest. *Gilia sedifolia* is ranked globally critically imperiled (G1) by NatureServe, and it is considered critically imperiled (S1) in Colorado. The USDA Forest Service Region 2 has designated this species as a sensitive species. It is not listed as threatened or endangered under the Endangered Species Act of 1973 (U.S.C. 1531-1536, 1538-1540).

Primary Threats

Observations and opinions of experts show that there are several tangible threats to the persistence of *Gilia sedifolia*. In order of decreasing priority these threats are off-road vehicle use and other recreation, sheep grazing and its secondary impacts, mining, exotic species invasion, effects of small population size, global climate change, and pollution.

Primary Conservation Elements, Management Implications and Considerations

The only verified occurrence of *Gilia sedifolia* is that from Half Peak, Hinsdale County, on the Gunnison National Forest, where it is unlikely to be impacted by some threats such as residential development. However, this occurrence is not in a designated wilderness area and is potentially subject to impacts from recreation, grazing, and resource extraction. Conservation efforts are needed for the Half Peak occurrence to ensure the long-term viability of this species. Research is needed to better understand any threats to the persistence of *G. sedifolia*, and threat mitigation is needed to ensure that the loss of this species is prevented. A protective land status designation, such as research natural area, is one possible means of safeguarding this site. Further species inventory work is a high priority for *G. sedifolia* and is likely to identify other occurrences. Research is needed to investigate the population biology and autecology of *G. sedifolia* so that conservation efforts on its behalf can be most effective.

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Introduction

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Gilia sedifolia* is the focus of an assessment because of its high degree of rarity and endemism, because of concern for its viability, and because it is designated a sensitive species in Region 2 (USDA Forest Service 2003). 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 in habitat capability that would reduce its distribution (FSM 2670.5(19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology of *G. sedifolia* throughout its range in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal of Assessment

Species assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with 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 or to provide specific management recommendations. However, it does provide the ecological background upon which management must be based, and it focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed outside of Region 2 and examines the success of management plan implementations both within and outside of Region 2.

Scope of Assessment

This assessment examines the biology, ecology, conservation status, and management of *Gilia sedifolia* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. This assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of *G. sedifolia* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but in a current context.

In producing the assessment, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. All publications on *Gilia sedifolia* are referenced in the assessment, although all published material was not considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. However, some non-refereed literature was used in the assessment when information was unavailable elsewhere. Unpublished data (e.g., state natural heritage program records) were important in estimating the geographic distribution. These data required special attention because of the diversity of persons and methods used in collection. All non-refereed publications and reports were regarded with greater skepticism than the refereed literature. Information provided by Susan Komarek was particularly important in the synthesis of this assessment, since she is the only living person to have seen this plant in the wild.

An almost complete lack of information about this species precludes all but the most general and inferential treatment of topics in this assessment. Basic survey work in the near future will almost certainly yield information of great relevance to this assessment. Due to the high importance of finding more occurrences of this species, special emphasis was placed on researching probable locations of occurrences in this assessment.

Treatment of Uncertainty in Assessment

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of 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 experiments that produce clean results in the ecological sciences. Often, observations, inference, good thinking, and models must be relied on to guide our understanding of ecological relations. Confronting uncertainty then is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

Publication of Assessment on the World Wide Web

To facilitate their use in the Species Conservation Project, species assessments 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 important, it facilitates their revision, which will be accomplished based on guidelines established by Region 2.

Peer Review of this Document

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the Web. This assessment 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

Gilia sedifolia was added to the Region 2 sensitive species list in 2003 (USDA Forest Service 2003). The single occurrence for which accurate location information is available is known from USFS land in the Gunnison National Forest. This location is not found in a designated wilderness area where it would benefit from some protection from motorized recreation. It is not included on the Bureau of Land Management (BLM) Colorado State Sensitive Species List (Bureau of Land Management 2000). NatureServe and the Colorado Natural Heritage Program consider *G. sedifolia* to be globally critically imperiled (G1). Because it is only found in Colorado, it is also considered critically imperiled at the state level (S1) by the Colorado Natural Heritage Program. It is considered critically imperiled because it is known from only two occurrences, one of which has not been seen in over 100 years. For explanations of NatureServe's ranking system, see the Definitions section of this document. *Gilia sedifolia* is not listed as Threatened or Endangered in accordance with the Endangered Species Act of 1973 (U.S.C. 1531-1536, 1538-1540). It is not listed as endangered or vulnerable by the International Union for Conservation of Nature and Natural Resources (1978).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Adequacy of current laws and regulations

Gilia sedifolia has no known enforceable protective designations, conservation agreements, or approved management plans that would prevent the destruction of individuals or their habitat. It is listed on the USDA Forest Service Region 2 sensitive species list (USDA Forest Service 2003), which affords it some protection on USFS land. Impacts to sensitive species must be determined in biological evaluations for any USFS projects that include suitable habitat, and impacts may be mitigated. Also, sensitive species may not be collected on USFS lands without a permit (USDA Forest Service 1995). The USFS can modify allotment management plans and projects or contracts to give consideration to *G. sedifolia* on a discretionary basis. The two reports of this species are from somewhat remote areas in the San Juan Mountains in the Gunnison and San Juan national forests. The extent to which it has been subjected to human impacts in which the adequacy of current laws would become apparent is unknown. As of this writing, neither the USFS nor any other federal agency has written a conservation strategy for this species at a national or regional level.

Because there are no laws in place that protect this species on private lands, current laws and regulations protecting this species are clearly inadequate to effectively conserve the species throughout its native range.

Gilia sedifolia is a conservation target for ecoregional planning in the Southern Rocky Mountain Ecoregion (Neely et al. 2001).

Adequacy of current enforcement of laws and regulations

There have been no known cases in which an occurrence of *Gilia sedifolia* was extirpated due to human activities or the failure to enforce any existing regulations. However, this does not necessarily indicate that current regulations or their enforcement are adequate for its protection.

Biology and Ecology

Classification and description

Gilia sedifolia (stonecrop gilia or Uinta gilia) is a member of the family Polemoniaceae. The family Polemoniaceae is in class Magnoliopsida (dicots), subclass Asteridae, order Solanales (USDA Natural Resources Conservation Service 2002). The Polemoniaceae is a small, monophyletic family with three subfamilies, eight tribes, 26 genera, and approximately 379 species (Porter and Johnson 2000). This family probably diversified in the mid-Tertiary, but it may have originated 100 million years ago or earlier (Porter and Johnson 2001). The family Polemoniaceae is most diverse in western North America (Heywood 1993), with the center of species diversity in California where approximately half (180 species) of all species in the family are found (Patterson 2002).

Gilia has historically been one of the more enigmatic genera of Polemoniaceae. It is a classic example of a "garbage can" genus, where taxa were placed that did not fit well into other genera (Porter personal communication 2002). *Gilia* has been shown to be an artificial, polyphyletic group and has been split into eight monophyletic genera (Porter 1998). In Porter's treatment, *G. sedifolia* is included within the genus *Aliciella*. This genus (named after Alice Eastwood) was initially circumscribed by Brand (1907) in his monograph of the Polemoniaceae but was not used in later treatments of the family (e.g. Wherry 1945, Grant 1959). The genus *Aliciella* was resurrected by Porter (1998) based on molecular genetic data. The evidence of Porter (1998) and Porter and Johnson (2000) suggesting that *G. sedifolia* is best treated as *A. sedifolia* is strong. However, in this report the original name is used to conform with the treatment of Kartesz (1999) used as a nomenclatural standard by the Network of Natural Heritage Programs (NatureServe 2002) and the USDA PLANTS database (USDA Natural Resources Conservation Service 2002). *Gilia* (*Aliciella*) *sedifolia* is in the genus *Aliciella*, subgenus *Aliciella*, section *Giliandra* (Porter 1993, Porter 1998).

Gilia sedifolia is a distinctive element of the flora of Colorado. It has several attributes that are very unusual within the Polemoniaceae family, and it represents an evolutionary direction not seen commonly in this family (Porter personal communication 2002). It is unlike any other species of *Aliciella* or other members of Polemoniaceae (Porter personal communication 2002). Like many other members of this family it appears to be a biennial, or possibly a short-lived, monocarpic perennial. The elevation at which *G. sedifolia* is found (11,800 to 13,400 feet) is far higher than any other member of the genus *Aliciella* (Porter personal communication 2002). It is morphologically unusual, with succulent, *Sedum*-like leaves. A parallel evolutionary trend is seen in at least one other member of the Polemoniaceae, *Ipomopsis globularis*, another narrow endemic in the high alpine of Colorado.

Gilia sedifolia has been collected three times over the course of 103 years. It was first collected in 1892 by Dr. Carl Albert Purpus. His collection (number 697) became the type specimen; a holotype is deposited at the University of California, Berkeley Herbarium (UC). Dr. Purpus worked closely with Dr. Townshend S. Brandegee and Katharine Brandegee as evinced by their frequent correspondence (Ertter 2002). T.S. Brandegee was the honorary curator of the University of California Herbarium in San Diego at that time (Ewan and Ewan 1981). Through his extensive fieldwork Dr. Purpus collected many of the type specimens eventually described by Dr. Brandegee. This is evident in the paper in which *G. sedifolia* is described, where 15 species are described from the collections of Dr. Purpus (Brandegee 1899).

Several attempts have been made to find *Gilia sedifolia* since it was first collected by Dr. Purpus. In 1992 Dr. J. Mark Porter attempted to find *G. sedifolia* at Sheep Mountain in Gunnison County, but it was not found (Porter personal communication 2002). Bob Clark from the Colorado Native Plant Society attempted to reach the location of Purpus' collection in 1994 but was thwarted by bad weather (Jennings personal communication 2002). Floristic and rare plant surveys have been done in the San Juan Mountains in which *G. sedifolia* was sought but not found. Numerous BLM and USFS botanists have searched likely habitat for it. The Needle Mountains were searched without finding *G. sedifolia* (Michener-Foote and Hogan 1999). Lyon and Denslow (2002) and Lyon et al. (2003) also searched appropriate habitat in San Juan County to no avail. This underscores the apparent rarity of *G. sedifolia*.

It was thought that *Gilia sedifolia* had gone extinct until it was collected again in 1995 by Susan Komarek (Clark and Hogan 2000). Susan Komarek has collected plants throughout the San Juan Mountains and wrote the *Flora of the San Juans- A Field Guide to the Mountain Plants of Southwestern Colorado* (Komarek 1994). When she collected *G. sedifolia* in 1995, she was not aware of the importance of her find until Dr. William Weber identified it as the long missing species last collected by Purpus in 1892. Had she known this in the field she would have more thoroughly assessed the habitat and the occurrence (Komarek personal communication 2002). Komarek returned to Half Peak on July 2, 2003 when she obtained more thorough data on this occurrence.

Non-technical description

The genus *Aliciella*, which includes *Gilia sedifolia* as circumscribed by Porter (1998), includes primarily rosette-forming annuals, biennials, and herbaceous perennials. Although many members of the Polemoniaceae have a densely mucilaginous seed coat when wetted, members of *Aliciella* display reduced mucilage formation (Porter 1998).

There are no similar taxa from which it is likely to be difficult to distinguish *Gilia sedifolia*. It is closely related to *G. pinnatifida* and *G. penstemonoides* (Porter 1998, Porter and Johnson 2000, Porter personal communication 2002). Other treatments have aligned *G. sedifolia* with *G. leptomeria* (e.g., Harrington 1954). However, these species occur in much different habitats and are readily distinguished from *G. sedifolia*. Porter (1998, p. 30) notes that *G. sedifolia* is "a very distinctive species...characterized by its simple entire, terete, succulent, sedum-like leaves, small stature, and dark blue corollas with lobes longer than the tube." Weber and Wittmann (2001, p. 272) write "Leaves succulent, the blades collapsing when dry, entire, linear, plants with a taproot, unbranched except somewhat in the spike-like inflorescence." Komarek (1995) includes the following descriptive notes: "flowers purple-blue; lateral branchlets few; few flowered, appressed to the spike; leaves succulent, simple and entire." The succulent leaves of *G. sedifolia* are particularly distinctive, and in living material they appear similar to those of some species of *Sedum* (Brandegee 1899). It has an abundance of old leaves at the base of the stem that suggests it may be a perennial; these were noted by Brandegee (1899).

Published descriptions, checklists, keys, and photos

Three sources offer technical descriptions of *Gilia sedifolia*, the most complete being that of Porter (1998). The original species description (Brandegee 1899) is also useful, and Weber and Wittmann (2001) offer some descriptive notes. Harrington (1954) mentions *G. sedifolia* under *G. leptomeria* but does not describe it.

Gilia sedifolia has not yet been rendered by a botanical illustrator. Carolyn Crawford has been commissioned to illustrate this species for the Flora of the San Juan Basin project (Crawford personal communication 2002).

Gilia sedifolia was photographed in the wild for the first time in 2003 by Susan Komarek. Copies of her photos were sent to the Colorado Natural Heritage Program, and selected photos are included in this document (**Figure 1**).

