Ipomopsis polyantha (Rydberg) V. Grant (Pagosa ipomopsis): A Technical Conservation Assessment

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Author's Biography

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Cover Photo Credit

Ipomopsis polyantha (Pagosa ipomopsis). Photograph by the author.

Going West

Someday I shall go West,
Having won all time to love it in, at last,
Too still to boast.

But when I smell the sage,
When the long, marching landscape line
Melts into wreathing mountains,
And the dust cones dance,
Something in me that is of them will stir.

Happy if I come home
When the musk scented, moon-white gilia blows,
When all the hills are blue, remembering
The sea from which they rose.
Happy again,
When blunt faced bees carouse
In the red flagons of the incense shrub,
Or apricots have lacquered boughs,
And trails are dim with rain!

Lay me where some contented oak can prove
How much of me is nurture for a tree;
Sage thoughts of mine
Be acorn clusters for the deer to browse.
My loving whimsies — Will you chide again
When they come up as lantern flowers?

I shall be small and happy as the grass,
Proud if my tip
Stays the white, webby moons the spider weaves,
Where once you trod
Or down my bleaching stalks shall slip
The light, imprisoning dew.
I shall be bluets in the April sod!

Or if the wheel should turn too fast,
Run up and rest
As a sequoia for a thousand years!

Mary Austin

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *IPOMOPSIS POLYANTHA*

Status

Ipomopsis polyantha (Rydberg) V. Grant (Pagosa ipomopsis) is an extremely narrow endemic whose global distribution is limited to a 13-mile range on outcrops of Upper Cretaceous Mancos Shale in Archuleta County, Colorado. It is known from three occurrences in the vicinity of Pagosa Springs, Colorado, two of which consist of small population sizes. The total population size of *I. polyantha* is estimated to be between 2,246 and 10,526 plants. It is ranked globally critically imperiled (G1S1) by NatureServe and the Colorado Natural Heritage Program. *Ipomopsis polyantha* is a sensitive species in Region 2 of the USDA Forest Service and is included on the Bureau of Land Management Colorado State Sensitive Species List in the San Juan Field Office. It is not listed as threatened or endangered on the Federal Endangered Species List, but it is a former Category 2 species. It is currently being evaluated for candidate status under the Endangered Species Act.

Primary Threats

Observations and quantitative data have shown that there are several threats to the persistence of *Ipomopsis polyantha*. In order of decreasing priority these are residential and commercial development, livestock grazing, exotic species invasion, right-of-way management, effects of small population size, recreation, wildflower gathering, global climate change, and pollution. The entire global range of *I. polyantha* is planned for residential development in the Archuleta County Community Plan. *Ipomopsis polyantha* does not tolerate livestock grazing and is thus largely limited to highway rights-of-way. Given the serious nature of the threats to *I. polyantha*, it is among the most endangered species in Colorado.

Primary Conservation Elements, Management Implications and Considerations

All of the known occurrences of *Ipomopsis polyantha* reside on private land and in highway rights-of-way, and there are no protected occurrences. Opportunities for the conservation of *I. polyantha* are thus limited largely to the establishment of conservation easements. While there are no provisions for the conservation of *I. polyantha* in the Archuleta County Community Plan, the purchase of conservation easements is recommended in the plan and could be used as a conservation tool. Much of the occupied habitat has already been subdivided and is being rapidly developed, making it difficult to set aside a large area for *I. polyantha*. Therefore, actions on behalf of *I. polyantha* need to occur soon to prevent the complete loss of its habitat. If *I. polyantha* becomes listed as an endangered species, greater protection could be afforded to some occurrences, including those along federal highway rights-of-way. Introduction of an occurrence to a protected location as close to the known occurrences as possible will help to buffer this species from extinction.

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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), USDA Forest Service (USFS). *Ipomopsis polyantha* is the focus of an assessment because it is a sensitive species in Region 2. Within the National Forest System, a sensitive species is a plant or animal species 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 (USDA Forest Service 2002). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Ipomopsis polyantha* throughout its range, which is completely within 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, discussions of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere, and where these have been implemented, the assessment examines their success.

Scope of Assessment

This assessment examines the biology, ecology, conservation status, and management of *Ipomopsis polyantha* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although some (or majority) of the literature relevant to the species may originate from field investigations outside the region, this document places that literature in the ecological and social context of the central Rockies. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *I. polyantha* 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 it is placed 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 known publications, reports, and element occurrence records for *Ipomopsis polyantha* are referenced in this assessment, and all of the available experts on this species were consulted during its synthesis. All available specimens of *I. polyantha* were viewed to verify populations and to incorporate specimen label data. Specimens were searched for at the University of Colorado Herbarium (COLO), the Colorado Statue University Herbarium (CS), the Rocky Mountain Herbarium (RM), the San Juan College Herbarium (SJNM), the Carter Herbarium (CC), the Great Sand Dunes National Park Herbarium, the University of Northern Colorado Herbarium (GREE), the New Mexico State University Range Science Herbarium (NMCR), and the University of New Mexico Herbarium (UNM). Specimen data available online and in publications and reports were also incorporated. This 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. Non-refereed publications and reports were regarded with greater skepticism than refereed literature. Unpublished data (e.g., state natural heritage program records) were important in estimating the geographic distribution and contain the vast majority of the useful information known on *I. polyantha*. However, these data required special attention because of the diversity of persons and methods used to in their collection. Because basic research has not been conducted on many facets of the biology of *I. polyantha*, literature on its congeners was used to make inferences.

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.

Treatment of this Document as a Web Publication

To facilitate use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More 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 their release on the Web. This assessment was reviewed through a process administered by the Center for Plant Conservation, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Ipomopsis polyantha is a sensitive species in USFS Region 2 (USDA Forest Service 2003). It is also listed on the Bureau of Land Management (BLM) Colorado State Sensitive Species List in the San Juan Field Office (Bureau of Land Management 2000). NatureServe (2003) considers *I. polyantha* to be globally critically imperiled (G1), and because it is only found in Colorado, it is also considered critically imperiled (S1) by the Colorado Natural Heritage Program (Colorado Natural Heritage Program 2003). It is considered critically imperiled because it is known from only three occurrences, and only one of these has a large population size. It is also imperiled by residential and commercial development, livestock grazing, exotic species invasion, right-of-way management, recreation, wildflower gathering, global climate change, and pollution. For explanations of NatureServe's ranking system, see the Definitions section of this document. It is not listed as threatened or endangered on the Federal Endangered Species List, but it is currently being evaluated for candidate status under the Endangered Species Act (Mayo personal communication 2004). *Ipomopsis polyantha* is a former Category 2 species (Anderson 1988, O'Kane 1988).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

No management plans have been drafted that specifically address the conservation needs of *Ipomopsis polyantha*. Potential Conservation Areas (PCAs) have been supplied to the San Juan National Forest (Lyon and Denslow 2002) and Archuleta County (Sovell et al. 2003) by the Colorado Natural Heritage Program to facilitate awareness of this species and its habitat by planners and land managers during planning and management activities. PCAs are an estimate of the primary area supporting the long-term survival of targeted species and plant communities, based on an assessment of the biotic and abiotic factors affecting the persistence and population viability of the targets within the area. The descriptions of PCAs include a discussion of the management and protection needs for maintaining the presence of the target species within them (see Appendix A).

The Archuleta County Community Plan (Archuleta County 1999) does not include any provisions for the conservation of *Ipomopsis polyantha*. Although there has been some local publicity of *I. polyantha* (Isberg 1992), no participants in the planning process were aware of this species (Miller personal communication 2003). Thus far no group or agency has assumed a leadership role in advocating the conservation of *I. polyantha*. The Colorado Rare Plant Technical Committee is planning to engage local stakeholders in meetings to discuss the conservation needs of *I. polyantha* (Lyon personal communication 2004).

Adequacy of current laws and regulations

Ipomopsis polyantha has no legal protection unto itself that would prevent the destruction of habitat or individuals. Because it is designated sensitive in USFS Region 2, the regional forester must give consideration to this species so as to maintain its habitat and population persistence (see USDA Forest Service Document 2600). As of this writing, a conservation strategy has not been written for this species at a national or regional level by the Forest Service or any other federal agency.

Although *Ipomopsis polyantha* is currently protected as a sensitive species by the USFS and the BLM, it is not currently known from public lands administered by these agencies. Thus, the known occurrences do not garner any protection under these designations. There are no laws in place that protect this species on private lands, where much of the known population resides. Occurrences in rights-of-way owned or managed by the Colorado Department of Transportation are also not explicitly protected under any known regulations or mandates. Thus, current laws and regulations protecting this species are clearly inadequate to effectively conserve the species within its native range. Given current human population growth trends and land use plans within the entire global range of this species, extinction within the foreseeable future is a very real possibility. The affinity of this species to some types of periodic anthropogenic disturbance, however, might allow it to persist in waste places for some time. Some occurrences have certainly been extirpated in the Pagosa Springs area as the size and population of the town have increased (Anderson 1988, Collins 1995, Sovell et al. 2003). Changes in existing land use plans are needed to ensure the long-term viability of occurrences. Establishing legal protections that pertain to private land, such as federal listing under the Endangered Species Act as recommended by Anderson (1988) and O'Kane (1988), might also confer protection needed to ensure the long-term persistence of *I. polyantha*. However, even this protective measure would not guarantee the protection of occurrences on private land since it only protects occurrences on private land that are affected by federally permitted or funded projects.

Several retailers have expressed interest in constructing a "big box" retail store within the known extent of the population of *Ipomopsis polyantha* (Allen personal communication 2004, Brinton personal communication 2004), but the town of Pagosa Springs currently has a moratorium on the construction of such stores (Allen personal communication 2004). No formal environmental impact statement or other National Environmental Policy Act considerations are required when building permits are issued, so this moratorium may be the strongest current means of protecting a portion of the known population. If development plans require the modification or addition of public infrastructure, an environmental review is required in which consideration may be given to *I. polyantha* (Allen personal communication 2004). However, the degree to which habitat and individuals would benefit from this process is unclear.

Adequacy of current enforcement of laws and regulations

There have been no known cases in which an occurrence of *Ipomopsis polyantha* was extirpated due to the failure to enforce any existing regulations. However, this does not necessarily indicate that current regulations or their enforcement are adequate for its protection. Human impacts, including residential development, have probably diminished the distribution and abundance of this species. Existing legal protections that apply to this species pertain only to occurrences residing on land owned by the USFS and BLM, but it is currently known only from private land and highway rights-of-way. Thus, there are currently no enforceable laws or regulations that confer any protection to occurrences of this species on private, state, or other federal lands.

Biology and Ecology

Classification and description

Ipomopsis polyantha (Rydb.) V. Grant (referred to variously as Pagosa ipomopsis, Pagosa gilia, Pagosa trumpet gilia, Pagosa skyrocket, and Archuleta County standing cypress) is a member of the Polemoniaceae. The Polemoniaceae is a small, monophyletic family with approximately 379 species in three subfamilies, eight tribes, and 26 genera (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) and has diversified greatly over the past 20 million years (Grant and Grant 1965). The family Polemoniaceae is in class Magnoliopsida (dicots), subclass Asteridae, order Solanales (USDA Natural Resources Conservation Service 2003). The family Polemoniaceae is most diverse in western North America (Heywood 1993, Zomlefer 1994), with the center of species diversity in California where approximately half (180 species) of all species in the family reside (Patterson 2002). Along with the Apiaceae and the Brassicaceae, it has proven difficult to confidently circumscribe genera within the Polemoniaceae due to morphological similarities among the species (Dorn 2003).

The genus *Ipomopsis* was first described in 1803 by André Michaux to include what is now known as *I. rubra* (Michaux 1803 as cited in Grant 1956). However, as Polemoniaceous species were described from North

America, other members of what are now included in *Ipomopsis* were placed most often in *Gilia*. *Gilia* has historically been one of the more enigmatic genera of Polemoniaceae. It is a classic example of a "garbage can" genus, where taxa that did not fit well into other genera were placed (Porter personal communication 2002). In most early 20th century floras, *Ipomopsis* was treated as a section within the genus *Gilia*. The most widely adopted concept of the genus *Ipomopsis* was circumscribed by Grant (1956) when he moved all members of the *I. aggregata* complex into the genus from *Gilia*. Most modern treatments of the Polemoniaceae follow this circumscription, as there is now considerable morphological and molecular phylogenetic evidence to support the treatment of *Ipomopsis* at the generic level (Grant 1956, Porter and Johnson 2000, Dorn 2003). The differing base chromosome number of *Gilia* and *Ipomopsis* also supports the recognition of *Ipomopsis* as a separate genus (Grant 1959). However, some notable contemporary sources (e.g., Cronquist et al. 1984) treated all *Ipomopsis* species within *Gilia*. Grant (1992) placed the genus *Ipomopsis* in the tribe Gileae with *Gilia*, *Eriastrum*, and *Langloisia*. However, based on a robust analysis of morphological and molecular gene sequence data, Porter and Johnson (2000) include *Ipomopsis* within the newly circumscribed tribe Loeseliae (Porter and Johnson 1998), which excludes *Gilia*. In a further revision of *Ipomopsis* presented in Porter et al. (2003), chloroplast and nuclear DNA sequence data suggest that *Ipomopsis* as circumscribed by Grant (1956) is well supported, but it is only monophyletic if four species are removed. As circumscribed by Grant (1956), *Ipomopsis* contains 27 species.

Within the genus *Ipomopsis*, Grant (1956, 1959) included *I. polyantha* in section *Phloganthea*, which he circumscribed based on morphological characters. Using nuclear and chloroplast DNA sequences, Porter et al. (2003) have now shown section *Phloganthea* to be polyphyletic and have relocated its component species in other sections. *Ipomopsis polyantha* is placed in section *Ipomopsis*, the largest section in the genus (Porter et al. 2003).

There has been some uncertainty regarding the taxonomic status of plants described as *Ipomopsis polyantha*. Two other taxa have been included within *I. polyantha* as synonyms or as varieties, and some current literature, including the PLANTS National Database (USDA Natural Resources Conservation Service 2003), still cite them as such. These taxa are *Gilia polyantha* var. *brachysiphon* and *G. polyantha* var. *whitingii* (Kearney and Peebles 1943). *Gilia polyantha* var. *brachysiphon* was first described as *G. brachysiphon* by Wooton and Standley (1915) from the Organ Mountains in southwestern New Mexico. *Gilia brachysiphon* has corolla lobes about equaling the tube, with a short tube that is not exserted from the calyx, apparently lacking the purple spots seen in *I. polyantha* (Wooton and Standley 1915). *Gilia brachysiphon* is included as a synonym of *I. multiflora* (Nutt.) V. Grant in *A Flora of New Mexico* (Martin and Hutchins 1980). *Gilia polyantha* var. *whitingii* was described by Kearney and Peebles (1943) from a specimen collected in the Grand Canyon in Arizona, and it is included as such in their *Arizona Flora* (Kearney and Peebles 1960). It has a pale violet corolla and narrow, oblanceolate lobes, whereas *I. polyantha* has a whitish corolla with purple spots and broader corolla lobes (**Figure 1** and **Figure 2**).

Recent taxonomic research suggests that neither *Gilia brachysiphon* (Wilken 1995) nor *G. polyantha* var. *whitingii* (Wilken 1995, Porter et al. 2003, Porter personal communication 2003) should be treated as infraspecific taxa under *Ipomopsis polyantha*. In a letter to Christine Collins, a master's student who did her research on *I. polyantha*, Dr. Dieter Wilken (1995) suggests that *brachysiphon* and *whitingii* are "nothing more than local, intergrading races of *I. multiflora* and probably don't deserve taxonomic status at all." However, Dr. J. Mark Porter (personal communication 2003) believes that *whitingii* should be regarded as a full species due to its distinctness from *I. multiflora* and *I. polyantha*. Porter et al. (2003) included *whitingii* (but not *brachysiphon*) in their phylogenetic analysis of *Ipomopsis*, and it does not appear closely related to *I. polyantha*. Thus, in both cases the most up-to-date sources available suggest that the distinctness of *I. polyantha* at the full species level has been verified. Conflicting information among many sources is likely to be confusing until a published revision of the taxonomy of this species and its relatives is available. Resolving taxonomic issues for rare species is fundamental to their protection (Standley 1992).

The closest relative to *Ipomopsis polyantha* is apparently *I. sancti-spiritus*, a federally listed, narrowly endemic species known from a single valley in New Mexico (Porter personal communication 2003, Porter et al. 2003). While somewhat of a surprise, this result is well supported by molecular data (Porter personal communication 2003).

Figure 1. The flowers of *Ipomopsis polyantha*, showing the diagnostic spots on the corolla (photograph by the author).

Figure 2. *Ipomopsis polyantha* (photograph by Bob Clearwater, provided by Sara Brinton and used with permission).

Contemporary sources cite this species as *Ipomopsis polyantha*. This name is used in this report to conform to the treatment of Kartesz (1999) used as a nomenclatural standard by the Network of Natural Heritage Programs (NatureServe 2003) and by the PLANTS database (USDA Natural Resources Conservation Service 2003). *Ipomopsis polyantha* is a distinctive element of the flora of Colorado.

History of knowledge

Ipomopsis polyantha was discovered in 1899 by Charles Fuller Baker who collected it on a trip to southwestern Colorado. Baker did not make a practice of numbering his specimens (Ewan and Ewan 1981), but he sent this specimen to Edward Lee Greene who probably numbered it. On the same trip Baker also collected the type specimen for *Lesquerella pruinosa*, another narrow endemic species that is sympatric with *I. polyantha* (Anderson 1988). *Ipomopsis polyantha* was formally described in 1904 by Per Axel Rydberg as *Gilia polyantha* (Rydberg 1904). In the following year, Aven Nelson described this species as *G. exserta* based on the same specimen (538) collected by Baker (Nelson 1905). Nelson (1905, p. 65) writes "The type...was distributed on Greene's determination as *G. multiflora* Nutt., which it certainly cannot be. It seems nearer *G. stenothyrsa* Gray of the section Giliandra." However, in his revision of Coulter's Manual of the Botany of the Rocky Mountain Region (Coulter 1885), it is added as *G. polyantha* Rydb. (Coulter and Nelson 1909). Despite Nelson's comments, Brand (1907) included it in his monograph of the Polemoniaceae as *G. multiflora* var. *polyantha* (Rydberg) A. Brand.

From the time of its discovery until the mid-1980s when it was documented in threatened and endangered species survey work, *Ipomopsis polyantha* was only collected nine times, all from the occurrence in the vicinity of Pagosa Springs extending south along Highway 84. In 1985, John Anderson, Steve O'Kane, and Barry C. Johnston discovered a small occurrence about ten miles west of Pagosa Springs at Dyke (Anderson 1988). Another small occurrence was discovered about 1.2 miles to the east of the occurrence at Pagosa Springs in 2002 near Mill Creek by Peggy Lyon (Colorado Natural Heritage Program 2003, Lyon personal communication 2003, Sovell et al. 2003). Please see **Table 1** for herbarium specimen label data for all the known specimens.

In 1985, *Ipomopsis polyantha* became a candidate for listing as threatened or endangered (Category 2). In 1988, John Anderson wrote a status report for *I. polyantha* for the U.S. Fish and Wildlife Service, and O'Kane published *Colorado's Rare Flora* (O'Kane 1988), which included *I. polyantha*. At this time *I. polyantha* became better known to the botanical community, and awareness of its imperilment was raised. In 1991, Christine Collins, a graduate student at California State University in Fullerton, began a study of the natural history and reproductive biology of this species. Her research is the only serious work of this sort that has been done on *I. polyantha*, and is thus relied upon heavily for the Reproductive biology and autecology section of this species assessment.

