Ipomopsis aggregata (Pursh) V. Grant ssp. *weberi* V. Grant and Wilken (scarlet gilia): A Technical Conservation Assessment

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AUTHOR'S BIOGRAPHY

Juanita A. R. Ladyman received her B.Sc. degree (with First-class honors) in Biochemistry from London University, England. Her first professional position was as plant pathology laboratory technician and, later, as greenhouse research supervisor with the Arid Lands Research Center on Sadiyat Island in the United Arab Emirates. She obtained her Ph.D. degree in Botany and Plant Pathology from Michigan State University where she was also a research assistant with the D.O.E. Plant Research Laboratory. She worked as a plant physiological ecologist and plant scientist for Shell Development Company conducting research on the physiology, ecology, and reproductive biology of economically important plant species and their wild relatives. She then worked for a plant biotechnology company in their Genetic Transformation and Plant Tissue Culture Division. For the last 13 years she has worked in the area of conservation, particularly on rare, endemic, and sensitive plant species in the southwest United States. For three years of that time, she was the botanist with the New Mexico Natural Heritage Program. She has conducted research and monitoring programs on both non-vascular and vascular species. She currently is a partner in *JnJ Associates*, an environmental consulting company in Colorado.

LIST OF ERRATA

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *IPOMOPSIS AGGREGATA* SSP. *WEBERI*

Status

The NatureServe Global (2003) rank for *Ipomopsis aggregata* ssp. *weberi* (scarlet gilia, Rabbit Ears gilia, or Weber's gilia) is G5T2 indicating that the species is demonstrably secure but the subspecies *weberi* is imperiled. It is ranked imperiled (S2) by the Colorado Natural Heritage Program and critically imperiled (S1) by the Wyoming Natural Diversity Database. It is designated a sensitive species by the USDA Forest Service Region 2 and the Wyoming Bureau of Land Management.

Primary Threats

Concern about the viability of *Ipomopsis aggregata* ssp. *weberi* is a result of its limited geographic range and the potential impacts of the multiple uses of its habitat. Recreational activities, such as mountain bike riding, snowmobiling, hiking, horseback riding, and development activities associated with recreation and urbanization, such as campsite development and road building, threaten some occurrences on the Routt National Forest. As the human population grows in areas within easy access to *I. aggregata* ssp. *weberi* habitat and as recreational use increases, the impacts may become substantially more significant. At current levels, grazing and trampling by native and non-native ungulates may have an impact, especially on smaller colonies. Activities associated with resource extraction are not currently perceived to be a threat although individual occurrences may have been impacted in the past. Invasive weeds are likely a threat to the long-term sustainability of some occurrences. If other subspecies or races of *I. aggregata* are introduced, for example in revegetation seed mixes, both hybridization and outbreeding depression are potential threats.

Primary Conservation Elements, Management Implications, and Considerations

Ipomopsis aggregata ssp. *weberi* is a rare taxon with a limited geographic range. It is known from the Park Range region in Colorado and the Sierra Madre Range in Wyoming. The majority of the total known occurrences (approximately 17 of 27) are located on the Routt National Forest. There are approximately three known occurrences on the Medicine Bow National Forest. There may have been some loss of range within the last century in Colorado. In 1903, a specimen was collected from the Chambers Lake area, which is currently managed by the Roosevelt National Forest. No specimens have been reported from that area since then. Chambers Lake has always been a popular recreational area, and it currently experiences heavy recreational use because it is in easy reach of the large urban areas of the Front Range. *Ipomopsis aggregata* ssp. *weberi* is restricted to areas with low vegetation cover, suggesting that it will be unable to compete with invasive plant species. It grows on old road cuts and in forest and shrub clearings and appears to be an early or mid-successional species. It can persist in, or re-colonize, areas after vehicle or animal disturbance although the sustainability of populations at high disturbance sites is unknown. The information currently available suggests that some occurrences are relatively secure. Known occurrences are typically avoided during development projects on the Medicine Bow and Routt national forests. The Wyoming Bureau of Land Management has supported development of a habitat model for *I. aggregata* ssp. *weberi* to assist in predicting potential habitat. The Wyoming Bureau of Land Management – Rawlins Field Office intends to develop a species-specific management plan for the taxon.

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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 aggregata* ssp. *weberi* (scarlet gilia, Rabbit Ears gilia, or Weber's gilia) is the focus of an assessment because it is a rare species that has a restricted geographic range. It is designated a sensitive species by the USDA Forest Service Region 2 (2003a) and by the Wyoming Bureau of Land Management (Wyoming BLM State Director's Sensitive Species List 2001). This assessment addresses the biology, ecology, and management of *I. aggregata* ssp. *weberi* throughout its range.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop 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, if the information is available it cites management recommendations proposed elsewhere, and when these have been implemented, the assessment examines their success.

Scope

This assessment examines the biology, ecology, conservation status, and management of *Ipomopsis aggregata* ssp. *weberi* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although some of the literature relevant to the species may originate from field investigations of other subspecies of *I. aggregata* outside the region, this document places that literature in the ecological and social context of the central Rockies. Similarly, this assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of *I. aggregata* ssp. *weberi* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting this synthesis, but is placed in a current context.

In producing this assessment, I reviewed peer-reviewed literature, publications that have not been peer-reviewed (non-refereed publications), research reports, and data accumulated by resource management agencies. The assessment emphasizes the peer-reviewed literature because this is the accepted standard in science. Some non-refereed literature was used in the assessment when information was otherwise unavailable. In some cases, non-refereed publications and reports may be regarded with greater skepticism. However, many reports or non-refereed publications on rare plants are often 'works-in-progress' or isolated observations on phenology or reproductive biology and are reliable sources of information. For example, demographic data may have been obtained during only one year when monitoring plots were first established. Insufficient funding or manpower may have prevented work in subsequent years. One year of data is generally considered inadequate for publication in a peer-reviewed journal but still provides a valuable contribution to the knowledge base of a rare plant species. Unpublished data (for example, state natural heritage program and herbarium records) were important in estimating the geographic distribution and population sizes. These data required special attention because of the diversity of persons and methods used in their collection. In some instances, records that were associated with locations at which herbarium specimens had been collected at some point in time may be considered more reliable than those where only observations were made.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions 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.

One element of uncertainty in evaluating the range of *Ipomopsis aggregata* ssp. *weberi* is the occasional sympatry with a related variety, *I. aggregata* ssp. *attenuata*, and the apparent difficulty in distinguishing between the two in the field by non-specialists. As mentioned above, observations without herbarium specimens, especially those made at the edge of the species' range, need to be regarded with some skepticism.

Publication of the Assessment on the World Wide Web

To facilitate their use, species conservation assessments are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. It will also facilitate their revision, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the Web. This assessment 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 aggregata ssp. *weberi* is a regional endemic of the Park Range region of Colorado and the Sierra Madre Range of Wyoming. Due to its rarity and limited geographic range, the U.S. Fish and Wildlife Service (USFWS) identified this taxon as a Category 2 (C2) candidate for listing in 1993 under the Endangered Species Act (U.S. Fish and Wildlife Service 1993). The C2 list included species that might have warranted listing as Threatened or Endangered, but for which the USFWS lacked sufficient biological data to support a listing proposal. In February 1996, the USFWS revised its candidate policy and eliminated the C2 designation (U.S. Fish and Wildlife Service 1996). *Ipomopsis aggregata* ssp. *weberi* has no federal legal status at the present time.

The NatureServe Global[1] rank (2003) for this taxon is G5T2. This rank indicates that the species, *Ipomopsis aggregata*, is "demonstrably secure" (G5) over its whole range. However, the subspecies *weberi* is ranked T2, indicating that this taxon is imperiled because of rarity or because of other factors demonstrably making it vulnerable to extinction. It is designated as imperiled (S2) by the Colorado Natural Heritage Program (2002) and as critically imperiled (S1) by the Wyoming Natural Diversity Database (Fertig et al. 1994).

Ipomopsis aggregata ssp. *weberi* is designated a sensitive species by Region 2 of the USFS (2003a). It is also designated a sensitive species by USDI Bureau of Land Management in Wyoming (2001). It is not designated a sensitive species by the Bureau of Land Management (2000) in Colorado, and therefore it has no protections on Bureau of Land Management (BLM) lands in Colorado.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Ipomopsis aggregata ssp. *weberi* occurs on land managed by the USFS and the BLM and on private land. The intention behind the USFS sensitive designation is to prevent a downward trend of the taxon, which would lead to its listing as threatened or endangered by the U.S. Fish and Wildlife Service. The designation of sensitive by the US Forest Service is also valuable because it raises the awareness of a species among professional botanists and other researchers. The designation requires that a biological evaluation be made prior to any significant federal project on National Forest System lands, such as a timber sale (USDA Forest Service 1994). A biological evaluation determines the project impacts to the taxon or to its habitat. If impacts are likely to cause substantial harm to the total population, the project may be redesigned or mitigation measures may be considered.

On National Forest System lands, *Ipomopsis aggregata* spp. *weberi* is restricted to the Medicine Bow and Routt national forests. Part of the population in the Medicine Bow National Forest, Wyoming, is within one mile of the western boundary of a proposed

[1] For definitions of ranking system see Rank in the Definitions section at the end of this document.

research natural area (RNA) (Jankovsky-Jones et al. 1995). However, plants have not been found within that proposed RNA. In fact, no occurrences have been found within the boundaries of any protected area, such as a wilderness area, a RNA, or an area of critical environmental concern.

Ipomopsis aggregata ssp. *weberi* was included in a sensitive plant species guide developed for the Medicine Bow National Forest (von Ahlefeldt 1993). This species guide was designed to assist field crews in recognizing sensitive plant species. *Ipomopsis aggregata* ssp. *weberi* plants on land managed by the USFS are generally not disturbed by Forest Service activity unless it is unavoidable and is determined to have no impact on the overall status of the taxon (Proctor personal communication 2003). For example, there was a loss of part of an occurrence due to road widening that was initiated due to safety concerns at a dangerous corner (Proctor personal communication 2003). Within the last two years *I. aggregata* ssp. *weberi* plants were found directly outside the boundaries of two timber sale areas. In these cases, no roading or skidding was permitted within occupied habitat (Proctor personal communication 2003). The most common measure taken to protect *I. aggregata* ssp. *weberi* in the Routt National Forest is to avoid occurrences using a 50-foot buffer zone (Skorkowsky personal communication 2003). A biological evaluation considering management of the Buffalo Pass grazing allotment on the Hahns Peak/Bears Ears Ranger District of the Routt National Forest was completed in 2002 (Bringuel et al. 2002). The conclusion was that a conservative approach to land management should be taken until the biology, physiology, and ecology of *I. aggregata* ssp. *weberi* is better understood (Bringuel et al. 2002).

Ipomopsis aggregata ssp. *weberi* is designated a sensitive species by the Wyoming BLM (2001). It occurs on land managed by the BLM Rawlins Field Office (USDI Bureau of Land Management 2001). Sensitive species designations are made in order to "maintain vulnerable species and habitat components in functional BLM ecosystems, ensure sensitive species are considered in land management decisions, prevent a need for species listing under the Endangered Species Act, and prioritize needed conservation work with an emphasis on habitat" (Wyoming Bureau of Land Management 2001). In general, due to constraints associated with manpower, field surveys and species status updates are made on BLM sensitive species approximately every ten years (Carroll personal communication 2003). The habitat of each BLM-designated sensitive species in Wyoming has been modeled (Fertig and Thurston 2003). Habitat models can aid in predicting potential habit when evaluating development permit requests (Carroll personal communication 2003). The Wyoming Bureau of Land Management will formalize species-specific management objectives and actions for *I. aggregata* ssp. *weberi* in the "near future" (USDI Bureau of Land Management 2003).

Ipomopsis aggregata ssp. *weberi* was reported as having been selected as a Management Indicator Species (MIS) on the Routt National Forest (Bringuel 2002). This is incorrect, and *I. aggregata* ssp. *weberi* remains a sensitive species but has no indicator status (Burkhart personal communication 2004). A MIS is typically a species that responds to habitat changes and is scarce or unique. *Ipomopsis aggregata* ssp. *weberi* was considered an appropriate candidate because it is likely to respond to changes as a result of grazing activity and might be used to assess different alternative management practices (Bringuel 2002). MIS essentially act as focal species. Focal species are defined in the proposed November 2000 regulations as "surrogate measures used in the evaluation of ecological sustainability including species and ecosystem diversity" (36 CFR 219.36).

Biology and Ecology

Classification and description

Systematics and synonymy

The genus *Ipomopsis* belongs to the Polemoniaceae, commonly known as the phlox family. Members of *Ipomopsis* are closely related to *Gilia*. Historically, many *Ipomopsis* species were originally included in *Gilia*. Species are known from both North and South America, but the main center of distribution lies in the Rocky Mountain region and the southwestern United States. There are approximately 27 species in the genus *Ipomopsis*. These species fall naturally into three sections, namely *Phloganthea*, *Microgilia*, and *Ipomopsis* (Grant and Grant 1965). Species with blue flowers, such as *I. multiflora*, or red, trumpet-shaped flowers, such as *I. tenuifolia*, are in the section *Phloganthea*. Species with whitish-colored, somewhat inconspicuous and clustered flowers, such as *I. congesta*, are in the section *Microgilia*. Species, such as *I. aggregata*, with red, trumpet-shaped flowers or long-tubed violet or white flowers are in the section *Ipomopsis*.

Members of the *Ipomopsis aggregata* group are widespread throughout western North America. There is substantial geographical and polymorphic variation among the group. Grant and Wilken (1986) revised this highly variable complex so that it consists of three species: *I. aggregata*, *I. arizonica*, and *I. tenuituba*. They recognized seven geographical subspecies of *I. aggregata*: namely subspecies *formosissima*, *aggregata*, *bridgesii*, *collina*, *attenuata*, *candida*, and *weberi*.

Grant and Wilken (1986) observed that *Ipomopsis aggregata* ssp. *weberi* is one of the morphological extremes of *I. aggregata*. Wolf and Soltis (1992) determined that gene flow among populations within each geographic race or subspecies of *I. aggregata* was relatively high. However, they concluded that, "although gene flow was an important evolutionary force shaping geographic variation for allozymes within the *I. aggregata* complex, it was insufficient to prevent the distinct morphological divergence among the taxa." In addition to distinctive morphological characters, the ecological distribution of *I. aggregata* ssp. *weberi*, in terms of altitude and plant associations, when compared to ssp. *attenuata* or ssp. *aggregata*, suggests that it has a unique genetic combination (Wilken personal communication 2003).

Ipomopsis aggregata (Pursh) V. Grant is synonymous with *Gilia aggregata* (Pursh) Spreng. *Ipomopsis aggregata* ssp. *weberi* has no synonyms (Kartesz 1994). Prior to its description in 1986, *I. aggregata* ssp. *weberi* was considered part of *I. aggregata* ssp. *attenuata*, which is synonymous with *G. aggregata* ssp. *attenuata* (Wherry 1946, Grant and Wilken 1986).

Non-technical description

Ipomopsis aggregata ssp. *weberi* is a herbaceous perennial. It has a taproot, a soft woody base, and one to several erect stems. The stems are 15 to 60 cm tall. The leaves are lobed, relatively large, and well-developed at the base of the plant. Leaves on the stems are much smaller. The flowers are arranged in a panicle on the upper parts of the stem. The flowers are particularly closely spaced, and the flowering stem looks congested. The congested arrangement of the flowers is a distinctive characteristic. The flowers are white, less often pinkish, and fragrant smelling. The calyx lobes are 3 mm long. The corolla has a long slender tube that abruptly flares into a circular limb that looks trumpet-shaped. The tube is slender, 10 to 22 mm long, circular in cross-section, approximately 1 mm wide at the base, and has a narrow orifice between 1 to 2 mm in diameter. Anthers are usually at the orifice or sometimes exerted (Grant and Wilken 1986). A line drawing of the plant is in **Figure 1**. Photographs of vegetative and flowering plants are provided in **Figure 2**.