Carl Albert Purpus' holotype specimen (number 697) is deposited at the University of California Herbarium in Berkeley (UC), and an isotype is deposited at Gray Herbarium at Harvard (GH) (Porter personal communication 2002). Susan Komarek's 1995 specimen (number 478) is housed at the University of Colorado Herbarium (**Figure 2**). No specimens of *Gilia sedifolia* are housed at the San Juan College, Colorado College, Colorado State University, Kalmbach, or the Rocky Mountain herbaria.

Figure 1. *Gilia sedifolia*. Photograph provided by Susan Komarek.

Figure 2. *Gilia sedifolia*. Photograph of specimen from the University of Colorado Herbarium, collected in 1995 by Susan Komarek (collection number 478).

Distribution and abundance

Gilia sedifolia is evidently an extremely rare endemic (Porter 1998, Clark and Hogan 2000, Weber and Wittmann 2001, Colorado Natural Heritage Program 2002). It is currently known from two locations, one of which cannot be mapped since it is from an uncertain location. See **Figure 3** for the global range of *G. sedifolia* with respect to USFS lands in Region 2. Further searches are needed, and more occurrences are possible. One occurrence is known from a collection by Dr. Carl A. Purpus, probably taken in 1892, and has apparently not been seen since. The other known occurrence of *G. sedifolia* was found in 1995 by Susan Komarek on Half Peak, Hinsdale County (**Figure 4**). Two stands were found by Komarek on Half Peak in 2003, one consisting of approximately 1,000 plants, and another consisting of approximately 100 plants (**Table 1**; Komarek 2003).

All of the known locations are documented on land managed by the USFS. The occurrence on Half Peak is in the Gunnison National Forest, but it is not included in a wilderness area or other area with protective designations. The Sheep Mountain occurrence's exact location is uncertain but may be in the Uncompahgre National Forest, San Juan National Forest, or the Rio Grande National Forest.

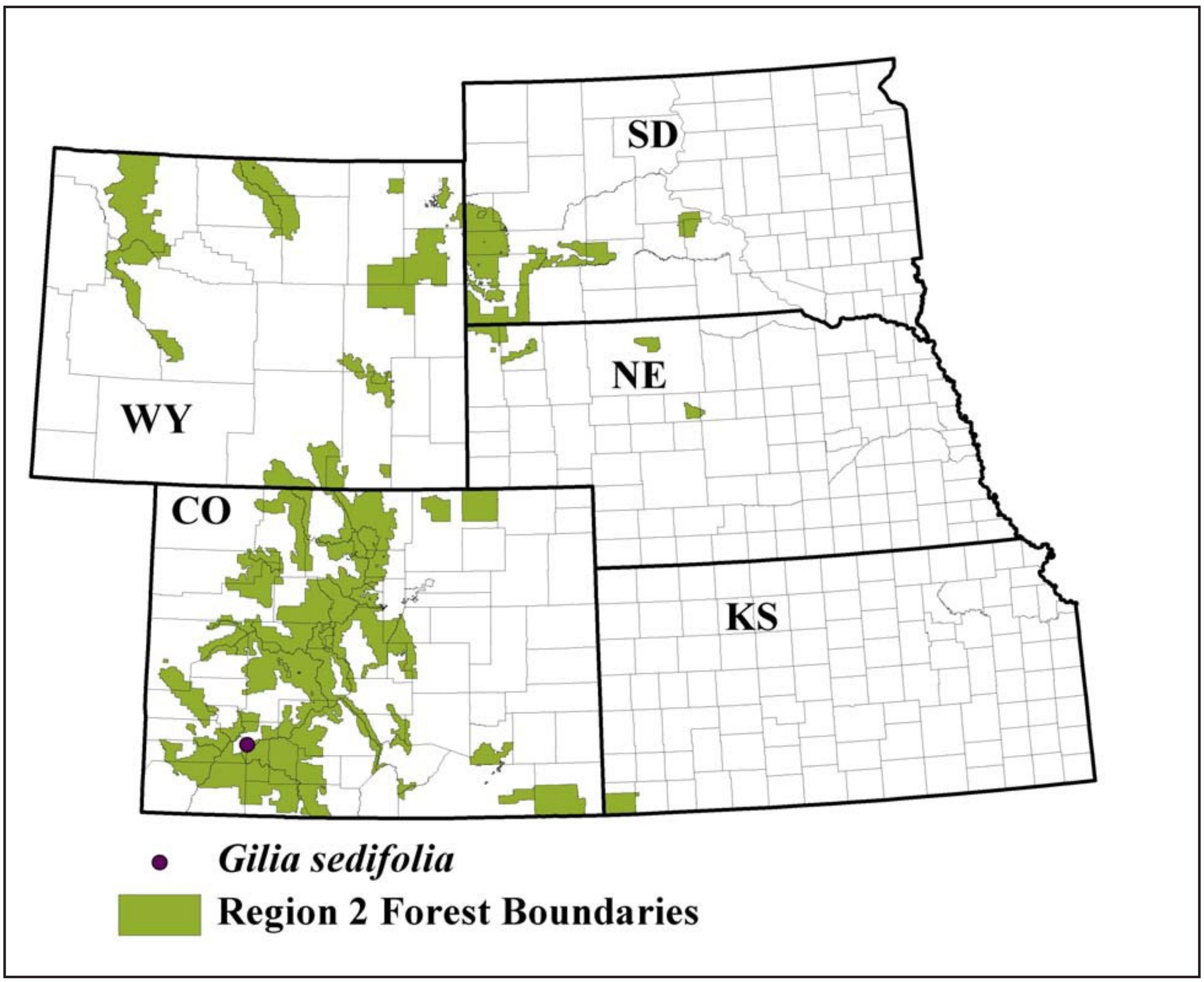

Figure 3. Distribution of *Gilia sedifolia* in the states of USDA Forest Service Region 2. Globally, *G. sedifolia* is known from a single occurrence last seen in 2003. The type locality remains uncertain.

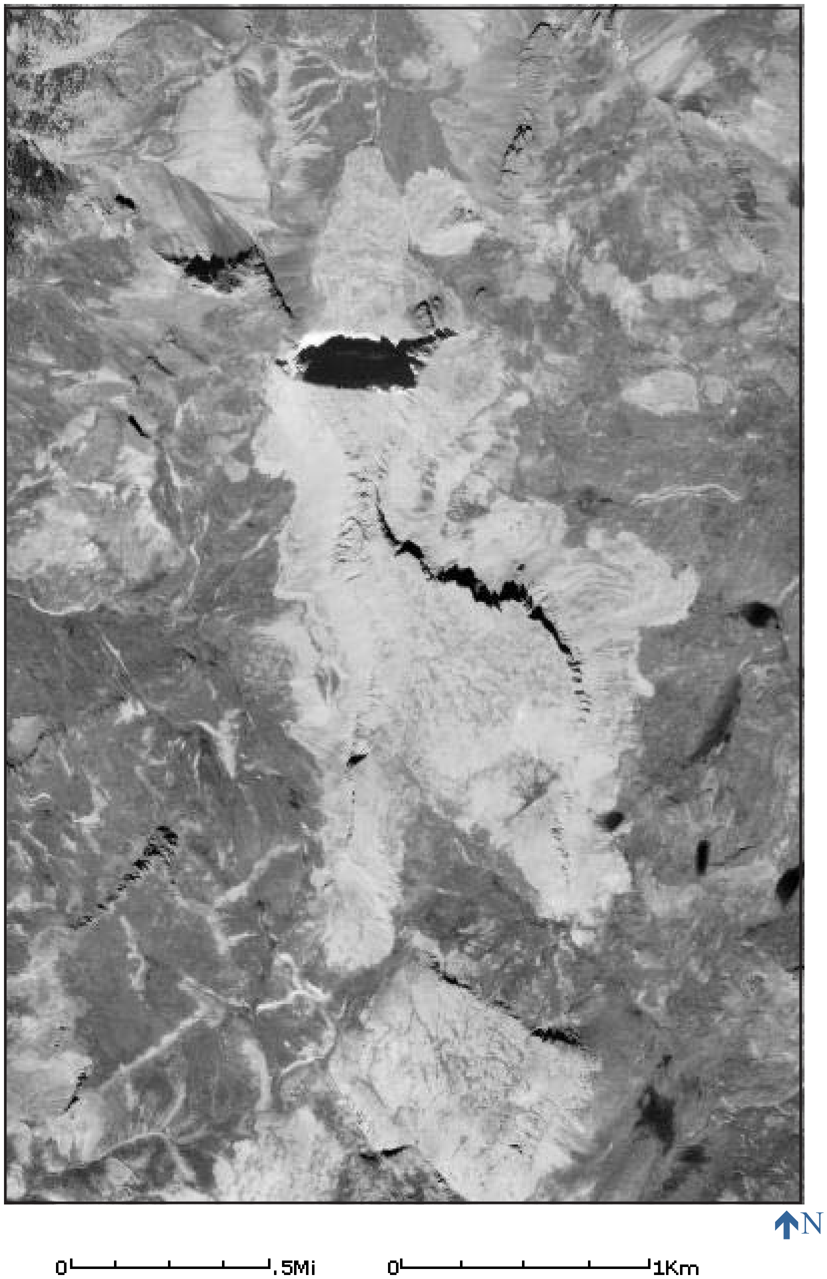

Figure 4. Half Peak, Hinsdale County, Colorado (elevation 13,841 ft). The south slopes of this mountain support the only recently visited population of *Gilia sedifolia*. Digital aerial photo courtesy of the U.S. Geological Service.

Table 1. Summary information for the known occurrences of *Gilia sedifolia*. Numbers 2a and 2b are considered one occurrence.

Arbitrary Number	County	Location	Date of Last Observation	Land Ownership	Elevation (ft.)	Occurrence Size	Habitat and Notes	Source I.D.
1	San Juan (?)	Sheep Mountain	July 1892	Possibly San Juan National Forest	11,800	not reported	Tuffaceous sandstone.	C.A. Purpus (#673) (Gray Herbarium at Harvard; University of California Herbarium at Berkeley)
2a	Hinsdale	Half Peak	July 2, 2003	Gunnison National Forest	13,400	~1,000 on 1 acre	Plants are scattered singly or in small groups over gravel patches. The alpine meadow community dominated by *Acomastylis rossii* forms a distinct boundary line around the gravel patches, which are virtually bare and contain *Gilia sedifolia*. Even where the meadow community is sparse there was no *G. sedifolia* found; they were only found in the large bare gravel patches that contained no other plants except some lichen and a very few scattered *Erysimum capitatum* and *Elymus scribneri*. Slope: 30 percent. Aspect: South. Light exposure: open. Slope shape: straight. Total tree cover: 0 percent. Total shrub cover: 0 percent. Total forb cover: almost 0 percent. Total graminoid cover: almost 0 percent. Total moss/lichen cover: 1 to 2 percent. Total bare ground cover: 98+ percent. Soil Moisture: Dry. Plants are growing in gravel that averages 0.5 inches in diameter.	S. Komarek 2003
2b	Hinsdale	Half Peak	July 2, 2003	Gunnison National Forest	12,920	~100 on 40 x 40 ft.	See 2a above except for: Slope: 0 percent	S. Komarek 2003

The location of Dr. Purpus' collection has been the source of a great deal of speculation. His label reads: "Gunnison County: Uncompahgre Range, Sheep Mtn., 11,800 ft, July 1893." Despite the relatively good locational information included, the actual location of this collection is uncertain. Given Purpus' label data, Sheep Mountains in Gunnison County are the first logical place to investigate as the true type location for *Gilia sedifolia*. There are five Sheep Mountains in Gunnison County (U.S. Geological Survey 2002), but only four are high enough to qualify as possible sites. Because Purpus was in the San Juan Mountains at this time (Ertter 2002), three other Sheep Mountains in northern Gunnison County are excluded, leaving only one. This peak is also in the area that would logically be referred to as the "Uncompahgre Range," since it is part of a group of mountains that includes as its highest mountain Uncompahgre Peak (14,309 ft). Thus, this location is a strong candidate for the other location of *G. sedifolia*. Purpus spent much time visiting mine sites in Gunnison County (Reveal personal communication 2002), and the boundaries of Gunnison County have not changed significantly since Purpus' time (Rand McNally 1895). This Sheep Mountain was searched in 1992 by Dr. J. Mark Porter, but *G. sedifolia* was not found (Porter personal communication 2002).

Although the evidence discussed above strongly suggests that the Gunnison County Sheep Mountain is the type locality for *Gilia sedifolia*, there are reasons to suspect other locations as well. In Dr. Purpus' time, the area around the Gunnison County Sheep Mountain was uncharted wilderness, extremely remote and difficult to access (Jennings personal communication 2002). Also, this Sheep Mountain does not appear to have the appropriate geology to support *G. sedifolia*. Of the several specimens collected by Purpus, one includes the description cited above, while another includes a note that it was collected on "tuffaceous sandstone" (Porter personal communication 2002). However, the geologic substrate of the Gunnison County Sheep Mountain is not consistent with this (**Table 2**). Dr. Porter stated that the geology of this location did not look suitable for *G. sedifolia* (Porter personal communication 2002). Areas to the east of the Gunnison County Sheep Mountain are underlain by ash-flow tuff (Tweto 1979). It is possible that Purpus was actually east of Sheep Mountain when he collected *G. sedifolia*, as it was not uncommon in the late 19th century for botanists to cite the nearest landmark as the collection site without providing specific details. The accuracy of Tweto (1979) at this scale (1:24,000) is somewhat questionable (see the Habitat section of this document), so it is possible that there are outcrops of tuff on the Gunnison County Sheep Mountain that cannot be resolved based on available geological data.