Drs. J. Mark Porter, Leigh Johnson, and Dieter Wilken are currently using DNA sequences (of both nuclear and chloroplast DNA) to estimate phylogenetic relationships within *Ipomopsis*. This ongoing research will add further refinements to our understanding of the relationships within the Polemoniaceae (Porter personal communication 2003). The only other cladistic analysis involving *I. polyantha* was a taxonomic revision of the *I. spicata* complex by Wilken and Hartman (1991) in which *I. polyantha* was an outgroup.

Non-technical description

Anderson (1988, p. 3) described *Ipomopsis polyantha* as follows: "Herbaceous perennial or possibly biennial (monocarpic) up to 30 to 60 cm (12 to 24 inches) tall, branched from near the base, with grayish deeply divided leaves with linear leaflets scattered up the stem. The inflorescences occur along the stem in the axils of the leaves as well as at the top of the stem. The white flowers may be flecked with purple dots and have short tubes with flaring lobes." These dots are occasionally so dense as to give the flower a pinkish or purplish hue (Colorado Natural Heritage Program 2003). The corolla is 10 mm long with a short throat (4.5 to 6.5 mm) and flaring lobes. The stamens are noticeably exserted (**Figure 1**; Harrington 1954, Weber and Wittmann 2001). All members of *Ipomopsis* have tubiform or salverform flowers (Grant 1956, Grant 1959).

Ipomopsis polyantha is not difficult to distinguish from four other congeners in the area, none of which are known to co-occur with it. *Ipomopsis longiflora* has long tubular flowers, whereas *I. polyantha* has short tubular flowers. The nearest known occurrences of *I. longiflora* are near La Plata, New Mexico and in several localities in the San Luis Valley near Alamosa (Wilken 2001, Wilken personal communication 2003). *Ipomopsis multiflora* is known from the Conejos River Valley to the east of Pagosa Springs and from areas

Table 1. Summary of specimen label data for *Ipomopsis polyantha*.

County	Elevation	Date	Precision*	Collectors	Collection Number	Herbarium**	Habitat, Location, and Notes
Archuleta	Unknown	July 28, 1899	G	C.F. Baker	538	NY	Pagosa Springs [Holotype].
Archuleta	Unknown	July 2, 1917	G	E. Bethel	7683	RM, CS	Pagosa Springs.
Archuleta	Unknown	June 29, 1920	G	E. Bethel	s.n.	CS	Pagosa Springs.
Archuleta	2,160 m (7,086 ft)	June 30, 1921	G	E. Bethel, F.S. Willey, and I.W. Clokey	4251	RM, UC	Hillsides, Pagosa Springs.
Archuleta	7,000 ft	July 20, 1943	G	B.H. Smith	23	UC	Pagosa Springs.
Archuleta	Unknown	June 20, 1951	G	W.A. Weber and C.F. Livingston	6334	RM, CS, UC	Grassy hills southeast of Pagosa Springs. On road to Chromo.
Archuleta	6,900 ft	June 13, 1956	M	H.D. Harrington	8242	CS	Dry open shaley slope 1 mile southeast of Pagosa Springs. Flowers white.
Archuleta	7,000 ft	June 14, 1967	M	H.D. Harrington	9981	CS	Open roadside 2.4 miles south of junction of US 84 and US 160, SE of Pagosa Springs. Flowers pale pink with rose-colored spots.
Archuleta	~2,170 m (7,119 ft)	July 3, 1970	M	Higgins	3574	BRY	1 mile south of Pagosa Springs along Highway 84, gravelly soil, pine-oak community.
Archuleta	2,170 m (7,119 ft)	June 5, 1985	S	S. O'Kane	2079	RM, CS	Corolla white with pink and purple spots; scarce on disturbed roadside with *Bromus* spp., *Hymenoxys* spp., *Trifolium* spp., and *Linum* spp. 1.2 mile south of junction of Highway 160 and 84.
Archuleta	2,097 m (6,880 ft)	June 5, 1985	S	S. O'Kane	2077	RM (2 copies), CS, UC	Corolla white with purple dots; on gray clay of Mancos Shale with *Townsendia* spp., *Oryzopsis* spp., *Chrysothamnus* spp., and *Chaenactis* spp. 0.2 mile east of Dyke.
Archuleta	2,165 m (7,103 ft)	June 5, 1985	S	S. O'Kane with J. Anderson	2081	SC, UC	Corolla white with purple spots; rare on decomposed Mancos Shale with *Oryzopsis* spp., *Trifolium* spp., and *Bromus* spp. 2.3 miles south of Pagosa Springs along Highway 84.
Archuleta	2,164 m (7,100 ft)	June 10, 1988	S	J. Anderson	88-51	UC	East end of Pagosa Springs at junction of Highways 160 and 84. Occurrence extends for 2.7 miles south from juction along Highway 84, approximately 2,000 plants.
Archuleta	2,164 m (7,100 ft)	June 8, 1993	S	W.F. Jennings	9319	KDH	On black clay/shale roadcut. West side of US 84, 0.6 miles south of junction with US 160 at east edge of Pagosa Springs, opposite real estate office, seen scattered on roadcuts for next 3 miles south.
Archuleta	Unknown	Unknown	Unknown	V. Grant and Latimer	9468	RSA	Pagosa Springs.

***:** G = general record (exact location cannot be determined); M = minutes record (location known within approximately 1 square mile); S = seconds record (precise location known).

****:** RM = Rocky Mountain Herbarium; CS = Colorado State University Herbarium; UC = University of Colorado Herbarium; KDH = Kathryn Kalmbach Herbarium; BRY= Brigham Young University; NY= New York Botanical Garden; RSA = Rancho Santa Ana Botanical Garden.

to the south in New Mexico. *Ipomopsis multiflora* and var. *whitingii* are both distinguished from *I. polyantha* by their more spreading habit with stems that curve upward in a decumbent fashion, versus the more upright habit of *I. polyantha* (Wilken personal communication 2003). The corollas of *I. multiflora* and var. *whitingii* are slightly bilateral, with dorsal petals slightly larger than the ventral petals, unlike that of *I. polyantha* which is more radially symmetrical (Wilken personal communication 2003). The white flowers of *I. polyantha* distinguish it from the common *I. aggregata*, which has bright scarlet red flowers and is also found in Archuleta County (Anderson 1988, University of Colorado Herbarium 2003).

Published descriptions and other sources

The best single source for a description, illustration, and photographs of *Ipomopsis polyantha* and its habitat is the *Colorado Rare Plant Field Guide* (Spackman et al. 1997). The illustration and habitat photograph from this document are included in this assessment (**Figure 3** and **Figure 4**). Photographs and a range map are also included in *Rare Plants of Colorado* (Colorado Native Plant Society 1997). The illustration of *Gilia polyantha* var. *whitingii* on page 125 of *Intermountain Flora* Volume 4 (Cronquist et al. 1984) is a very good rendition of the species *sensu stricto*; even the flowers in this illustration are more representative of those of *I. polyantha* than those of *G. polyantha* var. *whitingii* (Wilken personal communication 2003). A good description can be found in *Manual of the Plants of Colorado* (Harrington 1954). The original description is found in Rydberg (1904), and additional descriptions are available in floras (Rydberg 1907, Coulter and Nelson 1909, Rydberg 1922). Weber and Wittmann (2001) is the most readily available and up-to-date source with keys for field identification, but it does not include a full description. Photographs of the plant and its habitat are included in Anderson (1988) and Collins (1995), but these sources are not easily obtained. A digital image of Baker's holotype specimen can be obtained online from the New York Botanical Garden's Web site (New York Botanical Garden 2003).

Distribution and abundance

Ipomopsis polyantha is an extremely narrow endemic known only from Archuleta County, Colorado (**Figure 5**). Its global distribution is limited to private land and highway rights-of-way in the vicinity of the towns of Pagosa Springs and Dyke (**Figure 6**). The three known occurrences are in the vicinity of Mill Creek (Pagosa Springs and Mill Creek East occurrences) and Stollsteimer Creek (Dyke occurrence). All of the known occurrences are within 13 miles of each other and collectively occupy approximately 571.5 acres (Colorado Natural Heritage Program 2003). A small portion of the Dyke occurrence may extend onto adjacent public land managed by the BLM. However, almost all of the individuals in this occurrence are found in a narrow strip at the base of a hill within the highway right-of-way (Anderson 1988, Colorado Natural Heritage Program 2003).

Ipomopsis polyantha grows among the southern foothills of the San Juan Mountains drained by the San Juan River and some of its tributaries (Anderson 1988). It is limited to exposures of the Mancos Formation. The elevation range of *I. polyantha* is 6,800 to 7,300 feet. Please see **Table 2** for summary data on the three known occurrences.

There have been many botanical surveys targeting this species (e.g., Anderson 1988, Collins 1995, Lyon and Denslow 2002, Sovell et al. 2003). While these surveys have led to the discovery of the two additional small occurrences, they have not found other large occurrences. However, there is much potential habitat that remains to be searched (Anderson personal communication 2003). Limited access to private land has made it difficult to thoroughly search areas within the known distribution of *Ipomopsis polyantha*. While it is possible that this species is limited to the range as we know it, further focused inventory work is necessary to verify this (Anderson personal communication 2003).

There are several erroneous or misleading reports in the literature regarding the distribution of *Ipomopsis polyantha*. Rydberg's (1907) report of *I. polyantha* from Hotchkiss in Delta County, Colorado was based on misidentifications of *Gilia pinnatifida* (Wilken personal communication 2003).The state distribution of *I. polyantha* is misreported by the PLANTS National Database (USDA Natural Resources Conservation Service 2003). Arizona and New Mexico are included because two infraspecific taxa, var. *whitingii* and var. *brachysiphon*, are synonymized with *I. polyantha* by this source. The most recent taxonomic research does not support the treatment of these entities as infraspecific taxa under *I. polyantha* (Porter et al. 2003) (see the Classification and description section of this document for details).

There has been no rigorous quantification of the population size of *Ipomopsis polyantha*. It is known from three occurrences, but the vast majority of the population is found in one occurrence (**Table 2**). The

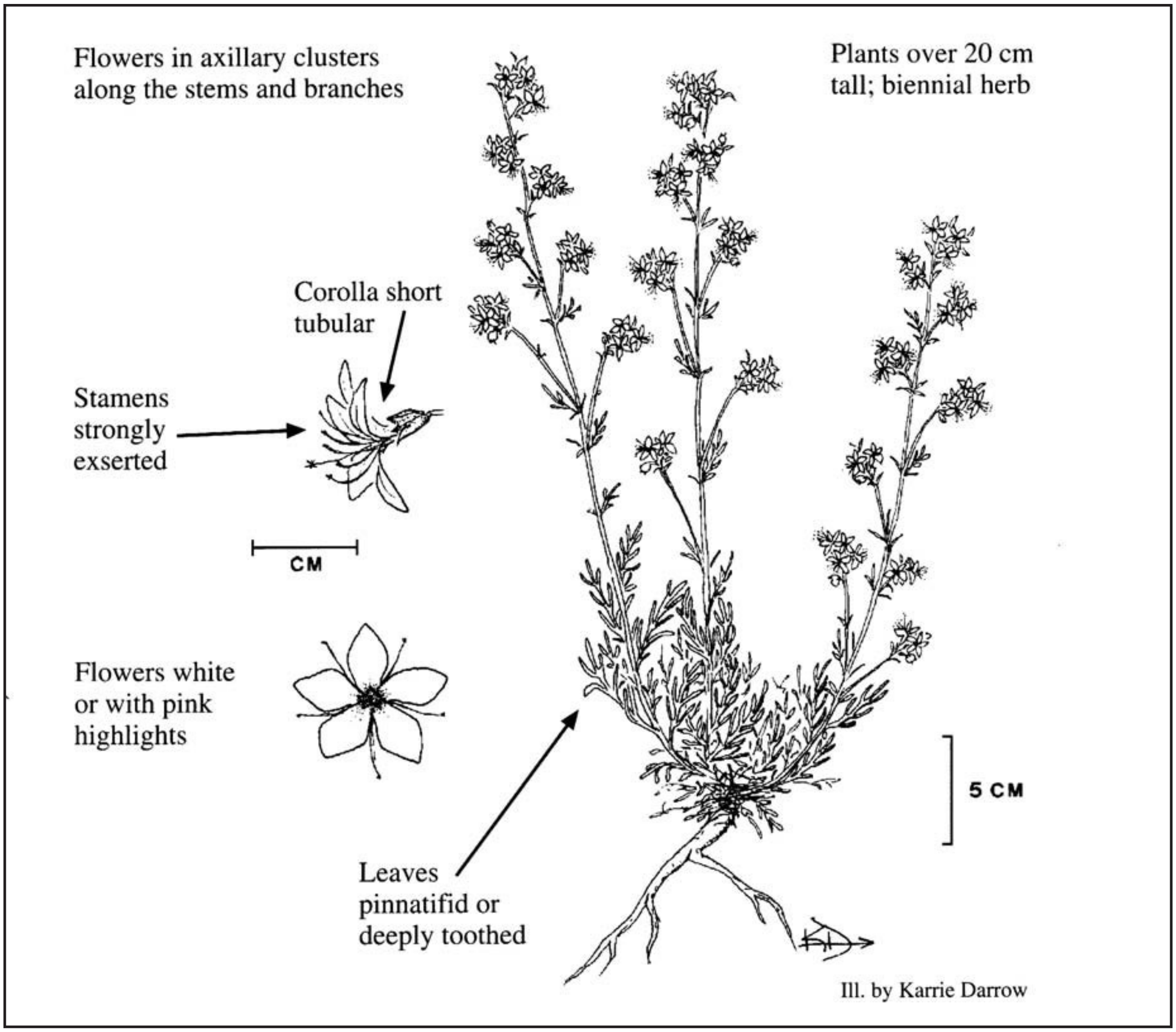

Figure 3. Illustration of *Ipomopsis polyantha* showing useful diagnostic characters (from Spackman et al. 1997).

Figure 4. Habitat of *Ipomopsis polyantha* (photograph by Bill Jennings, used with permission).

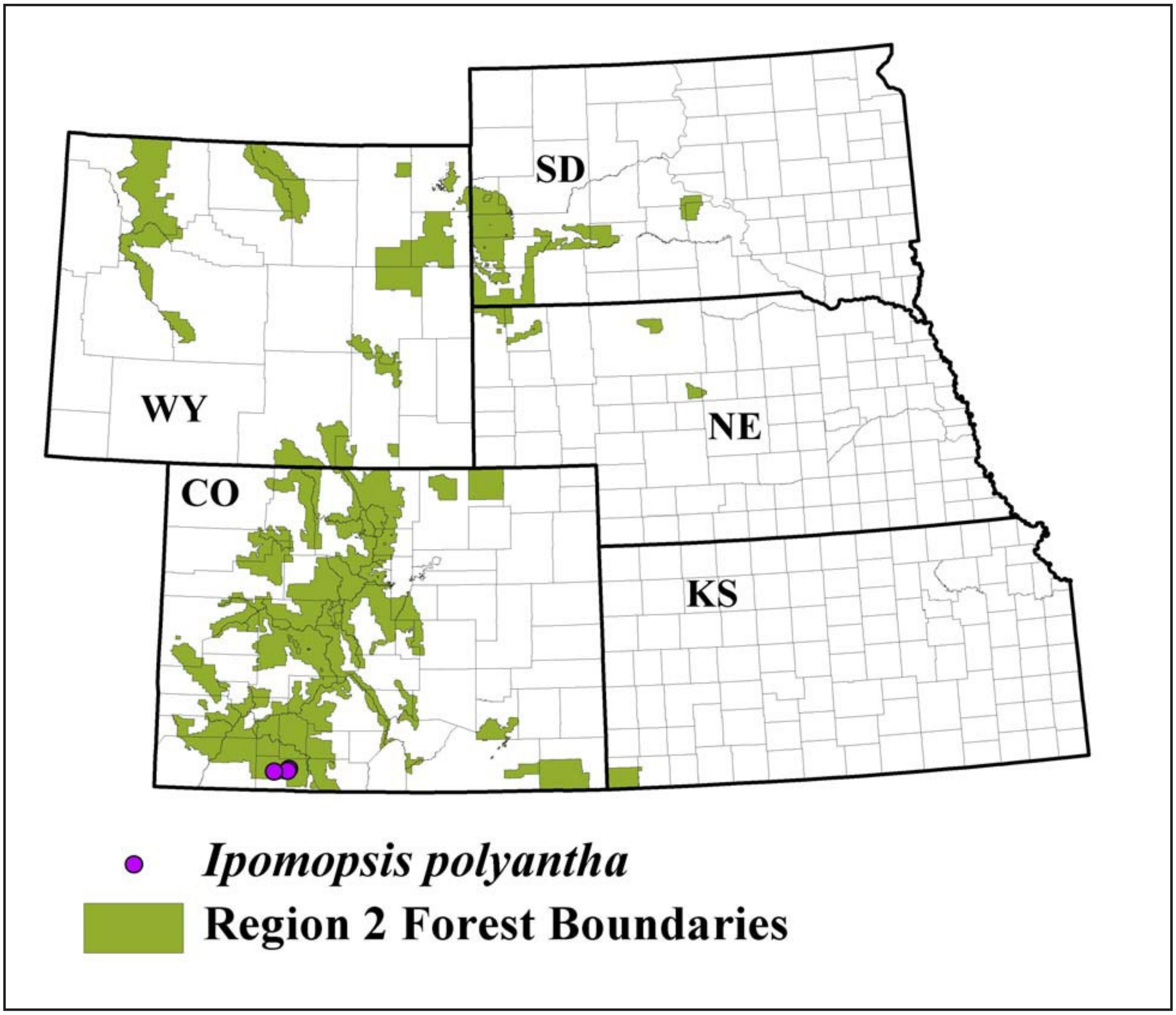

Figure 5. Global distribution of *Ipomopsis polyantha* relative to the USFS Region 2 forest and grassland boundaries and the states of Region 2.

largest occurrence is found just east of the town of Pagosa Springs. Population estimates for the Pagosa Springs occurrence range from 2,000 mature flowering plants (Anderson 1988, Colorado Natural Heritage Program 2003) to 10,000 or more plants (Brinton personal communication 2003). Population sizes of the other two occurrences are much lower. The occurrence at Dyke has been estimated to contain between 120 (Colorado Natural Heritage Program 2003) and 500 or more mature flowering plants (Anderson 1988). However, efforts to find plants at Dyke in 2004 were not successful (Lyon personal communication 2004, Mayo personal communication 2004). At the Mill Creek East occurrence 126 individuals were counted in 2002 (Colorado Natural Heritage Program 2003). In a brief survey on July 5, 2004, Al Pfister of the U.S. Fish and Wildlife Service found 282 plants at 12 locations along Highway 84 (Mayo personal communication 2004). Approximately 75 percent of the known population is found on highway rights-of-way, with the remaining 25 percent on private land (Brinton personal communication 2004). This species has not been found to date on USFS land.