A characteristic at the population level is that the plants have predominately white-colored flowers although there are occasionally some individuals with pink-colored flowers. The pink flowers are also congested and are not necessarily evidence of hybridization. *Ipomopsis aggregata* ssp. *weberi* intergrades with *I. aggregata* ssp. *attenuata*, with which it is parapatric at the outermost parts of its range in all the compass directions (Grant and Wilken 1986). The key differences between *I. aggregata* ssp. *attenuata*, ssp. *aggregata*, and ssp. *weberi* are listed in **Table 1**.

References to technical descriptions, photographs, line drawings and herbarium specimens

A detailed technical description and a line drawing are in Grant and Wilken (1986), Spackman et al. (1997), and Fertig et al. (1994). Another technical description is published in Weber and Wittmann (2001) and Dorn (2001). A description along with a location map, photographs, and a line drawing are published on the USGS Northern Prairie Wildlife Research internet site. See the Reference section for the internet site address.

Distribution and abundance

Ipomopsis aggregata ssp. *weberi* is endemic to the Park Mountain Range in Colorado and the Sierra Madre Range in Wyoming (**Figure 3**; Fertig 1999). It is known from Jackson, Grand and Routt counties in Colorado, and its range extends several miles over the state line into Carbon County, Wyoming. A single record, with no abundance information, was reported from Latah County, Idaho (Grant and Wilken 1986). However, this occurrence was later shown to be a small-flowered, white-pigmented population of *I. aggregata* ssp. *aggregata* (Wilken personal communication 2004). *Ipomopsis aggregata* ssp. *weberi* occurs on the Medicine Bow and Routt national forests in Region 2, on land managed by the BLM in Wyoming and Colorado, and on private land. The record of it occurring on BLM land in Wyoming comes from a single specimen with imprecise location data (Marriott 2003).

Grant and Wilken (1986) suggest that *Ipomopsis aggregata* ssp. *weberi* is relictual and may have been more widespread in the past, possibly during

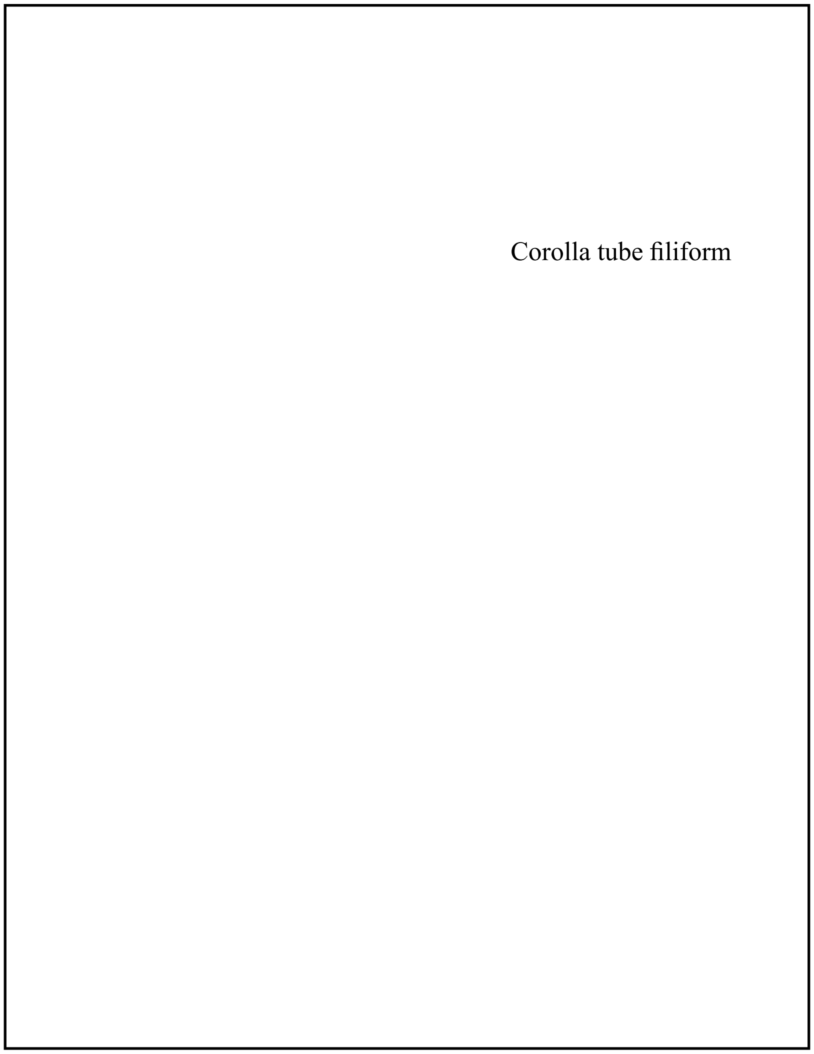

Figure 1. Illustration of *Ipomopsis aggregata* ssp. *weberi*. Illustration by Ann Fenwick, used with permission.

the Pleistocene when the world's climate underwent profound changes (Allen and Anderson 1999). The distribution of ssp. *weberi* is a function of its adaptation to a particular set of environmental variables, which cannot be easily quantified at the present time (Wilken personal communication 2003). A stand of gambel oak that represents the northernmost extension of that species' range in the Rocky Mountains is also at the northern edge of the range of *I. aggregata* ssp. *weberi* (Jankovsky-Jones et al. 1995). This situation may be coincidental. Alternatively this area may be at a point where significant changes in climate or environmental conditions occur, which are important to both species. The range of *I. aggregata* ssp. *weberi* is surrounded by *I. aggregata* ssp. *attenuata* and ssp. *aggregata*. *Ipomopsis aggregata* ssp. *attenuata* is hypothesized to be a stabilized hybrid that geographically lies between the two putative parents, namely ssp. *weberi* and ssp. *aggregata*. *Ipomopsis aggregata* ssp. *weberi* hybridizes with ssp. *attenuata* in regions of sympatry (Grant and Wilken 1986). There is no evidence that hybridization with ssp. *attenuata* affects the abundance or range of the taxon, *I. aggregata* ssp. *weberi*. *Ipomopsis aggregata* ssp. *attenuata* apparently has colonized land intervening the range of its purported parents and does not have the same habitat requirements as ssp. *weberi* (see Demography section).

Ipomopsis aggregata ssp. *weberi* is known from approximately 24 occurrences in Colorado and three occurrences in Wyoming. Sixteen of the occurrences have been located in the last decade (**Table 2**). The taxon is most abundant in Routt County within the Routt National Forest. Sixteen, or possibly 17, occurrences are on the Routt National Forest, one is on the Roosevelt National Forest, and three are on the Medicine Bow National Forest.

(A)

(B)

Figure 2. Photograph of *Ipomopsis aggregata* ssp. *weberi* (A) vegetative rosette (B) flowering individuals. Photographs by John Proctor, USDA Forest Service botanist; used with permission.

Table 1. Characteristics of *Ipomopsis aggregata* ssp. *aggregata*, ssp. *attenuata*, ssp. *weberi*, and *I. tenuituba*.

			Flower					
***Ipomopsis* species**	**Sub-species**	**Inflorescence**	**fragrance**	**color**	**corolla**	**tube**	**anthers**	**Pollination**
aggregata	*aggregata*	open	odorless	scarlet (rarely salmon)	long salverform with flaring tube	>1.5 mm wide at base, (15)18 to 22 (23)mm long, 3 to 7mm diameter orifice	well exserted	ornithiphilous; pollinated by hummingbirds
aggregata	*attenuata*	widely spaced	fragrant or odorless	pink to scarlet	subsalverform with flaring tube	1 mm wide at base, 18 to 22mm long, 2 to 3mm diameter orifice, filiform,	level with orifice or exserted	ornithiphilous
aggregata	*weberi*	congested	fragrant	white (few pink ones in a population)	short salverform with non-flaring tube	1 mm wide at base, 10 to 22mm long, 1 to 2mm diameter orifice, filiform.	level with orifice or exserted	information not published
tenuituba	(not applicable)	very open	fragrant	white, violet, pink	long salverform with non-flaring tube	19 to 45 mm long, 2 to 3 mm diameter orifice, not filiform.	below, or level with, orifice	sphingophilous; pollinated by hawk- or sphinx-moths

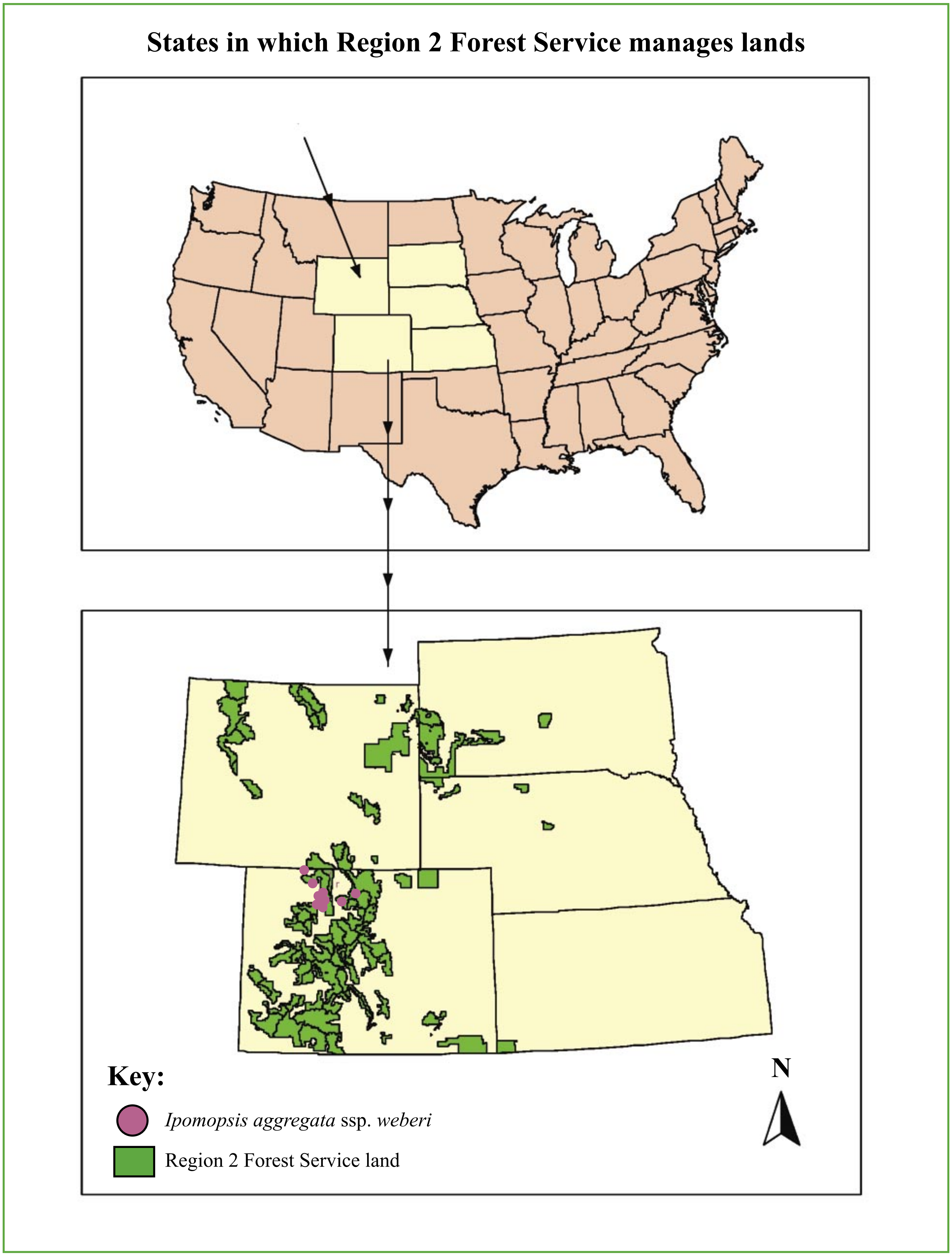

Figure 3. Range of *Ipomopsis aggregata* ssp. *weberi* in Region 2.

Table 2. Occurrences of *Ipomopsis aggregata* ssp. *weberi*. Information is from the Colorado Natural Heritage program, the Wyoming Natural Diversity database, the University of Colorado-Boulder herbarium, the Colorado State University Herbarium, Wilken and Grant (1986), and Kastening (1990). Herbaria abbreviations: COLO — University of Colorado, Boulder, CO. CS — Colorado State University, Fort Collins, CO. RM — Rocky Mountain Herbarium, University of Wyoming, Laramie, WY.

Arbitrary site no.	State	County	Management	Date of Observations	Location	Source
1	CO	Jackson, Grand	Routt National Forest	July 17, 1903	Rabbit Ears Range.	*L.N. Goodding 1583* COLO
2	CO	Jackson	Routt National Forest	June 16, 1993	Along FS 734 north of FS 106. Near Willow Creek in the Rabbit Ears Range.	*J.E. Tear, Jr. 258* CS
3	CO	Grand, Routt, Jackson	Routt National Forest	August 1930; August 1950; August 1951; July 1954; July 1979; July 1982; July 1989; July 1990; August 1995; September 1998	Within 3 mile radius of Rabbit Ears Pass. Dumont Lake Area. This occurrence is distributed over 8 sections and comprises approximately 24 suboccurrences.	*G.E. Osterhout 7284* 1930 COLO; *G.T. Robbins 3362* 1950 COLO; *W.A. Weber 7131* 1951 COLO; *D. Wilken & S. Rosenstock 13553* 1979 CS; *D. Wilken & S. Rosenstock 13554* 1979 CS; *D. Wilken & S. Rosenstock 13648* 1980 CS; *D. Wilken 13876* 1982 CS; *J.W. Flock 2052* 1989. *Grant & Wilken* 1986; Colorado Natural Heritage Program occurrence records
4	CO	Routt	Routt National Forest	August 18,1983	Near head of Walton Creek. Demographic site (Wilken 1996).	*D. Wilken & R. Henrickson 14008* 1983 CS
5	CO	Routt	Routt National Forest	July 10, 1979; 1982; 1983; August 10, 1995; August 20, 1998; September 9, 1998; September 10, 1998	North of Walton Peak and west of Rabbit Ears Pass. Occurrence distributed over 10 sections and extends into a “Federal Agency Protective withdrawal” area (Bureau of Land Management 1997; see Definitions section under withdrawal).	Colorado Natural Heritage Program occurrence records
6	CO	Routt	Routt National Forest	August 10, 1995	Area around Mount Werner. This occurrence extends over 6 sections. Demographic monitoring site (Wilken 1996).	Colorado Natural Heritage Program occurrence records
7	CO	Routt	Routt National Forest	September 3, 1998	Buffalo Mountain area.	Colorado Natural Heritage Program occurrence records
8	CO	Routt	Private	July 9, 1891; June 21, 1965	1891: Steamboat Springs. 1965: just northwest of Steamboat Springs.	*C.S. Crandall 729* 1891 CS; *W.A. Weber 12444* with *P. Salamun* 1965 COLO; Colorado Natural Heritage Program
9	CO	Routt	Routt National Forest	August 10, 1995; August 13,1999	West and north of Steamboat ski area, near or in a “Federal Agency Protective withdrawal” (Bureau of Land Management 1997; see Definitions section under withdrawal).	Colorado Natural Heritage Program occurrence records
10	CO	Larimer	Roosevelt National Forest	July 7, 1903	Chambers Lake area.	Colorado Natural Heritage Program occurrence records

Table 2 (concluded).