Table 2. Summary information on possible locations of Purpus' 1892 collection of *Gilia sedifolia* (all three are "Sheep Mountain") and on the known location on Half Peak.

Name	County	Latitude Longitude[c]	Quad Name	Geology[d]
Sheep Mountain	Gunnison	38°09'32" N 107°27'55" W	Sheep Mountain	Tpl[a]
Sheep Mountain	Dolores/San Miguel	37°47'07" N 107°53'08" W	Mount Wilson	Te/Tpl[a]
Sheep Mountain	San Juan	37°47'00" N 107°31'02" W	Howardsville	Tbm/Tur[b]
Half Peak	Hinsdale	37°51'51" N 107°27'56" W	Pole Creek Mountain	Taf[a]

a: from Tweto (1979)
b: from Luedke and Burbank (2000)
c: from U. S. Geological Survey (2002)
d: Explanation of Geology:

Taf: Ash-flow tuff of main volcanic sequence (includes many named units such as Tbm and Tur below) (Oligocene).
Tbm: Blue Mesa Tuff—Partly altered, moderately to densely welded, red-brown, rhyolitic ash-flow tuff (Oligocene).
Te: Prevolcanic sedimentary rocks—Arkosic sand and bouldery gravel of Echo Park Alluvium (Eocene)
Tpl: Pre-ash-flow andesitic lavas, breccias, tuffs, and conglomerates (Oligocene)
Tur: Ute Ridge Tuff—Gray to grayish-brown, crystal rich, moderately to densely welded, quartz-latitic ash-flow tuff (Oligocene).

There are 33 Sheep Mountains in Colorado (U.S. Geological Survey 2002). Eleven of these are found in counties that are in the vicinity of the San Juan Mountains (Archuleta, Gunnison, La Plata, Mineral, San Juan, Rio Grande, and San Miguel). Of these 11, eight are of sufficiently high elevation (greater than 11,700 feet) to support *Gilia sedifolia*.

Dr. Bill Jennings suspects that Purpus actually collected *Gilia sedifolia* on the Sheep Mountain northeast of Stony Pass, southeast of Howardsville, in San Juan County (Jennings personal communication 2002). This Sheep Mountain is shown in **Figure 5**, and it appears similar in some respects to Half Peak (**Figure 4**). Both mountains are surrounded by broad aprons of colluvium derived from the ash-flow tuff of the upper slopes, and both appear sparsely vegetated. This Sheep Mountain would have been readily accessible to Dr. Purpus via Stony Pass. It overlooks Stony Pass from the northeast, and its summit is less than a mile from the road. Stony Pass was crossed by a heavily used wagon road in 1892 and connects Howardsville to Creede and Lake City. Even in 1892 a trip to this Sheep Mountain from Silverton or Howardsville would have been a short excursion. On the trip when he collected *G. sedifolia*, Purpus went from Ouray to Silverton to Lake City via Stony Pass. Thus, Purpus almost certainly passed this Sheep Mountain at some time during this visit.

The geology of the San Juan County Sheep Mountain also appears favorable for *Gilia sedifolia* (**Table 2**). The upper portions of this peak are composed of Blue Mesa Tuff, underlain by Ute Ridge Tuff (**Figure 6**; Luedke and Burbank 2000). Below these strata are colluvial slopes that are probably also composed of these substrates at elevations consistent with that reported by Purpus (11,800 ft).

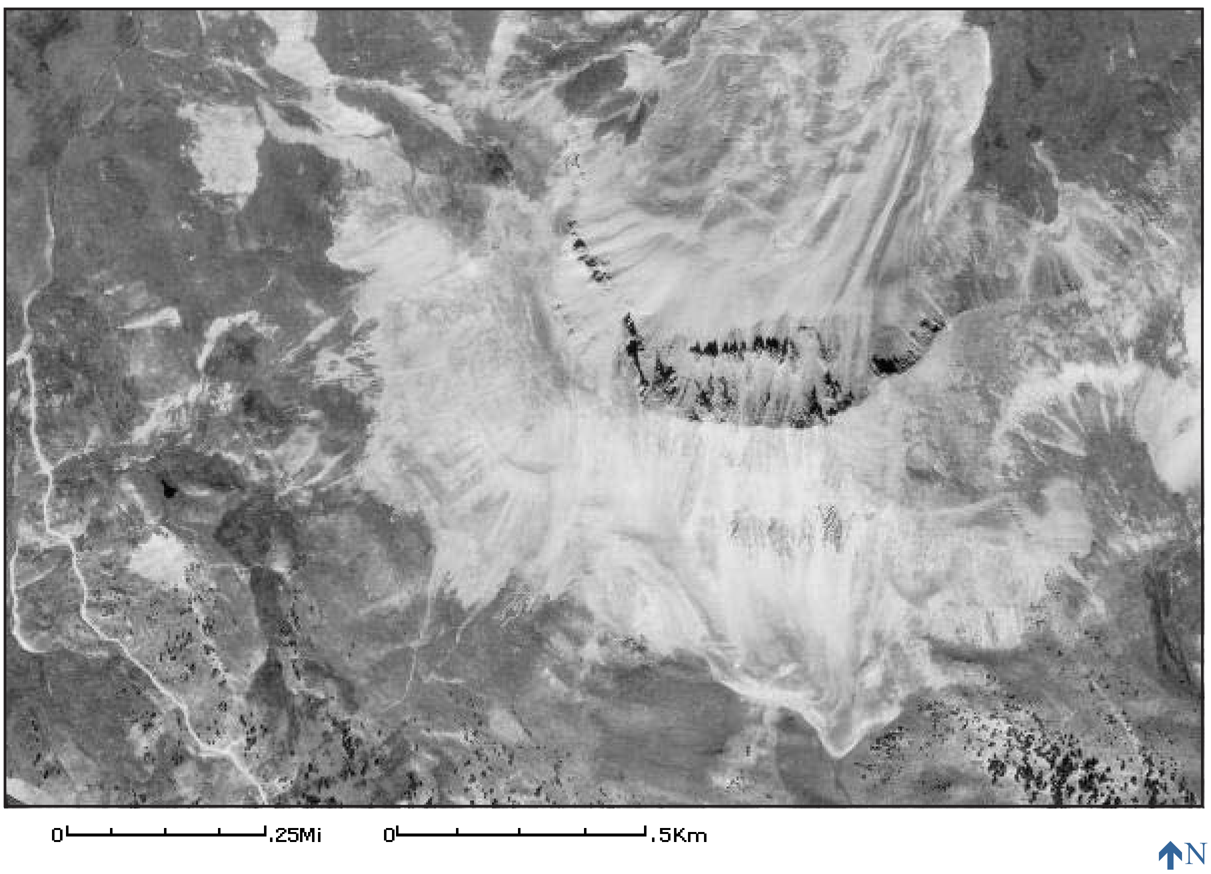

Figure 5. Sheep Mountain, San Juan County, Colorado (elevation 13,292 ft). Sheep Mountain is just right of the center of this photo. This is a possible site for the population of *Gilia sedifolia* visited by Dr. Purpus in 1892. The broad colluvial slopes to the south and west of the summit, as well as the upper reaches of the peak, appear suitable for *G. sedifolia*. The road over Stony Pass passes through the lower left corner of the photo. Digital aerial photo courtesy of the U.S. Geological Service.

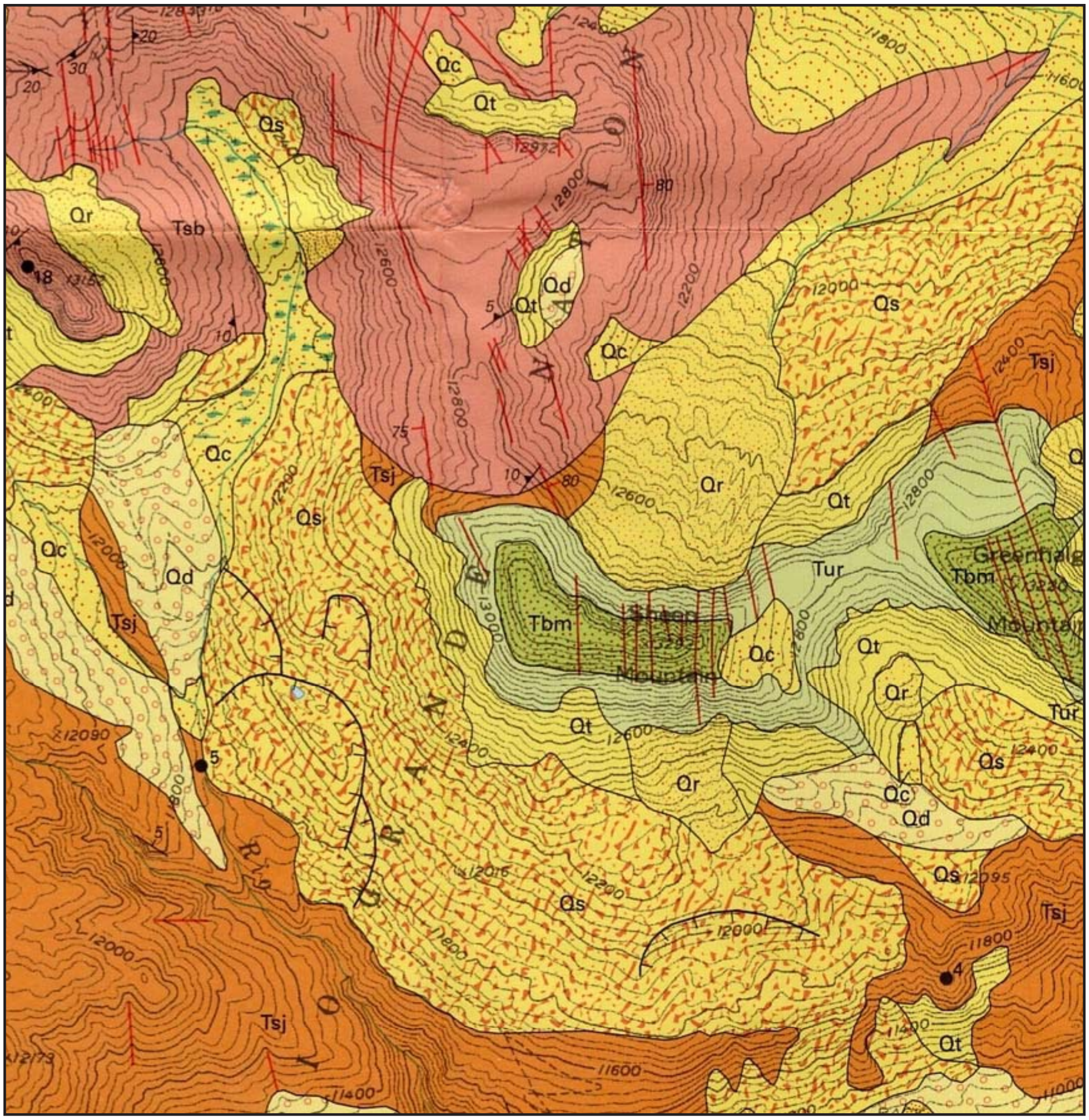

Figure 6. Surface Geology of Sheep Mountain, San Juan County, Colorado as mapped by Luedke and Burbank (2000). The yellow areas to the south and west of the summit are landslide materials (Qs), Talus (Qt), and rock glacier deposits (Qr). These are probably composed primarily of ash-flow tuff material from the upper slopes. The ash-flow tuff includes two strata: Blue Mesa Tuff (Tbm) at the summit and Ute Ridge Tuff (Tur) below.

The other Sheep Mountain nearest this area is located in San Miguel and Dolores counties in the Lizard Head Wilderness. This area is remote and is probably a less likely site than the other two Sheep Mountains previously discussed. The geology of this location is also not particularly favorable (**Table 2**).

Purpus's own specimen label data do not offer many clues as to his precise whereabouts when he collected *Gilia sedifolia*. Closely numbered specimens do not include any ancillary information besides collection number and species. Collection number 693 includes "Bear Cr., Aug, 1893" while collection number 703 says "grassy slopes, Sheep Mt, Unc R, Jul, 1893" (Ertter 2002). Apparently, his collections were numbered when they were prepared for sale and distribution, and not in the field (Ewan and Ewan 1981), which explains the chronological inconsistencies above. For this reason it is uncertain whether collection number 697 was taken in the intervening time between these other collections, or if their locations can be used to infer the location of the *G. sedifolia* collection. Ewan and Ewan (1981) write: "I do not know the dates of collection for his specimens taken at Engineer Mt., Ouray Co. (706), Sheep Mt., Gunnison Co. (607), and Lake City, Hinsdale Co. (721), but all evidently during 1892." Thus the date of 1893 might reflect the date the specimens were prepared and numbered and not the year in which they were collected. Dr. Purpus collected extensively in Gunnison County and around the Uncompahgre River.