Within the large occurrence of *Ipomopsis polyantha*, its distribution is discontinuous, due largely to fragmentation of its habitat and to the various disturbances imposed on the habitat. Anderson (1988, p. 8) wrote "*I. polyantha* occurs in discontinuous colonies...on open shale or forested areas, above intervening swales and creeks with wetlands. Because of its apparent sensitivity to surface disturbance or overgrazing, it is primarily restricted to weedy roadsides and fenced rights-of-ways, but sometimes extends into

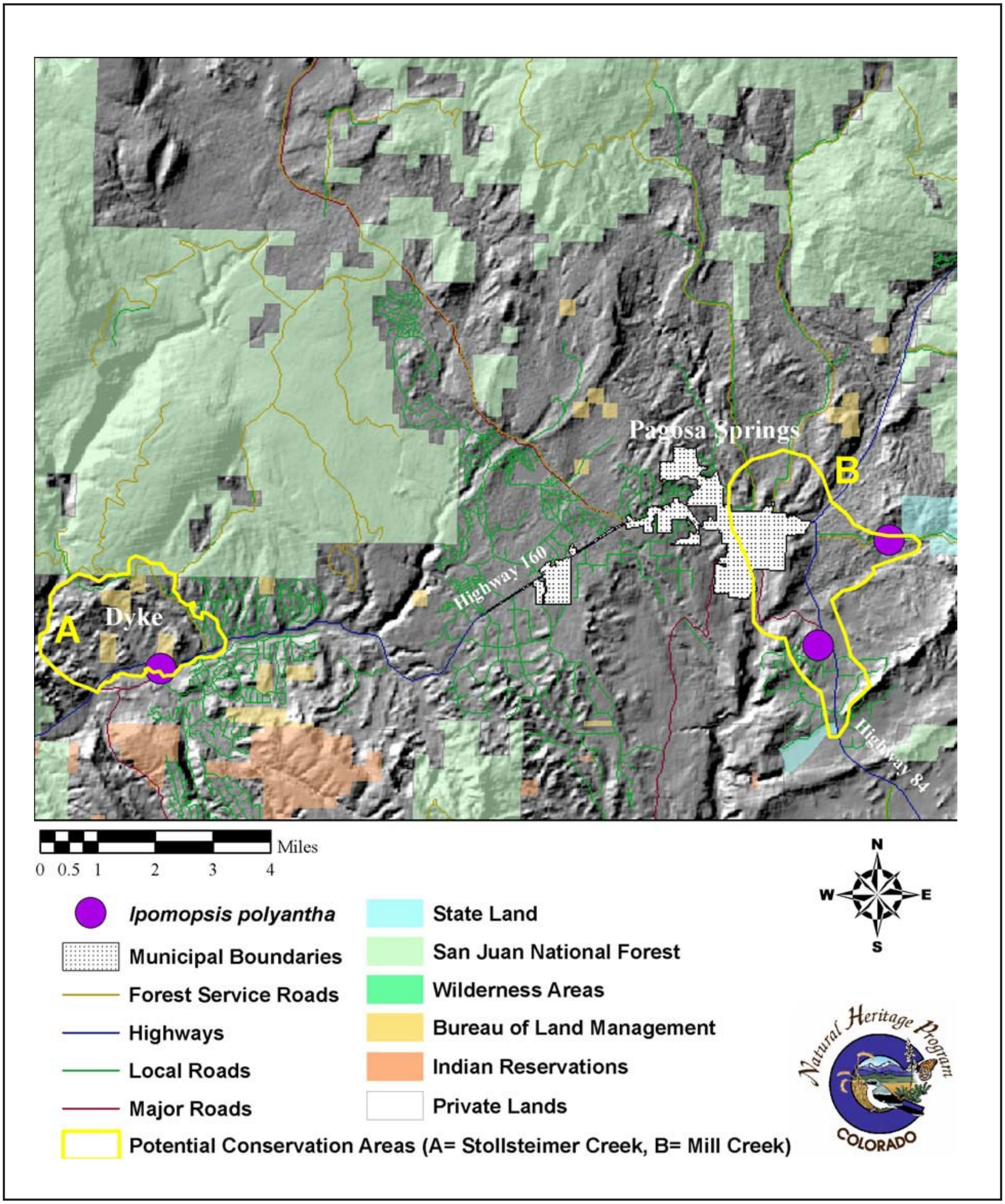

Figure 6. Global distribution of *Ipomopsis polyantha* showing relationship to physiographic features, municipalities, roads, land ownership, and potential conservation areas.

Table 2. Summary data on the three known occurrences of *Ipomopsis polyantha*.

Name	CNHP EO number*	Area (acres)	Area (hectares)	Estimated population number	Elevation (ft)
Mill Creek East	4	1.7	.7	126	7,280
Pagosa Springs	1	563.2	227.9	2,000 to 10,000+	7,100 to 7,300
Dyke	3	6.6	2.7	120 to 500+	6,800 to 6,880
Totals	—	571.5	231.3	2,246 to 10,526+	6,800 to 7,300

***:** Colorado Natural Heritage Program Element Occurrence Number (Colorado Natural Heritage Program 2003).

its more natural habitat of undisturbed vegetation inside of the fence." It is also found in residential areas, pastures, and vacant lots (Sovell et al. 2003), and on road cuts, around buildings, and around junked cars at a car repair garage (Anderson 1988).

Two hypotheses have been offered by Grant and Wilken (1986, 1988) to explain the diversification of *Ipomopsis aggregata* and its allies. One suggests that dispersal led to allopatric populations that diversified through speciation and genetic drift. Another hypothesis suggests that a widely distributed common ancestor had a somewhat continuous distribution in the cool, moist phases of the Pleistocene. The distribution of this ancestor then became discontinuous following mountain orogeny, formation of canyons, and contraction of its habitat, leading to divergence and speciation within the isolated populations and an increase in the diversity of the genus in Colorado, New Mexico, and Arizona.

Population trend

There are no quantitative data that could be used to infer the population trend of *Ipomopsis polyantha*. Population size estimates presented in **Table 2** are rough, and there has been no population monitoring that could provide insight into population trend. Human impacts to individuals and habitat for *I. polyantha* resulting from the establishment, growth, and development of Pagosa Springs strongly suggest that there has been a downward trend. Loss of habitat and anthropogenic disturbance of remaining habitat has probably caused a downward trend since the area was settled 120 years ago. No plants were observed at the known location at Dyke in 2004 (Mayo personal communication 2004), suggesting a downward trend, or possibly extirpation, at this location.

Population sizes are likely to fluctuate naturally due to annual climatic variation. As a stress-tolerant species, it is likely that while drought probably reduces or eliminates recruitment of seedlings, juvenile plants (rosettes) are probably capable of surviving one or more bad years. In favorable years, large numbers of plants have been observed to flower (Brinton personal communication 2003). This makes it difficult to assess the population size accurately in any given year because without rigorous census efforts there appear to be more plants in favorable years due to profuse flowering. Wilken (1996) describes census methods for *Ipomopsis aggregata* that apply to *I. polyantha* as well.

It is possible that *Ipomopsis polyantha* once ranged more widely than it does now (Anderson 1988, Collins 1995). Its extremely limited range now is suggestive of a relict species whose range has been diminished by habitat contraction. Outcrops of the highly erosive Mancos Shale substrates to which it is endemic might have ranged more widely in the past. There are currently no data suggesting that *I. polyantha* has a disjunct range. It is separated by approximately 125 miles from its nearest relative, *I. sancti-spiritus*.

Habitat

Ipomopsis polyantha is apparently restricted to Mancos Shale (Anderson 1988, Collins 1995, Colorado Native Plant Society 1997, Spackman et al. 1997). These soils are heavy, gray, fine-textured, and clayey (Anderson 1988, O'Kane 1988). They have been noted as "gravelly" on one herbarium specimen (Higgins 3574). In areas near Pagosa Springs, Colorado Native Plant Society (1997, p. 24) notes that "Mancos Shale does not weather completely into a gray mush, but retains small rock fragments. Here, shrubs such as rabbitbrush (*Chrysothamnus* spp.) not usually found on heavy clays can survive." Mancos Shale occurs in a wide swath through the center of Archuleta County from northwest to southeast (Tweto 1979), but all of the known occurrences of *I. polyantha* are found in soils derived from Mancos Shale formed in the late (Upper) Cretaceous Period (Bauer 1981, Collins 1995). Outcrops of this substrate form a narrow band that extends from Durango to Pagosa Springs, and curves north into Hinsdale County and south through Pagosa Springs and into New Mexico (Tweto 1979).

Soils derived from the weathering of Mancos Shale are included within the Winifred series (Bauer 1981). The Pagosa-Winifred soils are deep, moderately well-drained or well-drained, and fine textured. The pH of Winifred soils is close to neutral to slightly alkaline (6.6 to 8.4) (Collins 1995) and probably well-buffered. This contrasts with other soils in the Pagosa area that were not derived from Mancos Shale (referred to as "Pagosa area soils" but no location or soil series is cited) and that are somewhat acidic (5.1 to 6.0) (Collins 1995). It is possible that *Ipomopsis polyantha* is a calciphile that will take up toxic levels of phosphorus in slightly acidic soils as described by Musick (1976) for *Larrea divaricata* (creosote bush). This may be partially responsible for the restricted range of *I. polyantha* (Collins 1995).

Anderson (1988) cites the following soil map units for occurrences of *Ipomopsis polyantha*. Soils for the occurrences at Pagosa Springs and Dyke occur in alluvium derived from shale and sandstone, composed of Work silty clay loam (3 to 12 percent). Soils at the Pagosa Springs occurrence also contain Yawdim clay (3 to 25 percent) in residuum and local alluvium. These soils have are deficient in nutrients and have poor water retention properties (Collins 1995); any water that is retained is not readily available to plants.

Ipomopsis polyantha occurs in the Temperate Steppe Division of the Dry Domain in the Ecoregion classification of Bailey (1995). Within the Temperate Steppe Division, it is found on the margins of the Colorado Plateau Semidesert Province and the Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province.

Ipomopsis polyantha is found in a wide variety of vegetation types. Historically the area inhabited by *I. polyantha* was vegetated by shrubland, woodland, and forests, and it has been documented in all of these vegetation types. Much of the area in and around Pagosa Springs was historically a *Pinus ponderosa* (ponderosa pine) forest with an understory of *Quercus gambelii* (Gambel's oak; Sovell et al. 2003). *Ipomopsis polyantha* has been documented from *P. ponderosa*-dominated forests (Anderson 1988, Collins 1995, Colorado Division of Wildlife 1998), pinyon pine/juniper/oak scrub communities (Anderson 1988, Collins 1995, Spackman et al. 1997, Colorado Natural Heritage Program 2003), and a pine-oak community (Higgins specimen 3574). The remaining natural vegetation in the area is relatively dense compared to many locations on Mancos Shale, which are often barren (Colorado Native Plant Society 1997, Anderson personal communication 2003).

The definitions of high quality and marginal habitat are not clearly understood for *Ipomopsis polyantha*. Areas that have natural vegetation and minimal impact from human activities and that support dense occurrences would probably contain the best examples of high quality habitat. However, the specific locations of such sites are not known, and they may no longer exist. Although most occurrences have been documented from disturbed sites, Anderson (1988) stated that the highest densities were in the open *Pinus ponderosa* forests with montane grassland understory (presumably *Festuca arizonica* (Arizona fescue), and in the interspaces of a pine/juniper/oak community (Anderson 1988). However, there are few records of the species from within a forest or woodland, and there are no element occurrence records of dense occurrences in forest or woodland vegetation (Colorado Natural Heritage Program 2003). Documentation of sites that are relatively undisturbed by human intrusion is a high research priority for *I. polyantha*. Many observations (Collins 1995, Lyon and Denslow 2002, Colorado Natural Heritage Program 2003, Sovell et al. 2003) suggest that when *I. polyantha* is found associated with forests and woodlands, it is more often seen on the edges than within them; this is somewhat contradictory to the observations of Anderson (1988). Collins (1995) established study sites at the edge of a *P. ponderosa* forest and at the edge of a ponderosa pine/juniper/oak forest. The occurrence at Dyke is found primarily along the highway right-of-way, along the base of a hill adjacent to juniper/oak/ponderosa forest (Colorado Natural Heritage Program 2003). One source mentions that *I. polyantha* is often found under the canopy of *Chrysothamnus* spp. (rabbitbrush) (Colorado Native Plant Society 1997). **Figure 4** and **Figure 7** illustrate typical habitat for *I. polyantha*.

All known occupied habitat for *Ipomopsis polyantha* has been modified to some extent by human activities and management. While some of the natural vegetation remains, most of the habitat for *I. polyantha* has been converted to pastures or has been otherwise altered by residential development and road construction. Most of the documented occurrences are from areas that have been heavily impacted by human activities, such as weedy roadsides in fenced rights-of-way, roadcuts, vacant lots, pastures, and even around junked cars at a car repair garage (Anderson 1988, Collins 1995, Lyon and Denslow 2002, Sovell et al. 2003, Brinton personal communication 2003).

Figure 7. Habitat and surrounding area at the occurrence discovered in 2002 (photograph by Peggy Lyon, used with permission).

In general, habitats tend to be sites that have been disturbed at some point but are not severely disturbed. Brinton (personal communication 2003) has seen dense occurrences in unused pastures. *Ipomopsis sancti-spiritus*, the closest relative to *I. polyantha*, appears to have a similar tolerance or affinity for disturbance (U.S. Fish and Wildlife Service 2002), which may be related to the exclusion of more competitive species such as grasses in disturbed areas.

Ipomopsis polyantha is found predominantly on flat or gently sloping terrain such as the sides of drainages, but it is also found on hillsides and roadcuts (Anderson 1988). At the Mill Creek East location it is found on the south and west slopes of a small knoll (Colorado Natural Heritage Program 2003). It ranges from 6,800 to 7,300 feet in elevation.

From 1906 to 1998, annual rainfall reported in Pagosa Springs averaged 20.21 inches per year (Western Regional Climate Center 2003). It is relatively dry in the spring and early summer months (May and June) when *Ipomopsis polyantha* is most actively growing, but precipitation increases in July and August. Average maximum temperatures for May, June, and July are 68, 78, and 83 degrees Fahrenheit, respectively (Western Regional Climate Center 2003). Nighttime freezing temperatures occur frequently before June, and there is a 30 percent chance of them occurring in early July as well. Anderson (1988) reports a growing season of 100 days in five of 10 years, from June 9 to September 18. However, *I. polyantha* is clearly tolerant of periodic frost since it is actively growing in May (Collins 1995, Brinton personal communication 2003).

Pagosa Springs is situated near the west end of a valley underlain by shale and surrounded by Dakota and Mesa Verde sandstones (Chronic 1980). It is named after a cluster of hot springs south of the San Juan River; "Pagosah" is a Ute word for "healing waters" (Pagosa Springs Chamber of Commerce 2003). The water in these springs is rich in minerals, particularly silica. These minerals are precipitated around the springs and accumulate rapidly; the have even changed the course of the San Juan River (Chronic 1980). These minerals might have some influence on the soil chemistry of the surrounding area, but they are probably not responsible for the edaphic conditions to which *Ipomopsis polyantha* is adapted. There are other cases where a plant species such as the federally listed *Eriogonum ovalifolium* var. *williamsiae* (Steamboat buckwheat) is endemic to an area surrounding a single hot spring system (U.S. Fish and Wildlife Service 1995).

The full geographic distribution of suitable habitat for *Ipomopsis polyantha* may not be known. Many locations have been observed and searched repeatedly to no avail. Outcrops of Mancos Shale within the elevation range of *I. polyantha* are common in Archuleta County and throughout southwestern Colorado, yet *I. polyantha* is limited to a tiny portion of this formation. The results of seed germination experiments and pH measurements by Collins (1995) suggest that *I. polyantha* has very specific physiological requirements for germination and growth, and these might prevent its spread to other locations. However, it may also be dispersal limited, precluding its colonization of sites that are otherwise suitable. Reduction of its habitat through natural processes such as climate change and habitat contraction may also be responsible for its limited distribution. These hypotheses have been discussed (Anderson 1988, Collins 1995) but not investigated.

The area around Pagosa Springs has a long history of human use that has wrought formidable changes on the nature of the habitat for *Ipomopsis polyantha*. The hot springs at Pagosa were used by the Utes prior to European settlement of the area. In 1877 a toll road was constructed through the current site of the town, and lots were sold. In 1878 Fort Lewis was constructed to control the Utes, and municipal boundaries were established for the town of Pagosa Springs. The townsite included one square mile surrounding the hot springs. Cattle ranching certainly began early in the history of the town and continues today. In 1880 Fort Lewis was moved to Hesperus, but in 1881 the railroad reached the town which spurred the town's growth. A sawmill was built near the present day junction of Highways 160 and 84, and the area was logged ambitiously (Larason 2003). Some logging undoubtedly occurred within the habitat for *I. polyantha*, but the extent is unknown (Anderson 1988). There is no known documentation of the pre-settlement vegetation of the area.

Pagosa Springs is developing rapidly as a popular tourist destination and location for second homes. The population in 1997 was 1,767, but the projected population for 2020 is over 9,000. Between July 1, 1999 and November 30, 2000, 724 residential building permits were issued in Archuleta County, with 456 (63 percent) in the Pagosa hub area. Of the projected population of 9,000, 6,700 people are expected to reside in areas outside the current town boundaries (Archuleta County 1999).

Reproductive biology and autecology

In the Competitive/Stress-Tolerant/Ruderal (CSR) model of Grime (2001), characteristics of *Ipomopsis polyantha* most closely approximate those of a stress-tolerant ruderal species. As with many species of *Gilia* and *Ipomopsis*, *I. polyantha* is found on moderately disturbed sites. The most consistent feature of ruderal species in the CSR model is an annual or short-lived perennial life history (Grime 2001). *Ipomopsis polyantha* is probably a biennial under ideal conditions but can persist for several years as a rosette awaiting favorable conditions for flowering. There are probably no plant species that have an obligately biennial lifecycle (Harper 1977), and biennials might better be referred to as short-lived semelparous (monocarpic) perennials (Barbour et al. 1987). Like other members of *Ipomopsis*, *I. polyantha* ends its life by devoting all of its reserves to the production of numerous flowers on a tall inflorescence.

There are numerous observations suggesting that disturbance plays an important role in the autecology of *Ipomopsis polyantha*. It does not appear to tolerate prolonged or constant disturbance, such as sites that are grazed by horses and cattle (Anderson 1988, Brinton personal communication 2003, Sovell et al. 2003). Horse and cattle grazing have been observed to extirpate *I. polyantha* from pastures that are grazed every year (Brinton personal communication 2003, Colorado Natural Heritage Program 2003, Sovell et al. 2003). It appears to favor sites that are periodically disturbed but not constantly used, such as highway rights-of-way. Anderson (1988) includes a picture of plants growing in a junkyard among junked cars, where it is only infrequently disturbed. It also effectively colonizes newly disturbed or exposed shale surfaces, such as road cuts, if they are not continuously disturbed (Anderson 1988). Historically, *I. polyantha* probably benefited from a natural fire regime to maintain its habitat (Collins 1995). *Ipomopsis aggregata* populations have been observed to increase in years following a fire (Wilken personal communication 2003). Biennials are often found in sites that are disturbed periodically but not annually (Barbour et al. 1987). While *I. polyantha* has a strong affinity for disturbed areas, it may also persist in climax vegetation (Anderson 1988). Anderson (1988) noted that it can be either a pioneer on raw shale or a climax species under *Pinus ponderosa* forests or pine/juniper/oak communities. The erosive nature of Mancos Shale soils probably results in some level of natural chronic disturbance even in late seres.

Due to human alteration of their habitat, both *Ipomopsis polyantha* and *I. sancti-spiritus* appear to have shifted to habitats that are maintained by anthropogenic disturbance rather than natural disturbance. About 80 percent of the population of *I. sancti-spiritus* is found on the cut-slopes of a single USFS road (U.S. Fish and Wildlife Service 2002). While this shift might have permitted these species to persist despite severe modification of their habitat, reliance on human-imposed disturbance regimes puts them directly in the path of human impacts. The locations in which these species are found are managed for human needs such as transportation, animal husbandry, and construction, not for the ecological needs of these species.