Arbitrary site no.	State	County	Management	Date of Observations	Location	Source
11	CO	Routt	Routt National Forest	August 10, 1995; July 22, 1998	1995: South Fork Soda Creek area, north of Buffalo Mountain. 1998: Distributed along approximately a 3-mile length of Road 38 on way to Buffalo Pass.	*Spackman and Fayette 9803.a* 1998 CS; Colorado Natural Heritage Program
12	CO	Routt	Routt National Forest	September 3,1998	Spring Creek/South Fork of Soda Creek.	Colorado Natural Heritage Program occurrence records
13	CO	Routt	Routt National Forest, private	July 22, 1998; August 24, 1998	Spring Creek/Bear Creek Area.	Colorado Natural Heritage Program
14	CO	Routt	Routt National Forest	August 25, 1998; August, 26, 1998; August 27, 1998; September 1, 1998	Bear Creek and upper Gunn Creek.	Colorado Natural Heritage Program
15	CO	Routt	Private	August 31, 1948; July 7, 1960	Approximately 3 miles west of Steamboat Springs on road to Clark.	*J. and M. Douglas 60-22* 1960 CS; Colorado Natural Heritage Program
16	CO	Routt	Routt National Forest	August 10, 1995	South of Greenville Mine.	Colorado Natural Heritage Program
17	CO	Jackson	Private	July 1, 1985	North of Walden Reservoir on escarpment.	*S. O'Kane 2100* 1985 CS; Colorado Natural Heritage Program
18	CO	Routt	State of Colorado	August 10, 1995	Steamboat Lake Recreation Area.	*N. Snow 5050* RM; Colorado Natural Heritage Program, Colorado Natural Areas Program
19	CO	Routt	Routt National Forest	September 23, 1998	Northeast of Diamond Peak.	Colorado Natural Heritage Program
20	CO	Jackson	BLM or private (unlikely Routt National Forest)	July 7, 1903	Pinkham Creek.	*L.N. Goodding 1475* COLO
21	CO	Jackson	Routt National Forest or private	July 31, 1952	5 miles north of Cowdrey.	*K. Lafferty 26* COLO
22	CO	Jackson	Routt National Forest	July 23, 1950	Big Creek Lakes, Park Range.	*S. Shushan s.n.* COLO
23	CO	Jackson	Bureau of Land Management	June 14, 1989	Northeast of the Swedde Group Mine and south of Wheeler Creek	Colorado Natural Heritage Program
24	CO	Jackson	Routt National Forest; may extend into Medicine Bow National Forest	July 6, 1966	Near Beaver Creek. Population likely extends into Wyoming.	*Denham 1083* COLO
1	WY	Carbon	Medicine Bow National Forest. Bureau of Land Management, State of Wyoming	June 10, 1994; June 22, 1989	Battle Mountain, Sierra Madre, Park Range. Near Battle Mountain potential research natural area and Battle Mountain special botanical area. Occurrence distributed over 6 sections.	*N. Kastning 1923* 1989 RM; Wyoming Natural Diversity Database
2	WY	Carbon	Medicine Bow National Forest and/or private	July 8, 1993	West aspect of Battle Mountain, Sierra Madre, Park Range.	*C.H. Refsdal 102* 1993 RM
3	WY	Carbon	Medicine Bow National Forest	June 15, 1994	Occurrence is on the ridge between Hatch and Bear Creeks. The taxon identity at this site needs to be confirmed.	Wyoming Natural Diversity Database

A population can be defined as "a group of individuals of the same species living in the same area at the same time and sharing a common gene pool or a group of potentially interbreeding organisms in a geographic area" (National Oceanic and Atmospheric Administration 2004). A less restrictive definition of population, and the one that is used in this report since the species genetics is unknown, is that it is "a group of individuals of the same species that occurs in a given area" (Guralnik 1982). In this report occurrences, or populations, include plants in large areas of land where there are contiguous stretches of apparently suitable, or potential, habitat. One occurrence of *Ipomopsis aggregata* ssp. *weberi* usually consists of several suboccurrences (sub-populations). Interaction, through pollination or seed dispersal, is believed to occur between suboccurrences. However, without knowing the seed dispersal range and specifics of its pollination biology, it is very difficult to delineate what comprises a single interbreeding group of plants. For example, a particularly large occurrence around Rabbit Ears Pass on the Routt National Forest (occurrence 3 in **Table 2**) is considered to be composed of "thousands" of individuals distributed in approximately 24 suboccurrences that extend over seven sections (estimate made in 2000 by Colorado Natural Heritage Program in element occurrence records received 2002). There is currently insufficient information to know for certain if all of these suboccurrences are genetically linked or if some of them are actually genetically isolated. Many occurrences have been recorded within the central region of the Routt National Forest, but it may be that all of the plants belong to one or two extensive meta-populations (see **Figure 4** for the known distribution of patches within a portion of the Routt National Forest). Alternatively, several patches may be genetically isolated within that area.

Individuals may occur densely or can be sparsely distributed throughout an area. Both "sparse" and "abundant" have been used to describe the density and abundance of individuals within a population. The smallest occurrence was described as five individuals in approximately 10 square meters. An example of a large, dense suboccurrence is approximately 2,000 plants over 2 acres (Colorado occurrence 3, **Table 2**). More typically, occurrence sizes range from 100 to 500 individuals within an area of approximately 4 acres. Within such an area, between three and five discrete patches of plants are often easily visualized. Plants typically do not occur in all areas that to casual observation appear to be appropriate habitat, usually termed "potential habitat." Of 1,000 surveyed acres of habitat that looked similar to that occupied by plants, only one percent (10 acres) was found to be occupied (in Colorado Natural Heritage Program 2002, referring to regions within the Routt National Forest).

At the most northern edge of its range, two or three *Ipomopsis aggregata* ssp. *weberi* individuals were reported to be among a population of approximately 25 *I. aggregata* ssp. *attenuata* plants, but it was emphasized that this observation needs to be confirmed (Wyoming Natural Diversity Database 2002). Distinguishing between the subspecies *weberi* and *attenuata* appears to cause some difficulty in the field (Wyoming National Diversity Database 2002).

Occurrence data have been compiled from the Colorado Natural Heritage Program, the Wyoming Natural Diversity Database, the Rocky Mountain Herbarium (RM), the University of Colorado Herbarium at Boulder (COLO), the Colorado State University Herbarium (CSU), and from the literature (Grant and Wilken 1986). Element occurrence delineation in **Table 2** has in most cases followed that proposed by the Colorado Natural Heritage Program and the Wyoming Natural Diversity Database (element occurrence records received 2002). Additional information from herbarium specimens either increased the total number of occurrences, or the herbarium observation was included in an existing occurrence and generally increased the area the occurrence covered. It must be noted that many, particularly older, records do not have precise location information, and errors may have been made in determining the exact number of occurrences. In some cases a site may have been revisited and designated a new occurrence, or alternately discrete occurrences in the same general vicinity may have been estimated to be the same occurrence. Delineation of populations may also change in the future when the extent of the interaction between subpopulations is known. Therefore, it must be considered that the exact number of known occurrences is subject to error until more information about the biology and ecology of the species is available.

Population trend

There is insufficient information to determine the trends for *Ipomopsis aggregata* ssp. *weberi* within the last twenty to one hundred years. A significant problem is that relatively few sites have been revisited. In addition, where areas have been revisited, specific occurrences were not clearly defined during the first observation, and therefore plants are only known to persist in, or be absent from, the same general areas. It is also unknown whether additional reports of

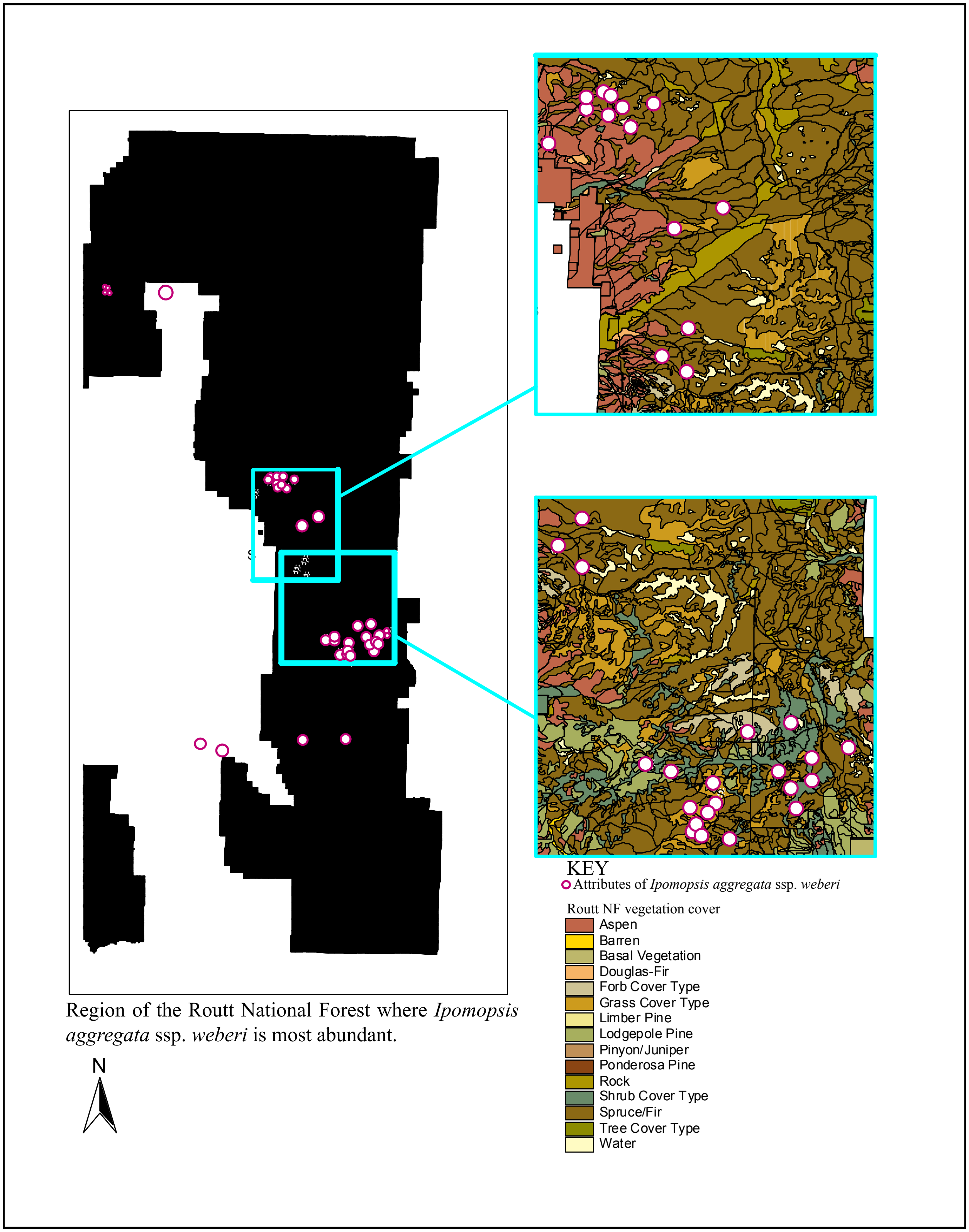

Figure 4. Suboccurrence and occurrence distribution on the Routt National Forest where *Ipomopsis aggregata* ssp. *weberi* is most abundant (see text for further discussion; the majority of occurrence information was provided by the Colorado Natural Heritage Program 2002).

suboccurrences within an occurrence area indicate an increase in the abundance of the species or whether local extirpations and colonizations typically occur, which result in no net gain.

Within one section in the Rabbit Ears Pass occurrences, individuals were described as 'abundant' in 1989 and as numbering approximately 2,000 in 1993 (a suboccurrence in Colorado occurrence 3 in **Table 2**). These estimations of population size made four years apart can be considered to be approximately the same, and thus the occurrence can be considered to have been stable during this time. In 1989, several thousand plants were observed over two sections on Battle Mountain, Wyoming (Kastening 1990, Wyoming Natural Diversity Database element occurrence records 2002). In 1994, three *Ipomopsis* plants, which were not identified to species, were found after a survey of one quarter of each of the two sections (Proctor personal communication 2003). It may be that these observations indicate a reduction in numbers between the two years, but due to insufficient location data, this cannot be ascertained. In addition, fluctuations in population size may be attributed to periodic variation in the recruitment of seedlings or differential survival of juvenile plants due to environmental conditions. During drought years, especially in years of poor snowfall, population size may be significantly reduced (Wilken personal communication 2004). In 1903, a specimen was collected from the Chambers Lake area, which is managed by the Roosevelt National Forest, Colorado. No specimens have been reported from this area since then. In summary, the current evidence indicates that the taxon is locally abundant and persistent in some areas, but it may have experienced local extirpations in some areas of Colorado within the last century.

Habitat

Ipomopsis aggregata ssp. *weberi* occurs in open sites with other herbaceous perennials in various vegetation cover types. A summary of the habitat reported at each occurrence site is provided in **Table 3**. The vegetation cover types in which *I. aggregata* ssp. *weberi* is found on the Medicine Bow - Routt National Forest are listed in **Table 4** (USDA Forest Service 2003b). The shrub and grass species were not identified on this large vegetation-typing scale (**Figure 4**). *Ipomopsis aggregata* ssp. *weberi* is most commonly associated with sagebrush (*Artemisia* species) and less often with snowberry, brushy serviceberry, rabbitbrush, and chokecherry (**Table 5**; Colorado Natural Heritage Program element occurrence records 2002, herbarium records, Wilken 1996). There is no cover type on the Routt National Forest that appears to be particularly favored by *I. aggregata* ssp. *weberi*. It should be noted that when this species is indicated to be within a forested cover type, it is not so much a member of the forest community *per se* but grows in open or partly shaded clearings or where trees are widely spaced.

Ipomopsis aggregata ssp. *weberi* grows at elevations between 2,000 m and 3,200 m (**Figure 5**). When elevation was reported, most occurrences were between 2,800 m and 3,000 m. *Ipomopsis aggregata* ssp. *weberi* grows on ridge tops, in mountain meadows, and on variable slopes, ranging from 0 to 35 percent. Plants have most often been reported from slopes with west, south, and east aspects. Of 27 descriptions of habitat where aspect was mentioned, only one indicated that the plants were at a site with a northern aspect. It has been most frequently reported from xeric slopes, but occasionally it grows in moister sites. For example it was found at one site in full sun on a moist hillside below the *Populus tremuloides-Abies lasiocarpa* forest (Colorado occurrence site 24 in **Table 2**). It has also been found in subalpine fir/Englemann spruce/willow habitat and subalpine fir/alder habitat (**Table 3**). Although willow habitat is not always wet, willows often indicate that relatively moist conditions prevail. Alders (*Alnus tenuifolia*) grow along mountain stream banks and at pond borders (Weber and Wittmann 2001). Another associated species was reported to be *Aster junciformis*, which usually grows in moist habitats (Weber and Wittmann 2001).

Ipomopsis aggregata ssp. *weberi* typically grows in rocky, gravelly soils of a sandy and coarse texture. In Colorado habitat, soils have been reported as being derived from the Coalmont formation and from Miocene age silts and sandstone (Colorado Natural Heritage Program element occurrence records 2002). As the name implies, coal is found below the sandstones and shale of the Coalmont formations (Tweto 1979). The lack of specifics in some of the location data makes it difficult to determine the associated geologic formation. Plants in Wyoming (Battle Mountain area) grow on soils derived from Miocene age rocks and do not apparently grow in areas with soils derived from basalt flows and intrusive igneous rock (according to the geologic map of Love and Christiansen 1985). Initially this observation suggests that geology might account for its distribution in that area, but it appears that *Ipomopsis aggregata* ssp. *weberi* can be found in soils that are derived from a variety of geological formations. According to the available location data, some of the geologic formations with which it is associated in Colorado include volcanic rocks (Tv), volcanic rock interlaced

Table 3. Habitat and notes on occurrences of *Ipomopsis aggregata* ssp. *weberi* (see **Table 2**). Information is from the Colorado Natural Heritage program, the Wyoming Natural Diversity database, the University of Colorado-Boulder herbarium, the Colorado state University Herbarium, (Wilken and Grant 1986), and Kastning (1990).