There are four "Bear Creeks" in the vicinity of the three suspected peaks listed in **Table 2**. One of these is a tributary to the Uncompahgre River, located south of Ouray and 13 miles southwest of the Gunnison County Sheep Mountain (over very steep and rugged terrain). The headwaters and mainstem of the Uncompahgre River are also about 13 miles southwest and west of the Gunnison County Sheep Mountain. However, there does not appear to be a Sheep Mountain anywhere in close proximity to the Uncompahgre River that would match up well with collection number 703. This is evidence for the possibility that the name "Sheep Mountain" used by Dr. Purpus was a local name for one or more peaks that is no longer used.

There is a Bear Creek 11 miles east of the San Miguel County Sheep Mountain, and two Bear Creeks (one three miles southeast and one nine miles west) of the San Juan County Sheep Mountain. Thus, the proximity of Bear Creeks to the suspected Sheep Mountains is not a particularly helpful clue in finding the location of Purpus' collection 697. More research into the details of Dr. Purpus' travels could lead to further clues about the location of his collection of *Gilia sedifolia*.

There are currently no data suggesting that *Gilia sedifolia* has a disjunct range. All of the suspected sites for Dr. Purpus' collection are within 38 miles of each other. Half Peak and the San Juan County Sheep Mountain are approximately 6 miles apart. As is characteristic of many alpine species, occurrences of *G. sedifolia* are probably isolated on islands of suitable habitat surrounded by lower elevation, forested areas.

Other members of the genus *Aliciella* are primarily found in the Mojave and Sonoran Deserts, and in surrounding mountains. Seven other species of *Aliciella* are found in western Colorado (Weber and Wittmann 2001).

Population trend

There are insufficient data to make any inferences regarding the population trend for *Gilia sedifolia*. The population size of the Half Peak occurrence was estimated for the first time in 2003, but there have been no revisits or monitoring efforts from which a trend could be determined. It is very likely that other occurrences remain to be discovered, so more species inventory work is needed before the population trend can be accurately assessed.

Habitat

Information on the habitat of *Gilia sedifolia* is sparse; available habitat data are summarized in **Table 1**. Collections of this species were in sites at or above treeline, at 11,750 feet on Sheep Mountain (12,000 feet according to Brandegee 1899), and at 12,920 to 13,400 feet on Half Peak. It is apparently restricted to dry, rocky or gravelly talus of tuffaceous sandstone (Porter 1998, Komarek personal communication 2002, Komarek 2003). The Half Peak location is exposed and probably blows free of snow in the winter (Komarek personal communication 2002). *Gilia sedifolia* was collected on a shallow south-facing slope on Half Peak (Komarek 1995). The smaller occurrence on Half Peak is located on a flat site that is otherwise similar to the larger occurrence.

On Half Peak, *Gilia sedifolia* is found exclusively in gravelly patches that are surrounded by denser vegetation dominated by *Geum rossii* (Ross's sedge; **Figure 7** and **Figure 8**). The adjacent plant community forms a distinct boundary line around these gravel patches (Komarek 2003). *Gilia sedifolia* was never found to occur even in sparsely vegetated portions of areas dominated by *Geum rossii*. The processes responsible for this interesting microscale pattern are not known. They may be chiefly biotic, such as might arise from gradual spreading and stabilization of fine scree by *G. rossii*. Frost heave may also play a role in the creation and maintenance of the sharp boundaries observed between the gravel patches and denser vegetation. However, the soil is coarse and droughty, probably with very little organic matter. Coarse soils are not typically subject to intense disturbance by frost heave (Walker and Peters 1977, Washburn 1979).

Figure 7. A juvenile and an adult *Gilia sedifolia*, highlighting the very low cover of the gravelly areas in which it is found. The crustose lichen left of center appears to be *Lecidea atrobrunnea*. Photograph provided by Susan Komarek.

Figure 8. Habitat of *Gilia sedifolia* at Half Peak. *Gilia sedifolia* is found in the gravelly areas; vegetated areas visible in this photo are dominated by *Geum rossii*. Photograph provided by Susan Komarek.

The geology of the known sites is apparently similar. Purpus noted on one duplicate collection that *Gilia sedifolia* was collected on "tuffaceous sandstone" (Porter personal communication 2002). Half Peak is underlain by ash-flow tuff as delineated by Tweto (1979). This layer includes many named strata, but no information is available regarding the specific geology of Half Peak. Unfortunately no detailed geological map is available for the Pole Creek Mountain Quadrangle where Half Peak is located. A gravel sample sent by Susan Komarek is apparently welded rhyolitic ash-flow tuff, although there is some possibility that is a rhyolitic lava flow (Magloughlin personal communication 2004). However, the apparent tendency for it to weather and decompose rapidly is more suggestive of rhyolitic ash-flow tuff. This substance is chemically simple, consisting commonly of 70 percent SiO_2 and 15 percent Al_2O_3. The concentration of sodium and potassium is often high in these rocks, but magnesium and iron concentrations are very low (Magloughlin personal communication 2004). It is possible that the mineralogy of this substrate in the San Juan Mountains is not conducive to optimal plant growth.

The geology in the vicinity of one possible location of Purpus' collection on Sheep Mountain has been mapped in detail on the adjacent quad to the west (Howardsville). Two strata are exposed on the upper slopes of this Sheep Mountain that might also be those that occur on Half Peak. These are Blue Mesa Tuff (a reddish-brown, moderately to densely welded tuff), which sits atop Ute Ridge Tuff (gray to grayish-brown and moderately to densely welded) (Luedke and Burbank 2000). **Figure 6** illustrates the geology of the San Juan County Sheep Mountain as mapped by Luedke and Burbank (2000). The physiography of these two mountains is similar (**Figure 4** and **Figure 5**).

The geology of the area around Silverton is complex and includes many strata. A massive profusion of volcanic activity in the Tertiary resulted in the formation of the San Juan Mountains (Griffitts 1990). The original volcanoes in this field have been heavily eroded and glaciated, exposing deeper strata. The Silverton and San Juan Calderas were major vents in this area (Luedke and Burbank 2000). The rim of the Silverton Caldera passes within five miles to the northwest of Half Peak and contains rich mineral deposits that have been mined extensively. Numerous mining claims remain in this area.

Figure 9 illustrates the distribution of ash-flow tuff (sensu Tweto 1979) throughout the San Juan Mountains above 11,700 ft. This is included as a rough estimate of possible habitat for *Gilia sedifolia*. Significant refinements of this map will be possible when 1) more detailed geological data are available (at 1:24,000 scale or better), and 2) better habitat specificity data for *G. sedifolia* are available. Comparisons of Tweto (1979) and Luedke and Burbank (2000) show many inconsistencies, so the utility of **Figure 9** is probably greatest at coarser scales.

The definitions of high quality and marginal habitat are not known for *Gilia sedifolia*. Alpine areas on ash-flow tuff parent material that are not occupied may be suitable but unoccupied habitat, or they might instead be unsuitable for reasons we do not yet understand.

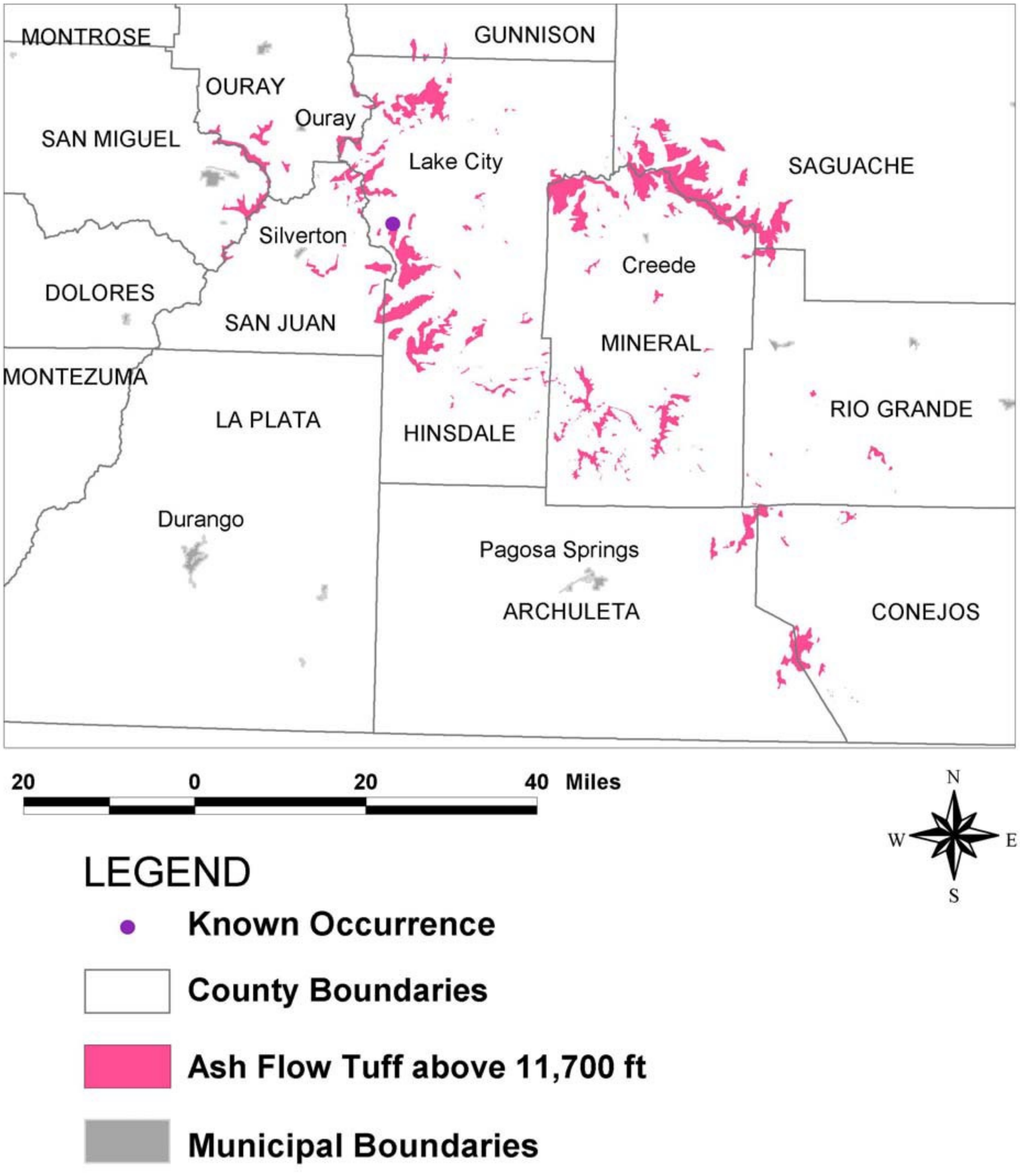

Figure 9. Distribution of potential habitat for *Gilia sedifolia*. Potential habitat is defined here as areas in the San Juan Mountains above 11,700 feet in elevation underlain by Ash Flow Tuff (sensu Tweto 1979). When more data are available this map can be revised and refined to reflect better the distribution of potential habitat.

Reproductive biology and autecology

In the Competitive/Stress-Tolerant/Ruderal (CSR) model of Grime (2001), characteristics of *Gilia sedifolia* most closely approximate those of a stress-tolerant ruderal species. As with many species of *Gilia* and *Ipomopsis*, *G. sedifolia* is found on moderately disturbed sites (Porter personal communication 2002). In the case of *G. sedifolia* these are naturally disturbed sites on colluvial slopes.

The disturbance regime to which *Gilia sedifolia* is subjected is probably maintained by mass wasting and erosion, and possibly by frost heave. The ash-flow tuff substrate on which *G. sedifolia* occurs is easily weathered into gravel-size particles that are unconsolidated at the surface.

The most consistent feature of ruderal species in the CSR model is an annual or short-lived perennial life history (Grime 2001). *Gilia sedifolia* appears to be a biennial (Porter 1998) or a short-lived monocarpic perennial (Inouye personal communication 2003). However, there may be no plants that have an obligately biennial lifecycle (Harper 1977), and biennials might better be referred to as short-lived semelparous perennials (Barbour et al. 1987). The biennial life history is an adaptation to a short growing season because it makes it possible for plants to produce a much larger seed crop than they could in only one year (Barbour et al. 1987). There is, however, a cost to this strategy since there is a significant chance that the second year will not be favorable for growth or that a disturbance will occur. Biennials are often found in sites that are disturbed periodically but not every year.

In arctic and alpine habitats, the dominant source of stress is low temperature. Low growing season temperatures retard metabolic processes and inhibit biomass accumulation, thus limiting productivity. In a discussion of stress-tolerant ruderals, Grime (2001) notes that areas with a combination of severe stress and disturbance in terrestrial habitats tend to be devoid of vegetation, since there are no plant strategies that can cope with both simultaneously (hence the "untenable triangle"). Thus, life history is a limiting factor for the colonization of the alpine by biennials since their ability to grow and complete their life cycle rapidly, which is advantageous in a disturbed site, is thwarted by low productivity (Porter personal communication 2002). However, where the effects of stress and disturbance are slightly less severe, environments are encountered in which certain specialized plants, often small annuals, can survive (Grime 2001).

As a biennial with relatively large amounts of biomass allocated to the production of propagules, the life history pattern of *Gilia sedifolia* is best classified as r-selected (using the classification scheme of MacArthur and Wilson 1967). The instability of its habitat also typifies *G. sedifolia* as r-selected.