While its life history, tolerance of (or perhaps affinity for) disturbance, and ability to colonize disturbed sites typify *Ipomopsis polyantha* as a ruderal species, it also has attributes of a stress-tolerator as defined by Grime (2001). Its ability to thrive in soils that are heavy, droughty, and deficient in nutrients suggests that it tolerates the stresses imposed by the aberrant edaphic conditions of its habitat.

As a biennial or monocarpic perennial with relatively large amounts of biomass allocated to the production of propagules, the life history pattern of *Ipomopsis polyantha* is best classified as r-selected (using the classification scheme of MacArthur and Wilson 1967). The role of disturbance in the autecology or *I. polyantha* also typifies it as an r-selected species, as do its semelparous life history and lack of strong competitive interactions (Pianka 1970). Because biennials have a short life span and lack the ability to reproduce vegetatively, there is strong selective pressure for successful reproduction (Spira and Pollak 1986).

Reproduction

Like all members of *Ipomopsis*, *I. polyantha* has perfect, actinomorphic flowers. Many experts have suggested that *I. polyantha* is probably self-incompatible and an obligate outcrosser based on the floral biology of many of its congeners (Grant 1956, Anderson 1988, Wilken 1995). However, in pollination experiments conducted in 1991-1993, Collins (1995) observed self-compatibility. Although seed and fruit set were low in self-pollinated plants, *I. polyantha* appears capable of selfing when stressed. Using the outcrossing index (OCI) of Cruden (1977), Collins (1995) determined that *I. polyantha* has an OCI value of 4, indicating that it is partially self-compatible, outcrossing, and has a demand for pollinators. Although *I. polyantha* is somewhat self-compatible, reproductive output is much greater when plants are outcrossed (Collins 1995). Thus, *I. polyantha* is best characterized as facultatively xenogamous. Collins (1995) speculated that seedlings produced as a product of self-pollination would probably have lower survivorship than outcrossed seedlings.

Ipomopsis sancti-spiritus, the closest relative of *I. polyantha* (Porter et al. 2003), has also been shown to be self-compatible, but unlike *I. polyantha* it requires a pollinator for fertilization to occur (Maschinski 1996). In *I. sancti-spiritus*, Maschinski (1996) observed fruits in 57 percent of self-pollinated flowers, while outcrossing resulted in fruit set 9.5 to 77 percent of the time depending on the pollen donor. The variation in percent of fruit set of outcrossed flowers observed in this experiment suggests that there is discrimination between paternal pollen sources. This has also been observed in *I. aggregata* (Waser and Price 1989).

Collins (1995) made some very detailed observations of the floral phenology of *Ipomopsis polyantha*. Her observations are paraphrased here. *Ipomopsis polyantha* is protandrous, in which the anthers dehisce prior to receptivity of the stigma. As the flower buds open, the petals turn white with purple spots, and by the second or third day the stamens are exerted above the corolla and the closed stigma. The flowers begin with the male phase, and on the fourth day the anthers dehisce and release pollen. By about the seventh day anthesis is complete, and the empty stamens reflex. As the stamens reflex the stigma becomes exerted from the corolla, and nectar appears around the base of the ovary. The stigma becomes receptive by opening its tripartite lobes while the corolla lobes reflex, advertising the availability of nectar. This female phase of the flower continues for three or four days, and by the eleventh day the flower is beginning to senesce.

Clearly, *Ipomopsis polyantha* has several adaptations that promote outcrossing. By temporally separating the release of pollen and the receptivity of the stigma, protandry promotes outcrossing (Grant and Grant 1965, Cruden 1977). The spatial (herkogamous) and temporal (dichogamous) separation of anthers and the stigma within the flowers are strategies to avoid self-pollination. The offer of a nectar reward only during the female phase may also promote outcrossing (Heinrich 1979).

Paige and Whitham (1987) made some interesting observations regarding the life history of *Ipomopsis aggregata* that involve pollinator visitation. Like *I. polyantha*, *I. aggregata* is typically semelparous. However, when pollinators are excluded, *I. aggregata* shifts to an iteroparous mode of reproduction. The iteroparous plants persist by producing an ancillary rosette that persists after the parent rosette dies. Very low intensity fire caused the formation of clonal rosettes in *I. aggregata* (Paige 1992a). It is not known if *I. polyantha* is capable of an iteroparous life history or if it can reproduce clonally following fire.

Ipomopsis includes both diploids and natural allotetraploids. *Ipomopsis polyantha* is diploid (2N = 14) (Grant 1959).

Pollinators and pollination ecology

The pollination ecology of the Polemoniaceae has been the topic of extensive study, particularly in the genera *Ipomopsis* and *Gilia*. Although highly specialized breeding systems are found in some members of the Polemoniaceae, *I. polyantha* is apparently a generalist pollinated by a broad suite of insects. It has a relatively shallow corolla tube when compared with specialists such as *I. aggregata*, which largely depends on hummingbirds for its pollination (Grant and Grant 1965). 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). The timing of the floral phenology in *I. polyantha* serves to broaden the range of possible pollinators by providing opportunities for visitation and pollen deposition on insects of different body size and feeding position (Grant and Grant 1965). Deposition of foreign pollen to the stigmas of *I. aggregata* results in the closure of the stigma lobes, which reduces further receptivity and results in reduced seed set (Waser and Fugate 1986). However, a promiscuous plant such as *I. polyantha* may be less sensitive to deposition of foreign pollen than a more specialized species such as *I. aggregata*. Waser and Price (1991) observed that the addition of self-pollen reduced seed set by 42 percent in *I. aggregata*. Both of these scenarios are possible in occurrences of *I. polyantha* depending on population size, the kinds of plant species present, and the behavior of insects within the overall population. However, there is no evidence to determine if pollen loads of self- or foreign pollen are impacting the fecundity of *I. polyantha* (Wilken personal communication 2003).

Collins (1995) observed insect visitation and pollination of *Ipomopsis polyantha* at three sites in the Pagosa Springs area in 1992 and 1993. *Ipomopsis polyantha* is visited and pollinated by a wide range of small and medium-small bees and beeflies (Collins 1995). The primary pollinators observed at the three sites in order of decreasing number of visits were *Apis mellifera*, *Augochlorella* spp., *Anthophora* spp., *Bombus* spp., *Dialictus* spp., *Megachile* spp., *Lasioglossum* spp., *Halictus rubicundus*, *Osmia ednae*, and *Evylueus* spp. *Apis mellifera* is not native and is known to be a successful competitor with native bees (Wilken personal communication 2003). Because Collins' study did not determine pollen loads, it is uncertain which insect is most important for the pollination of *I. polyantha* (Wilken personal communication 2003).

Collins (1995) made some particularly interesting observations of the relationship between disturbance and other site attributes and pollinator diversity. Her first site (1A) was open and sparsely vegetated, close to the highway, and more disturbed than the other two sites. Plants at this site were pollinated by approximately 10 species, particularly *Augochlorella striata*, *Bombus* spp., *Lasioglossum*, and *Apis mellifera*. Site 2A was a later successional site with more vegetation, at the edge of a forest dominated by ponderosa pine, juniper, and oak. This site was visited by approximately 12 species of pollinators, most notably *A. mellifera*, *Anthophora* spp., and *Dialictus* spp. The third site (3A) was near a creek in an unused pasture with annuals and perennials that bloomed throughout the summer. Plants at this site were pollinated by approximately 15 species, including species of *Bombus*, *Augochlorella*, *Anthophora*, and *Apis mellifera*. These results suggest that greater habitat diversity, availability of a wide range of nectar and pollen resources, proximity to natural habitat, and availability of water enhance the diversity of pollinators for *Ipomopsis polyantha*, while disturbance and proximity to a highway diminish pollinator resources. These factors also affect the species composition of pollinators present.

Phenology

Ipomopsis polyantha bears numerous flowers in a narrow, thyrsoid inflorescence (Harrington 1954). *Ipomopsis polyantha* has a somewhat protracted period of flowering and is in flower through most of the summer months. In 1991 to 1993, plants were observed in the early flowering stage during the first week of June (Collins 1995). Anderson (1988) also observed plants flowering in the first week of June. Flowering probably begins as early as late May (Anderson 1988, Collins 1995). Baker's type was collected on July 28 in full flower. By late August *I. polyantha* is still flowering, but most flowers have dried up by then, giving way to fruits (Anderson 1988, Collins 1995). Most plants are probably primarily in fruit in August. Because *I. polyantha* occurs in xeric sites, the periodicity of successful recruitment may coincide with wet or otherwise favorable years during which seedlings can become established.

Fertility and propagule viability

Seed germination tests under natural conditions resulted in an 18 percent germination rate for the seeds of *Ipomopsis polyantha* when germinated in Mancos Shale soil. The germination rate dropped to 5 percent for seeds sown in soil from outside the range of *Ipomopsis polyantha* in the Pagosa Springs area (Collins 1995). Germination trials in a greenhouse also observed the highest rates of germination in Mancos Shale soil, even higher than germination in commercial potting soil and on filter paper in petri dishes. This may be the result of a lack of appropriate mycorrhizal symbionts in the commercial potting soil and petri dish experiments (Wilken 1995), or due to differences in soil chemistry (pH, presence of nitrates which stimulate germination, etc.) (Wilken personal communication 2003). Seeds germinated in 17 days in Mancos Shale soil but required 42 days in soil from outside the range of *I. polyantha* in the Pagosa Springs area. The seeds of *I. sancti-spiritus* appear to have no special germination requirements, but the highest percentage of germination occurs after four to eight weeks of cold treatment (Maschinski 1996).

The formation of the mucilaginous coat upon hydration of the seed appears to help remove germination inhibitors in the seeds of *Eriastrum densifolium* ssp. *sanctorum*, another member of the Polemoniaceae (Wheeler 1991). Collins (1995) observed that hydrated seeds germinated three days faster than non-hydrated seeds, possibly due to the additional time required for the mucilaginous coat to remove the germination inhibitors from the seeds. When the seeds were first wetted to induce formation of the mucilaginous coat and then germinated in soils, the germination time was reduced (Collins 1995). Wilken (personal communication 2003) notes that the primary function of mucilaginous seed coats, which are widespread in the Polemoniaceae, appears to be the retention of water and protection of the embryo during intermittent droughts between early rain storms, or to prevent germinating seedlings from washing away by attaching the seed to soil particles.

The type specimen contained 13 ovules per fruit, while Bethel, Willey, and Clokey's specimen (4251) contained 10 ovules per fruit (Kearney and Peebles 1943). While open pollinated controls assessed by Collins (1995) produced an average of 3.3 seeds per fruit, plants at all of her study sites averaged 15 ovules per fruit. Pollen to ovule ratios from this study determined that there are 245.7 pollen grains per ovule. Pollen viability was determined from three sites in 1991 to average 87 percent; poor viability was ruled out as a possible cause of the rarity of *Ipomopsis polyantha* (Collins 1995).

Dispersal mechanisms

The seeds of many species of *Ipomopsis* and other members of the Polemoniaceae are coated with a mucilaginous substance that may play a role in seed dispersal. Bray (1898 as cited in Grant 1959) hypothesized that this mucilaginous coating caused the seeds of an ancestral member of *Ipomopsis* to stick to the feet of migratory birds, resulting in the establishment of the genus in South America. Collins (1995) observed no specialized mechanism for long distance seed dispersal in *I. polyantha*, with seed capsules bursting open and dispersing seeds 20 to 30 centimeters from the parent plant. The mucilaginous layer of the seeds of *I. polyantha* is reported to be depauperate (Nelson 1905), but it is present (Collins 1995). Whether it can augment the dispersal of *I. polyantha* seeds is not known and has not been studied. The seeds are probably dispersed primarily by wind and water (Anderson 1988).

Movement of soil by humans has clearly spread the plant around and has probably led to its introduction in some sites. In 1990, city road crews scraping the Highway 84 right-of-way distributed seeds 2 to 3 kilometers further south where the species became established (Collins 1995). Seeds of *Ipomopsis polyantha* germinated and grew from fill dirt in a private yard in Pagosa Springs in 2002 (Lyon personal communication 2003). However, observations suggest that these established occurrences often do not persist (Brinton personal communication 2003).

As a biennial or short-lived monocarpic perennial, seed bank dynamics are particularly important in the life cycle of *Ipomopsis polyantha*. However, the longevity and dormancy of the seeds of *I. polyantha* have not been studied. Ruderal species tend to have greater seed longevity than other species (Rees 1994). Recruitment, establishment, and population stability are probably not limited by annual seed production or by the number of seeds in the seed bank (Anderson 1988, Wilken personal communication 2003).

Phenotypic plasticity

Ipomopsis polyantha does not exhibit a great degree of phenotypic plasticity. Plants vary in size, stature, and reproductive effort, probably due to year-to-year variations in climate. Collins (1995) observed that plants collected at higher elevations were smaller than lower elevation plants. There is some variation in the purple spotting of the corolla, with some individuals lacking spots while the spots on others are so dense that they make the corolla appear pink (Colorado Natural Heritage Program 2003).

Studies of other members of Polemoniaceae have suggested some degree of plasticity in response to various types of biomass removal. There has been much debate in the literature over the response of *Ipomopsis aggregata* to browsing by herbivores. Some studies have indicated that early grazing of inflorescences results in higher reproductive output (overcompensation) (Paige 1992b, Paige 1999, Paige et al. 2001). However, other studies (Bergelson and Crawley 1992, Juenger and Bergelson 1997, Juenger and Bergelson 2000) did not observe overcompensation; rather, they observed negative impacts on *I. aggregata* such as delayed phenology, altered plant architecture, and reduced plant fitness. Overall, the results of these and many other studies suggest that overcompensation does not occur in most cases for *I. aggregata* (Wilken personal communication 2003). The specific response of *I. polyantha* to browsing by herbivores has not been studied. An overview of plant tolerance to consumer damage is presented in Stowe et al. (2000).

Mycorrhizal relationships

Roots of *Ipomopsis polyantha* have not been assayed for the presence of mycorrhizal symbionts. Arbuscular mycorrhizal (AM) fungi have been reported to form symbioses with members of the genus *Gilia* (Laspilitas.com 1995) and *Phlox* (Bethlenfalvay and Dakessian 1984). 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 diversity at the genetic (Sanders et al. 1996, Varma 1999) and single plant root (Vandenkoornhuyse et al. 2002) levels. 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

Interspecific hybridization has not been observed in *Ipomopsis polyantha*. *Ipomopsis aggregata* has also been observed within the range of *I. polyantha*, so it is possible that there is geneflow between these species, but there are no observations suggesting that this is occurring. The closest relative of *I. polyantha*, *I. sancti-spiritus*, is not found within 125 miles and consists of a very small population (U.S. Fish and Wildlife Service 2002), so gene flow between *I. polyantha* and *I. sancti-spiritus* is highly unlikely.

Hybridization has played a major role in the evolution of many groups of Polemoniaceae, including *Ipomopsis* section *Ipomopsis* (Grant 1959, Porter et al. 2003). The influence of hybridization is so strong in some groups that Grant (1959, p. 203) wrote "if we are to base our ideas of macroevolution on inductive methods of inquiry we will have to give up, in many plant groups, the old symbolism of the phylogenetic tree in favor of the symbolism of a phylogenetic net." Hybridization is ongoing between many taxa in the family and contributes to many of the taxonomic difficulties in the genus *Ipomopsis*. There have been numerous studies of the hybridization between *I. aggregata* and *I. tenuituba* (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, and others). 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 levels of inbreeding and outbreeding depression that prevent the loss of heterozygosity is an important management consideration for *Ipomopsis polyantha*. As a primarily outcrossing species, *I. polyantha* is vulnerable to inbreeding depression in small populations or in populations with limited pollinator activity. Given the high degree of disturbance and fragmentation of the habitat for *I. polyantha*, it is likely that genetic diversity is being lost. Evidence of inbreeding depression was observed in small populations (less than 100 individuals) of *I. aggregata* (Heschel and Paige 1995, Paige and Heschel 1996). 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 *I. aggregata* (Ellstrand 1992).

The lifespan of *Ipomopsis polyantha* has not yet been determined through demographic studies or observations in the greenhouse. As is typical of members of its genus, *I. polyantha* is monocarpic (semelparous), producing seeds once followed by the death of the entire plant (Anderson 1988). *Ipomopsis polyantha* can flower at the end of its second growing season, but it can certainly persist for several years as a rosette. The survivorship of *I. polyantha* was measured in a small sample by Collins (1995). Of 100 young seedlings tagged in 1991, 93 survived and flowered in 1992. Due to copious production of flowers and seeds, their reproductive output was not quantified. There are no data regarding the proportion of individuals within an occurrence that are reproducing in a given year, as this was not observed by Collins (1995). In favorable years, many or most of the plants in the rosette stage probably set seed (Brinton personal communication 2003). As in most plants, it is likely that the highest rate of mortality takes place between seed placement in the seed bank and the first cohort of vegetative plants (Wilken personal communication 2003); this was observed in a demographic monitoring study of *I. aggregata* ssp. *weberi* (Wilken 1996). For a hypothetical life cycle graph for *I. polyantha* based on the data of Collins (1995) please see **Figure 8**.

No Population Viability Analysis (PVA) has been performed for *Ipomopsis polyantha*. 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, U.S. Fish and Wildlife Service 2002), but there has been no PVA of this species to date. Monitoring and preliminary quantitative assessment of population viability has been conducted for this species (Maschinski 2001), and conducting a viability workshop is among the recommendations for the recovery of this species (U.S. Fish and Wildlife Service 2002).

The relatively short lifespan of monocarpic perennials such as *Ipomopsis polyantha* results in a rapid turnover of occurrences, requiring that new individuals be recruited into occurrences at frequent intervals (Spira and Pollak 1986). Clearly, reproductive output is much higher in favorable years, when *I. polyantha* has been observed to flower abundantly, than in unfavorable years, when few if any flowers have been observed. The optimal conditions for reproduction are not known for *I. polyantha*, but observations suggest that *I. polyantha* responds positively to high soil moisture during wet summers and remains in the rosette form during dry summers.

Collins (1995) made two observations relevant to the spatial characteristics of *Ipomopsis polyantha*. It apparently has no specific adaptations to long distance dispersal. 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 in general. However, the role of the mucilaginous seed coat was not explored by Collins (1995) and has been implicated in the dispersal of the genus *Ipomopsis* to other continents by birds (see the Reproductive biology and autecology section of this document for details). *Ipomopsis polyantha* is an effective colonist of abandoned pastures and newly exposed surfaces (Collins 1995). The germination experiments of Collins (1995) suggest that seeds landing on unsuitable substrates (soils not derived from Upper Cretaceous Mancos Shale) are not likely to reach maturity. Pollinator-mediated pollen dispersal is largely limited to the flight distances of pollinators (Kearns and Inouye 1993). Thus, the Dyke occurrence is probably genetically isolated from plants in the Pagosa Springs vicinity. It is possible that this occurrence was introduced by humans during some activity associated with the highway.