Arbitrary site no.	Management	Habitat	Comment
1	Routt National Forest	Rocky hillsides.	No information.
2	Routt National Forest	Uncommon, erect herb on rocky soil of gentle south slope.	No information.
3	Routt National Forest	On open dry southeast, east, north, and west-facing sparsely vegetated slopes and mountain meadows with coarse or silty clay gravel soils. Subalpine fir/Engelmann spruce/willow on dry convex-shaped, -facing slope with open exposure. Coarse sandy soil. Abundant pocket gophers On dry southeast and west-facing sparsely vegetated slopes and mountain meadows with coarse or silty clay gravel soils. Dry concave-shaped southeast facing slope with open exposure. East- and south- facing gravelly open sites. In 1979, among *Picea* species. Also on relatively flat terrain.	The occurrence extended over 8 sections. 1980: Corollas white to pink among plants; scattered. 1979: Corollas white; scattered. Colorado Natural Heritage program 1998: The maintenance and/or expansion of the highway, power line, Forest Service roads and campground that exist within the occurrence may contribute to the reduction or extirpation of suboccurences.
4	Routt National Forest	Southeast facing slope.	No information.
5	Routt National Forest	On open gravelly slopes with *Artemisia tridentata*, *Artemisia* species-*Festuca idahoensis*. Shaded to open sites. Very rocky soils. On glaciated mountain slopes and ridges. East facing, concave-shaped, dry slopes (25 to 30 percent incline). Open exposure. On rolling uplands on south and east facing open dry slopes with spruce/fir plant community and spruce/fir habitat type. Coarse sandy soils. On a dry open (usually convex-shaped) slope in coarse sandy soils, associated plant community spruce/fir in spruce/fir habitat type. Subalpine fir/ Englemann spruce/willow dry open slopes open exposure, west and southwest facing rocky sandy slopes.	Over 10 sections. Found in conjunction with scarlet gilia (1998).
6	Routt National Forest	No information.	No information.
7	Routt National Forest	West and south-facing concave-shaped dry slopes (20 to 30 percent incline) on rocky, sandy and red, gravelly soils. Plants on aspen clearings, roadsides, and mountain meadows. Associated species aspen, subalpine fir, serviceberry.	No information.
8	Private	1891: No information. 1965: Shale outcropping. Slopes and drainage.	No information.
9	Routt National Forest	On glaciated mountain slopes and ridges. On open dry concave-shaped slopes (0 to 5% incline).	No information.
10	Roosevelt National Forest	Mountainside.	No information.
11	Routt National Forest	1995: No information. 1998: Roadside and continuing into mountain meadows and aspen forests. Found on red gravelly soil with *Geranium* spp., *Lupinus* spp., *Eriogonum* spp., *Penstemon* spp. Dominant in small areas. Hundreds of plants.	No information.
12	Routt National Forest	No information.	No information.

Table 3 (concluded).

Arbitrary site no.	Management	Habitat	Comment
13	Routt National Forest, private	West-facing open slopes (5 to 20 percent incline).	1998: a few plants were near the road.
14	Routt National Forest	Over 4 sections. Glaciated mountain slopes. On dry southeast-facing slopes (20 to 35% exposure) in open to partly shaded sites. In coarse and rocky soils. Aspen dominant.	No information.
15	Private	Dry ground.	No information.
16	Routt National Forest	No information.	No information.
17	Private	East to southeast facing, steep slopes on soils derived from sandstone (Coalmont formation). Associated taxa include *Chrysothamnus* spp., *Artemisia* spp., *Orycopis* spp. [*Oryzopsis*], *Agropyron* spp.	Corolla ranging from white to light red; abundant.
18	State of Colorado	Miocene age silt and sandstone.	No information.
19	Routt National Forest	Dry rocky slopes.	No information.
20	Bureau of Land Management or private (unlikely Routt National Forest)	Mountainside.	No information.
21	Routt National Forest or private	Roadside, sagebrush association, in red soil at 8,300 feet.	No information.
22	Routt National Forest	No information.	No information.
23	Bureau of Land Management	Miocene age silt and sandstone with sagebrush on west facing slopes.	No information.
24	Routt National Forest; may extend into Medicine Bow National Forest	In full sun on moist hillside below *Populus tremuloides*-*Abies lasiocarpa* forest.	No information.
1	Medicine Bow National Forest. Bureau of Land Management, State of Wyoming	Sagebrush hillsides, and ridgetop transition zone between big sagebrush-snowberry and brushy serviceberry-rabbitbrush-chokecherry plant community. The ridgetop area is slightly south-facing, a slope of 0 to 15 percent, with gravelly clay/loam soil of moderate to low moisture.	No information.
2	Medicine Bow National Forest and/or private	No information.	Flowering.
3	Medicine Bow National Forest	Ridge top and south-facing top of slope of 3 to 5 percent with big sagebrush-bitterbrush-snowberry community.	Occurrence size 2 acres.

Table 4. Cover types with which *Ipomopsis aggregata* ssp. *weberi* is associated. The data was generated from plotting the occurrence location information with vegetation coverages received from the USDA Forest Service Region 2 (2003b).

State	Cover type	Species composition
CO	Lodgepole pine	*Pinus contorta*
CO	Aspen	*Populus tremuloides*
CO	Spruce/Fir	*Abies lasciocarpa*, Picea engelmannii, Pinus contorta*
CO	Spruce/Fir	*Picea engelmannii*
CO	Spruce/Fir	*Abies lasciocarpa*, Pinus contorta*
CO	Spruce/Fir	*Abies lasciocarpa*, Picea engelmannii, Pseudotseuga menziesii*
CO	Spruce/Fir	*Abies lasciocarpa*, Populus tremuloides, Picea engelmannii*
CO	Spruce/Fir	*Abies lasciocarpa*, Picea engelmannii, Populus tremuloides*
CO	Spruce/Fir	*Picea engelmannii, Abies lasciocarpa*, Pinus contorta*
WY & CO	Shrub	Shrub species undefined
CO	Forb	Forb species undefined
CO	Grass	Grassland with undefined species
WY	Basal vegetation	Undefined species under *Populus tremuloides*
CO	Lodgepole pine	*Pinus contorta*
CO	Aspen	*Populus tremuloides*
CO	Spruce/Fir	*Abies lasciocarpa*, Picea engelmannii, Pinus contorta*
CO	Spruce/Fir	*Picea engelmannii*
CO	Spruce/Fir	*Abies lasciocarpa*, Pinus contorta*
CO	Spruce/Fir	*Abies lasciocarpa*, Picea engelmannii, Pseudotseuga menziesii*
CO	Spruce/Fir	*Abies lasciocarpa*, Populus tremuloides, Picea engelmannii*
CO	Spruce/Fir	*Abies lasciocarpa*, Picea engelmannii, Populus tremuloides*
CO	Spruce/Fir	*Picea engelmannii, Abies lasciocarpa*, Pinus contorta*
WY & CO	Shrub	Shrub species undefined
CO	Forb	Forb species undefined
CO	Grass	Grassland with undefined species
WY	Basal vegetation	Undefined species under *Populus tremuloides*

***Note:** Weber and Wittmann (2001) report that *Abies lasiocarpa* is a species of the coastal Pacific Northwest. *Abies bifolia* is the species that occurs in the Rocky Mountains.

with biotite gneiss (Xfh), Pierre shale (Kp), Colorado group of shale formations (Kc), sedimentary rock (Xb), glacial deposits (Qd), Dakota sandstone (Kd), granitic (Xg) and gneiss and schist (Xb) metamorphic rocks (from Tweto 1979).

The associated species with which *Ipomopsis aggregata* ssp. *weberi* has been reported are listed in **Table 5**. This is not an exhaustive list and represents only the observations that were made on herbarium sheets, in the Wyoming Natural Diversity Database records (Wyoming Natural Diversity Database 2002), and in the literature (Wilken 1995, Grant and Wilken 1986). At one suboccurrence (within occurrence 3, **Table 2**) the species were noted as being atypical for the habitat at that elevation. *Sibbaldia procumbens*, which usually grows in areas of high snow accumulation, was given as an example of an atypical species. *Bromus inermis* (smooth brome) and *Dactylis glomerata* (orchardgrass) are both introduced non-native species and both have been widely cultivated for hay. *Bromus inermis* has also been used for reseeding western mountain ranges (Hitchcock and Chase 1971).

A habitat model has been developed for *Ipomopsis aggregata* ssp. *weberi* in Wyoming using a range/intersection (RI) modeling method (Fertig and Thurston 2003). Because of the few occurrence sites in Wyoming and thus the limited amount of available data, the RI model was created entirely in

Table 5. Plant species reported to be associated with *Ipomopsis aggregata* ssp. *weberi*. See the Definitions section for synonyms.

Species	Common name	Species	Common name
Abies lasiocarpa	subalpine fir	*Iris missouriensis*	iris
Achillea lanulosa	common yarrow	*Linum lewisii*	blue flax
Agoseris glauca	false dandelion	*Lupinus* species	lupine species
Agropyron species	wheatgrass species	*Mentha* species	mint species
Amelanchier alnifolia	serviceberry	*Oryzopsis* species*	ricegrass species
Artemisia species	sagebrush species	*Penstemon* species	penstemon species
Artemisia tridentata	big sagebrush	*Phleum* species	timothy** species
Aster junciformis	northern bog aster	*Picea engelmannii*	engleman spruce
Balsamorhiza sagitatta	balsamroot	*Pinus contorta*	lodgepole pine
Bromus inermis	smooth brome (introduced non-native species)	*Poa* species	bluegrass species
Chrysothamnus species	rabbitbrush	*Populus tremuloides*	aspen
Dactylis glomerata	orchardgrass (introduced non-native species)	*Rosa* species	wild rose species
Elymus species	wheatgrass	*Rubus parviflorum*	thimbleberry
Eriogonum species	wild buckwheat species	*Sibbaldia procumbens*	creeping sibbaldia
Eriogonum umbellatum	sulphur-flower buckwheat	*Stipa comata*	needle-and-thread
Festuca idahoensis	Idaho fescue	*Stipa lettermanii*	needle-and-thread
Festuca species	fescue species	*Wyethia* species	mule's ears
Geranium species	geranium		

*reported as as *Orycopsis* species.

***Phleum commutatum* is a native of subalpine meadows; *P. pratense* is an alien species.

a Geographic Information System (GIS) and did not use statistical software. The range of environmental values at all sites where *I. aggregata* ssp. *weberi* was present was intersected in GIS to identify areas with similar attributes across the state. No environmental information from absent locations was used for model development. The final distribution maps produced by the RI method could be validated in the same way as any statistically developed model, although in the case of *I. aggregata* ssp. *weberi* present points were used in the model construction and none were available for validation purposes. Two present points and 963 absent points were known, and 71 absent points were validated (Fertig and Thurston 2003).

The minimum and maximum values of all continuous environmental variables used in the construction of Fertig and Thurston's (2003) RI model for *Ipomopsis aggregata* ssp. *weberi* were: elevation (2,113 to 2,429 m), local relief (63 to 375 m), total January precipitation (5.26 to 6.72 cm), total April precipitation (5.74 to 6.86 cm), total July precipitation (3.19 to 3.71 cm), total October precipitation (5.86 to 6.85 cm), total January shortwave radiation (6.86 to 7.7 megajoules(MJ)/m^2/day), total July shortwave radiation (23.38 to 26.11 MJ/m^2/day), average January air temperature (-8.21 to 5.9 °C), average April air temperature (2.13 to 4.75 °C) , average July air temperature (15.58 to 18.15 °C), average October air temperature (3.81 to 6.32 °C).

The Categorical Variables used to develop the model were:

1. bedrock geology that were formations of the Miocene/Pliocene;

2. landcover of aspen forest, mesic upland shrub grassland, and mountain big sagebrush;

3. soils of
   a. Typic Dystrocryepts and Lithic Cryorthents, loamy-skeletal, mixed and Rock Outcrop,
   b. Typic Dystrocryepts and Typic Cryorthents, loamy-skeletal, mixed,
   c. Typic Dystrocryepts, loamy-skeletal, mixed and Rock Outcrop, and
   d. Ustic Haplargids and Ustic Natrargids, fine-loamy, frigid;

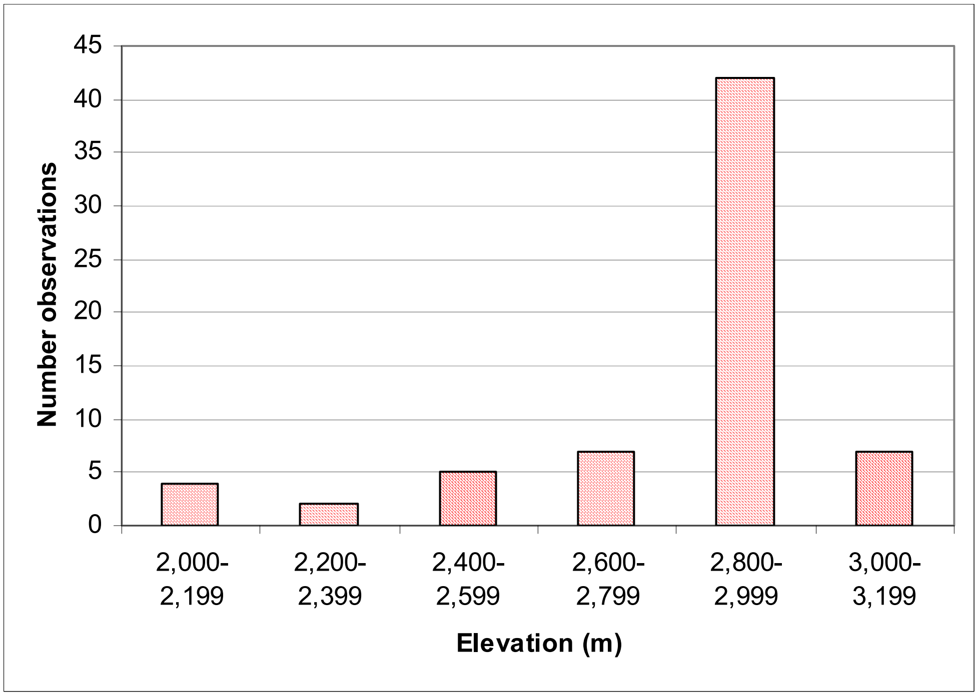

Figure 5. Range in elevation at which *Ipomopsis aggregata* ssp. *weberi* has been reported.

4. surface geology that were
   a. landslide mixed with scattered deposits of slopewash, residuum, tertiary landslides, bedrock outcrops, and landslides too small and numerous to show separately,
   b. residuum mixed with alluvium, eolian, slopewash, grus, and/or bedrock outcrops, and
   c. slopewash and colluvium mixed with scattered deposits of slopewash, residuum, grus, glacial, periglacial, alluvium, eolian, and/or bedrock outcrops (Fertig and Thurston 2003).

The biomes used for validation were the foothills, which were defined as the transition between Rocky Mountain forest and Great Plains grasslands/ Intermountain desert steppe and Rocky Mountain forest itself (Fertig and Thurston 2003). Using this model, the area of *Ipomopsis aggregata* ssp. *weberi*'s predicted distribution in Wyoming was 68 km^2 or 0.03 percent of the land area of Wyoming (Fertig and Thurston 2003).

Reproductive biology and autecology

Ipomopsis aggregata ssp. *weberi* is a monocarpic perennial species that reproduces by seed. It does not exhibit vegetative reproduction and cannot spread by vegetative growth. Over several years the rootstock may produce two or more rosettes (Waser and Price 1989). In a Colorado study of over two hundred flowering plants, all *I. aggregata* plants were monocarpic (Wilken 1996). In contrast, in another Colorado study, four percent of reproductive *I. aggregata* ssp. *aggregata* plants produced seeds in more than one year before dying, making that taxon only primarily, but not exclusively, monocarpic or semelparous (Waser and Price 1989).

In Arizona, *Ipomopsis aggregata* individuals were relatively iterparous, or polycarpic. In these cases the reproductive rosette died, but the plants produced ancillary rosettes that survived to flower in a subsequent year (Paige and Whitham 1987b). Apparently if an individual plant set less than 36 percent of the average amount of fruit, it would be likely (77 percent) to produce an additional rosette(s) that would reproduce another year. Interestingly, the ability to switch from semelparity to iteroparity appears to be a local adaptation of plants in environments where pollinator activity, and thus fruit set, is unpredictable (Paige and Whitham 1987b). Plants at low elevations are rarely iteroparous, even if fruit set is near to zero. Plants that grow at higher elevations where there is an unreliable source of pollinators are very likely to have flexible life history behavior (Paige and Whitham 1987b). Unfortunately, the population studied by Paige and Whitham (1987a, 1987b) was likely composed of hybrids between *I. tenuituba*, which grow at the highest elevations in the subalpine zone, and *I. aggregata* ssp. *formosissima*, which grow at slightly lower elevations in coniferous forest or sagebrush (Grant and Wilken 1988a, 1988b, Wilken personal communication 2004). This potential for genetically controlled variation is thus likely to confound conclusions regarding patterns of ecological variation.