The extent to which *Gilia sedifolia* is capable of selfing is unknown. Both self-compatibility and self-incompatibility are present in the genus *Aliciella*. As its name implies, *A. heterostyla* is heterostylous and exhibits a mixed mating system with some degree of both self-compatibility and self-incompatibility (Tommerup and Porter 1998). This is a very unusual mating system and appears to be uniquely derived in *A. heterostyla*.

The base chromosome number for many species in the genus *Gilia* is x = 9 (Grant 2002). *Gilia* includes both diploids and natural allotetraploids.

The pollination ecology of the Polemoniaceae has been the topic of extensive study, particularly in the genera *Ipomopsis*, *Gilia*, and *Polemonium*. However, there has been no research on the pollination ecology and pollinators of *G. sedifolia*. *Gilia pinnatifida* and *G. penstemonoides* are pollinated primarily by bumble bees (*Bombus* spp.), megachilid bees (*Megachile* spp.), and anthophorid bees (Porter personal communication 2002). However, as elevation increases, visitation by various species of flies becomes more prevalent. Halictid and megachilid bees are less active in the alpine than at lower elevations (Porter personal communication 2002). Although highly specialized breeding systems are common in the Polemoniaceae, the floral morphology of *G. sedifolia* is not suggestive of a highly specialized breeding system. The flower tube is shorter with relatively long, narrow corolla lobes when compared with other species of *Aliciella* and *Ipomopsis*. Some species in the Polemoniaceae have a modified glandular disc that facilitates beetle pollination. More specimens are needed to investigate whether such features are present on *G. sedifolia* (Porter personal communication 2002).

Plants with very little floral specialization are considered "promiscuous plants" because they utilize unspecialized, generalist pollinators as pollen vectors (Grant 1949, Bell 1971). Reliance on a broad suite of pollinators for pollinator services probably buffers promiscuous plants from population swings of any one pollinator (Parenti et al. 1993) and might be advantageous in the barren habitats of *Gilia sedifolia*. The floral biology of *G. sedifolia* must be investigated to ensure that conservation actions on its behalf include the protection of its pollinators.

Because biennials have a short life span and lack the ability to reproduce vegetatively, there is strong selective pressure for successful reproduction. The reproductive success of some alpine biennials is augmented by self-pollination (Spira and Pollak 1986).

Paige and Whitham (1987) made some interesting observations regarding the life history of *Ipomopsis aggregata* that involve pollinator visitation. *Ipomopsis aggregata* is typically semelparous, as also presumed for *Gilia sedifolia*, but when pollinators are excluded, *I. aggregata* may shift to an iteroparous mode of reproduction. The iteroparous plants persist by producing an ancillary rosette that persists after the parent rosette dies. However, there is no evidence of such a shift in populations in the area around the Rocky Mountain Biological Laboratory in Gothic, Colorado (Inouye personal communication 2003).

Anthesis occurs from July to August, and possibly as late as September in *Gilia sedifolia* (Porter 1998). *Gilia sedifolia* produces numerous flowers in a spikelike inflorescence. Each flower produces a capsule containing 1 to 5 seeds (Porter 1998) or as many as 15 seeds (Brandegee 1899). When collected by Komarek on August 5, 1995, most reproductive plants were in the fruiting stage (Komarek personal communication 2002). On July 2, 2003, about half of the occurrence on Half Peak was either in flower or in fruit, while the other half was non-reproductive. Because *G. sedifolia* occurs in xeric sites, the periodicity of successful recruitment may coincide with wet or otherwise favorable years during which they can become established. The viability of seeds from *G. sedifolia* is not known.

The seeds of *Gilia sedifolia* are decidedly winged (Brandegee 1899). Winged seeds are rare as a dispersal mechanism among arctic plant species (Savile 1972). Seeds from plants growing on exposed sites are probably dispersed effectively by wind. Disseminules of numerous taxa were found in snow samples from St. Mary's Glacier, Colorado, exhibiting the efficacy of wind as a dispersal agent in the alpine (Bonde 1969).

As a biennial, the seed bank dynamics are particularly important in the life cycle of *Gilia sedifolia*. However, there is no information from which to attempt to deduce the seed longevity, dormancy, and germination requirements of *G. sedifolia*. Ruderal species tend to have greater seed longevity than other species (Rees 1994). Some annual plants are seed-limited (with easily depleted seed banks), while others have a sufficiently large seed bank to make up for any shortfalls in years where productivity is low (Crawley 2000).

The few available collections of *Gilia sedifolia* do not suggest that it is a particularly phenotypically plastic species. Some studies of other members of the Polemoniaceae have suggested some degree of plasticity in response to various types of biomass removal. In *Ipomopsis aggregata*, increased branch growth and early flowering were observed in damaged plants, as a response to herbivory (Juenger and Bergelson 2000a). Fire caused the formation of clonal rosettes in *I. aggregata* (Paige 1992a).

Arbuscular mycorrhizal (AM) fungi have been reported to form symbioses with members of the genus *Gilia* (Laspilitas.com 1995). AM fungi belong to a group of nondescript soil fungi (Glomales) that are difficult to identify because they seldom sporulate (Fernando and Currah 1996). They are the most abundant type of soil fungi (Harley 1991) and infect up to 90 percent of all angiosperms (Law 1985). AM fungi are generally thought to have low host specificity, but there is increasing evidence for some degree of specificity between some taxa (Rosendahl et al. 1992, Sanders et al. 1996). While this group has not previously been thought of as particularly diverse, recent studies are suggesting that there is unexpectedly high genetic diversity among AM fungi (Sanders et al. 1996, Varma 1999), and that a single plant root may host surprisingly high AM fungal diversity (Vandenkoornhuyse et al. 2002). As root endophytes, the hyphae of these fungi enter the cells of the plant roots where water and nutrients are exchanged in specialized structures.

Hybridization is unlikely in *Gilia sedifolia*, since there are no congeners nearby with which it could exchange pollen. Its closest relative, *G. penstemonoides*, is approximately 53 miles away in very different habitats and elevation, so gene flow between these populations is very unlikely. Morphological intermediates where their ranges overlap suggest that *G. penstemonoides* hybridizes with the closely related *G. pinnatifida* (Grey 1985).

Hybridization has been documented in some members of Polemoniaceae. There have been numerous studies of the hybridization between *Ipomopsis aggregata* and *I. tenuituba* (e.g. Grant and Wilken 1988, Wolf and Soltis 1992, Wolf et al. 1993, Campbell et al. 1997, Wolf et al. 1997, Melendez-Ackerman and Campbell 1998, Campbell et al. 1998, Alarcon and Campbell 2000, Campbell and Waser 2001, Wolf et al. 2001, Campbell et al. 2002a, Campbell et al. 2002b). Natural hybrids occur between *I. aggregata* and *I. tenuituba* that are less resistant to damage to the developing seeds by fly larvae (Campbell et al. 2002b). The overall fitness of these hybrids depends largely on which species is the maternal parent (Campbell and Waser 2001).

Demography

Maintaining genetic integrity and eliminating inbreeding and outbreeding depression are important management considerations for *Gilia sedifolia*. *Gilia sedifolia* is more vulnerable to genetic concerns if it is heavily dependent on outcrossing. Maintaining distinct genetic populations and natural levels of gene flow are also important for its conservation. Hybridization may lead to extinction by outbreeding depression in naturally small populations of *Ipomopsis aggregata* (Ellstrand 1992). Signs of inbreeding depression were observed in small populations (less than 100 individuals) of *I. aggregata* (Heschel and Paige 1995, Paige and Heschel 1996). In the self-incompatible species *Hymenoxys acaulis* var. *glabra*, small populations were found to be vulnerable to extinction due to incompatibility of mating types. Where genetic drift or bottlenecking had reduced the number of mating types to a point where the probability of pollination by a compatible mating type was extremely low, the breeding system ceased to function (DeMauro 1993).

The lifespan of *Gilia sedifolia* has not yet been determined through demographic studies or observations in the greenhouse. As previously stated, it appears to be a biennial (Brandegee 1899, Porter 1998) but may be capable of surviving more than two years. As a biennial or short-lived monocarpic perennial, *G. sedifolia* is semelparous, dying after it completes seed production. In 2003, approximately half of the individuals observed on Half Peak were reproductive and half were vegetative (Komarek 2003). See **Figure 10** for an illustration of the life cycle of *G. sedifolia*, and **Figure 11** for the life cycle graph of *G. sedifolia* (after Caswell 2001).

No Population Viability Analysis (PVA) has been performed for *Gilia sedifolia*. Apparently there has never been a PVA of any member of the genus *Gilia* or other members of the Polemoniaceae from which inferences could be drawn for this report. One species of *Ipomopsis* (*I. sancti-spiritus*) is currently listed endangered (U.S. Fish and Wildlife Service 1999), but there has been no PVA of this species to date.

The short lifespan of biennials results in a rapid turnover of populations, requiring that new individuals be recruited into populations at frequent intervals (Spira and Pollak 1986). However, recruitment rates in the alpine are generally low (Bliss 1971), and juvenile mortality is sometimes high (Bonde 1968). Thus, selective pressure for high reproductive effort is strong in alpine biennials. Alpine floras consist primarily of perennial species such as small evergreen shrubs and herbs, which are better suited to tolerance of the stresses imposed by low temperature and short growing season in the arctic and alpine (Grime 2001). Thus, species with biennial life histories are uncommon in the alpine, lending weight to speculation that *Gilia sedifolia* may be a short-lived monocarpic perennial (Inouye personal communication 2003). Some alpine biennials rely on self-pollination to ensure that they produce seeds successfully (Spira and Pollak 1986).

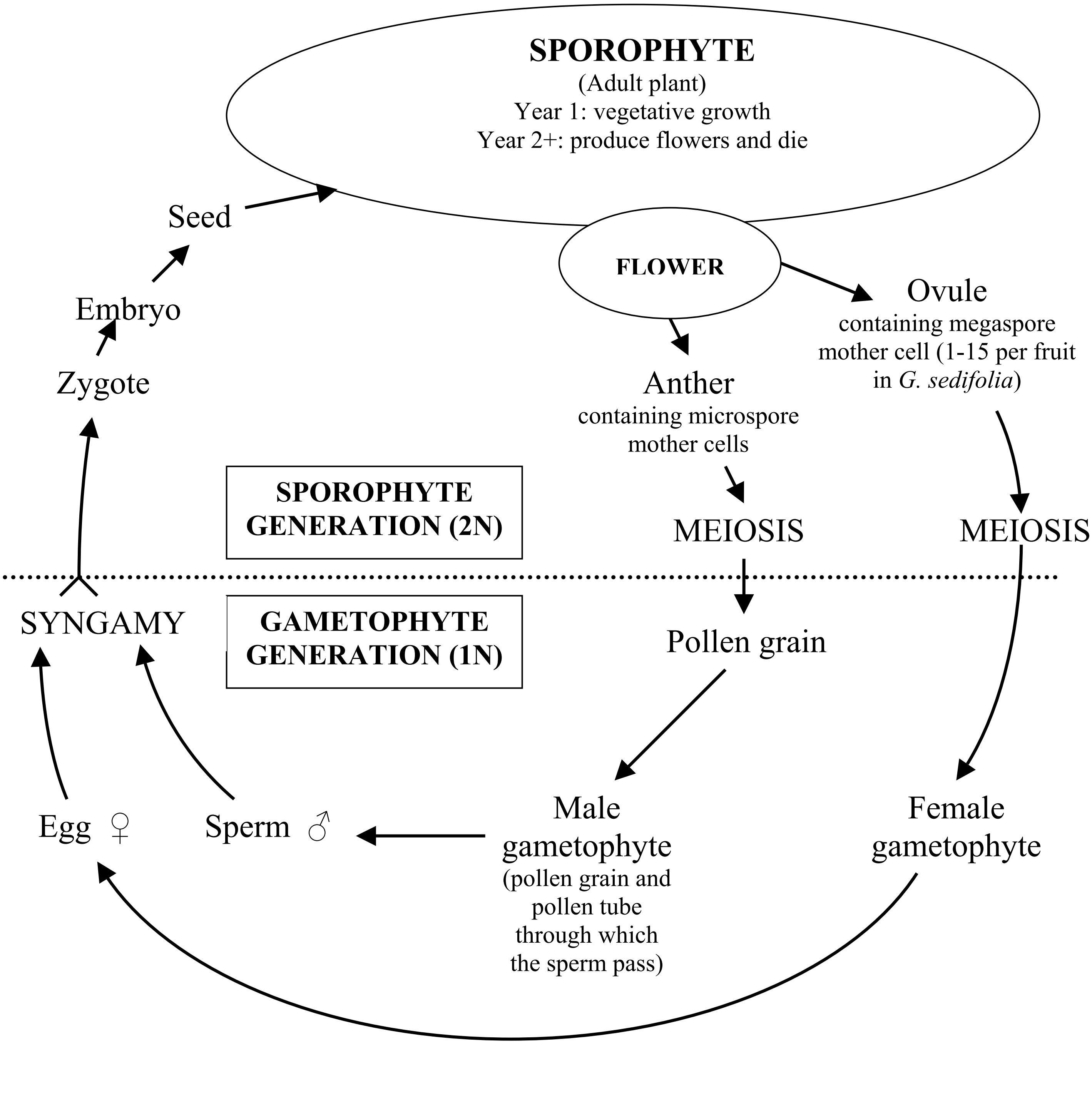

Figure 10. Life cycle diagram for *Gilia sedifolia* (after Stern 1994).