As a habitat specialist, population sizes of *Ipomopsis polyantha* are naturally limited by the availability of its Upper Cretaceous Mancos Shale habitat. It is not known if annual seed production or the number of seeds in the seed bank limits recruitment and establishment of *I. polyantha*, but it appears that this is not the case (Anderson 1988). Collins (1995) also noted that plant fecundity is not contributing to the limited distribution of *I. polyantha*. Factors controlling seedling recruitment success are also not known. Higher germination rates were observed in Mancos Shale

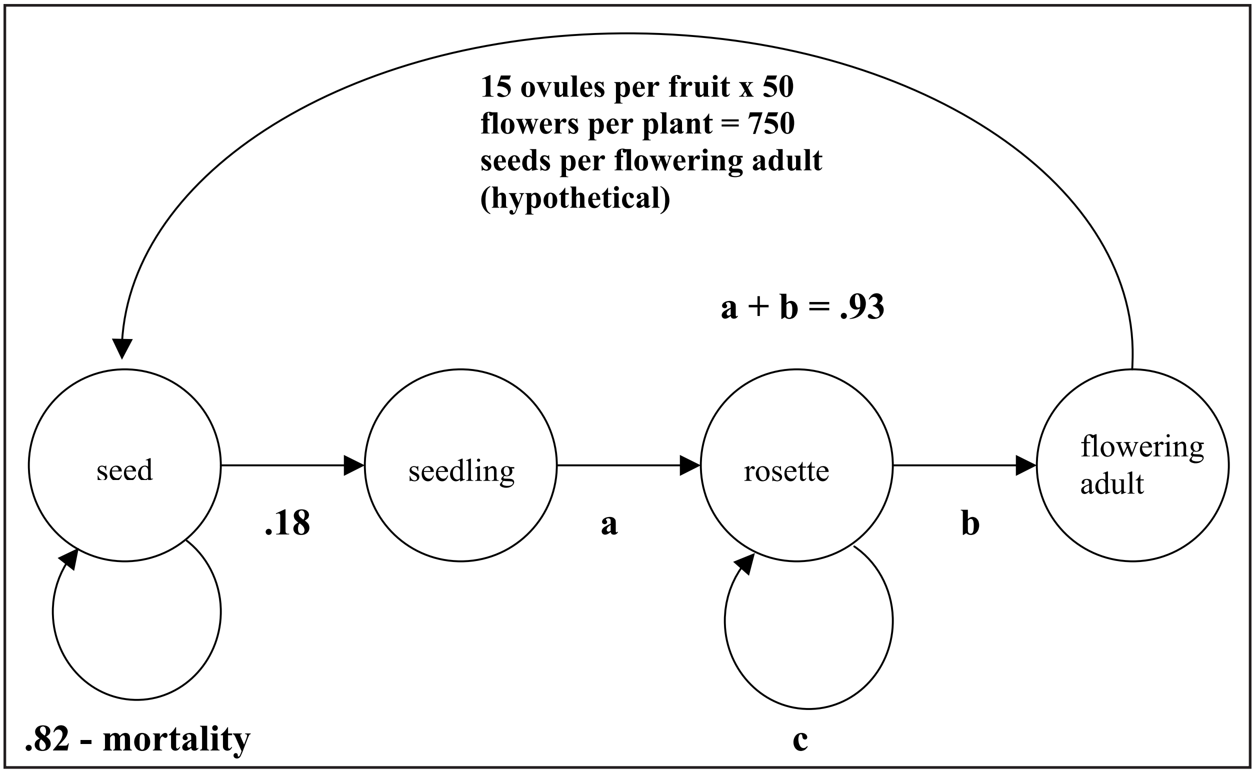

Figure 8. Hypothetical life cycle graph (after Caswell 2001) for *Ipomopsis polyantha*, showing transition probabilities determined by Collins (1995) and including the known life history stages gleaned from observations of Brinton (personal communication 2003). Transition probabilities were measured by Collins (1995) for seed to seedling (.18) on Upper Cretaceous Mancos Shale in natural conditions. 100 seedlings were tracked from their germination in 1991 to the end of the growing season in 1992. At the end of the second growing season 93 individuals flowered. Thus, a + b = .93. No data were obtained from which the transition probabilities of reaching or leaving the rosette stage could be determined. In poor years, c is large, while in favorable years such as that observed by Collins (1995), c is small. As a monocarpic species, there is no return arrow in the flowering adult stage. Because reproductive effort per plant was not determined by Collins (1995), the transition probability of flowering adult to seed presented here is for a hypothetical flowering adult with 50 flowers, using the average number of ovules per fruit determined by Collins (1995). The transition probabilities presented in this graph are based on limited data; larger sample sizes over a longer timeframe are needed for verification.

soils than in other soils from the Pagosa Springs area (Collins 1995). This may preclude the establishment of occurrences on substrates derived from other parent materials. Collins' observations also suggest that the dispersal abilities of *I. polyantha* are limited. *Ipomopsis polyantha* probably needs an appropriate periodic disturbance regime to persist at a site. Human impacts may also be responsible for limiting population growth. Habitat destruction and fragmentation are occurring rapidly throughout the area occupied by *I. polyantha*.

Community ecology

The habitat of *Ipomopsis polyantha* has been subjected to extensive modification and intensive land use practices for at least 120 years. Thus, the natural vegetation and associated species for *I. polyantha* have been disrupted or removed. The natural vegetation of the area is predominantly *Pinus ponderosa* forest with an understory of *Quercus gambelii* (Gambel's oak), and pine/juniper/oak woodlands. Please see the Habitat section of this document for details on the vegetation types associated with *I. polyantha*. A list of all associated species that have been documented with *I. polyantha* is included in **Table 3**. An envirogram is presented in **Figure 9**; it portrays the generalized interactions between *I. polyantha* and its environment.

Three other rare plant species are known to occur on Mancos Shale with *Ipomopsis polyantha*: *Lesquerella pruinosa*, *Townsendia glabella*, and *Phlox caryophylla*. *Lesquerella pruinosa*, another narrow endemic, is

Table 3. Associated species for occurrences of *Ipomopsis polyantha*.

Rare/Exotic	Associated Species	Mill Creek East	Pagosa Springs	Dyke	Common Associates
	Achillea lanulosa	x			
	Allium cernuum	x			
	Alyssum spp.	x			
	Amelanchier spp.	x	x	x	
	Amelanchier utahensis	x			
	Antennaria spp.	x			
	Apocynum spp.	x			
	Artemisia frigida	x			
	Artemisia ludoviciana	x	x	x	
	Astragalus lonchocarpus		x		*
	Astragalus pattersonii		x		
	Astragalus spp.	x	x	x	
E	*Bromus inermis*		x		
E	*Bromus tectorum*		x		
	Chaenactis spp.		x	x	
	Chrysothamnus spp.			x	
	Chrysothamnus depressus	x			
	Chrysothamnus nauseosus	x	x		*
	Erigeron spp.		x		
	Erigeron flagellaris	x			
	Eriogonum lonchophyllum		x		*
	Eriogonum racemosum	x			
	Eriogonum spp.	x			
	Erythrocoma triflora	x			
	Forestiera pubescens		x		
	Geum spp.		x		
	Heterotheca spp.		x		
	Heterotheca villosa		x		
	Hymenopappus newberryi	x			
	Hymenoxys spp.		x		
	Hymenoxys acaulis		x		
	Juniperus spp.		x		
	Juniperus osteosperma		x		
	Juniperus scopulorum	x	x		
R	*Lesquerella pruinosa*		x	x	
	Leucocrinum montanum	x			
	Linum spp.		x		
	Linum lewisii	x	x		
	Lupinus spp.		x		
	Mahonia repens	x	x		*
E	*Melilotus indica*		x		
E	*Melilotus officinale*		x		
	Oenothera caespitosa	x			

Rare/Exotic	Associated Species	Mill Creek East	Pagosa Springs	Dyke	Common Associates
	Oryzopsis hymenoides		x	x	
	Penstemon crandallii		x		
	Penstemon glabella	x			
	Penstemon linarioides		x		
R	*Phlox caryophylla*		x		
	Pinus edulis		x		
	Pinus ponderosa	x	x		
	Poa spp.	x	x	x	
	Poa fendleriana	x			
E	*Poa pratensis*		x		
	Potentilla hippiana	x			
	Prunus virginiana	x			
	Pseudocymopterus montana		x		
	Purshia tridentata		x		
	Quercus gambelii	x	x		
	Rhus trilobata	x		x	
	Ribes cereum	x			
	Rosa spp.		x		
	Rosa woodsii	x			
	Senecio spp.		x		
	Senecio oodes		x		
	Symphoricarpos oreophilus	x			
	Tetraneuris torreyana	x			
	Townsendia spp.	x	x	x	*
R	*Townsendia glabella*	x	x		*
E	*Tragopogon* spp.		x		*
	Trifolium spp.		x		

found with *I. polyantha* at Dyke and at Pagosa Springs (Anderson 1988, Lyon and Denslow 2002, Colorado Natural Heritage Program 2003, Sovell et al. 2003). However, *L. pruinosa* is more widely distributed than *I. polyantha* and is found at several locations where *I. polyantha* does not occur. *Lesquerella pruinosa* appears to tolerate grazing better than *I. polyantha* (Anderson personal communication 2003); this may be partly responsible for its greater range and abundance. The occurrence of *L. pruinosa* at Ant Hill (approximately 12 miles north of Pagosa Springs) has been searched repeatedly for *I. polyantha*, but it has not been found there (Anderson 1988, Sovell et al. 2003).

Herbivores

The relationship of *Ipomopsis polyantha* with herbivores has been observed frequently. All observations suggest that *I. polyantha* does not tolerate livestock grazing. Several observers (Collins 1995, Sovell et al. 2003, Brinton personal communication 2003) have described occurrences that were apparently extirpated after a site was grazed continuously. It is frequently found along fencelines, with no individuals found inside the fence where animals graze (Anderson 1988). It is never found in pastures currently grazed by cattle (Collins 1995). While the sources cited above note that it is excluded by horse grazing as well, Collins (1995) reports one observation where horses grazed up to *I. polyantha* and then turned and grazed in another direction; she speculated that odor or bad taste might have been responsible. Although *I. polyantha* is excluded from grazed pastures, large occurrences have been observed in abandoned pastures (Collins 1995, Brinton personal communication 2003). It is not known whether exogenous seed sources or if in situ dormant

INDIRECT ENVIRONMENT		DIRECT ENVIRONMENT	
2	1		
		RESOURCES	
	Canopy openness	Light energy	
	Slope, aspect, albedo	Thermal energy (climate)	
Local geology	Soil texture	Soil moisture	
	Climate		
		Oxygen, carbon dioxide	
Local geology	Calcium concentration (affecting nutrient uptake)	Nutrients	
		REPRODUCTION	
	Other plant resources	Pollinators	
	Nest sites		
	Other *E. exilifolium* inds.	Genetic diversity	***Ipomopsis polyantha***
	Microsite attributes	Safe sites	
	Wind		
	Seed dispersers		
		PREDATORS/ HERBIVORES	
	Other food resources	Herbivores	
	Site accessibility	Humans (collectors)	
		Seed predators	
		Nectar robbers	
		MALENTITIES	
	Industrial complex	Airborne pollutants	
		Thermal energy (climate)	
Economic variables	Human population density	Humans (residents, developers)	
	Site/microsite attributes	Competitors	
	Drought	Soil moisture	

Figure 9. Envirogram for *Ipomopsis polyantha*, showing resources, reproduction, predators/ herbivores, and malentities (after Niven and Liddle 1994).

plants or seeds gave rise to these occurrences (Collins 1995). The length of time needed for extirpation under grazing and for colonization or re-growth in abandoned pastures is not known. The specific responses of *I. polyantha* to consumer damage have not been investigated, but there are numerous studies that explore the effects of browsing and grazing on *I. aggregata*. Some studies (e.g., Juenger and Bergelson 2000b) suggest that browsing and grazing (simulated in clipping experiments) significantly reduce the production of flowers, fruits and seeds, while other studies (e.g., Paige 1992b) suggest that the plants are benefited by grazing through a plastic response known as overcompensation, where reproductive fitness is improved by herbivory. The latter scenario appears to be extremely unlikely for *I. polyantha*. For more information on this phenomenon please see the Reproductive biology and autecology section of this document.

Competitors

There has been no formal study of the community ecology and interspecific relationships of *Ipomopsis polyantha*. As a habitat specialist, *I. polyantha* may be a poor competitor, leaving it vulnerable to negative impacts from introduced species. Alternatively, Collins (1995) suggested that because of its adaptations to surviving in Mancos Shale substrates, *I. polyantha* may be a superior competitor under suitable edaphic conditions. Anderson (1988) noted that *I. polyantha* appears to tolerate the presence of weedy species. Dr. J. M. Porter (personal communication 2002) offered some generalities regarding the Polemoniaceae that are relevant to *I. polyantha* 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 species tend to avoid competition. They are somewhat ruderal, but they are 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.

For a detailed discussion of the threats to *Ipomopsis polyantha* from exotic species, please see the Threats section of this document.

Parasites and disease

Herbarium specimens observed showed no signs of parasites and disease. Caterpillars and meloid beetles attacked plants in 1991 at two study sites, but they were not observed again at any site in 1992 and 1993 (Collins 1995). The caterpillars attacked the fruits and seeds of *Ipomopsis polyantha*. The insects were not identified to species. The seeds and seedlings of *Ipomopsis* species are reportedly susceptible to fungal infection in moist environments (Wilken 1995, Wilken personal communication 2003). Floral larceny occurs when insects take pollen or nectar (sometimes by piercing the corolla) from a flower without pollinating it, and this has been well studied in *I. aggregata* (Irwin et al. 2001). The impacts of larceny on plant fitness, recruitment, and population dynamics have been assessed in recent studies, and while this has not been observed in *I. polyantha* it is worth noting in future research. As a generalist, *I. polyantha* is probably less susceptible to parasitism of this nature than a specialist like *I. aggregata*.

Symbioses

There have been no substantiated reports of symbiotic and mutualistic interactions between *Ipomopsis polyantha* and other species. However, one source notes that *I. polyantha* is most often found in the shade of *Chrysothamnus* spp. (Colorado Native Plant Society 1997). It is plausible that *I. polyantha* benefits from a commensal relationship with *Chrysothamnus* or other shrub species, wherein the shrubs provide shade that prevents desiccation of seedlings or conceals them from herbivores (Barbour et al. 1987).

Conservation

Threats

Observations and quantitative data have shown that there are several threats to the persistence of *Ipomopsis polyantha*. In order of decreasing priority these are residential and commercial development, livestock grazing, exotic species invasion, right-of-way management, effects of small population size, recreation, wildflower gathering, 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 sections below for specific treatments of these threats to habitat, individuals, exotic species, and over-utilization.

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 significantly affect 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 Fahrenheit of warming (U.S. Environmental Protection Agency 1997). Because the habitat for *Ipomopsis polyantha* is already xeric, lower soil moistures in the growing season induced by decreased precipitation could have serious impacts.

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, Gold 2000). 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

Residential development is the greatest short-term threat to the quality and availability of habitat for *Ipomopsis polyantha*. The growth of the town of Pagosa Springs has already resulted in a significant decline in the amount of available habitat. The actual amount of habitat lost thus far is unknown and contingent upon the concise definition of appropriate habitat for *I. polyantha*. Subdivision of property into ranchettes and construction of second homes represents a greater threat to *I. polyantha* than high density development at the periphery of the town. Low and medium density development, such as that planned for entire global range of *I. polyantha*, fragments large areas of natural habitat (Knight et al. 2002). The proliferation of roads and disturbance from construction are likely to encourage the spread of weeds into habitat for *I. polyantha*. In addition, a natural fire regime is incompatible with dispersed development, resulting in fire suppression at the expense of the functional needs of the ecosystem. See the Habitats and Evidence of populations in Region 2 at risk sections of this document for details on future land use plans and population projections for Pagosa Springs.

Commercial development threatens at least one area known to be occupied by *Ipomopsis polyantha*. Several large retailers (including Wal-Mart, Albertsons, and The Home Depot) are interested in constructing a “big box” (greater than 100,000 square feet) store at the intersection of Highways 84 and 160 (**Figure 10**). Three privately owned 33-acre parcels are under consideration for this development, as well as other sites in Archuleta County. Currently, the town of Pagosa Springs has a moratorium on the construction of big box stores that is supported by a strong consortium of local businesses (Allen personal communication 2004). However, Wal-Mart has successfully used legal and political methods to circumvent local regulations, sometimes despite strong public opposition (Sullivan 2004). Currently this area is planned as a “concentrated commercial area” (**Figure 11**; Archuleta County 1999).

While periodic disturbance might benefit *Ipomopsis polyantha*, the regular disturbance imposed by many livestock grazing regimes probably renders habitat unsuitable for *I. polyantha*. The primary impacts from livestock grazing are probably the direct result of herbivory, but grazing can affect habitat in many other ways. In fragile soils such as those inhabited by *I. polyantha*, grazing enhances erosion. Horse grazing on ranchettes often results in serious degradation and erosion caused by overgrazing.

While no documentation of recreational impacts to *I. polyantha* is known, off-road vehicle use is a threat to rare plant species and their habitat on barren sites in the vicinity of Pagosa Springs. Barren shale areas are frequently exploited for off-road vehicle recreation because of their challenging slopes and the lack of interference from vegetation (Lyon and Denslow 2001).

Influence of management activities or natural disturbances on individuals

Residential and commercial development presents the single greatest threat to *Ipomopsis polyantha* (Anderson 1988, Collins 1995, Lyon and Denslow 2002, Brinton personal communication 2003, Colorado Natural Heritage Program 2003, Lyon personal communication 2003, Sovell et al. 2003). While its primary impact on *I. polyantha* is reduction of habitat, it also impacts individuals and occurrences directly and indirectly. Fragmentation resulting from subdivision

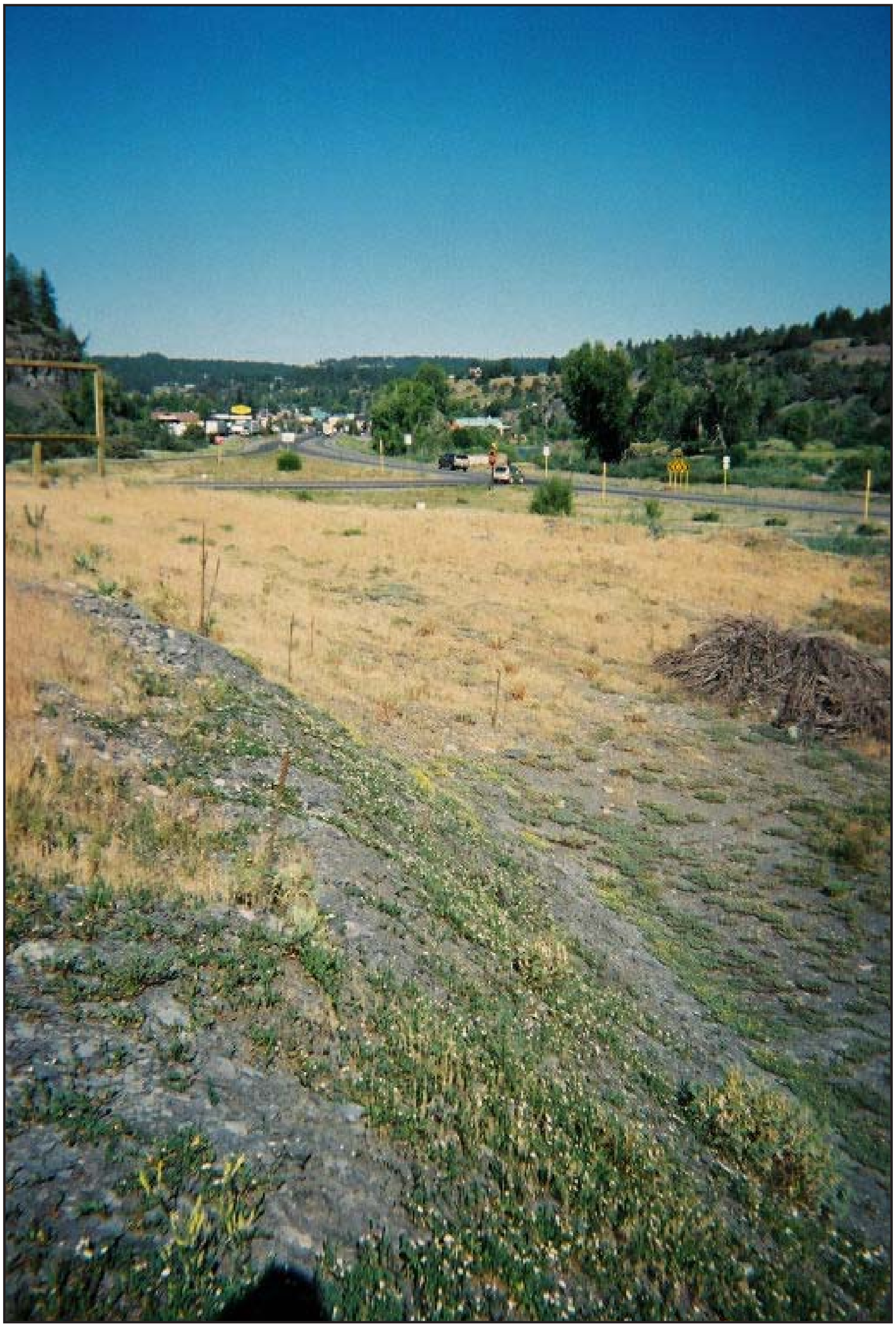

Figure 10. The intersection of Highway 160 and Highway 84, east of Pagosa Springs, where *Ipomopsis polyantha* is found. Residential and commercial development is proceeding rapidly in this area. Current plans are to develop this site as a "concentrated commercial area" (Archuleta County 1999). Other threats at this location include weed invasion, right-of-way management, utility maintenance and installation, and off-road vehicle use (photograph by Al Pfister, provided by Ellen Mayo and used with permission).