Ipomopsis aggregata ssp. *weberi* plants flower between early-July to mid-September. In rare instances flowering plants have been observed in late June. Plants typically produce from 50 to 100 flowers per plant (Wilken 1996, Colorado Heritage Program element occurrence records 2002). Mean seed set among plants in four different populations ranged from 1.4 to 3.3 per flower (Wilken 1996).

Ipomopsis aggregata has a floral formula of 5-5-5-3; that is five petals, five sepals, five stamens, and three carpels. The number of flower parts is considered one of the most constant features of a vascular plant species and is almost invariant amongst members of the Polemoniaceae (Grant 1959, Ellstrand 1983). It is therefore noteworthy that nearly 33 percent of plants in 13 occurrences of ssp. *aggregata* studied in Colorado had at least one anomalous flower and almost 10 percent of flowers displayed abnormal floral formulas (Ellstrand 1983). The gynoecium was the most variable part, varying from the normal three-carpel condition in 44 of the 74 abnormal flowers (Ellstrand 1983). The cause of the variability is not known but may be due to environmental stress or a genetic predisposition to variability. In addition, the biological (for example, effect on seed production) or ecological significance of the unusually high variability has not been determined (Ellstrand and Mitchell 1988). It is not known whether some occurrences of *I. aggregata* ssp. *weberi* have a similarly high number of atypical flowers.

The flowers are likely to require cross-pollination. Waser and Price (1989) reported a high degree of self-incompatibility in populations of *Ipomopsis aggregata* ssp. *aggregata* in western Colorado, but it has not been confirmed that a high degree of self-incompatibility is universal among ssp. *weberi* populations. *Ipomopsis aggregata* ssp. *aggregata* has hermaphroditic, protandrous flowers (Campbell 1998). The anthers shed mature pollen for one or more days before the style finishes elongating and the stigma becomes receptive to pollen. Therefore, the first flowers to open on a plant will tend to reach their female phase when later flowers are in male phase, whereas the last flowers to open will reach the female phase when no other flowers on the plant are in male phase (Brunet and Eckert 1998). Although a level of within-flower self-pollination is likely advantageous, since it can provide reproductive assurance whereas between-flower self-pollination provides no such assurance, no evidence exists that autogamy (self-pollination) is exhibited within the *I. aggregata* complex (Brunet and Eckert 1998, Eckert 2000).

Hummingbirds are the primary pollinators of red-flowered and pink-flowered forms of the *Ipomopsis aggregata* complex, such as subspecies *aggregata* and *attenuata*; white and violet flowered *Ipomopsis* species, such as *I. tenuituba*, are pollinated primarily by hawk moths and sphinx moths (Grant and Grant 1965). In a population where *I. aggregata* and *I. tenuituba* grew together hummingbirds preferentially visited *I. aggregata* (Meléndez-Ackerman et al. 1997). Solitary bees, lepidopterans, and other insects account for 5 to 10 percent of pollen transfer among Colorado occurrences of *I. aggregata* ssp. *aggregata* (Waser 1978, Waser 1982, Campbell et al. 1996). Some studies have demonstrated that floral color and shape may not be the primary reason for hummingbird preference and more subtle cues exist for pollinator visitation. When hummingbirds were presented with red (*I. aggregata* ssp. *aggregata*) and white (*I. tenuituba*) flowers, they showed a preference for red (Meléndez-Ackerman et al. 1997). However, when *I. tenuituba* flowers were painted and hummingbirds were presented with all red flowers, they still visited the *I. aggregata* flowers. A difference between flowers of *I. aggregata* ssp. *aggregata* and *I. tenuituba* is the size of the nectar reward; the former has a much larger nectar reward than the latter. When the nectar reward was experimentally manipulated and white-flowers were given relatively large rewards, hummingbirds would choose them over low-reward red flowers (Melendez-Ackerman et al. 1997).

The pollinators of *Ipomopsis aggregata* ssp. *weberi* have not been well defined, but they are unlikely to be hummingbirds (Wilken personal communication 2004). *Ipomopsis aggregata* ssp. *weberi* flowers are relatively too small for hummingbird pollination. The nectar glands are too small to produce large quantities of nectar at any one time, and the tubes are too small to accumulate the volumes of nectar required to attract and provide an adequate reward for hummingbirds (Wilken personal communication 2004). By comparison with other *Ipomopsis* species that have small, salverform, white flowers with a low nectar reward, it is most likely that the most effective pollinators include moths, bee flies, flies, and bees (Wilken personal communication 2004). Hawk moths and sphinx moths are important pollinators of *Ipomopsis tenuituba*. However, although both ssp. *weberi* and *I. tenuituba* have pale colored flowers, the size and shape of the flowers are significantly different. The corolla and tubes of *I. tenuituba* flowers are much larger than those of ssp. *weberi*. In addition, the stamens are included in the tube of *I. tenuituba* whereas they are exserted in ssp. *weberi*. The latter is a characteristic trait of flowers pollinated by small flies, bees, or moths (Wilken personal communication 2004). Flies have been observed visiting flowers of *I. aggregata* ssp. *weberi* in Colorado and were speculated to be pollinators (Colorado Heritage Program 2002). Unidentified small nocturnal moths were observed feeding on *I. aggregata* occurrences near Fairplay, Colorado (Grant and Grant 1965). These specific occurrences are out of the range of ssp. *weberi*, but similar species of moth are likely pollinators of ssp. *weberi*.

Judging which are the most important pollinators of *Ipomopsis aggregata* ssp. *weberi* is likely to be a complex issue. The 'most effective pollinator principle' is based on the theory that floral characteristics reflect adaptation to the pollinator that transfers the most pollen, through a combination of a high number of flower visits and effective deposition of pollen during each visit (Mayfield et al. 2001). Mayfield et al. (2001) investigated the positive correlation between quantity and quality of pollinator visits to *I. aggregata* during a five-year study. As expected, they found that the most common floral visitors were hummingbirds. However, they observed that long-tongued bumblebees deposited on average three times as much outcross pollen per visit to virgin flowers, and elicited four times as much seed production, compared to hummingbirds. Therefore they concluded that relatively infrequent visitors, which are also unexpected given the 'pollination syndrome' of the species, could be surprisingly good pollinators (Mayfield et al. 2001).

Pollinator abundance and availability is very important for successful reproduction in protandrous and self-incompatible species. In studies on ssp. *aggregata*, hand pollinations increase the production of fruits and seed, suggesting that the pollen is limited, at least in some years (Hainsworth et al. 1985, Juenger and Bergelson 1997). In a separate study, *Ipomopsis aggregata* shifted from semelparous reproduction to iteroparous in response to reduced levels of pollinators and pollination (Paige and Whitham 1987b). This shift was apparently in response to reduced pollination *per se* rather than lack of fruit set. As mentioned previously, this population is likely to have been composed of hybrids, and thus the results must be interpreted cautiously. Hybridization may uncouple trait combinations that are present in parental species (Meléndez-Ackerman 1997).

Seed dispersal mechanisms are not well documented for *Ipomopsis aggregata* ssp. *aggregata*. The small seeds appear to lack any specialized dispersal mechanisms. Dispersal by zoochory, specifically ants and rodents, is likely. Given the very windy environment in which this species grows, wind may also be effective in dispersing seed although wind-dispersed seeds frequently move only short distances (Silvertown 1987). Waser and Price (1983) reported a seed dispersal area around *I. aggregata* ssp. *aggregata* of only 0.38 m^2. The clumped distribution pattern of many *I. aggregata* ssp. *weberi* populations suggests that dispersal distances are similarly short. Seeds may also be dispersed by water during rain showers and storms.

Demography

Some cross-pollinating (out-crossing) species may be susceptible to both inbreeding and outbreeding depression. Inbreeding depression is characterized by a lack of fitness due to weakness in some aspect of the physiology. For example, an individual's germination, competitive ability, over-wintering ability, or reproductive effort may be compromised in some way. Inbreeding depression may be due to deleterious recessive or partially recessive alleles that are masked at heterozygous loci by dominant alleles and become fully expressed in homozygotes, or, alternatively, alleles may interact in an overdominant manner such that the fitness of either type of homozygote is lower than that of heterozygotes (Dudash and Carr 1998). In contrast, outbreeding depression may result when crosses are made between widely spatially separated plants or when local adaptations are disrupted after non-local genotypes are introduced (Waser and Price 1989).

Waser and Price (1989) made a study of the fitness of *Ipomopsis aggregata* ssp. *aggregata* individuals in western Colorado. They made experimental crosses between individuals that were 1 m, 10 m, and 100 m apart and examined fitness as measured by seed set, seedling survival, and fecundity of the offspring. Mean seed set was higher with an outcrossing distance of 1 m and 10 m than at a distance of 100 m. In addition, offspring from crosses between individuals that were 10 m apart had "higher survival, greater chance of flowering, and earlier flowering, than those from 1 m or 100 m crosses". Their results suggested that both inbreeding and outbreeding depression might be operative in some populations.

Hybridization between members of the *Ipomopsis aggregata* complex is common, but loss of the genetic integrity of *I. aggregata* ssp. *weberi* through hybridization is unlikely unless "foreign" races are artificially introduced (see Threats section). Pollinator preference, such as hummingbirds preferring red flowers, is often cited as a reason why hybrids are not found among some populations where two or more races grow together. There may be other more complex reasons. An interesting lack of hybrids between *I. aggregata* and *I. arizonica* has been reported, even though the two species can be growing just a few meters apart (Wolf et al. 2001; see Systematics and synonymy section). Results of pollination experiments using trained hummingbirds indicated that "asymmetric barriers" likely contributed to the lack of hybrids. "Asymmetric barriers" refer to the condition where little pollen is transferred in one direction and little fertilization occurs in the other. Sparse pollen was transferred from *I. aggregata* to *I. arizonica*, and even though considerable pollen was transferred from *I. arizonica* to *I. aggregata*, it performed very poorly on *I. aggregata*'s pistils (Wolf et al. 2001).

Wilken (1996) conducted demographic studies on four populations of *Ipomopsis aggregata* ssp. *weberi* populations to estimate seedling recruitment, survivorship, longevity, and seed production. His studies were conducted during years of above-average or average snowfall and summer precipitation. Seedling recruitment at each of the four sites was correlated with moisture availability from snowmelt. Seedlings were not observed after periods of summer rainfall. The highest mortalities occurred amongst seedlings during the first year due to early summer drought. Plants that survived to reproductive maturity lived from two to over five years, with an average life span of three years. In contrast, the life span of *I. aggregata* ssp. *aggregata* individuals has been reported to be up to 10 years (Campbell 1998). A simple life cycle model of *I. aggregata* ssp. *weberi*, primarily based upon the studies by Wilken (1996), is diagrammed in **Figure 6**. Dashed arrows indicate the potential for iteroparity (see Reproductive biology and autecology section).

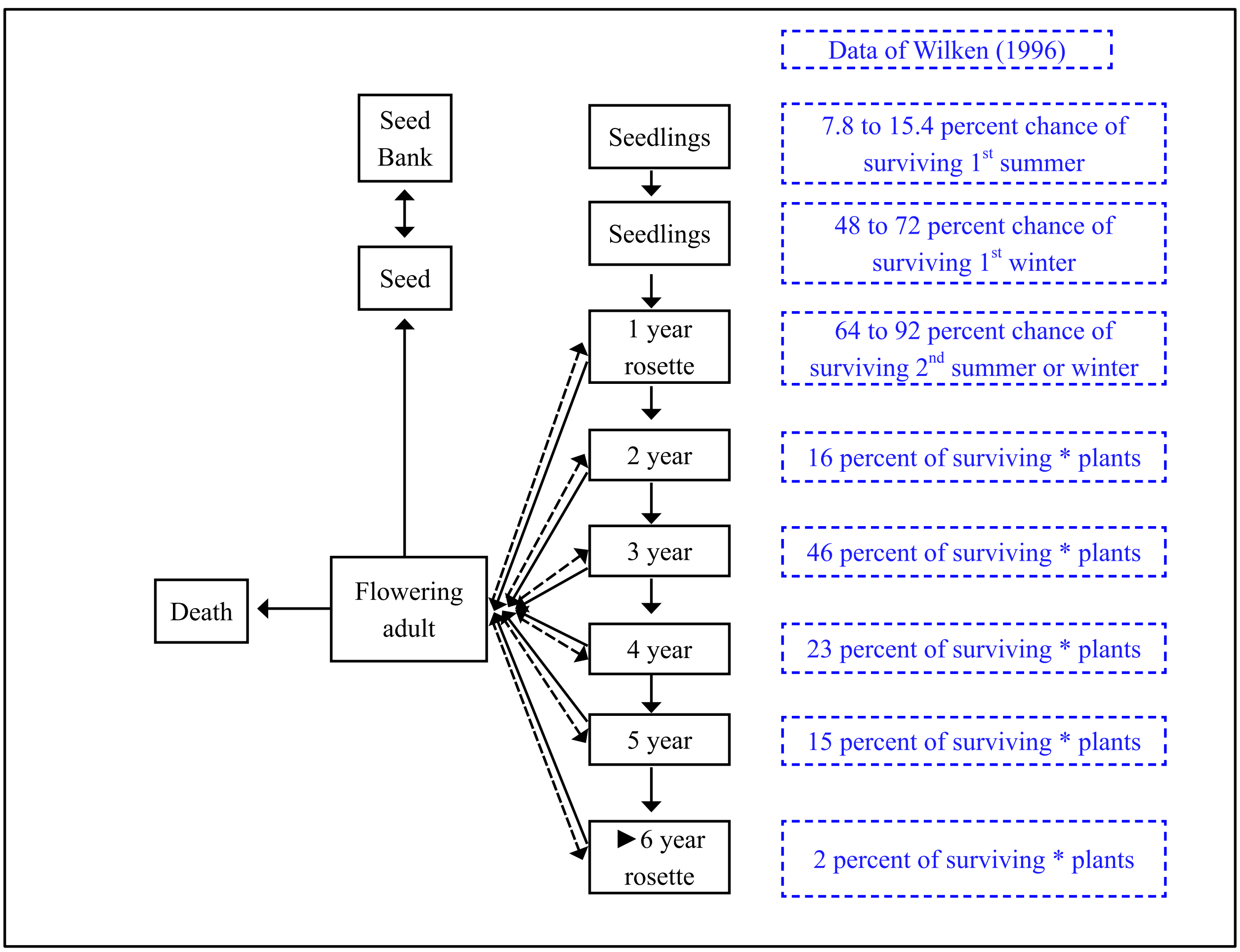

Figure 6. Life cycle of *Ipomopsis aggregata* ssp. *weberi*. Transition probabilities and the observations on the proportion of flowering plants that survive the first two years (*) are from Wilken (1996). See text for further details.

Wilken's results indicated that although there was a range among the populations, there were also similarities in the basic life history characteristics. Within the first year there was approximately a ninety percent mortality rate in all four populations. Plants that survived the first summer were much more likely to survive in successive seasons and years (Wilken 1996). Whereas probabilities of surviving the first summer ranged from 0.078 to 0.154, the probability of surviving the first winter was consistently much better, ranging from 0.49 to 0.59 (Wilken 1996). The probability of surviving the second summer ranged from 0.64 to 0.91 and the second winter from 0.7 to 0.92. Of the 417 plants that survived the first year, at least 229 survived to flowering. Transition probabilities estimated by Wilken (1996) are reported in the blue dotted boxes in the life cycle diagram (**Figure 6**).