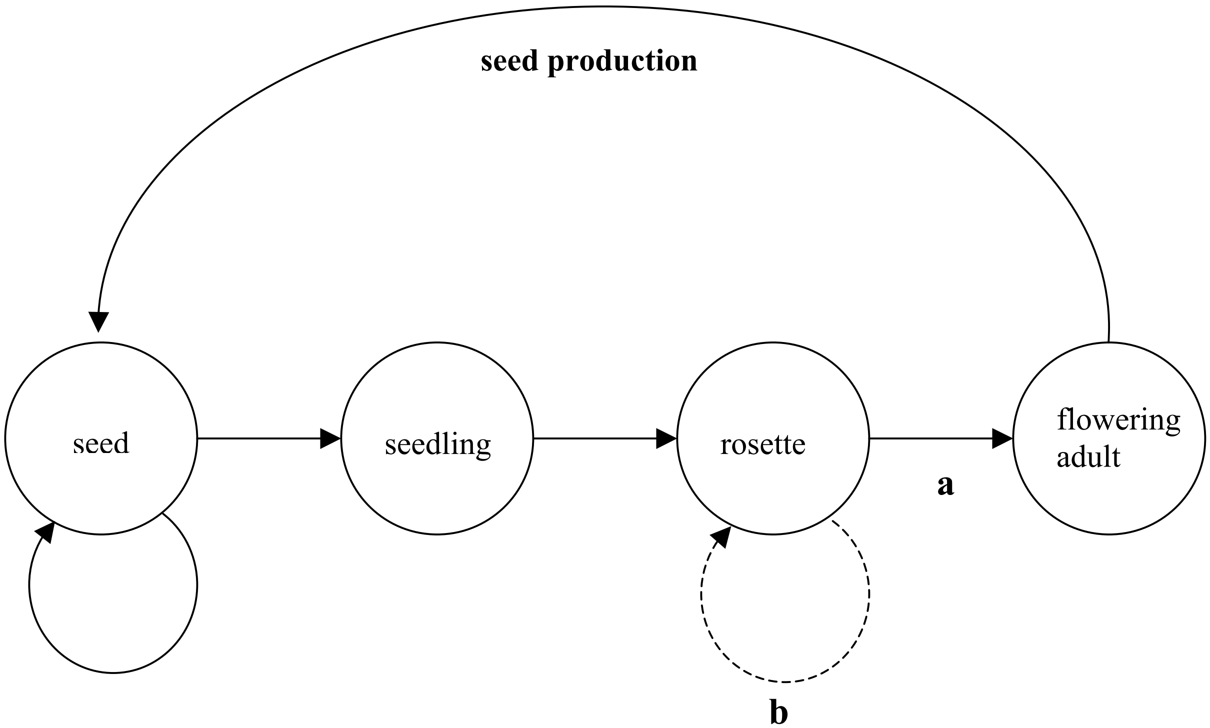

Figure 11. Hypothetical life cycle graph (after Caswell 2001) for *Gilia sedifolia* including the probable life history stages determined by Brandegee (1899), Porter (1998), and Inouye (personal communication 2003). As a monocarpic species, there is no return arrow in the flowering adult stage (a). If *G. sedifolia* is a biennial, there is no return arrow for the rosette stage (b). However if it is a short-lived monocarpic perennial then it can persist for more than one year as a non-reproductive individual. There has been no research to determine transition probabilities between any life history stage in *G. sedifolia*.

The probability of dispersal of seeds and other propagules decreases rapidly with increasing distance from the source (Barbour et al. 1987). Thus, long distance dispersal events are rare. Pollinator-mediated pollen dispersal is largely limited to the flight distances of pollinators (Kearns and Inouye 1993). Due to the formidable physical limitations to dispersal of seeds and pollen, the rate of geneflow between the two occurrences of *Gilia sedifolia* (assuming that the Sheep Mountain site remains extant) is probably quite low.

As a habitat specialist, population sizes of *Gilia sedifolia* are naturally limited by the availability of habitat. The high elevation outcrops of ash-flow tuff on which *G. sedifolia* lives are insular and often separated from other suitable patches by many miles of unsuitable habitat. Within an area of suitable habitat, the availability of microsites suitable for *G. sedifolia* is probably also limited, possibly precluding the development of a large population. Thus, the distribution and physiognomy of habitat for *G. sedifolia* imposes constraints on population growth at a variety of scales. It is not known if *G. sedifolia* is seed limited or what factors control seedling recruitment success.

Community ecology

Gilia sedifolia is found in sites where very few other plant species occur. Komarek (1995) noted that it was collected in "gravelly patches with no other vegetation." At Half Peak, very low percent cover of two species, *Erysimum capitatum* and *Elymus scribneri*, was observed in the gravelly patches where *G. sedifolia* was found (Komarek 2003). Lichens were also observed on cobbles found near *G. sedifolia*, as seen in **Figure 7**. Areas adjacent to the gravel patches are dominated by *Geum rossii* (Komarek 2003). It is likely that the combination of stresses (short growing season and xeric conditions during the growing season) and disturbance (from mass wasting and erosion) in sites occupied by *Gilia sedifolia* preclude the advancement of successional processes and maintain its habitat in a state of arrested succession. Other species in the San Juan

Mountains that are found primarily or exclusively on disturbed, sparsely vegetated substrates include *Besseya ritteriana*, *Stellaria irrigua*, and species of *Botrychium*.

There has been no documentation of interactions of *Gilia sedifolia* with herbivores. *Gilia sedifolia* may occur near habitat for pikas (*Ochotona princeps*), which might utilize it in their diet. Browsing and grazing (simulated in clipping experiments) significantly reduced the production of flowers, fruits, and seeds in *Ipomopsis aggregata* (Juenger and Bergelson 2000b). However, other studies have shown that herbivory resulted in an increase in flowers and fruits compared to ungrazed plants (e.g., Paige 1992b).

Given the lack of other vascular plant associates with *Gilia sedifolia*, it is unlikely to have any competitors. However, as a habitat specialist it might be a poor competitor, which may leave it vulnerable to negative impacts from introduced species.

Dr. J. M. Porter (personal communication 2002) offered some generalities regarding the Polemoniaceae that are relevant to *Gilia sedifolia* in the absence of information specific to this species. Members of this family share many traits with respect to competitors and habitat affinities. They are often found on eroding, chronically disturbed slopes, particularly throughout the deserts and badlands of western North America. Even in the tropics they are typically found in light gaps or along rivers where there is disturbance of some sort. Most members of this family are not particularly competitive. They are somewhat ruderal but not typically found in seral communities. Sites such as wasting slopes and badlands are chronically disturbed and maintained in a state of arrested succession, which probably excludes many potential competitors that are not well-adapted to these sites.

There have been no reports in the literature or other observations of parasite or disease attack on *Gilia sedifolia*. Herbarium specimens show no obvious damage resulting from herbivory.

Conservation

Threats

Observations and opinions of experts show that there are several tangible threats to the persistence of *Gilia sedifolia*. In order of decreasing priority, these threats are off-road vehicle use and other recreation, sheep grazing and its secondary impacts, mining, exotic species invasion, effects of small population size, global climate change, and pollution. These threats and the hierarchy ascribed to them are somewhat speculative, and more complete information on the biology and ecology of this species may elucidate other threats. Assessment of threats to this species will be an important component of future inventory and monitoring work. Please see the following sections for specific treatments of these threats to habitat and individuals, and from exotic species and over-utilization.

Recreational impacts (off-road vehicle use, hiking, and trampling) and sheep grazing likely present the greatest threats to *Gilia sedifolia*. Road construction is a threat to occurrences outside of wilderness areas such as Half Peak. Roads threaten occurrences of *G. sedifolia* directly by altering habitat and killing individuals and indirectly by providing sources of erosion and dispersal corridors for exotic species. If *G. sedifolia* is a highly outcrossing species, roads and trails might act as barriers to pollinators and prevent effective gene flow by disrupting their traplines, depending on the foraging behavior of its pollinators. The barrier effect of roads is known to have broad demographic and genetic consequences, which are reviewed in Forman and Alexander (1998). Roads also provide access to off-road vehicles, the use of which is extremely destructive in the alpine. Vehicle tracks affect species composition and decrease species richness, and a single pass may be visible on the landscape for years (Forbes 1992). Komarek (2003) noted the vulnerability of the Half Peak occurrence to off-road vehicle use if someone started a track up this peak, and she determined that a single pass through the occurrence by an all-terrain vehicle (ATV) could disrupt hundreds of plants due the instability of the substrate.

Sheep grazing has the potential for severe impacts to *Gilia sedifolia*. The allotment that includes Half Peak (the Cataract-Cuba-Middle Pole allotment) is currently vacant but remains active (Mason personal communication 2004). However, 1,000 ewes and lambs were grazed on this allotment until 2000. This allotment consists of approximately 10 square miles. Until the late 1970's, this allotment had been divided into three separate allotments, when each allotment was grazed with 1,000 sheep. Thus, this area has been subjected to intense grazing pressure historically. However, the low forage value and high elevation of *G. sedifolia* habitat may leave it undesirable for sheep, which prefer richer bottomlands (Mason personal communication 2004). Unless occurrences are near water sources, such as snow banks, or in areas through which sheep travel to get to better forage, they are probably somewhat naturally protected from grazing impacts. Careful surveys and monitoring are needed to substantiate this, and as more information is available the magnitude of this threat may need to be reconsidered. Recent studies of *Ipomopsis aggregata* observed overcompensation in grazed populations, suggesting that grazing by deer and elk actually increases individual fitness (Paige 1999, Paige et al. 2001). However, the fragility of alpine habitats and the poor productivity of habitat for *G. sedifolia* suggest that these results are probably not relevant to *G. sedifolia*. In clipping experiments, other studies (e.g. Juenger and Bergelson 1997) did not observe overcompensation but negative impacts on *I. aggregata* such as delayed phenology, altered plant architecture, and reduced plant fitness.

Although there are no known cases where resource extraction is impacting *Gilia sedifolia*, mining presents a tangible threat. The ash-flow tuff on which it grows does not contain valuable mineral resources, but other strata in the area do. It is conceivable that mining projects that disturb or remove ash-flow tuff to access deeper strata might destroy habitat or individuals of *G. sedifolia*. Active mining claims and a mine are present in Cataract Gulch near Half Peak. These do not directly threaten the known occurrence on Half Peak.

Global climate change is likely to have wide-ranging effects in the near future. Projections based on current atmospheric CO_2 trends suggest that average temperatures will increase while precipitation will decrease in Colorado (Manabe and Wetherald 1986). This will have significant effects on nutrient cycling, vapor pressure gradients, and a suite of other environmental variables. Temperature increase could cause vegetation zones to climb 350 feet in elevation for every degree F of warming (U.S. Environmental Protection Agency 1997). Because the habitat for *Gilia sedifolia* is already xeric, lower soil moistures in the growing season induced by decreased precipitation could have serious impacts.

Other models predict increased winter snowfall (e.g., Giorgi et al. 1998), which has other implications for *Gilia sedifolia*. Increased snowfall could delay the onset of the growing season for *G. sedifolia* if persistent snow covers populations late into the spring. This scenario appears unlikely at Half Peak, where the area is probably blown free of snow most of the time anyway. Increased snowfall may result in habitat amelioration through higher soil moisture that permits the encroachment of other, more competitive species, which would likely be deleterious to *G. sedifolia*.

Atmospheric nitrogen deposition (of both organic and inorganic forms) is increasing worldwide. Experimental nitrogen enrichment of alpine sites suggests that ecosystem processes will be altered and result in species turnover (Bowman et al. 1993, Bliss and Gold 1999). Relatively low levels of nitrogen enrichment are advantageous to some species but deleterious to others, making it difficult to predict species- and community-level responses.

Influence of management activities or natural disturbances on habitat quality

Off-road vehicle and foot traffic are likely to compact soils and accelerate erosion in *Gilia sedifolia* habitat. While *G. sedifolia* is probably well adapted to some level of natural disturbance (such as erosion or mass wasting), increasing the level of disturbance slightly would probably be sufficient to render them uninhabitable (see the discussion under the Reproductive Ecology and Autecology section of this document). Other activities that accelerate erosion or cause disturbance, such as road building, should be assumed to have negative impacts on *G. sedifolia* habitat. Sheep grazing will also have impacts if sheep enter habitat for *G. sedifolia*, or if sheep access areas above its habitat and affect it in ways that alter the conditions downslope. For example, trampling and devegetation of areas upslope might accelerate erosion above *G. sedifolia* habitat, which in turn would accelerate erosion downslope if surface runoff is increased.

Indirect effects on habitat quality for *Gilia sedifolia* caused by fragmentation and hydrologic alteration are also possible. The impact of these factors on habitat quality for *G. sedifolia* depends largely on the importance of ecological connectivity between populations, which is not known.