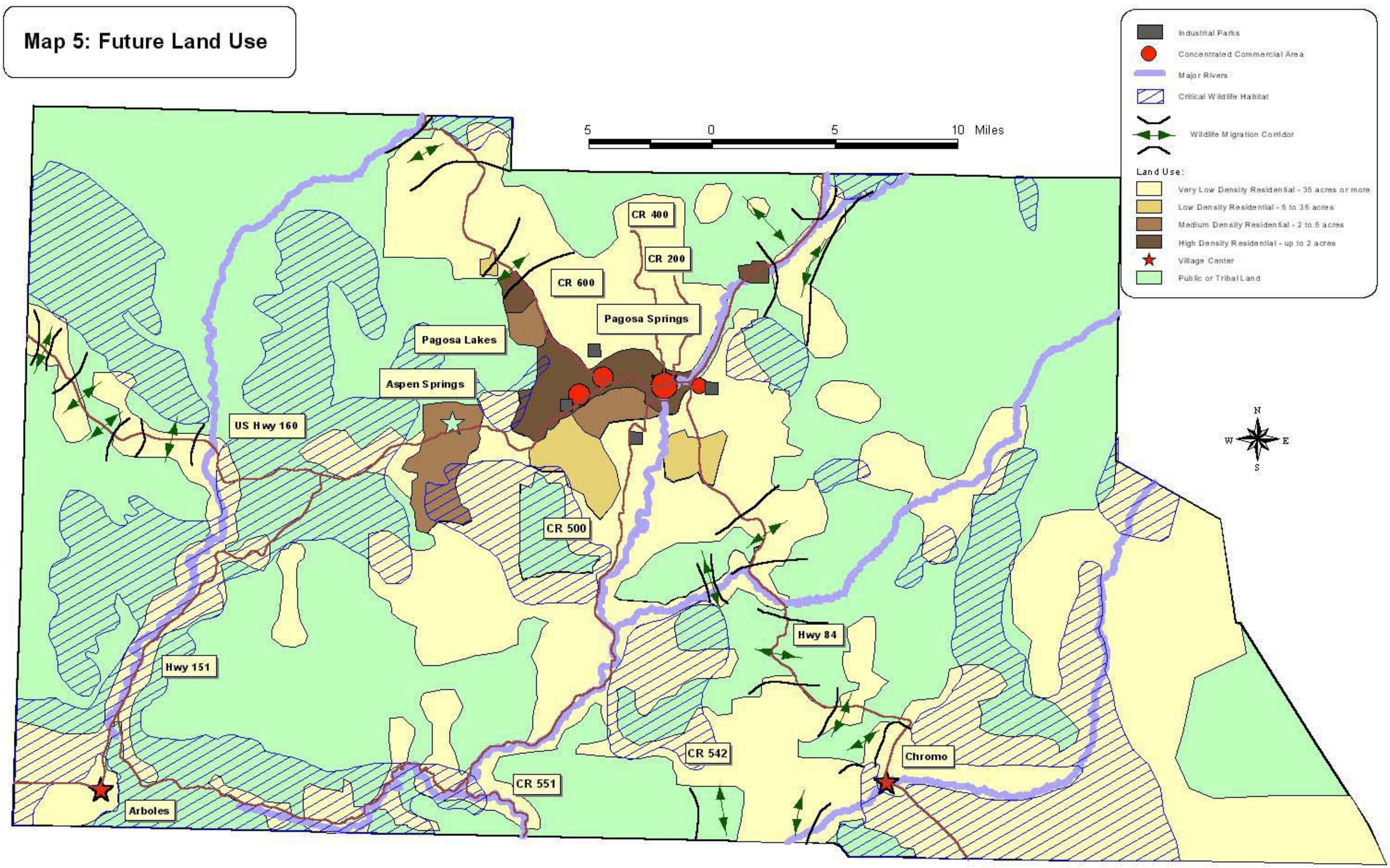

Figure 11. Map of future land use in Archuleta County (from Archuleta County 1999).

of property, residential and commercial development, and road construction presents numerous threats to *I. polyantha*. Disturbed sites offer fewer species of pollinators for *I. polyantha* than natural sites. Road and other infrastructure construction threatens occurrences of *I. polyantha* directly by altering habitat and killing individuals and indirectly by increasing erosion and opening dispersal corridors for exotic species. Roads probably act as barriers to pollinators for this outcrossing species and prevent effective geneflow by disrupting the traplines of pollinators. The widening of Highway 84 has been noted as a threat to a large portion of the *I. polyantha* population that resides within its right-of-way. The widening of Highway 160 would also impact most or all of the plants in the population at Dyke. The installation of buried pipelines and cables along Highway 84 occurred during Christine Collins' research project. Fortunately, she was able to mark areas where the plants occurred so that the crews could avoid damage to those areas. However, without someone to advocate for the plant, activities such as this are likely to impact the species. The La Plata Electric Association will be upgrading electric lines along Highway 84 between 2004 and 2007 (Behnken 2004). Clearance surveys are planned for 2005, when populations of *I. polyantha* will be marked to minimize impacts.

A better understanding of the impacts to grazing on *Ipomopsis polyantha* is needed for proper stewardship of this species. All observations report that the plant is extirpated where livestock grazing occurs, and it is never found in pastures where cattle and horses are grazed (Collins 1995, Brinton personal communication 2003, Colorado Natural Heritage Program 2003). It is most often found in fenced highway rights-of-way, where it can escape continual surface disturbance and grazing (Anderson 1988). There has been much research on the impacts of grazing on other members of the genus *Ipomopsis*, particularly on *I. aggregata*. Some insights into management options for *I. polyantha* that might improve its survivorship under various grazing regimes might be gained from this literature, but observations made thus far suggest that *I. polyantha* is more sensitive to grazing than *I. aggregata*. The incidental grazing by elk and deer that has resulted in limited observations of overcompensation is far less intensive than the grazing by cattle and horses in a pasture that is likely to be experienced by *I. polyantha* (Wilken personal communication 2003). Overcompensation, if it exists, probably does not apply to cattle and horse grazing (Wilken personal communication 2003). Please see the Reproductive biology and autecology and the Community ecology sections of this document for discussions of overcompensation and other research.

Interaction of the species with exotic species

It is ironic that the greatest threat from exotic species to *Ipomopsis polyantha* might be the management practices used to control them. Anderson (1988) and Collins (1995) both noted that spraying roadside weeds along Highway 84 would probably decimate occurrences of *I. polyantha* in these locations. Impacts to *I. polyantha* that apparently resulted from herbicide use were observed along Highway 84 in 2004 (**Figure 12**; Mayo personal communication 2004). Use of herbicides for range management also threatens *I. polyantha*. Because roadsides support a large percentage of the known population, their management is important to ensure the continued survival of this species. Mowing and scraping roadsides to control weeds when *I. polyantha* is flowering could remove the entire local seedbank, but might also serve to disperse the plant if it is done in late August (Collins 1995).

Surprisingly few exotic species have been documented with *Ipomopsis polyantha*. The species that have been documented are goatsbeard (*Tragopogon* c.f. *dubius*), yellow sweet clover (*Melilotus officinale*), smooth brome (*Bromus inermis*), cheatgrass (*B. tectorum*), and Kentucky bluegrass (*Poa pratensis*). There have been no observations where non-native species were implicated in negatively impacting *I. polyantha*, and Anderson (1988) notes that *I. polyantha* appears to tolerate some weeds well. However, at least three of the above species are of some concern for *I. polyantha*. Smooth brome occupies large areas of potential habitat in the Pagosa Springs area where it is probably displacing individuals. Invasion of its habitat by non-native turf-forming grasses is cited as a significant threat to the federally listed *I. sancti-spiritus* (U.S. Fish and Wildlife Service 2002). Given the similarity in habitat and the close phylogenetic relationship between this species and *I. polyantha*, smooth brome and Kentucky bluegrass should also be considered threats to *I. polyantha*. In habitat for *I. sancti-spiritus*, "*B. inermis* and *P. pratensis* are especially aggressive and quickly produce sodbound areas that appear to exclude *I. sancti-spiritus*" (U.S. Fish and Wildlife Service 2002, p. 13).

Melilotus is a Eurasian genus that is widely naturalized in North America (Mabberley 1997). *Melilotus officinalis* has invaded occurrences of *Astragalus ripleyi*, a rare Colorado and New Mexico endemic, and it apparently results in decreased density of *A. ripleyi* (Colorado Natural Heritage Program 2003). The behavior of this species on the Mancos Shale around Pagosa Springs should be watched, but current

Figure 12. The right-of-way of Highway 84 within one mile south of Pagosa Springs, looking south. Of the 29 *Ipomopsis polyantha* individuals observed at this site in 2004, five to seven appeared to have been killed by herbicide (Mayo personal communication 2004; photograph by Al Pfister, provided by Ellen Mayo and used with permission).

Figure 13. A cheatgrass (*Bromus tectorum*) infestation near the intersection of Highways 84 and 160, where four *Ipomopsis polyantha* individuals were found in 2004 (photograph by Al Pfister, provided by Ellen Mayo and used with permission).

information does not suggest that it presents a serious threat to *Ipomopsis polyantha*.

Cheatgrass is present in Archuleta County (University of Colorado Herbarium 2003) and has been documented with *Ipomopsis polyantha* (**Figure 13**; Mayo personal communication 2004). Cheatgrass aggressively invades native plant habitat, and its spread throughout the Intermountain West has been well documented (Young and Blank 1995). Its spread through pinyon-juniper woodlands has resulted in increased erosion as perennial understory species are outcompeted (West and Young 2000). The dramatic changes invoked by cheatgrass on the fire ecology of woodland ecosystems are also cause for concern if it becomes widespread in the woodland and forest habitats of *I. polyantha*.

Yellow starthistle (*Centaurea solstitialis*) is present on Colorado's western slope (Dillon 1999), and it poses a very real threat to *Ipomopsis polyantha* and many other native plant species if ongoing efforts to contain it fail. It has a wide ecological range and the potential to spread widely in Colorado. It currently infests 10 million acres in California (Colorado Weed Management Association 2002).

Other exotic species of concern for *Ipomopsis polyantha* include halogeton (*Halogeton glomeratus*), Russian knapweed (*Acroptilon repens*), and medusa head rye (*Taeniatherum caput-medusae*). These species have not yet been documented with *I. polyantha*, but they are aggressive species that have invaded large areas of native plant habitat throughout the Intermountain West.

Threats from over-utilization

There are no known commercial uses for *Ipomopsis polyantha*, and there are no reports of over-utilization of the species (Anderson 1988). Some members of the Polemoniaceae are popular for gardening (*Phlox* and *Polemonium* species). There are no indications that they are sought for use in the herb trade, but *I. polyantha* is vulnerable to potential impacts from harvesting wild populations if for some reason it became sought as a medicinal herb. No members of the Polemoniaceae are cited for any particular toxicity (Burrows and Tyrl 2001). Over-collection for scientific purposes, particularly in small occurrences, presents the greatest threat from over-utilization. Heavy collection for herbarium specimens has contributed to the imperilment of other species, such as the federally endangered *Potentilla robbinsiana* (NatureServe 2003). The proximity of *I. polyantha* to the town of Pagosa Springs increases the likelihood that casual wildflower gathering could impact occurrences. Wildflower gathering is cited among the threats to *I. sancti-spiritus* (U.S. Fish and Wildlife Service 2002).

Conservation Status of the Species in Region 2

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

Given the dramatic changes that have taken place within the occupied habitat of *Ipomopsis polyantha* over the last 120 years, it can be assumed that in many places the distribution of this species has been diminished. However, movement of soil and anthropogenic disturbance might have spread this species to new locations, resulting in occasional small increases in its distribution. Because the pre-settlement population size of *I. polyantha* is not known, it is difficult to assess the effects of infrastructure and management regimes on abundance. While prolonged or constant disturbance, such as construction and livestock grazing, have been observed to extirpate occurrences, periodic light to moderate disturbance is probably beneficial. However, plants that have benefited from human disturbance are also imperiled by it. With so many different landowners within the distribution of *I. polyantha*, it is likely that management of some properties is not compatible with the persistence of *I. polyantha* but that a few properties are managed appropriately. While the net human impact on the distribution and abundance of *I. polyantha* is difficult to assess, the cumulative impact of construction, livestock grazing, disturbance, and habitat fragmentation wrought by a rapidly growing human presence is almost certainly resulting in a current decline of *I. polyantha*. Reliance on human disturbances such as road maintenance and livestock grazing would be an extremely tenuous existence for *I. polyantha*, since areas thus disturbed are not managed on its behalf. Observations in 2004 suggest that the occurrence known from the vicinity of Dyke may no longer be extant. Further focused inventory and monitoring work will help to determine the current population trend of this species.

Do habitats vary in their capacity to support this species?

Habitats where *Ipomopsis polyantha* is found vary greatly in their capacity to support it. However, many apparently suitable sites do not support *I. polyantha*, which makes it difficult to assess the capacity of habitats to support it. These sites may be highly suitable but simply unoccupied. The nature of the disturbance regime of a given site factors largely into its capacity to support *I. polyantha*. However, much remains unknown about the nature of the disturbance regime to which *I. polyantha* is adapted. While observations of its response to disturbance have been made, they have not identified the specific role of disturbance in the life history and ecology of *I. polyantha* and the periodicities and intensities at which it is benefited and harmed. It is likely that fire once played an important role in the creation of habitat for *I. polyantha*, so habitats with natural vegetation and a natural fire regime might be expected to support robust occurrences of *I. polyantha*. Observations that pollinator species richness is greatest where natural vegetation and water are available suggest that landscape context will affect the ability of *I. polyantha* to outcross effectively. In areas where vegetation and disturbance are largely the product of human activities, as appears to be the case throughout most of the range of *I. polyantha*, areas that are disturbed infrequently probably afford the best conditions for *I. polyantha*. Areas grazed by livestock apparently have a low capacity to support *I. polyantha* while other areas, including roadside rights-of-way and abandoned pastures, have a higher capacity to support *I. polyantha*. Refinements of our understanding of the relationships between *I. polyantha* and its habitat will be possible when more research is conducted on this topic.

Vulnerability due to life history and ecology

The unfortunate overlap of *Ipomopsis polyantha*'s narrow endemism and the town of Pagosa Springs is the primary source of its vulnerability and high degree of imperilment. Its narrow tolerance of edaphic conditions appears to limit it to soils of a very specific geologic stratum that is being developed rapidly as Pagosa Springs grows and is being intensively utilized for livestock grazing and agriculture. Thus, its high habitat specificity leaves it extremely vulnerable to extirpation.

Its poor response to livestock grazing renders *Ipomopsis polyantha* extremely vulnerable to livestock. It is not known if *I. polyantha* can respond positively to certain grazing scenarios through overcompensation as has been observed in some studies of *I. aggregata*, but observations indicate that where grazing occurs, *I. polyantha* is excluded. As its habitat is subdivided and developed, many residents can be expected to graze horses on their ranchettes. Viable populations of *I. polyantha* are unlikely to survive on these properties under such an intense grazing regime.

Despite the sensitivity of *Ipomopsis polyantha* to some types of disturbance, its ruderal tendencies and its ability to persist or even to thrive under some disturbance regimes has allowed it to survive against large odds. However, most of the known population resides in sites that are maintained by anthropogenic disturbance that is not imposed on its behalf. Thus, changes in transportation or weed management needs could dramatically impact occurrences of *I. polyantha*. Reliance on human disturbance is an insecure mode of existence that will need to be addressed in conservation plans for *I. polyantha*.

As a biennial species, *Ipomopsis polyantha* may be somewhat vulnerable to environmental stochasticity. The degree to which it can survive unfavorable years will depend largely on how long it can persist as a rosette or remain dormant as seeds. The high population turnover of biennials leaves them more vulnerable to seasonal environmental stochasticity than perennials.

The minimum viable population size is not known for *Ipomopsis polyantha*, but even small populations by the standards of the 50/500 rule of Soulé (1980) may still be viable and of conservation importance. The Colorado Natural Heritage Program considers occurrences of *I. polyantha* containing 10 or more plants as viable, but this threshold will be revised when a minimum viable population size is determined (Colorado Natural Heritage Program 2003).

Evidence of populations in Region 2 at risk

There is ample evidence that all of the known populations of *Ipomopsis polyantha* are at risk, and authorities (Anderson 1988, O'Kane 1988, Collins 1995, Anderson personal communication 2003, Heil personal communication 2003, Lyon personal communication 2003) agree that because of its rarity and the precariousness of its remaining occurrences, *I. polyantha* is very endangered. Lyon (personal communication 2003) places this species at the top of a list of species at risk of extinction in Colorado, and the Colorado Rare Plant Technical Committee has identified it as among approximately five high priority species.

Plans for the development of Pagosa Springs affect the entire global range of *Ipomopsis polyantha*, but they include no provisions to ensure the long-term viability of any portion of the population. There are no protected areas or conservation easements that include *I. polyantha*, and no occurrences are found on public land where they might be protected from development. Much of the area around Mill Creek and Pagosa Springs has already been subdivided, making conservation action difficult. Future land use plans have been developed by Archuleta County and are documented in the Archuleta County Community Plan (Archuleta County 1999). In this plan, all areas inhabited by *I. polyantha* are planned for very low-density (35 acre or more), low-density (3 to 35 acres), and medium-density (2 to 5 acres) residential development (**Figure 11**). A "village center" is planned for the Dyke Area. This was evidently not intentional; the participating parties were not aware of the species during the development of the plan, and there was no public input regarding the plant (Miller personal communication 2003). Two projects conducted by the Colorado Natural Heritage Program (Lyon and Denslow 2002, Sovell et al. 2003) have provided data to Archuleta County regarding *I. polyantha* that could be incorporated into any plan revisions. If occurrences remain to be discovered on USFS land, they are probably less imperiled than any of the known occurrences.