Wilken (1996) estimated that each cohort of seeds had a life expectancy of five years. Therefore, in a given area, if there were no reproduction and no migration of seed into that area, the seed bank of *Ipomopsis aggregata* ssp. *weberi* would likely become depleted after five years. This consideration may be important when evaluating reestablishment of occurrences in highly disturbed sites. In addition, recruitment from the seed bank is not equal over subsequent years. Approximately 50 percent of seedlings observed in sites free from seed immigration were recruited in the first two years (Wilken 1996). Therefore, reproductive effort may be closely linked to population size and to recovery after disturbance. Using the observed reproductive plant density that ranged from 1.2 to 2.3 per 1 m^2 per year among the four populations, he estimated that from 79 to 518 seeds might fall within 1 m^2 area per year. This exceeded the numbers of seedlings (59 to 440) that were recruited each year.

Individual plants range from being sparsely distributed to being densely clustered within occurrences. The population size of this species is also quite variable, with from approximately five to greater than 2,000 individuals comprising a suboccurrence (see Distribution and abundance section). A combination of environmental variables, as well as aspects of the species' biology such as short seed-dispersal distance, may influence the spatial distribution of individuals within an occurrence. The patchy distribution of snow accumulation in an otherwise xeric environment was speculated to contribute to variability in plant density (Colorado Heritage Program element occurrence records 2002). Wilken (1996) suggested that the absence of rock is also important. At the present time, evidence suggests that population growth is restricted by extrinsic factors such as exposure and vegetative cover. Stable occurrences are found in sites with less than 50 percent cover, suggesting that a combination of reduced competition and availability of open sites promote reproduction, establishment and long-term population stability (Wilken 1996). Apparently plants are excluded from adjacent sites with greater than 65 percent cover (Wilken 1996). In addition to physical parameters influencing seedling mortality, the amount of seed production by individual plants will also affect spatial patterns (Platt et al. 1974). Plants with fewer flowers are likely to produce fewer seeds that will in turn lead to potentially fewer seedlings around the parent plant.

Population viability analyses for this species have not been undertaken. *Ipomopsis aggregata* ssp. *weberi* usually exists in patches in a subdivided population. It is unknown if there is a balance of frequent local extirpations and colonizations within a colonized area or whether, once established, microsites are occupied for long periods of time. The information available suggests that once established, populations are quite long-lived but this should not be assumed without additional monitoring studies. Small (<100 flowering individuals) populations may be vulnerable to a lack of fitness. Seed size and germination success were significantly reduced in small populations of *I. aggregata*, most likely of the subspecies *aggregata* (Heschel and Paige 1995). The observed reduction in fitness was ascribed to either genetic drift or inbreeding depression or a combination of the two (Heschel and Paige 1995).

The current evidence suggests that *Ipomopsis aggregata* ssp. *weberi* is a monocarpic perennial species that is maintained in established, relatively long-lived populations. These characteristics are consistent with those of a k-selected species having a stress-tolerant life strategy (MacArthur and Wilson 1967). Grime et al. (1988) expanded the concept to categorize herbaceous plants into one of seven life-strategies. *Ipomopsis aggregata* ssp. *weberi* fits best into their concept of a stress-tolerant ruderal (S-R) strategist.

Community ecology

Ipomopsis aggregata is apparently an early to mid-successional species. It is found in forest openings, in open shrub and grassland, and along road cuts. It either does not colonize, or it does not flourish, in highly competitive communities. It typically grows in areas with relatively sparse vegetation cover and few exotic weedy species. Stable populations occur in sites with less than 50 percent cover (Wilken 1996; see Demography section).

Occurrences have been reported along road cuts and in semi-disturbed roadside areas, suggesting that the species is tolerant of disturbance or is capable of re-colonizing disturbed sites (Fertig 1999). Fire is another form of disturbance. The role of fire in maintaining populations is undocumented. The low levels of litter accumulation in its native habitat suggest that it may have evolved in areas subjected to only light or infrequent fires. In fact, the low vegetation cover and lack of canopy cover suggests that the areas in which it occurs may act as refugia from hot fires at the landscape level.

Late-season grazing by large ungulates or small mammals, such as rodents, never promotes the growth of *Ipomopsis aggregata* root or shoot tissue (Bergelson and Crawley 1992b). Such late-season grazing is called "nipping" (Bergelson and Crawley 1992a). Any seeds on the inflorescence of the nipped plants will be eaten along with the vegetative tissue. The fate of those seeds is unknown. It is not clear whether animals are a source of dispersal or whether the seeds are just digested. If the latter is true, late-season grazing would also be detrimental to population growth. Because the taxon is monocarpic, the plant will die and never contribute seeds to the next generation.

In contrast to the effects of late-season grazing, the research on the effects of early-season ungulate grazing on *Ipomopsis aggregata* has resulted in two opposing views. One view is that herbivory is beneficial. The other is that it has substantial negative impacts on population size. The view that early-season mammalian herbivory is beneficial is supported by the studies of Paige and Whitham (1987a) and Paige (1992). In Arizona, when *I. aggregata* plants were exposed to high levels of mule deer and elk grazing early in the season, they produced a 2.4-fold increase in the numbers of seeds compared to ungrazed control plants (Paige and Whitham 1987a). This was due to the grazed plants producing multiple stems, each having a similar number of flowers as the single stems of ungrazed plants (Paige and Whitham 1987a, Paige 1992). Clipping the plants to remove 95 percent of their aboveground biomass had similar results. The weight and subsequent germination rate of seeds from the grazed and clipped plants were also equivalent to those from ungrazed control plants (Paige and Whitham 1987a). Rosette formation by clipped plants was not significantly different from undamaged plants (Paige and Whitman 1987a). Clipping also had no effect on shifting the plants from a semelparous to iteroparous mode of reproduction. In these experiments *I. aggregata* remained monocarpic. The populations in 1987 were likely composed of hybrids (Wilken personal communication 2004; see Reproductive Biology and Autecology section). Therefore, heterosis might have made a significant contribution to the observed behavior (Allard 1960).

Other research has demonstrated that although *Ipomopsis aggregata* exhibited considerable regrowth after the loss of its initial stem, there was no evidence of greater fecundity, termed "overcompensation," of grazed individuals (Bergelson and Crawley 1992a, Bergelson et al. 1996). During a two-year study when plants were clipped to simulate herbivory, the clipped plants exhibited earlier flowering and increased plant height as compared to unclipped plants, but no increase in seed set was observed (Juenger and Bergelson 1997). In addition to fecundity studies, population size was compared at several locations around the western United States. Bergelson and Crawley (1992a) compared individual status and abundance on either side of grazing exclosures and found consistent and highly significant differences between the grazed and ungrazed sides of the exclosure fences. Plant density was an average of 25-fold (2.6 to 595-fold) more on the ungrazed side of the fence. Plant fecundity did not appear to be affected by grazing pressure, and therefore the reduction in plant density must be related to other factors, such as an increase in seedling mortality.

Simulated herbivory, that is clipping off the inflorescence, has the same effect as natural browsing by elk and mule deer (Paige and Whitham 1987a). Mule deer and elk eat the whole inflorescences, never just flowers alone (Paige and Whitham 1987b). This is likely the case for all livestock species (cattle, sheep goats, and horses) as well. Much of the grazing research has considered elk and mule deer grazing in the context of their impact on the individual plant. Although clipping may simulate the mechanics of all types of mammalian grazing, it does not indicate the sociological aspects. The length of time spent at a site, the extent of disturbance by hoof action, and the time of year the animals visit the site should all be considered. The effect of grazing on the long-term survival of a particular plant species likely depends upon the combination of animal species (Mack and Thomson 1982). Different species of animals with complementary plant species preferences at any given site will have far less impact than those with additive preferences. Grazing animals rely on a variety of different physical (such as color, texture, sward structure) and chemical (such as fragrance and taste) cues when selecting food (Mayland and Shewmaker 1999). Cattle and sheep sometimes prefer different plant species. Cattle are more sensitive to sweet and salty flavors, whereas sheep are more sensitive to bitter flavors (Goatcher and Church 1970). Sheep tend to be particularly species-selective. Species that are selected by sheep have been reported to be more abundant on ungrazed land, implying that grazing negatively affects their abundance (Strasia et al. 1970, Bonham 1972). In a mountain forb community, sheep clearly preferred sour and sweet plants over bitter-tasting plants (Krueger et al. 1974). The time of year may also affect the preference of sheep. For example, sheep utilized wheatgrass (*Agropyron* spp.) more than globemallows (*Sphaeralcea* species) in the fall, but the converse was true during spring pasturing (Rumbaugh et al. 1993). This may be a function of the availability of alternative forage, or it may reflect a difference in secondary plant product concentration (taste) or some other physical difference in the *Sphaeralcea* plant during different seasons.

The interactions between *Ipomopsis aggregata* and arthropods may increase the complexity of determining the impacts of mammalian herbivory. Arthropod herbivores, principally stem-boring and meristem-feeding moths, can be abundant in *Ipomopsis* species habitat, and they too can cause multiple stem growth (Paige 1992). Without careful experimental controls, there is the potential for some confounding results. For example, although simulated early season browsing of *I. aggregata* was observed to reduce plant fitness, subsequent insect attacks were also reduced (Juenger and Bergelson 1998). Therefore, the results on the consequences of early season herbivory on overall population performance will be very difficult to compare between years with different levels of arthropod pressure.

Unrelated to direct impacts on the plants, domestic sheep can also have indirect effects on bee-pollinated plant species. Sugden (1985) reported that sheep grazing in the habitat of *Astragalus monoensis*, a perennial endemic species, endangered bee pollinators by destroying potential and existing nest sites and removing food resources. These types of complex ecological relationships are important to consider when dealing with a species that relies on pollinators for reproduction.

Bumblebees and flies are potential pollinators of *Ipomopsis aggregata* ssp. *weberi* (see Reproductive biology and autecology section). Small flies have been observed visiting both *I. aggregata* ssp. *weberi* and adjacent *Achillea* species (Colorado Natural Heritage Program element occurrences records 2002). Flies also appeared to be pollinating flowers on a cool morning whereas bumblebees (*Bombus* spp.) were observed visiting on warmer days (Colorado Natural Heritage Program element occurrences records 2002). However, the latter did not enter the flower through the corolla but entered with their proboscis at the base of the calyx and corolla. This behavior is termed nectar robbing or floral larceny (Irwin and Brody 1999). The relationship between bumblebees and *I. aggregata* depends upon the species of bumblebee. *Bombus appositus* queens will forage at *I. aggregata*, whereas *B. occidentalis* queens occasionally rob for nectar (Waser 1978).

Considering that bees and flies are potential pollinators, spatially disjunct suboccurrences may have high levels of gene flow between them (see Systematics and synonymy section and Reproductive Biology and Autecology section). Osborne et al. (1999) tracked individual bumblebees using harmonic radar and recorded that most bees regularly fly over 200 m (range 70-631 m) from the nest to forage even when apparently plentiful food was available nearby. There are two caveats to the effectiveness of bee pollination. Bees are density-dependent foragers, and few-flowered individuals or patches may be ignored depending upon the alternative flower sources (Geer and Tepidino 1993). Studies on hawk moths, which are likely applicable to many species of moth, indicate that they may be unreliable pollinators in some years. The annual numbers of hawk moths fluctuate considerably due principally to weather conditions and the amount of herbaceous material available to their larvae (Casey 1976, Miller 1978). Their flight is also related to evening temperature; hawk moths are less inclined to fly on a cool evening (Stockhouse 1973). In spite of the vagaries of pollinators, the evidence suggests that suboccurrences of *Ipomopsis aggregata* ssp. *weberi* within 200 m of each other are exchanging genetic material to some degree, at least in some years.

Studies on the frequency of seed predation have been made on populations of *Ipomopsis aggregata* near Crested Butte in Colorado (Brody and Mitchell 1997). The *I. aggregata* subspecies was not reported for this study. A common pre-dispersal arthropod seed-predator was observed to be the dipteran, *Hylemya* spp., Anthomyiidae (Campbell 1991, Brody and Mitchell 1997). In some years it can destroy 80 percent of the seeds produced by an individual plant (Brody and Mitchell 1997). However, seed predation by arthropods is not necessarily bad at levels under which the species has evolved. In some cases it may have had an important influence on population dynamics and diversity within some genera (Green and Palmbald 1975, Mancuso and Moseley 1993).

An envirogram is a graphic representation of the components that influence the condition of a species and reflects its chance of reproduction and survival. Envirograms have been used especially to describe the conditions of animals (Andrewartha and Birch 1984) but may also be applied to describe the condition of plant species. Those components that directly impact *Ipomopsis aggregata* ssp. *weberi* make up the centrum, and the indirectly acting components comprise the web. Unfortunately, much of the information to make a comprehensive envirogram for *I. aggregata* ssp. *weberi* is unavailable. The envirogram in **Figure 7** is constructed to outline some of the components known to directly impact the species and also includes some more speculative factors. Resources have been listed to include precipitation in the form of snowmelt to promote germination and seedling establishment. Pollinators have been included, but the relative importance of pollinator species is not known. Disturbance has been included in the envirogram, but the beneficial types are not defined. Natural disturbances, such as those caused by rodents and rainstorms, and human-induced disturbances, such as those caused by all terrain vehicles, have vastly different consequences. Similarly, the long-term ecological consequences of a tree that is uprooted, causing soil disturbance and opening up the canopy, but left to slowly decompose, are different than the removal of timber after the disturbance and soil compaction pressures of commercial logging. The association with seed predatory arthropods has been omitted because insufficient information exists to suggest which species and levels could be classed as resources.

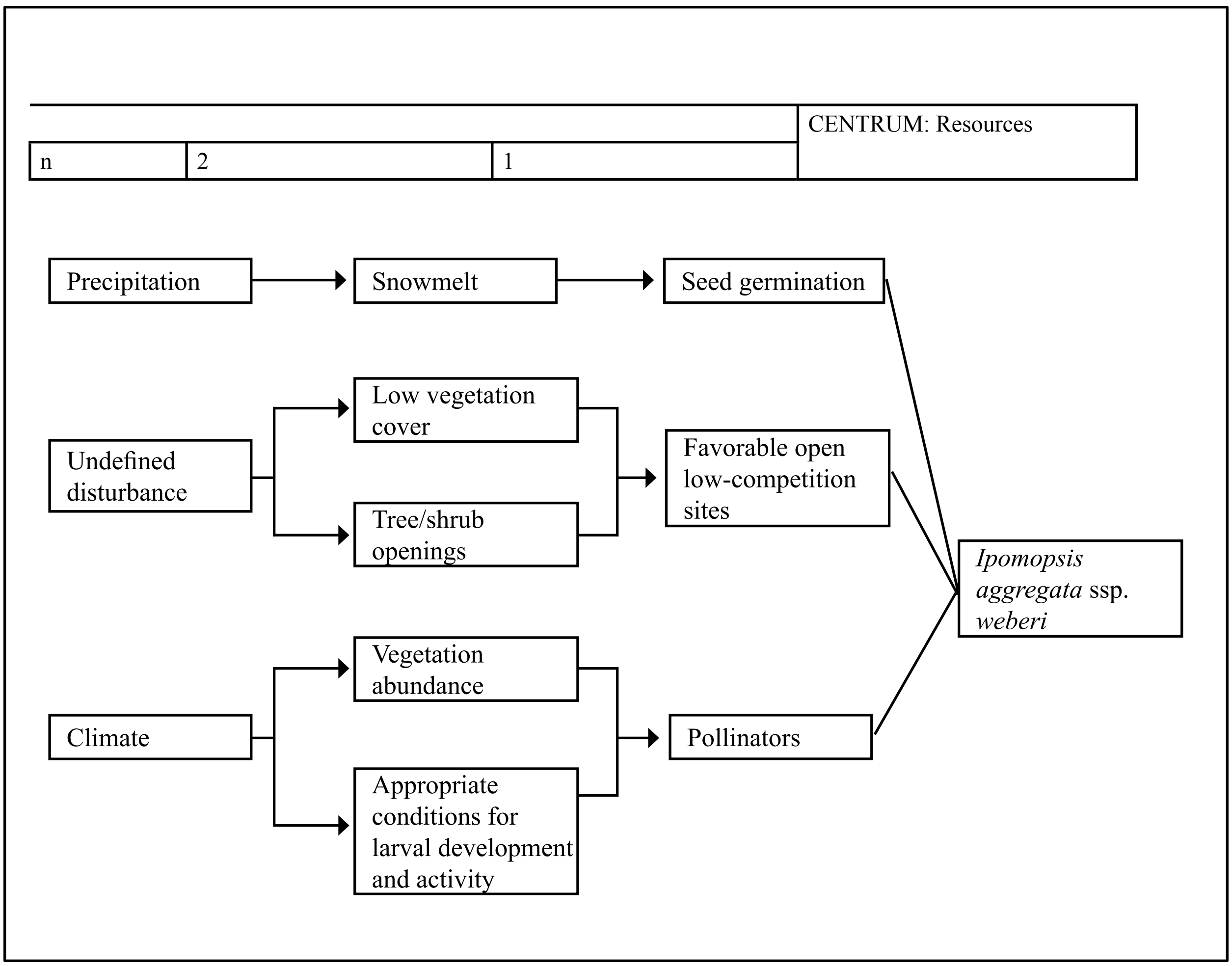

Figure 7. Envirogram of the resources of *Ipomopsis aggregata* ssp. *weberi*.