Influence of management activities or natural disturbances on individuals

Management activities that reduce trampling by hikers and livestock are likely to prevent mortality of *Gilia sedifolia* individuals. An experimentally imposed disturbance regime caused decreased recruitment of rosettes in *Ipomopsis aggregata* (Juenger and Bergelson 2000c). Because additional occurrences of *G. sedifolia* probably remain to be documented, clearances should take place before management actions within potential habitat.

Interaction of the species with exotic species

Currently there is no specific information suggesting that *Gilia sedifolia* is threatened by exotic species. However, 10 percent of Colorado's native plant species have been displaced by exotic species while weeds have continued to spread (Colorado Department of Agriculture 2001). Although weeds are more problematic at lower elevations, some such as *Linaria vulgaris* have been found in the Colorado alpine. While the probability of infestation by exotics in *G. sedifolia* habitat is small, the potential ecosystem impacts from exotic species must also be considered, such as their effects on pollinators. For example, pollinators may be drawn away from *G. sedifolia* individuals and habitat by dense infestations of exotic species nearby. Exotic plant species are not common in the habitat for *G. sedifolia*. Because new exotic species are arriving all the time, vigilance in monitoring for their impacts is crucial nonetheless. It is possible that an insipient weed could favor the habitat for *G. sedifolia* when it arrives, and require costly management efforts for its control.

Threats from over-utilization

There are no known commercial uses for *Gilia sedifolia*. Members of the Polemoniaceae are popular for gardening, but there are no indications that they are sought for use in the herb trade. No members of the Polemoniaceae are cited for any particular toxicity issues (Burrows and Tyrl 2001). *Gilia sedifolia* is vulnerable to potential impacts from harvesting wild populations if for some reason it becomes sought after as a medicinal herb. Over-collection for scientific purposes is a concern in small populations. However, limited collections from robust populations are needed to better understand this taxon and of critical importance to plant systematics and conservation research.

Conservation Status of the Species in Region 2

Is distribution or abundance declining in all or part of its range in Region 2?

There is no information on population trend for *Gilia sedifolia*. If the Sheep Mountain population visited by Dr. Purpus is extirpated then it may be in decline, although there has not yet been enough survey work to make any inferences. Thus, survey work is needed to assess the status of *G. sedifolia*. Grazing or recreational use could be negatively impacting occurrences of this species, but its remoteness and the poor forage value of its habitat offer it some degree of protection.

Do habitats vary in their capacity to support this species?

The dearth of information on *Gilia sedifolia* leaves it impossible to speculate on the capacity of habitats to support it. It is likely that key environmental variables have significant effects on the ability of different locations to support *G. sedifolia*. However, until research is conducted to understand the relationships between this species and its habitat, this cannot be assessed.

Vulnerability due to life history and ecology

As a biennial species, *Gilia sedifolia* may be somewhat vulnerable to environmental stochasticity. The degree to which it can survive unfavorable years (i.e., years that are particularly dry or cold at critical times) will depend largely on whether it can remain dormant or survive a third year. The longevity of its seed bank may also contribute to its ability to survive periods of poor conditions. The high population turnover of biennials leaves them more vulnerable to seasonal environmental stochasticity than perennials. Its xeromorphic features (particularly its succulent leaves) probably help it to tolerate desiccation and drought, but the limits of this tolerance are not known.

Because it is found with no associated species, it is possible that *Gilia sedifolia* is tolerant of conditions that approach the physiological limits of vascular plants. If this is true, then small changes in environmental variables that cause added stress or disturbance will compromise population viability by causing the extirpation of individuals or populations. Conversely, habitat amelioration might allow other, more competitive species to invade and to displace *G. sedifolia*. The response of *G. sedifolia* to disturbance and succession is unknown, making it difficult to predict the outcomes of various potential natural and anthropogenically induced modifications of environmental variables.

The minimum viable population size is not known for *Gilia sedifolia*, but even small populations by the standards of the 50/500 rule of Soulé (1980) may still be viable and of conservation importance. Somewhat arbitrarily, the Colorado Natural Heritage Program considers populations of *G. sedifolia* containing 10 or more plants as viable, but this threshold will be revised when a minimum viable population size is determined. Signs of inbreeding depression were observed in small populations (fewer than 100 individuals) of *Ipomopsis aggregata* (Heschel and Paige 1995, Paige and Heschel 1996).

Evidence of populations in Region 2 at risk

There is much evidence to suggest that occurrences of *Gilia sedifolia* are at risk. Its habitat specificity, high level of endemism, and small number of occurrences suggest that *G. sedifolia* is imperiled. *Gilia sedifolia* is very poorly understood, which is a liability because well-intended conservation actions cannot be as effective when basic information is not available. The population visited by Purpus in 1892, if it remains extant, is at risk because its location is uncertain and no protective efforts on its behalf can begin until it is found. Often when a species thought to be rare is actively sought and inventoried, it is discovered that the species is not as rare as previously believed.

The single known location of *Gilia sedifolia* is located in a remote location on land managed by the USFS. Although this offers it protection from some impacts that are possible on private land, it is not included in a wilderness area or other protected area. Thus, it is at risk from impacts resulting from motorized vehicle use and resource extraction. Though unlikely at present, the fact that there are no protective measures for this occurrence places it at risk.

Management of the Species in Region 2

Implications and potential conservation elements

The most current data available strongly suggest that *Gilia sedifolia* is naturally very rare and is imperiled due to its small number of occurrences. Thus, the loss of any occurrence is significant and will probably result in the loss of important components of the genetic diversity of the species.

Because it is found on unstable substrates in the high alpine, it is likely that even light or moderate levels of human activity will result in habitat alteration. The degree to which these activities would be detrimental to *Gilia sedifolia* is not known. However, it is likely that *G. sedifolia* is sensitive enough that small changes in some environmental variables that human activities would alter within populations are likely to be maleficent. Particular management actions or natural events that are likely to have the greatest impacts are not known but will be contingent on the autecology of *G. sedifolia*. Further research is needed before meaningful inference can be offered regarding restoration policy and mitigation of threats to *G. sedifolia* resulting from management.

Desired environmental conditions for *Gilia sedifolia* include sufficiently large areas where the natural ecosystem processes on which this species depends can occur, permitting it to persist unimpeded by human activities and their secondary effects, such as weeds, erosion, and soil compaction. This includes a satisfactory degree of ecological connectivity between populations to provide corridors and other nectar resources for pollinators if necessary. For *G. sedifolia*, it is probably particularly important that local-scale ecological processes (i.e., those contributing directly to the maintenance of populations) remain intact. Given the current paucity of detailed information on this species, it is unknown how far we are from achieving this ideal. It is possible that most or all of the ecosystem processes on which *G. sedifolia* depends are functioning properly at many or most of the occurrences of this species. Further research on the ecology and distribution of *G. sedifolia* will help to develop effective approaches to management and conservation. Until a more complete picture of the distribution and ecology of this species is obtained, priorities lie with conserving the known occurrence.

Within the last 15,000 years, the climate in the southern Rocky Mountains has been both warmer and colder than it is at present. There is much evidence to suggest that the elevational and latitudinal distributions of many plant species were much different in these periods than they are today. Given the changes predicted in the global climate for the next 100 years, incorporation of higher elevation refugia for *Gilia sedifolia* into preserve designs and conservation plans will help to increase the likelihood of its long-term viability.

Tools and practices

Species and habitat inventory

At present, species inventory work for *Gilia sedifolia* is complicated by the lack of information regarding this species. It is likely that it will be relatively easy to develop a search image for *G. sedifolia* if sites are visited at phenologically appropriate times. Finding *G. sedifolia* will also be facilitated by the lack of associated species. The greatest difficulty in conducting species inventories for *G. sedifolia* is in accessing appropriate habitat, since known and potential occupied sites are rugged and remote.

Gilia sedifolia could benefit greatly from inventory and mapping using GPS technology to precisely mark occurrence boundaries. This would provide land managers with useful data for generating land use plans and permitting, for example. The value of such a project would be greatly augmented by the collection of quantitative census data with ecological data, from which a density surface could be created and population size could be fairly accurately determined.

Aerial photography, topographic maps, soil maps, and geology maps can be used to refine surveys of large areas, and could be highly effective for refining survey areas for *Gilia sedifolia*. It is most effective for species about which we have basic knowledge of its substrate and habitat specificity from which distribution patterns and potential search areas can be deduced.

Searches for *Gilia sedifolia* could be aided by modeling habitat based on the physiognomy of known occurrences. The potential habitat map presented in this report (**Figure 9**) is based on the intersection of geology and elevation known for *G. sedifolia*. When more information becomes available, there will be potential for much refinement of this map. Techniques for predicting species occurrences are reviewed extensively by Scott et al. (2002). Habitat modeling has been done for other sensitive plant species in Wyoming (Fertig and Thurston 2003), and these methods are applicable to *G. sedifolia* as well.

Areas that warrant further search efforts are discussed in the Distribution and Abundance section of this document in detail. Areas in the vicinity of Half Peak that may warrant further search efforts include Spring Creek Pass and the area north of Half Peak between Campbell and Boulder gulches (Mason personal communication 2004).

Population monitoring

A monitoring program for *Gilia sedifolia* would begin by targeting the single known occurrence, and add other occurrences to the program if they are discovered. A monitoring program that addresses recruitment, seed production, seed and plant longevity, population variability, and pollinators would generate data useful to managers and the scientific community. Population monitoring would also be a useful means of detecting population trends under different management and human use scenarios.

The most sensitive measure of population change will be gleaned from recruitment success, which may not be difficult to determine for *Gilia sedifolia* since it is found in barren sites with few other species. Suitable methods for monitoring pollinators are discussed in Kearns and Inouye (1993). It will be important to define *a priori* the changes that the sampling regime intends to detect and the management actions that will follow from the results (Schemske et al. 1994, Elzinga et al. 1998).

Resampling of monitoring plots will be necessary every year at first to gain insight into the population dynamics of *Gilia sedifolia*. To document important demographic parameters (mainly seedlings and fruitset), two trips per growing season may be required: one in early spring to observe seedlings and one in mid August to observe seed set.

A commonly used method involves tracking marked individuals over several years. Lesica (1987) described one possible approach that is suitable for non-rhizomatous perennials. Although *Gilia sedifolia* appears to be a biennial or short-lived monocarpic perennial, these methods are probably suitable for use with it as well. Ideally, a discrete subset of the population would be selected randomly and individuals within quadrats or transects are marked using aluminum tags or other field markers. It is important that plots be large enough and contain a reasonable sample size. This will help to ensure that changes within plots resulting from death and recruitment do not eventually result in the obsolescence of the plot. Elzinga et al. (1998) offers additional suggestions regarding sampling design and protocol.

A simple method has been worked out for demographic modeling of *Ipomopsis aggregata* that is probably applicable to *Gilia sedifolia* as well (Inouye personal communication 2003). The leaves in the basal rosette are counted, and the rosette diameter (or length of longest leaf) is measured. These measurements can be taken rapidly, and repeating them annually permits the construction of a transition matrix.

Several methods of monumentation are recommended in Elzinga et al. (1998) depending on the site physiography and frequency of human visitation to the site. This is an important consideration that will reap long-term benefits if done properly at the outset of the monitoring program.

Estimating cover and/or abundance of associated species within the plots described above could permit the investigation of interspecific relationships through ordination or other statistical techniques. In very sparsely vegetated plots this can be difficult, but it can be done accurately using appropriate cover classes or subdivided quadrat frames. Understanding environmental constraints on *Gilia sedifolia* would facilitate the development of beneficial management practices for this species. Gathering data on slope, aspect, and edaphic characteristics (particularly moisture, texture, and soil chemistry) from the permanent plots described above would permit the canonical analysis of species-environment relationships. These data would facilitate hypothesis generation for further studies of the ecology of this species.

Adding a photo point component to this work following recommendations offered in Elzinga et al. (1998) could facilitate the tracking of individuals and add valuable qualitative information. A handbook on photo point monitoring (Hall 2002) is available that offers excellent instructions on establishing photo point monitoring plots.

To address the metapopulation structure of *Gilia sedifolia*, one approach might be to select highly suitable but unoccupied sites and attempt to observe colonization events through presence/absence monitoring. Selection of such sites would require more *a priori* research on the habitat requirements of *G. sedifolia*. Even for plants in which metapopulation dynamics can be successfully inferred from regional extinction and colonization data, focusing efforts on monitoring of individual populations is more likely to provide an accurate assessment of the species (Harrison and Ray 2002).

At present the priorities lie in gathering baseline data on distribution and population sizes for *Gilia sedifolia*. Gathering population size data can be done rapidly and requires only a small amount of additional time and effort (Elzinga et al. 1998). Thus, presence/absence monitoring is not recommended for *G. sedifolia*. Further rationale for this is that it is likely to be time consuming and difficult to reach some or all occurrences of *G. sedifolia*, so the additional time investment of gathering population size and other data are worthwhile to maximize the information gleaned during each visit.