The total population size of *Ipomopsis polyantha* is somewhat small (estimates range between 2,246 and 10,526 plants). While populations of this size are probably viable, the fragmentation of its habitat suggests that geneflow throughout the population may be obstructed, leading to smaller effective population sizes. Fragmentation also impacts the movement of pollinators. While *I. polyantha* is capable of self-fertilization, it is likely that heavy reliance on this means of reproduction will rapidly reduce the genetic diversity of the species. Human disturbance regimes and reduction in plant biodiversity were shown to reduce pollinator species richness by Collins (1995), so the cumulative effects of these impacts probably conspire to put *I. polyantha* at further risk.

Much of the population of *Ipomopsis polyantha* resides in sites that are maintained by an anthropogenic disturbance regime. While *I. polyantha* appears to benefit to some extent from these disturbances, it has not been shown that human disturbance can be counted on to ensure the long-term viability of this species. It is likely that with increased densification and urbanization of the sites where *I. polyantha* is currently found, these areas will no longer be managed as they are now and *I. polyantha* might be excluded by the new management practices.

Management of the Species in Region 2

Implications and potential conservation elements

The most current data available suggest that *Ipomopsis polyantha* is a narrowly endemic species imperiled due to a small number of occurrences, a high level of endemism, and threats to its habitat. It is not currently known from Region 2 USFS lands, but there is potential for undiscovered occurrences on the San Juan National Forest. Potential habitat is also known from areas on the San Juan National Forest, where introduction of *I. polyantha* may be worthy of consideration as part of a conservation strategy for this species.

Due to the rarity of *Ipomopsis polyantha*, the loss of a population, or a portion thereof, would result in the loss of important components of the genetic diversity of the species. Conservation easements and translocation offer the best chance for the conservation of this species. Given its extreme rarity, threats to its habitat, demonstrable impacts, and declining range and available habitat, management policies must take proactive steps to ensure that this species persists. Available data strongly suggest that *I. polyantha* warrants federal listing, at least as Threatened, and possibly as Endangered. Restoration policies will need to address grazing regimes, human and natural disturbance regimes, pollinator resources, and restoration of native plant communities.

Establishment of occurrences on USFS land is a conservation action worthy of consideration if other measures are not taken to ensure the survival of this species. Given (1994) offers much practical advice regarding restoration and translocation that will assist with the development of effective management and restoration policies. Identifying the extent of potential habitat for *Ipomopsis polyantha* on USFS land and implementing measures to prevent degradation of this habitat are also conservation measures that may benefit *I. polyantha*. Please see the Tools and practices and Threats sections of this assessment for information on mitigating threats resulting from management.

Desired environmental conditions for *Ipomopsis polyantha* include sufficiently large areas where the natural ecosystem processes on which *I. polyantha* depends can occur, thus permitting it to persist unimpeded by human activities and their secondary effects, such as weeds. This includes a satisfactory degree of ecological connectivity between occurrences to provide corridors and other nectar resources for pollinators. From a functional standpoint, ecosystem processes on which *I. polyantha* depends appear to remain intact to some extent. Whether this will remain true at the human population densities projected for the area is uncertain. Although *I. polyantha* occurrences are apparently viable at present, the natural ecosystems and ecosystem processes have been drastically altered, and the habitat is heavily disturbed and fragmented. Further research on the ecology and distribution of *I. polyantha* will help to develop effective approaches to management and conservation. Given the extreme rarity and imperilment of this species, conserving the three known occurrences is a high priority for biodiversity conservation.

It is likely that a thoughtful assessment of current management practices on lands occupied by *Ipomopsis polyantha* would identify some opportunities for change that would be inexpensive and have minimal impacts on the livelihoods and routines of local residents, ranchers, managers, stewards, and recreationists while conferring substantial benefits to *I. polyantha*. Please see the Tools and practices section of this document for potential beneficial management actions on behalf of *I. polyantha*.

Tools and practices

Species and habitat inventory

Species inventory work is a high priority for research on *Ipomopsis polyantha*. Collecting baseline information and developing a detailed map of the known distribution and abundance of this species will provide a reference from which population trends can be assessed. There have been several concerted efforts to find other *I. polyantha* occurrences. A new occurrence was found in 2002 by Peggy Lyon, a Colorado Natural Heritage Program botanist. This suggests that further searches could yield other yet undiscovered populations. Species inventories are simple, inexpensive, and effective, and they are necessary for acquiring a sufficient understanding of the target species to develop a monitoring program. Contracting experts on this species to search for more occurrences and to update historic records would contribute greatly to our knowledge of *I. polyantha*.

Ipomopsis polyantha is conspicuous and showy, and it is not difficult to distinguish from other members of the genus *Ipomopsis*. It also tends to grow in open habitats, which makes it easy to find. Field crews could be quickly taught to recognize it in the field. Searching for *I. polyantha* is complicated by the need to obtain permission to enter private land throughout its known range. Also, it can be difficult to find in dry years when most plants remain in the inconspicuous rosette stage.

Areas with the highest likelihood of new occurrences are those with the appropriate geologic substrate in the immediate area of the known occurrences. Many areas within the known range of *Ipomopsis polyantha* remain to be searched because of the difficulties in obtaining permission to visit private land. When willing landowners are identified, the opportunity should be taken to search for the species on their property.

There may be other occurrences on Mancos Shale outcrops many miles away from Pagosa Springs, particularly if it was once more widespread. Outcrops of Upper Cretaceous Mancos Shale extending from Pagosa Springs west to Durango and north into Hinsdale County are all worthy of further inventory work. The East Fork of the San Juan River to the northwest of Pagosa Springs and the vicinity of Piedras Creek and Chimney Rock to the west of Pagosa Springs are other places in need of inventory work (Anderson personal communication 2003). Although Ant Hill (about 12 miles northwest of Pagosa Springs) has been searched, there is much potential habitat in that area, on both private and Region 2 USFS land; *Ipomopsis polyantha* may yet be found there (Anderson personal communication 2003). Identifying the extent of potential habitat for *I. polyantha* on USFS land and implementing measures to prevent degradation of this habitat are conservation measures that may benefit *I. polyantha*.

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

Searches for *Ipomopsis polyantha* could be aided by modeling habitat based on the physiognomy of known occurrences. The intersection of topography, geologic substrate, and vegetation could be used to generate a map of a probabilistic surface showing the likelihood of the presence of *I. polyantha* in given locations. This would be a valuable tool for guiding and focusing future searches. 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 would apply to *I. polyantha* as well. However, this approach might be complicated by the extent of habitat that is apparently suitable but unoccupied.

Population monitoring

The best time for inventory and monitoring of *Ipomopsis polyantha* is from late May to late July when the plants are flowering most actively. A monitoring program for *I. polyantha* would begin by targeting the three known occurrences and would add other occurrences to the program if they are discovered. Multiple-sample sites with different levels of anthropogenic disturbance should be selected within the large occurrence at Pagosa Springs. Monitoring sites under a variety of land management scenarios will help to identify appropriate management practices for *I. polyantha* and to understand its population dynamics and structure. Selection of monitoring sites with different grazing regimes (e.g., ungrazed for 1 year, ungrazed for 3 years, lightly grazed, heavily grazed), sites in rights-of-way with different management regimes, and other anthropogenically altered sites as well as sites in natural or semi-natural settings will provide the most valuable information.

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. The most sensitive measure of population change will be gleaned from recruitment success, using techniques similar to those used by Collins (1995) but with a larger sample size. Methods used for demographic monitoring of *Ipomopsis aggregata* ssp. *weberi* are described by Wilken (1996); these would be suitable for *I. polyantha* as well. Monitoring interactions with pollinators could be effectively done using a scaled-back version of the methods employed by Collins (1995). Suitable methods for monitoring pollinators are also discussed in Kearns and Inouye (1993). Measuring seed production will require a visit later in the summer after fruit set. 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).

Lesica (1987) described a technique for monitoring populations of non-rhizomatous perennial plant species that would apply to *Ipomopsis polyantha*. Standard monitoring methods generally employ the use of randomly-arrayed, systematic sampling units. Within each plot, plants are marked and tracked using an aluminum tag or other field marker. Recruitment within each plot is quantified by counting seedlings. To reduce the chance of missing seedlings, a quadrat frame subdivided with tight string can help observers to search each quadrat systematically and objectively. Elzinga et al. (1998) offers additional suggestions regarding this method.

Several methods of monumentation are recommended in Elzinga et al. (1998), depending on the site physiography and the 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 *Ipomopsis polyantha* would facilitate the management of this species. Gathering data on edaphic characteristics (moisture, texture, and soil chemistry, particularly pH, if possible) 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. Gathering data from unoccupied but hypothetically suitable sites is also very useful in establishing the autecological requirements of the species (Wilken personal communication 2003). This approach has been used productively for other rare species, and it often reveals critical ecological variables that would otherwise have been missed. Comparing lysimetry data between occupied and unoccupied habitat could help to refine the definition of potential habitat if soil chemistry controls the distribution of *I. polyantha*.

Adding a photo point component to this work, following the 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) offers excellent instructions on establishing photo point monitoring plots. Monitoring sites should be selected carefully, and a sufficient number of sites should be selected if the data are intended to detect population trends.

At present, the priorities lie in gathering data on distribution and population sizes for *Ipomopsis polyantha*. Gathering population size data can be done rapidly and requires only a small amount of additional time and effort (Elzinga et al. 1998). Thus, mere presence/absence monitoring is not recommended for *I. polyantha*.

To address the metapopulation structure of *Ipomopsis polyantha*, one approach might be to select highly suitable but unoccupied sites and attempt to observe colonization events. The recommendations for selecting monitoring sites from different anthropogenic disturbance regimes offered above would offer data from which a metapopulation structure for *I. polyantha* could be investigated. Observations of local extirpations, which are fairly likely to occur in plots where grazers are introduced, would also add to our understanding of the metapopulation structure of *I. polyantha*. Establishing artificial occurrences in carefully studied suitable sites is one approach to testing metapopulation theory as it applies to *I. polyantha* that also provides the benefit of establishing additional occurrences (Wilken personal communication 2003). Even for plants in which metapopulation dynamics can be successfully inferred from regional extinction and colonization data, focusing efforts on monitoring of individual occurrences is more likely to provide an accurate assessment of the species (Harrison and Ray 2002).

Habitat monitoring

Habitat monitoring, as recommended by Anderson (1988), would particularly benefit *Ipomopsis polyantha*. Anderson (1988, p. 13) wrote "Because of the precarious nature of the plant's roadside habitat and the difficulty of maintaining roadside monitoring plots, monitoring should consist of periodic site visits twice a year, at the beginning and end of summer, to ensure that the plants within the highway rights-of-ways have not been sprayed, mowed, or otherwise disturbed." Habitat monitoring in the absence of *I. polyantha* individuals could be conducted on currently grazed sites within the known distribution. Documenting the nature of the grazing regime and other management actions on the site will help to better understand the impacts of grazing on *I. polyantha*.

For sites that are occupied by *Ipomopsis polyantha*, 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 this species' 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. Making special note of signs of degradation from overgrazing may help managers to proactively prevent serious degradation by implementing changes in the grazing regime. 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 occurrences.

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 consistently rate the severity of the impact.

The use of photopoints for habitat monitoring is described in Elzinga et al. (1998). This is a powerful technique that can be done quickly in the field. Though it does not provide detailed cover or abundance data, it can help to elucidate patterns observed in quantitative data.

Beneficial management actions

The establishment of areas that would be managed for the conservation of *Ipomopsis polyantha* is needed to prevent its extinction. Land conservation action must occur soon while the window of opportunity remains open. As the human population increases in the area, occurrences of *I. polyantha* will be lost and its habitat will become increasingly fragmented. Conservation easements, fee purchase, and other land trust activities would be useful conservation tools to protect occurrences on private land (Anderson 1988, Lyon and Denslow 2002, Sovell et al. 2003). Acquisition of conservation easements is cited in the Archuleta County Community Plan as a tool for maintaining the "desired future condition" of the county (Archuleta County 1999). Increasing mill levies with voter approval and seeking other funding sources, such as Great Outdoor Colorado funds, for the purchase of easements and open space are suggested in the plan to achieve this. Although it appears that *I. polyantha* does not occur on any existing conservation easements, there remain many opportunities for the County or other entities to purchase the development rights to parcels that support robust occurrences of *I. polyantha*. Purchasing conservation easements, even on small properties, may confer significant benefits to the conservation of *I. polyantha*, given the high degree of imperilment of this species (Sovell et al. 2003). Sovell et al. (2003) noted that several private landowners expressed interest in the plant and could be approached for conservation easements or management agreements if *I. polyantha* occurs on their property. Land exchanges that bring sites on private land into federal ownership, such as the BLM, would be a useful conservation tool for the Dyke population (Anderson 1988). Land exchange may also be a means of adding lands occupied by *I. polyantha* to the San Juan National Forest.

Ipomopsis polyantha has suffered from benign neglect. Although there has been considerable loss and degradation of habitat throughout its entire range, no conservation plans have been developed or implemented on its behalf. No group or agency has assumed a leadership role in conservation efforts for this species, due in part to the absence of this species on public land. Recent effort by the Colorado Rare Plant Technical Committee to engage local stakeholders in meetings to discuss conservation planning for this species is a positive step that is likely to benefit it.

Management practices that reduce the impacts from livestock grazing to occurrences of *Ipomopsis polyantha* are likely to contribute greatly to the achievement of conservation goals for this species. Research is needed to identify grazing regimes that are compatible with *I. polyantha*. Given our current limited knowledge based solely on observations, exclusion of grazing in selected areas from May through August when the plant is growing and reproducing is most likely to be compatible with the persistence of *I. polyantha*. Other approaches that might be considered on a site-by-site basis include the use of exclosures and reducing stocking rates, but it is not known what stocking rates are compatible with *I. polyantha*.

Weed control efforts have the potential to negatively impact *Ipomopsis polyantha*. Avoiding the use of herbicides for weed control within occurrences of *I. polyantha* (particularly along Highway 84) is likely to be highly beneficial (Anderson 1988, Brinton personal communication 2003, Colorado Natural Heritage Program 2003). Avoiding right-of-way mowing from May until late August is also likely to be beneficial (Collins 1995). In road-cut occurrences of the federally listed *I. sancti-spiritus*, hand pulling of weeds is recommended for weed control (U.S. Fish and Wildlife Service 2002). Any management strategies that work to prevent the infestation of uninfested occurrences of *I. polyantha* are likely to confer the greatest benefits.

Other right-of-way management activities can be modified to benefit *Ipomopsis polyantha*. Installation and maintenance of utilities in rights-of-way could impact large portions of the population, but careful attention to avoiding *I. polyantha* can greatly reduce impacts. Christine Collins was able to stake out occurrences in the Highway 84 right-of-way to alert utility crews. Continued awareness of the species during future projects of this sort will help to ensure its viability. Clearances of areas in question by someone who is familiar with *I. polyantha*, such as those planned for 2005 along Highway 84, are needed to mitigate impacts from all projects along roads in the Pagosa Springs area.

Managing for large pollinators, which can travel farther than small pollinators, might be beneficial to *Ipomopsis polyantha* as residential development decreases the amount of natural habitat in the area while increasing the distance each pollinator needs to travel to reach nectar resources. Incorporating native plantings and native bee nesting boxes into landscape designs as recommended in Buchmann and Nabhan (1996) will help to ensure that pollinator services are available to *I. polyantha*.

The introduction of *Ipomopsis polyantha* to protected locations would help to ensure its long-term persistence. Two sites have been identified as areas that are currently uninhabited but possibly suitable for *I. polyantha*. Echo Lake State Wildlife Area to the south of Pagosa Springs contains apparently suitable Mancos Shale substrate and some of the species commonly associated with *I. polyantha* (Brinton personal communication 2003, Lyon personal communication 2003, Sovell et al. 2003). This area is within a mile of known *I. polyantha* occurrences and is protected from development. Thus it may offer a refuge for *I.*

polyantha as Pagosa Springs grows. On land managed by the USFS, *I. polyantha* would receive the benefits of that agency's sensitive species status. Locations along Piedra Road northwest of Pagosa Springs, including the O'Neal Hill Special Botanical Area, have been identified as possible translocation sites on USFS land (Brinton personal communication 2003, Lyon personal communication 2003). Anderson (1988) recommended land exchange as a means for the BLM to acquire occupied habitat. Given (1994) offers many practical suggestions for establishing occurrences of plants at new sites (translocation and reestablishment) and cites numerous sources and case studies. Because *I. polyantha* is somewhat ruderal, it may be well suited to translocation simply by distributing seed at selected new sites.

Appropriate management of natural vegetation in the vicinity of occurrences of *Ipomopsis polyantha* is likely to benefit pollinators and may improve the likelihood of persistence for currently unknown populations. Two valuable sources of information for the management of the shrubland, woodland, and forest ecosystems where *I. polyantha* is found are Johnston et al. (1999) and West and Young (2000). There have been no active population or habitat management efforts on behalf of *I. polyantha*.

Further inventory and monitoring efforts would be highly beneficial to *Ipomopsis polyantha*. Identifying high quality occurrences in which the population size, condition, and landscape context are excellent will help managers to prioritize conservation efforts. Much potential suitable habitat within the range of *I. polyantha* remains to be searched. Determining the extent of potential habitat on the San Juan National Forest followed by intensive survey efforts of that habitat is needed to try to identify occurrences where conservations efforts can be made by the USFS. This will also determine what sites may be suitable for introduction of *I. polyantha*, should that become necessary.

Seed banking

No seeds or genetic material for *Ipomopsis polyantha* are currently in storage at the National Center for Genetic Resource Preservation (Miller personal communication 2003). 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. *Ipomopsis polyantha* is a reasonable candidate for seed banking and cultivation for reintroduction (Sovell et al. 2003).

Information Needs

Distribution

Further species inventory work specifically targeting *Ipomopsis polyantha* is a high research priority. Until we have a complete picture of its distribution and population size, it will not be possible to accurately assess the conservation needs and priorities for this species. Often when a species thought to be rare is actively sought and inventoried, it is found that the species is not as rare as previously believed. Because *I. polyantha* has already been actively sought in several studies, this scenario is less likely. However, recent floristic inventory work by Peggy Lyon (presented in Sovell et al. 2003) has been successful, suggesting that other occurrences might await discovery. Places to focus future search efforts include private land in the vicinity of Pagosa Springs, the East Fork of the San Juan River to the north of Pagosa Springs, Ant Hill (about 12 miles northwest of Pagosa Springs), and Piedras Creek in the vicinity of Chimney Rock (Anderson personal communication 2003). Ant Hill has been searched for *I. polyantha* by Anderson (1988) and Lyon (Sovell et al. 2003), but there is much potential habitat in the area and it still has not all been searched.

Life cycle, habitat, and population trend

While information on the life cycle of *Ipomopsis polyantha* can be inferred to some extent from the very well-studied *I. aggregata*, specific research on *I. polyantha* is needed to understand its population ecology. Some life history parameters were investigated by Collins (1995), but a more thorough investigation of its lifespan and autecology is needed.