CONSERVATION

Threats

The majority of known occurrences (approximately 17 of 24) of *Ipomopsis aggregata* ssp. *weberi* are on the Routt National Forest in Colorado (**Table 2**). All of the three known occurrences in Wyoming are on the Medicine Bow National Forest. The management areas in which *I. aggregata* ssp. *weberi* occurs on the Routt National Forest are listed in **Table 6** (USDA Forest Service 2001). The lack of precise location information for some occurrences and the coarse details of the maps available provide only a general overview of the populations relative to the management areas. However, the information is useful in considering potential management alternatives that may impact the taxon.

Threats specific to some occurrences have been documented. Plants at occurrence sites 3 and 5 (**Table 2**) on the Routt National Forest are near a highway, a power line, USFS roads and campgrounds (Colorado Natural Heritage Program 2002). Maintenance or expansion of any of these may damage or destroy individuals. In 1998, one suboccurrence within occurrence site 3 was on an old roadbed, and the road was being reopened for parking lot construction (Colorado Natural Heritage Program 2002). The fate of that occurrence is unknown. Highway maintenance was considered a potential threat to some plants at occurrence 13 in 1998 (Colorado Natural Heritage Program 2002). Plants in occurrences 7 and 12 are also near USFS roads, trails, and campgrounds. At these sites, hiking and horseback riding are particularly popular. For these occurrences, new recreation developments and the spread of invasive non-native weeds were perceived as being serious potential threats in 1998 (Colorado Natural Heritage Program 2002). In the Steamboat Lake Recreation Area (see **Table 2**) horses and horse trails are also common. Although the general policy of the USFS is not to impact any *Ipomopsis aggregata* ssp. *weberi* individuals or occurrences, some improvement developments are undertaken within occupied habitat. One occurrence was impacted as a consequence of highway straightening in the Routt National Forest within the last (2003/2004) year (Proctor personal communication 2003). This project was allowed to proceed because it was determined to be a safety issue, and the loss of the plants at the development site was judged to have little effect on the taxon as a whole.

Mountain biking and horseback riding are very popular in the Steamboat Springs area. The number of mountain bike trails in the area has been described "prolific" (Moving Mountains Company 2003; see internet site in the Reference section). Mountain biking around Steamboat Springs (on Mt. Werner in the Medicine Bow and Routt national forests, along the Greenville Mine Loop, and in the Rabbit Ears/Buffalo Pass region) is advertised as offering "many thrills and challenges" (Moving Mountains Company 2003; see internet site in the Reference section). The impacts from such activities are expected to be proportional to the extent of use and the amount of disturbance. Considering fundamental ecological principles, two scenarios can be envisaged. Low numbers of people, bikes, and horses may provide open habitat and a level of disturbance that would have little impact or perhaps even stimulate this early to mid-successional taxon. However, large numbers of people, horses, and bikes can cause soil compaction and soil erosion that might interfere with the seed bank. In addition, high levels of trampling can interfere with plant reproduction and seedling establishment. From the results of demographic studies on populations in Colorado, Wilken (1996) suggested that both survivorship and reproductive capacity contribute to the short-term stability of established populations. Recreation may have already taken a toll on this species' range within Colorado. In 1903, a specimen was collected from the Chambers Lake area, which is currently managed by the Roosevelt National Forest. No specimens have been reported from that area since that time. It is notable that this has always been a popular recreational area, and currently experiences heavy recreational use. Chambers Lake is within easy reach of the large urban areas of the Front Range and has at least 45 formal campsites in its vicinity.

High use of snowmobiles within occupied habitat is another potential threat. Play areas and snow routes, especially in the Rabbit Ears and Buffalo Pass area, are in open meadows where *Ipomopsis aggregata* ssp. *weberi* is found (Proctor 2004). Seedlings, shrubs, and other exposed vegetation are commonly broken, and shallow roots and rhizomes can be crushed or damaged (Neumann and Merriam 1972, Ryerson et al. 1977). During shoulder seasons or drought, snowmobiles sometimes ride from snow patch to snow patch across vegetation and bare ground, causing soil disturbance, soil removal, vegetation compaction, plant biomass removal, and changes in hydrology (Proctor 2004). In addition, observations have been made at Dumont Lake near Rabbit Ears Pass of "black fuel and oil deposits" and a change in the aquatic vegetation of a pond in the area including a decrease in the number of *Isoetes*, or quillworts (Proctor 2004). How these conditions have impacted *I. aggregata* ssp. *weberi* is not known.

Table 6. Principle activities in management area prescriptions (RX) on land that is occupied by *Ipomopsis aggregata* ssp. *weberi* on the Routt National Forest (table condensed from USDA Forest Service 2001). Abbreviations used: nso = no surface occupancy; csu = controlled surface use; ss = standard stipulation.

Management Area (RX) No.	Management Area (RX) Name	Road Construction	Timber Harvest	Grazing	Motorized Recreation winter/summer	Developed Recreation	Oil & Gas	Locatable Minerals
1.32	Backcountry Recreation Nonmotorized with Winter Limited Motorized	no	no	yes	yes/no	no	yes/nso	yes
3.23	Municipal Watersheds	minimal	minimal	yes	yes/yes	yes	yes/nso	no
4.2	Scenery	minimal	minimal	yes	yes/yes	yes	yes/csu	yes
4.3	Dispersed Recreation	minimal	minimal	yes	yes/yes	yes	yes/csu	yes
5.11	General Forest and Rangelands-Forest Vegetation Emphasis	yes	yes	yes	yes/yes	yes	yes/ss	yes
5.12	General Forest and Rangelands-Range Vegetation Emphasis	yes	yes	yes	yes/yes	yes	yes/ss	yes
5.13	Forest Products	yes	yes	yes	yes/yes	yes	yes/ss	yes
7.1	Residential/Forest Interface	yes	yes	yes	yes/yes	yes	yes/csu	yes
8.22	Ski Resorts: Existing/Potential	yes	yes	yes	no/no	yes	no	no

The potential for snow compaction due to recreational activities, especially snowmobiling, is another cause for concern. Snow compaction can cause considerable below-surface vegetation damage (Neumann and Merriam 1972). Significant reductions in soil temperatures, which retard soil microbial activity and seed germination, may also result from snow compaction (Keddy et al. 1979, Aasheim 1980). These impacts may be exacerbated by compaction of the underlying soil layers.

Ipomopsis aggregata ssp. *weberi* is apparently palatable to many mammalian species, including deer, elk, sheep, cows, and horses. In the Routt National Forest, it grows in areas with large herds of mule deer and elk and is likely used by these species throughout all or parts of its range. Domestic livestock grazing is restricted on Colorado state park lands, but trespass cattle commonly encroach and horses, used in horseback riding, also graze (West personal communication 2002). Livestock grazing is permitted in most of the areas occupied by *I. aggregata* ssp. *weberi* in the Routt National Forest (see **Table 6**). It is found primarily on sheep, rather than cattle, grazing allotments (Skorkowsky personal communication 2003). Although some subspecies of *I. aggregata* have been reported to be somewhat tolerant of grazing, the impacts of the many variables associated with wildlife and domestic livestock grazing on *I. aggregata* ssp. *weberi* still need to be determined (Bergelson et al. 1996). The degree of tolerance likely depends upon the number of animals, the animal species, the prevailing environmental conditions, and the specific interactions between them (see Community ecology section). In addition, the effects of ungulate grazing on *I. aggregata* may also depend on the race or subspecies (Bergelson and Crawley 1992b, Bergelson et al. 1996). Studies showing a beneficial effect of early season grazing were all made in Arizona on *I. aggregata* ssp. *tenuituba* (*I. tenuituba*), *I. aggregata* ssp. *formosissima*, and hybrids between the two (Paige and Whitham 1987, Paige 1992, Bergelson et al. 1996). No grazing studies have been made on subspecies *weberi*, and basing management decisions on studies of other races in other geographic locations is subject to error.

Invasive weed species are highly competitive and are likely to be a threat to *Ipomopsis aggregata* ssp. *weberi*. It has been associated with *Bromus inermis* (suboccurrence of occurrence site 3, **Table 2**) and *Dactylis glomerata* (occurrence site 7, **Table 2**). Both are non-native weedy species, but the vegetation cover was still low at both sites. There is no data to indicate an imminent invasion of more aggressive weeds at any of the known occurrences.

Most of the areas on the Routt National Forest in which *Ipomopsis aggregata* ssp. *weberi* has been found are subject to "site-specific analysis" prior to resource extraction activities (USDA Forest service 2001, 2002). Mining may have impacted some occurrences, for example, at the Greenville Mine from which gold, silver, and copper were all once extracted; this mine is no longer in operation. There are no known occurrences of *I. aggregata* ssp. *weberi* that are under imminent threat from resource extraction activities.

Hybridization may occur between members of the *Ipomopsis aggregata* complex (see the Reproductive biology and autecology section and the Community ecology section). Because of this, it is very important that *I. aggregata* seed not be included in any of the seed revegetation mixes within *I. aggregata* ssp. *weberi*'s range unless it is certified as being from local *I. aggregata* ssp. *weberi* stock. It is also important that the seed source be truly local to the site being re-vegetated because outbreeding depression has been reported for other races of *I. aggregata* (see the Demography section). *Ipomopsis* species are common native forbs that are often recommended for re-vegetation seed mixes (for example Colorado Natural Areas Program 1998, Wildlife Crossings Toolkit 2002)

It is unclear how global climate change may affect this species. In the last one hundred years, the average temperature has increased 1.5 °F in Laramie, Wyoming and 4.1 °F in Fort Collins, Colorado (U.S. Environmental Protection Agency 1997, 1998). During the same time period, precipitation decreased by approximately 20 percent within northern Colorado and southern Wyoming (U.S. Environmental Protection Agency 1997, 1998). Based on projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom Hadley Centre's climate model (HadCM2), by 2100 temperatures in Colorado could increase by 3 to 4 °F in spring and fall (±1 to 8 °F) and 5 to 6 °F in summer and winter (± 2 to 12 °F). Similarly, based on the same model, by 2100 temperatures in Wyoming could increase by 4 °F in spring and fall (± 2 to 7 °F), 5 °F in summer (± 2 to 8 °F), and 6 °F in winter (± 3 to 11 °F). Precipitation is estimated to decrease slightly in summer (± 0 to 10 percent), increase by 10 percent in spring and fall (± 5 to 20 percent), and increase by 30 percent in winter (± 10 to 50 percent). The consensus is that weather will become more extreme. That is, the amount of precipitation on extreme wet or snowy days in winter is likely to increase, and the frequency of extreme hot days in summer will increase because of the general warming trend. These changes may not profoundly affect on *Ipomopsis aggregata* ssp. *weberi* because it is apparently adapted to xeric conditions. One scenario is that even if currently occupied sites become too inhospitable, it will be able to colonize sites that have opened up and become too xeric for other plant species. Alternatively, one can conjecture that invasive non-native weed species will have become more established, and if the current sites become too inhospitable, the species will suffer site-by-site extirpation.

The effect of climate change on pollinator species and abundance may also be significant. Initially at least, the warming temperatures may increase the abundance of moths, which may migrate to more northerly latitudes or higher elevations as climate changes. Alternatively, the increasingly xeric conditions may substantially reduce or eliminate pollinators. Because the specific pollinators of *Ipomopsis aggregata* ssp. *weberi* are not known, it is difficult to evaluate these possibilities.

This species may also be vulnerable to declines in pollinator populations due to other causes. Pesticide use, habitat alteration and fragmentation, and the introduction of alien plants and animals all contribute to reducing pollinator population size as well as causing the extirpation or extinction of pollinator species (Bond 1995). It appears that there are several species that can contribute to *Ipomopsis aggregata* ssp. *weberi* pollination. Therefore, it may be argued that only plant species dependent upon small numbers of specific pollinator species are vulnerable and that the pollination strategy of *I. aggregata* ssp. *weberi* is fairly robust. However, other factors may be just as important. Bond (1995) makes the argument that when the diversity of threats is sufficiently high, whole assemblages of mutualists may be eliminated and that no mutualistic relationship is completely guaranteed.

Although there are several isolated occurrences, *Ipomopsis aggregata* ssp. *weberi* appears to be most abundant in only a few areas (**Figure 2** and **Figure 3**). This distribution suggests that it would be vulnerable to any environmental or man-made event that is localized to those areas. For example, events such as non-selective herbicide spraying in the two localized areas on the Routt National Forest where it is most abundant (see **Figure 3**) could have a significant impact on a large proportion of the total population even though the impact on the total land area in the national forest would be relatively small.

Populations of *Ipomopsis aggregata* with fewer than 100 individuals appeared to exhibit inbreeding depression (see Demography section). From a genetic perspective, natural populations often behave as if they were smaller than a direct count of individuals would suggest (Barrett and Kohn 1991). Locally endemic species tend to exhibit reduced levels of polymorphism (Karron 1991, Gitzendanner and Soltis 2000). However, Gitzendanner and Soltis (2000) emphasized that considering rare species are lacking genetic variation is an overgeneralization and that each species must be treated as a unique entity. Without genetic evaluation of *I. aggregata* ssp. *weberi* populations it is not possible to predict its genetic vulnerability.

The envirogram of **Figure 8** is constructed to outline some of the factors that directly impact *Ipomopsis aggregata* ssp. *weberi*. Disturbance is included in the envirogram, but the types and levels that are deleterious to long-term sustainability need to be defined. Disturbance can be of two types: direct impacts and consequences directly attributable to the initial disturbance. Direct trampling by hikers, large mammals, and off-road vehicle traffic can physically disturb plants. Disturbance also contributes to soil erosion. Although disturbance opens areas to colonization by *I. aggregata* ssp. *weberi*, it can also lead to invasion by weed species and eventually result in loss of habitat. Invasive plant species directly compete for resources as well as often secreting allelopathic substances into the soil (Sheley and Petroff 1999). An important consideration, indicated by a faint dotted line in the envirogram, is the significant contributions that off-road vehicles and large mammals make to the spread of weed species. This type of interaction can be overlooked when considering the impact of any given management action. The impacts of potential colonization by invasive plant species that will be exacerbated by anthropogenic disturbances, and possible climate change should not be underestimated in any area. Threats associated with herbivory by livestock and native ungulates have been included although the significance of current levels has not been studied for ssp. *weberi*. Pollinators are important to this species, and a reduction in their abundance or proportion is a potential threat. The suite of arthropod species may alter in response to climate change but also as a consequence of some management practices. For example, some pesticides are very detrimental to bees (Larmer 1997) while others will target Lepidoptera (Cranshaw 1998). In addition, sheep grazing can destroy wild bee nests (see Community ecology section).