Habitat monitoring

Habitat monitoring in the absence of *Gilia sedifolia* individuals could be conducted on sites within the known distribution with suitable soils, geologic substrate, and vegetation. For sites that are occupied by *G. sedifolia*, habitat monitoring should be conducted concurrently with population monitoring, if population monitoring is conducted. Documenting habitat attributes, disturbance regime, and associated species during all population monitoring efforts will greatly augment our present understanding of its habitat requirements and management needs. This could be incorporated into the field forms used for the quantitative sampling regimen described above. If carefully selected environmental variables are quantified during monitoring activities, they will help to explain observations of population change. Habitat monitoring of known occurrences will alert managers of new impacts such as weed infestations and damage from human disturbance and grazing. Change in environmental variables might not cause observable demographic repercussions for several years, so resampling the chosen variables may help to identify underlying causes of population trends. Evidence of current land use practices and management is important to document while monitoring populations.

Observer bias is a significant problem with habitat monitoring (Elzinga et al. 1998). Thus, habitat monitoring is usually better at identifying new impacts than at tracking change in existing impacts. For estimating weed infestation sizes, using broad size classes helps to reduce the effects of observer bias. To assess trampling impacts, using photos of impacts to train field crews will help them to rate consistently the severity of the impact

Beneficial management actions

It is likely that "leaving it alone" is among the best management practices for *Gilia sedifolia*. However, an assessment of ongoing impacts has not been done from which to infer beneficial management practices. Management actions that reduce impacts from human use to *G. sedifolia* and its habitat are likely to procure significant benefits for the species.

The establishment of protected areas that would be managed for the conservation of *Gilia sedifolia* is an important conservation strategy for this species. Designation of research natural area status for Half Peak in the Gunnison National Forest is a possible approach to ensure the protection of this species.

Livestock management practices that prevent access to occurrences of *Gilia sedifolia* by sheep are likely to confer significant benefits to the species. Since habitat for *G. sedifolia* is of very low forage value it is unlikely that actions on behalf of *G. sedifolia* will affect the grazing regime or have economic impacts.

Routing new trails and rerouting any existing trails around known occurrences are probably the best ways to reduce direct human impacts to *Gilia sedifolia*. Roads that provide access to habitat for *G. sedifolia* should be assessed and efforts to discourage off-road vehicle use in appropriate habitat should be taken. This could include fences or strategically placed rocks that block access to habitat units and known occupied sites.

No seeds or genetic material are currently in storage for *Gilia sedifolia* at the National Center for Genetic Resource Preservation (Miller personal communication Miller 2002). It is not among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (Center for Plant Conservation 2002). Collection of seeds for long-term storage will be useful if future restoration work is necessary.

There have been no active population or habitat management efforts on behalf of *Gilia sedifolia*. Research natural area designation for Half Peak could provide protection for this occurrence from off-road vehicle impacts and grazing, while encouraging much needed research on *G. sedifolia*.

Information Needs

Distribution

The distribution of *Gilia sedifolia* is poorly known, and further species inventory work is arguably the top research priority for this species. Much suitable habitat remains to be searched. Of two known occurrences, the exact location of one is uncertain. Until we have a better picture of its distribution and population size it will not be possible to assess accurately the conservation needs and priorities for *G. sedifolia*. Nonetheless, preliminary conservation strategies can be formulated given our present knowledge of the species. Although the distribution of *G. sedifolia* is poorly known, garnering some protection for the Half Peak occurrence is warranted given the strong evidence and the wide agreement among experts that this taxon is very rare.

Life cycle, habitat, and population trend

Very little is known about the lifecycle of *Gilia sedifolia*. However, as an alpine biennial with an unusual life history, information regarding this is relevant for appropriate stewardship and management of this species. The two documented occurrences were both found on similar geologic substrates, but very little is known about the habitat of *G. sedifolia*. Autecological research is needed to help refine our definition of appropriate habitat and facilitate effective habitat monitoring and conservation stewardship of this species. Population trend is unknown for *G. sedifolia*.

Response to change

Rates of reproduction, dispersal, and establishment and the effects of environmental variation on these parameters have not been investigated in *Gilia sedifolia*. Thus, the effects of various management options cannot be assessed during project planning. *G. sedifolia* populations could be expected to respond quickly to environmental impacts since it is a biennial species and populations turn over rapidly.

Understanding the breeding systems employed by *Gilia sedifolia* will assist managers by determining the importance of pollinators for reproduction and population genetics. At this time, it is not known how management changes that affect insect visitors will affect *G. sedifolia*.

The importance of herbivory in the ecology of *Gilia sedifolia* is not understood. Observations made thus far do not suggest that it has a significant impact on biomass reduction and disturbance of the species but this has not been assessed.

The specific responses of *Gilia sedifolia* to disturbance and succession are not clear and warrant further investigation. Depending on the role of disturbance in the maintenance of habitat, and the nature of the disturbance to which *G. sedifolia* is adapted, it may be tolerant of some sorts of human disturbance. See the Reproductive Biology and Ecology section of this document for further discussion of disturbance.

Metapopulation dynamics

Research on the population ecology of *Gilia sedifolia* has not been done to determine the importance of metapopulation structure and dynamics to its long-term persistence at local or regional scales. Migration, extinction, and colonization rates are unknown for *G. sedifolia*. Baseline population dynamics and viability must first be assessed.

Demography

The value of demographic data for conservation planning and species management cannot be overstated. Population size has not been assessed for occurrences of *Gilia sedifolia*. Growth, survival, and reproduction rates are also unknown. Our knowledge of the distribution of the species is incomplete. Therefore much work is needed in the field before local and rangewide persistence can be assessed with demographic modeling techniques. Short term demographic studies often provide misleading guidance for conservation purposes, so complementary information, such as historical data and experimental manipulations should be included whenever possible (Lindborg and Ehrlén 2002).

Population trend monitoring methods

Methods are available to monitor population trend reliably in *Gilia sedifolia*. However, they are contingent upon knowing the majority of the distribution and population sizes of *G. sedifolia* so that a meaningful subset of the population can be sampled. The population monitoring methods of Lesica (1987) could be applied for monitoring *G. sedifolia* since it is not a rhizomatous species.

Restoration methods

Because no attempts have been made to restore populations of *Gilia sedifolia*, there is no applied research to draw from in developing a potential restoration program. There have been many studies developing restoration techniques for alpine plants (e.g., Conlin and Ebersole 2001, Fattorini 2001). However, the utility of the methods described in these studies is dubious given the absence of soil and turf in *G. sedifolia* habitat. Restoration and revegetation of gravelly sites in the Alaskan arctic has not been particularly successful (Forbes and Jefferies 1999). It is possible that *G. sedifolia* may be readily propagated in a greenhouse environment, but plants would probably be very difficult to transfer successfully into a natural or quasi-natural (restored) setting given the remoteness of the occurrences and the nature of the habitat.

Research priorities for Region 2

Gilia sedifolia is among the most poorly known vascular plant species in North America. Basic information regarding almost all of its biological parameters has not been obtained. Opportunities for discovery of this sort among the vascular flora of North America are uncommon today, although they are not in many other parts of the world such as the tropics. Veritably resurrected from the list of extinct species by Susan Komarek's discovery, *G. sedifolia* is surrounded by a veil of intrigue that ought to capture the interest of many botanists. Its distinctiveness as a very unusual plant will not be diminished when its distribution, habitat, life history, and other biological parameters are better understood.

Species inventory work is the first step towards developing a better understanding of *Gilia sedifolia*. Revisiting the occurrence on Half Peak and searching the Sheep Mountain locations cited in this report to find the location of Dr. Purpus' 1892 collection are starting points. Collecting detailed notes on associated species, habitat, geology, soil, and other natural history observations at Half Peak and other locations if they are found will be extremely useful information. Documentation of any threats will help to develop conservation strategies, and will help managers act to mitigate these threats. Refining the potential habitat map for *G. sedifolia* with finer scale geological data and other data such as slope and vegetation type will help to identify other search areas.

Demographic studies are needed for *Gilia sedifolia*. Demographic data are far more useful for assessing status and developing recovery efforts than genetic information (Schemske et al. 1994). A monitoring program that determines the population size and the growth, survival, and reproduction of individuals within populations will have considerable practical value and will help to determine the conservation status of *G. sedifolia*. As a biennial in the high alpine, *G. sedifolia* is a species of considerable scientific interest, and demographic information on this species will facilitate a better understanding of the survival strategies of alpine biennials. Counting the ratio of old to new leaves might give an indication of how long it lives, assuming that it puts out about the same number of leaves every year (Inouye personal communication 2003).

The role of disturbance in the autecology of *Gilia sedifolia* is of significant scientific and conservation interest. An understanding of the disturbance regime to which *G. sedifolia* is adapted will assist with developing conservation strategies and management plans by determining the types of disturbance most likely to negatively impact *G. sedifolia*.

Understanding the breeding systems employed by *Gilia sedifolia* is another research priority for this species due to the practical and scientific value of such studies. Answers to questions about whether *G. sedifolia* reproduces mostly by asexual means or is instead an obligate or frequent outcrosser will provide needed guidance for developing appropriate management practices. If *G. sedifolia* is heavily dependent on self-pollination, the genetic population structure is more stable than if the species is an obligate outcrosser.

Thus, a trail near a primarily asexual population will not be as detrimental as one near a population of obligate outcrossers.

Physiological ecology studies will help to determine what substrate characteristics are required by *Gilia sedifolia*, which will be valuable information in the event that a population needs to be restored. Understanding the plant-environment relationship for *G. sedifolia* will be insightful in understanding the unique strategies employed by this species, and it will help to model the potential distribution of the species.

Additional research and data resources

Several endeavors are underway that are relevant to *Gilia sedifolia*. The Flora of the San Juan Basin Project does not include the Half Peak location within its study area, but *G. sedifolia* may be included within this flora nonetheless. Dr. David Jamieson, curator of the Fort Lewis College Herbarium, is involved in this project, and it is rumored that there are several specimens of *G. sedifolia* in the backlog of this herbarium. Attempts were made to contact Dr. Jamieson, but he did not return telephone calls. In a forthcoming volume of the Flora of North America, a treatment of Polemoniaceae by Dr. J.M. Porter will include *G. sedifolia* (as *Aliciella sedifolia*). Dr. J.M. Porter has two papers in press, one dealing with the molecular phylogenetics of the Polemoniaceae (using molecular data from both the ITS nuclear ribosomal and the chloroplast tRNA L and F regions) and another looking at phylogeny based on morphological characteristics.

Definitions

50/500 rule: A generalized rule stating that isolated populations need a genetically effective population of about 50 individuals for short-term persistence, and a genetically effective population of about 500 for long-term survival (Soulé 1980).

Biennial: Plants that complete their lifecycle in two years, through vegetative growth in the first growing season during which resources are sequestered to support reproduction in the second year, after which the plant dies (Allaby 1998).

Heterostyly: A mechanism that encourages outcrossing by insects in which flowers have different style lengths; usually the anthers of one morph are at the same level as the stigma of another morph (Allaby 1998).

Iteroparous: The production of offspring in a series of separate events, occurring two or more times during the lifespan of an organism (Art 1993).

Monocarpic: A plant that dies after flowering, although it may take several years to flower. Synonymous with semelparous (Silvertown 1993).

Monumentation: Markers used to permanently mark plots (Elzinga et al. 1998).

Photo point monitoring: A method of monitoring vegetation in which a camera is used to take photos of a site repeatedly to detect changes in selected variables (Hall 2002).

Semelparous: The production of all of an individual's offspring in one event (Art 1993).

Imperilment Ranks used by Natural Heritage Programs, Natural Heritage Inventories, Natural Diversity Databases, and NatureServe.

Global imperilment (G) ranks are based on the range-wide status of a species. State-province imperilment (S) ranks are based on the status of a species in an individual state or province. State-province and Global ranks are denoted, respectively, with an "S" or a "G" followed by a character. **These ranks should not be interpreted as legal designations.**	
G/S1	Critically imperiled globally/state-province because of rarity (5 or fewer occurrences in the world/state; or very few remaining individuals), or because of some factor of its biology making it especially vulnerable to extinction.
G/S2	Imperiled globally/state-province because of rarity (6 to 20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range.
G/S3	Vulnerable through its range or found locally in a restricted range (21 to 100 occurrences).
G/S4	Apparently secure globally/state-province, though it might be quite rare in parts of its range, especially at the periphery.
G/S5	Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.
GX	Presumed extinct.
G#?	Indicates uncertainty about an assigned global rank.
G/SU	Unable to assign rank due to lack of available information.
GQ	Indicates uncertainty about taxonomic status.
G/SH	Historically known, but not verified for an extended period, usually.
G#T#	Trinomial rank (T) is used for subspecies or varieties. These taxa are ranked on the same criteria as G1-G5.
S#B	Refers to the breeding season imperilment of elements that are not permanent residents.
S#N	Refers to the non-breeding season imperilment of elements that are not permanent residents. Where no consistent location can be discerned for migrants or non-breeding populations, a rank of SZN is used.
SZ	Migrant whose occurrences are too irregular, transitory, and/or dispersed to be reliable identified, mapped, and protected.
SA	Accidental in the state or province.
SR	Reported to occur in the state or province, but unverified.
S?	Unranked. Some evidence that the species may be imperiled, but awaiting formal rarity ranking.
Notes: Where two numbers appear in a G or S rank (e.g., S2S3), the actual rank of the element falls between the two numbers.	

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