The habitat for *Ipomopsis polyantha* has been described, but the nature of its natural habitat and natural disturbance regime is poorly understood. An explanation for the extremely limited range of *I. polyantha* is lacking. Mancos Shale outcrops can be found throughout much of Archuleta County and in many other parts of western Colorado, but the particular environmental variables that *I. polyantha* responds to are unknown. Hypotheses regarding the roles of pH, soil texture, dispersal ability, disturbance, community ecology, and historic versus contemporary habitat availability as causes of rarity for *I. polyantha* need to be tested. Collins (1995) found that the pH of soils where *I. polyantha* is found is less acidic than that of soils from the surrounding area, and she observed poor germination in soils from elsewhere in the area where *I. polyantha* does not occur. However, further investigation of this sort is needed to fully understand the species-environment relationships for *I. polyantha*. Understanding its habitat and being able to identify suitable habitat is particularly important for the conservation and management of *I. polyantha*. Autecological research is needed to refine our definition of appropriate habitat and to facilitate effective habitat monitoring and conservation stewardship of this species.

The population trend of *Ipomopsis polyantha* is not known and may be difficult to quantify. Lack of access to many occurrences on private land and difficulties in seeing the plant in its rosette stage will further complicate this research. However, understanding the population biology of *I. polyantha* is important for appropriate stewardship and management of this species.

Response to change

Rates of reproduction and establishment and the effects of environmental variation on these parameters have not been thoroughly investigated in *Ipomopsis polyantha*. Thus, the effects of various management options cannot be assessed during project planning. *Ipomopsis polyantha* populations could be expected to respond quickly to environmental impacts since it is a relatively short-lived, ruderal species and populations turn over rapidly.

The work of Collins (1995) was important for gaining an understanding of the pollination ecology and for understanding the importance of maintaining robust populations of pollinators to reduce the risk of inbreeding depression in *Ipomopsis polyantha*. She also determined that this species is a poor disperser, but further investigation of dispersal is needed to understand how it colonizes so effectively. This will also be important for understanding any metapopulation dynamics relevant to the conservation of *I. polyantha*.

Understanding the specific responses of *Ipomopsis polyantha* to disturbance is important for determining appropriate management practices, but they are not clear and need further investigation. The effects of livestock grazing on the survival and population ecology of *I. polyantha* warrant careful study. Identifying the causes of the poor performance of *I. polyantha* when grazed will greatly assist with the development of compatible land management practices. See the Reproductive biology and ecology section of this document for further discussion of disturbance.

Change in the amount of residential development and infrastructure in the habitat of *Ipomopsis polyantha* will probably decrease the availability and diversity of pollinators. Collins (1995) noted that large-bodied species have greater nutrient reserves, enabling them to travel further to pollinator resources. Thus we might expect a shift towards larger pollinators as the area densifies and populations of *I. polyantha* become more insular. Pollinators capable of residing in disturbed habitats are also likely to be favored. Further study of the effects of disturbance on pollinator species richness will help to reduce the loss of genetic diversity of *I. polyantha*.

Metapopulation dynamics

Research on the population ecology of *Ipomopsis polyantha* 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 *I. polyantha*. Baseline population dynamics and viability must first be assessed. Given the complex patchwork of varying disturbance and management regimes within the known range of *I. polyantha*, it is probably constantly being extirpated at some sites while colonizing others. Because this is probably all occurring within the single population at Pagosa Springs, this does not constitute a true metapopulation structure as described for the *Pedicularis furbishiae* (Furbish's lousewort; Menges and Gawler 1986).

Demography

Only the broadest generalizations can be made at present regarding the demography of *Ipomopsis polyantha*. Population size has not been assessed for occurrences of *I. polyantha*. Growth and survival rates are also unknown, and the rate of reproduction is poorly understood. Our knowledge of the distribution of the species is incomplete. Therefore much work is needed in the field before local and range-wide 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). However, the value of demographic data for conservation planning and species management cannot be overstated.

Population trend monitoring methods

There has been no monitoring of populations of *Ipomopsis polyantha*, but methods are available to begin a monitoring program. Lesica (1987) described a technique for monitoring populations of non-rhizomatous perennial plant species that would apply to *I. polyantha*. Selection of monitoring sites from a variety of land use scenarios will be necessary to monitor trend at the population level.

Restoration methods

There have been no known attempts to restore habitat or occurrences of *Ipomopsis polyantha*. Therefore, there is no applied research to draw from in developing a potential restoration program. It is likely that *I. polyantha* may be readily propagated in a greenhouse environment, but it may be difficult to transfer plants successfully into a natural or quasi-natural (restored) setting.

Translocation may be one approach to decreasing the imperilment of this species. Although conservation of occurrences within its known range in its native habitat is by far the best approach to species conservation, this may not be enough in the case of *Ipomopsis polyantha*. The ongoing destruction of its habitat and the prospects for the future of its habitat suggest that extinction is a very real possibility in the near future for *I. polyantha*. Thus, establishment of occurrences in protected areas might offset the immediate threat of extinction. Please see the beneficial management actions offered in the Tools and practices section of this document for a discussion of possible sites for introduction.

Research priorities for Region 2

Further species inventory work is needed to identify all occurrences of *Ipomopsis polyantha*. Focusing on private land in the vicinity of Pagosa Springs is the best first step towards developing a complete understanding of the distribution of *I. polyantha*. Targeted search efforts at phenologically appropriate times (late May to mid August) in suitable habitat on Upper Cretaceous Mancos Shale substrates in the Pagosa Springs vicinity will help to confirm the distribution and abundance of *I. polyantha* and may identify other opportunities for its conservation. The identification of large, healthy occurrences on properties where land owners are interested in establishing conservation easements is needed so that conservation action on behalf of *I. polyantha* can begin. Identifying robust occurrences in natural settings is important for setting conservation targets and priorities. Collecting detailed notes on associated species, habitat, geology, soil, and other natural history observations at all locations will be extremely useful information. Documentation of any threats and visible impacts to *I. polyantha* will help to develop conservation strategies, and will help managers act to mitigate these threats.

Search efforts are needed on USFS lands on the San Juan National Forest in Archuleta County. The area along Piedra Road north of Pagosa Springs has been searched, but further efforts are needed. Continued search efforts on any outcrop of Mancos shale in the Pagosa Springs area where permission can be gained from land owners are needed to continue to better document the extent of the known population.

Demographic studies are needed for *Ipomopsis polyantha*. Demographic data are far more useful for assessing status and developing recovery efforts than genetic information (Schemske et al. 1994). Determining the critical life history stages of *I. polyantha* will allow managers to focus their efforts on implementing management protocols that benefit those critical stages. A monitoring program that determines effective population sizes and investigates the growth, survival, and reproduction of individuals within populations will have considerable practical value and will help to determine the measures needed to ensure the survival of *I. polyantha*. Collins (1995) noted that at least two consecutive years of study are needed to determine the effects of environmental variation on reproductive output. However, since this would only track one cohort, this is an insufficient amount of time to track the effects of long-term environmental variables like fluctuating patterns in temperatures and precipitation (Wilken personal communication 2003).

Reaching a better understanding of the influence of livestock grazing and human activities on individuals and habitat of *Ipomopsis polyantha* will confer substantial practical benefits for land managers and planners. Identifying life history and phenological stages when *I. polyantha* is less sensitive to grazing impacts would help greatly to mitigate threats by developing grazing practices that are compatible with *I. polyantha*. Exploring the effects of different stocking rates, timing of grazing, and resting pastures is likely to yield valuable information. An investigation of overcompensation in *I. polyantha* would also have significant practical value for the development of compatible range management practices. Documentation of the impacts of grazing on *I. polyantha* is needed to monitor the status of the species.

The role of disturbance in the autecology of *Ipomopsis polyantha* remains poorly understood. An understanding of the specific tolerances of *I. polyantha* to different human and natural disturbance regimes will assist with developing conservation strategies and management plans by determining the types of disturbance most likely to negatively impact it.

Information gleaned from studies of the physiological and community ecology of *Ipomopsis polyantha* will be valuable in the event that an occurrence needs to be restored, and it will help to determine biotic and abiotic factors that contribute to its survival. Understanding the plant-environment relationship for *I. polyantha* will be insightful in understanding the coping strategies employed by this species, and will help to model its potential distribution. Examination of hypotheses regarding the causes of rarity in *I. polyantha* will help to gain an understanding of management practices, locations for further searching, and potential reintroduction sites.

The experimental introduction of *Ipomopsis polyantha* to suitable habitats in sites that are protected from development is worthy of consideration. While introduced populations are of lesser conservation value than populations in their known range (Given 1994, Anderson personal communication 2003), their establishment would help to reduce the probability of its extinction.

Additional research and data resources

The draft manuscript of Porter et al. (2003) was provided by Dr. J. Mark Porter. At the time this assessment was completed, this paper was not yet published. Although further revisions of this assessment may occur before publication, the results from their paper are unlikely to change the information presented here regarding the taxonomic relationships of *Ipomopsis polyantha*. Population counts were made in 2004, but these data were not yet available for inclusion in this document.

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).

Actinomorphic — Flowers that are radially symetrical (Harris and Harris 1999).

Competive/Stress-tolerant/Ruderal (CSR) model — A model developed by J.P. Grime in 1977 in which plants are characterized as Competitive, Stress-tolerant, or Ruderal, based on their allocation of resources. Competitive species allocate resources primarily to growth; stress-tolerant species allocate resources primarily to maintenance; and ruderal species allocate resources primarily to reproduction. A suite of other adaptive patterns also characterize species under this model. Some species show characteristics of more than one strategy (Barbour et al. 1987).

Cyme — A flat-topped or round-topped determinate inflorescence, paniculate, in which the teminal flower blooms first (Harris and Harris 1999).

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).

Monophyletic — Applied to a group of species that share a common ancestry (Allaby 1998).

Outcrossing — The breeding of individuals with strains having a different genotype (Art 1993).

Perfect — Flowers that include both male and female structures; bisexual (Weber and Wittmann 2001).

Polyphyletic — Applied to a group of species that are derived from many interbreeding populations and that do not share a common ancestry (Allaby 1998).

Potential Conservation Area (PCA) — A best estimate of the primary area supporting the long-term survival of targeted species or natural communities. PCAs are circumscribed for planning purposes only (Colorado Natural Heritage Program Site Committee 2002). They are ranked as follows based on their biodiversity significance:

- B1 Outstanding Significance: only location known for an element or an excellent occurrence of a G1 species.
- B2 Very High Significance: one of the best examples of a community type, good occurrence of a G1 species, or excellent occurrence of a G2 or G3 species.
- B3 High Significance: excellent example of any community type, good occurrence of a G3 species, fair occurrence of a G2 species, or a large concentration of good occurrences of state-rare species.
- B4 Moderate or Regional Significance: good example of a community type, fair occurrences of a G3 species, excellent or good occurrence of state-rare species.
- B5 General or State-wide Biodiversity Significance: good or marginal occurrence of a community type, S1, or S2 species.

Protandrous — Dehiscence of the anthers prior to receptivity of the stigma. A mechanism to encourage out-crossing (Grant and Grant 1965).

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

Sere — The characteristic sequence of developmental stages occurring in plant succession (Allaby 1998).

Sympatric — Applied to species whose habitats (ranges) overlap (Allaby 1998).

Thyrse — A compact, cylindrical, or ovate panicle with an indeterminate main axis and cymose sub-axes (Harris and Harris 1999).

Xenogamy — Fertilization involving pollen and ovules from different flowers on genetically distinct plants. Synonymous with outcrossing (Allaby 1998).

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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Appendix A: Potential Conservation Areas

Mill Creek at Pagosa Springs

Biodiversity Rank: B1. Irreplaceable.
The Mill Creek at Pagosa Springs PCA supports two of the only three populations known of the critically imperiled (G1 S1) *Ipomopsis polyantha* (Pagosa gilia).

Protection Urgency Rank: P1. Immediately threatened.
Occurrences are fragmented, on private land and along highway right of way.

Management Urgency Rank: M1. Very high urgency.
Management actions may be required within one year or the element occurrences could be lost or irretrievably degraded. Drastic actions may need to be taken to prevent the extinction of this species.

Location: Archuleta County. Both sides of State Highway 84, south of Pagosa Springs.

Size: 1,877 ha.

Elevation: Approximately 7,100 to 7,700 ft.

General Description: The Mill Creek PCA encompasses Mancos Shale slopes north and south of Pagosa Springs, on both sides of a major highway, Colorado State Highway 84. The area is primarily residential, with some small businesses and the county fairgrounds located within it. The eastern end of the PCA is more rural, but rapidly developing. Patches of several rare native plants, including the Pagosa gilia, survive in residential areas, pastures, roadsides and vacant lots, but populations are extremely fragmented and vulnerable to extinction. The plants are restricted to soils derived from the Mancos Shale formation that extends in a wide swath from northwest to southeast through the central part of Archuleta County. Natural vegetation of the site is predominantly ponderosa pine forest, with Gambel's oak in the understory. However, much of the natural vegetation has been removed with development of the area.

Biodiversity Rank Justification: The site is drawn for an excellent (A ranked) occurrence of Pagosa gilia, a plant that is critically imperiled (G1) on a global scale. A good (B ranked) occurrence of the same species is included in the site. A fair (C ranked) occurrence of Pagosa bladderpod, imperiled (G2) globally, a fair (C ranked) occurrence of Pagosa phlox, vulnerable (S3) in Colorado, and two unranked (E) occurrences of Townsend's Easter daisy, thought to be imperiled globally (G2?) fall within the site.

Natural Heritage element occurrences at the Mill Creek at Pagosa Springs PCA.

Element	Common Name	Global Rank	State Rank	Federal Status	State Status	Federal Sensitive	EO Rank	Last Observed
Plants:								
Ipomopsis polyantha	Pagosa gilia	G1	S1			BLM/FS	A	2002
Ipomopsis polyantha	Pagosa gilia	G1	S1			BLM/FS	B	2002
Lesquerella pruinosa	Pagosa bladderpod	G2	S2			BLM/FS	C	1994
Townsendia glabella	Townsend's Easter daisy	G2?	S2?			BLM/FS	E	2002
Townsendia glabella	Townsend's Easter daisy	G2?	S2?				E	1985
Phlox caryophylla	Pagosa phlox	G4	S3				C	2002

Boundary Justification: The boundary is drawn to encompass all known occurrences of Pagosa gilia south of Pagosa Springs. It includes much unoccupied habitat between small remnant populations of the plant. Adjacent areas within the city and to the north that support other rare plant species and contain suitable habitat for the Pagosa gilia are included in the site.

Protection Comments: All of the land on which the Pagosa gilia occurs is privately owned or along the state highway. Several private landowners have expressed interest in the plant, and could be approached for conservation easements or management agreements. Some incentive would probably be required. Most of the plants are on very small parcels, containing only a fragment of the total population. Areas of this size are usually considered too small for easements. However, the risk of losing an entire species may dictate that small easements are worthwhile in this case.

Management Comments: Management strategies for the Pagosa gilia are complicated by the fact that the species often colonizes disturbed areas. However, extreme disturbances such as horse grazing have been shown to extirpate the species. Much of the population in this site is along the right of way of Highway 84. Widening of the highway would probably exterminate these plants. On the other hand, it has been noted that the population has been extended southward along the highway, perhaps due to movement of soils from shoulder maintenance. Spraying of roadside weeds would probably be extremely detrimental. Due to the extreme rarity of the Pagosa gilia, drastic steps may be necessary to preserve the species. One such measure would be to collect seed and introduce the plants in suitable habitat that is protected. The area around Echo Canyon Reservoir, owned by the Colorado Division of Wildlife is within a mile of the southern extent of the plant population in this site, and appears to have the required soils. This species would also be a reasonable candidate for seed banking and cultivation for reintroduction.

Stollsteimer Creek North

Biodiversity Rank: B2 Nearly irreplaceable. This PCA supports one of only three known occurrences of the critically imperiled (G1S1) *Ipomopsis polyantha* (Pagosa gilia).

Protection Urgency Rank: P2 The private land in this PCA may be threatened by development within 5 years.

Management Urgency Rank: M2 Ongoing, recurrent management action (weed control) is necessary to maintain the current quality of element occurrences.

Location: Archuleta County, along State Highway 160 and north, about 11 miles west of Pagosa Springs.

Size: 3,018 acres

Elevation: 6,750 to 7,614 feet

General Description: The site comprises disturbed areas along Highway 160 at Dyke, and foothills north of the highway to the National Forest boundary. It is characterized by low hills of Mancos Shale, with sparse to moderately dense vegetation including *Juniperus scopulorum* (Rocky Mountain juniper), *Rhus trilobata* (skunkbrush), *Chrysothamnus nauseosus* (rabbitbrush), *Prunus virginiana* var. *melanocarpa* (chokecherry), *Purshia tridentata* (bitter brush), *Quercus gambelii* (Gambel's oak) and a mixture of native and introduced grasses and forbs, including *Oryzopsis hymenoides* (Indian rice grass), *Bouteloua gracilis* (blue gramma) and *Hilaria jamesii* (galleta). Upper slopes have *Pinus ponderosa* (ponderosa pine) and Gambel's oak, with *Pseudotsuga menziesii* (Douglas-fir) present on cooler sites. The PCA also includes an irrigated pasture on the south side of the highway.

Natural Heritage element occurrences at the Stollsteimer Creek North PCA.

Scientific Name	Common Name	Global Rank	State Rank	Fed/State Status	EO Rank*
Ipomopsis polyantha	Pagosa gilia	G1	S1	FS/BLM	B
Lesquerella pruinosa	Pagosa bladderpod	G2	S2	FS/BLM	B
Lesquerella pruinosa	Pagosa bladderpod	G2	S2	FS/BLM	E
Lesquerella pruinosa	Pagosa bladderpod	G2	S2	FS/BLM	D

***:** EO Rank* is "Element Occurrence" Rank

Biodiversity Comments: This PCA includes one of only three known occurrences of the critically imperiled (G1) *Ipomopsis polyantha* (Pagosa gilia), in the entire world. The occurrence is ranked good (B). Although it is a roadside site, the continuing existence of this species requires that no location be lost. The site also contains good (B), unranked (E) and poor (D) occurrences of the *Lesquerella pruinosa* (Pagosa bladderpod), a globally imperiled (G2) plant.

Boundary Justification: The site encompasses three occurrences of the Pagosa bladderpod and one occurrence of the Pagosa gilia, along with some unoccupied or unsurveyed but suitable adjacent habitat. The boundaries incorporate areas of Mancos Shale and alluvial soils that are subject to some degree of natural erosion. Boundaries may be further refined with future surveys.

Protection Rank Comments: The majority of this PCA is privately owned. There is a small area (approximately 100 acres) of National Forest on the north, and three isolated parcels of BLM land comprising about 320 acres, surrounded by private land. One occurrence of Pagosa bladderpod is located on BLM land. The other occurrences in this PCA are on private land within an area undergoing rapid development. Protection of this site should be a high priority. Although small isolated parcels of BLM land are often identified for disposal or exchange, BLM could help to preserve this site by continuing its ownership and giving special protection, such as designation as an Area of Critical Environmental Concern, to these three very important parcels. The site is included in the area that The Nature Conservancy has identified as a high priority for conservation action in their Southern Rocky Mountain Ecoregional Plan (Neely et al. 2001).

Management Rank Comments: The Pagosa gilia population is extremely vulnerable to highway maintenance activities and grazing management. State highway personnel should be made aware of the location of the Pagosa gilia along Highway 160 and avoid spraying or other actions that would threaten the plants. The plants on the south side of the highway may be vulnerable to changes in grazing and irrigation management of the pasture in which they occur. Present management of this area is unknown.