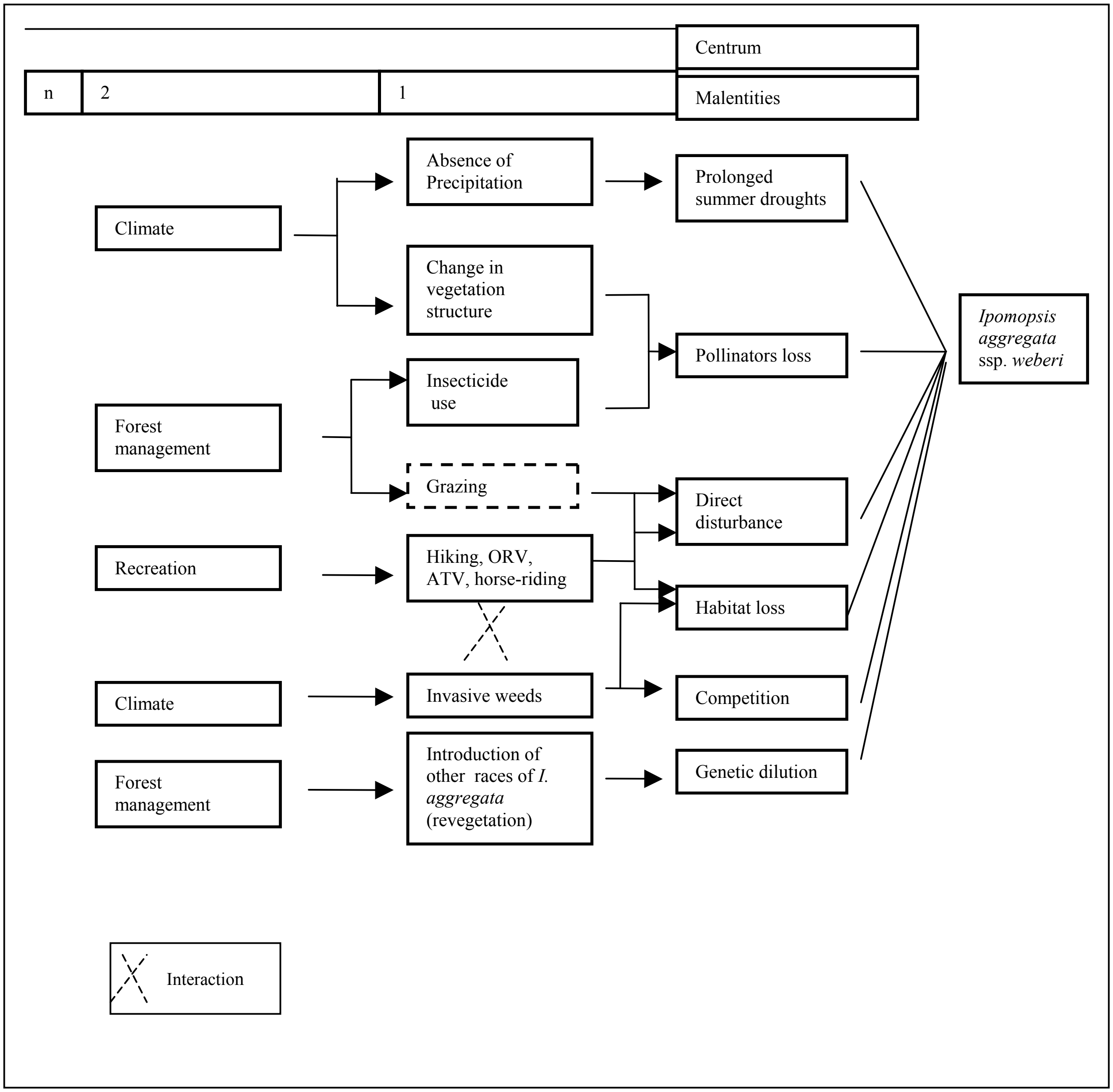

Figure 8. Envirogram outlining the malentities and threats to *Ipomopsis aggregata* ssp. *weberi* (see Community ecology section).

In summary, the primary threats to this taxon appear to be from activities associated with road development and recreation. Additional threats and potential threats include those from grazing, an increase in the abundance of invasive weeds, and activities associated with resource extraction. Less easily managed potential threats also include global climate change and demographic and genetic stochasticity. In addition, because the taxon is in a localized geographic area, it is vulnerable to environmental stochasticity.

Conservation Status of the Species in Region 2

At the present time *Ipomopsis aggregata* ssp. *weberi* appears to exist in stable populations under the current management guidelines and levels of threat. However, the emphasis is on "current." Even if the intensity of a threat remains the same, an increase in its area of impact will eventually have negative consequences on the species' abundance. Thus the magnitude of the threats to *I. aggregata* ssp. *weberi*, including those concerned with global climate change, largely depend upon the extent and intensity of the activity and the rarity of the species at the time the threats are incurred.

The protections and considerations given to management of *Ipomopsis aggregata* ssp. *weberi* are influenced by its status. *Ipomopsis aggregata* ssp. *weberi* is designated sensitive by the USDA Forest Service – Region 2 (2003a) and the Wyoming Bureau of Land Management (2001). A biological evaluation is required for any federal project that may impact known populations of the taxon on land managed by both these agencies. The Colorado Natural Areas Program also considers *I. aggregata* ssp. *weberi* a sensitive species, and when it occurs within a Colorado state park, it is considered in their management practices (West personal communication 2003). It is not designated a sensitive species by the Colorado Bureau of Land Management, and therefore it has no protections on those lands.

Management of the Species in Region 2

Implications and potential conservation elements

There are at least five main conservation elements for *Ipomopsis aggregata* ssp. *weberi*:

- ❖ the patchy distribution within its restricted geographic range
- ❖ the potential for inbreeding and outbreeding depression
- ❖ the potential for loss of habitat
- ❖ the importance of pollinator interactions
- ❖ the likelihood of hybridization with introduced races of *I. aggregata*.

The majority of known occurrences, 17 of 27, tend to be clustered together on the Routt National Forest (**Figure 3**). This concentration in one area may increase the vulnerability of the species to environmental, anthropogenic, and genetic uncertainties. There is little information on the minimum size for a viable population, and therefore it is difficult to predict the consequences of actions that reduce the size of any one occurrence. From studies on *Ipomopsis aggregata*, but not specifically ssp. *weberi*, the taxon may be susceptible to inbreeding depression, especially in small (<100 individuals) populations (see the Demography section). However, when considering which populations have most value to protect, it is important to remember that rare species often exhibit genetic differences between populations (see Threats section). Even though small populations are often considered genetically depauperate as a result of changes in gene frequencies due to inbreeding or founder effects, alleles that are absent in larger populations may only be found in small populations (Karron et al. 1988, Menges 1991). Local adaptation, and therefore unique gene combinations, in small populations is quite likely because outbreeding depression has also been observed in populations of *I. aggregata* (see Demography section). In the absence of genetic data, in order to conserve genetic variability it is likely most important to conserve as many populations as possible in as large a geographic area as possible and to keep in mind that a larger population is not automatically the best one to conserve.

The results of demographic studies led Wilken (1996) to suggest that reduced competition and availability of open sites promotes reproduction, seedling establishment, and long-term population stability (see Demography and Community ecology sections). Invasive weeds may contribute to loss of habitat. Sustainability of *Ipomopsis aggregata* ssp. *weberi* appears to rely on relatively long-lived vegetative individuals and a seed bank that may become depleted within five years (see Demography section). Thus management practices that either increase or decrease the frequency or intensity of natural perturbations or provide additional stresses may negatively impact population viability. Because it frequently grows on old road cuts and is apparently persistent in lightly disturbed sites, *I. aggregata* ssp. *weberi* is likely tolerant of, or even requires, periodic disturbance. The problem is that there is little information on which to base predictions as to the taxon's response to specific disturbance types or levels. A fundamental gap in knowledge is that it is not known how quickly disturbed areas are re-colonized or if plants are able to persist at frequently disturbed sites. The likelihood of hybridization with other races of *I. aggregata* suggests that introduction of varieties other than ssp. *weberi* in re-vegetation seed mix is a significant conservation concern (see Threats section).

Tools and practices

Documented inventory and monitoring activities are needed for this species because there is little information on population structure and the persistence or colonization rate of individuals.

Species inventory

More surveys would facilitate determining the abundance of *Ipomopsis aggregata* ssp. *weberi*. The current field survey forms for endangered, threatened, or sensitive plant species used by the Gunnison National Forest, the Colorado Natural Heritage Program, and the Wyoming Natural Diversity Database all request the collection of data that is appropriate for inventory purposes (see Reference section for Internet addresses). The number of individuals and the area they occupy are important data for occurrence comparison. The easiest way to describe populations over a large area may be to count patches, making note of their extent, and estimate or count the numbers of individuals within patches. A statement like "many individuals" or "abundant" is subjective, and on the field survey form an estimate of the number observed is more helpful (see Abundance and distribution section for examples of the difficulties in evaluating subjective versus specific estimates). The estimate may be a range such as "less than 10" or "between 50 and 100." Collecting information on phenology is also valuable in assessing the vigor and fecundity of a population. Observations on habitat should also always be recorded. In the case of new occurrences it is useful to collect a specimen and deposit it in a herbarium. However, it is not appropriate to take specimens from small populations. The advisability of collecting a specimen needs to be considered on a species-specific and a site-specific basis. A general guideline should be established for field technicians. For example, the guideline may be that a specimen can be collected if there are at least 50 individuals or greater than 20 flowering plants observed. If there are fewer than 20 flowering individuals, a close-up colored photograph and an additional photograph of the plant to show its habitat should be taken in order to document the occurrence. It is important that the collected specimens have flowers and a note of the color is made prior to pressing the specimen.

Habitat inventory

Although the habitat model of Fertig and Thurston (2003) has helped to define the conditions in which *Ipomopsis aggregata* ssp. *weberi* grows in Wyoming, the available information on habitat suggests that it is not possible to make a critical inventory of areas that have the potential for colonization in Colorado. In addition, there are no studies that relate the abundance or vigor of populations to specific habitat conditions, and so defining the quality of the habitat or likelihood of colonization is unlikely to be effective with the currently available information. The patchy distribution pattern of *I. aggregata* ssp. *weberi* and the large amounts of unoccupied but ostensibly suitable habitat (see Distribution and abundance section) suggest that specific microclimate conditions may need to be met in order to support plants. Interspecific competition, or rather the lack of it, is important to its ecology, and so inventory of areas experiencing initial invasion by non-native species may indicate where it is more unlikely to be found in the future.

Population monitoring

The demographic study by Wilken (1996) provided five years of information on four populations in Colorado, but no other monitoring studies have been reported (see Demography section). Lesica (1987) discussed a technique for monitoring non-rhizomatous, perennial plant species using permanent belt transects. He also described life stage or size classes and reproductive classes that would be appropriate to consider for *Ipomopsis aggregata* ssp. *weberi*. He applied the technique to *Astragalus scaphoides*, which grows at moderate to low densities. Following Lesica's guidelines, Rittenhouse and Rosentreter (1994) established similar permanent transects for making demographic studies and monitoring *A. amblytropis*, an endemic of east-central Idaho. They also described a modified transect method that they used in the second year of study to increase the sample size. The latter method marked each plant individually within 1 m of the transect line. Permanent transects appear to be the most accurate way to study long-term trends. Elzinga et al. (1998) and Goldsmith (1991) have discussed using a rectangular quadrant frame along transect lines to effectively monitor the clumped-gradient nature of populations. The population dynamics of *I. aggregata* ssp. *weberi* are not known, and shifts in stands within a population need to be noted. Because it can be a biennial or a short-lived perennial, a series of colonizations and localized extirpations of small suboccurrences may be expected. The monitoring scheme should address the patchy and possibly dynamic nature of some of these occurrences. Problems associated with spatial auto-correlation can occur when using permanent plots to monitor a dynamic population. If the size of the plot is too small or the establishment of new plots is not part of the original design, when plants die and no replacement occurs it is impossible to know the significance of the change without studying a very large number of similar plots.

Establishing photo points and taking appropriate photographs is very helpful in describing site conditions. Even though digital copies are convenient and easy to store, many museums and researchers suggest storing additional slides or even hardcopies, as in 50 years time the technology to read memory sticks and CDs may no longer be available.

Monitoring populations is the only way to determine the effects of management practices. In 1989, several thousand plants were observed over two sections on Battle Mountain, Wyoming (Wyoming Natural Diversity Database 2002). In 1994, only three *Ipomopsis* plants were found after a survey of one quarter of each of the two sections (see Population trend section) (Wyoming Natural Diversity Database 2002). It may be that these observations indicate a reduction in numbers between the two years, but due to insufficient location data, this cannot be confirmed. One potentially important event that occurred between the two years was that in 1991, 2,4-D, a broad-spectrum dicot herbicide, was applied to control shrubs (serviceberry and big sagebrush) in the area (Fertig 1999). Insufficient data was collected to evaluate the impacts of this action. Formal monitoring plots over that period would have been valuable. Similarly, the impacts of grazing on occurrences need to be monitored. Because fluctuations in population size are also affected by environmental conditions, it is important that long-term studies are carried out and occurrences be monitored over consecutive years, otherwise trends may be obscured by natural variation. Some additional considerations in monitoring efforts are discussed in the Community Ecology section of this report.

Habitat monitoring

Habitat monitoring in the presence of plant occurrences should be associated with population monitoring protocols. Descriptions of habitat should always be recorded during population monitoring activities in order to link environmental conditions with abundance over the long-term. Conditions several years prior to the onset of a decrease or increase in population size may be more important than conditions existing during the year the change is observed. Current land use designation and evidence of land use activities are important to include with monitoring data. For example, where possible it should be noted if populations are on an active grazing allotment even though no use by livestock is observed. Because there is a general understanding of what areas might represent potential habitat, it may be possible to monitor total habitat conditions. For example, one could observe gross changes in vegetative cover, invasive weed cover, and erosion patterns in apparently appropriate, but un-colonized, habitat that is near to known populations.

Population or habitat management approaches

Because *Ipomopsis aggregata* ssp. *weberi* is designated a USFS Region 2 sensitive species, surveys for the taxon are made prior to projects on all National Forest System lands in Region 2. If *I. aggregata* ssp. *weberi* plants are in the way of a proposed project, plants are typically avoided and awarded a 50-foot buffer zone around occupied habitat on the Routt National Forest (Skorkowsky personal communication 2003). In some instances projects have proceeded on the Routt National Forest, and plants have been lost when other considerations such as safety took precedence and when the impact was not expected to cause a downward trend leading to listing as threatened or endangered by the U.S. Fish and Wildlife Service (see Threats section).

Conservative grazing practices are being implemented within *Ipomopsis aggregata* ssp. *weberi* habitat on the Routt National Forest (Bringuel et al. 2002, Vogel 2003). For example, only one band of sheep (1,000 sheep, ewe/lamb) will graze the Buffalo Pass grazing allotment where a two-unit rest-rotation system is being implemented (Bringuel 2002). The rest-rotation system typically presents fewer potential negative impacts to the vegetation in comparison to the more common deferred rotation system (Bringuel 2002). The rest-rotation scheme incorporates rest periods of 12 consecutive months, or at least one growing season, for individual grazing units within a grazing allotment whereas the deferred-rotation grazing system provides for a systematic rotation of deferment among pastures during the growing season (Howery et al. 2000, Society of Range Management 2003). *Ipomopsis aggregata* ssp. *weberi* also occurs within the Rabbit Ears grazing allotment. A slightly larger band of sheep (1,100 sheep, ewe/lamb) will be permitted in this region in anticipation of a larger amount of available forage. When *I. aggregata* ssp. *weberi* populations are found within stocked grazing allotments on the Routt National Forest, they will be monitored to determine the impact of the grazing system on this specific taxon (Vogel 2002, 2003).

Management practices, such as restricting recreational vehicle traffic and recreational development in some areas, have been implemented on the national forests within Region 2 (USDA Forest Service 2001, 2002). By reducing the potential spread of invasive species and limiting anthropogenic disturbance, such practices benefit most native plant species, including *Ipomopsis aggregata* ssp. *weberi*.

All of these conservation measures have been relatively recently implemented, and there have been no systematic monitoring programs for the *Ipomopsis aggregata* ssp. *weberi* occurrences. Therefore the benefits of restricting vehicle traffic and modifying grazing procedures cannot be evaluated.

Information Needs

At the present time *Ipomopsis aggregata* ssp. *weberi* appears to be a naturally uncommon species restricted to specific community types within a limited geographic range. It does not appear to have significantly declined in abundance over the last few decades, but one cannot say with certainty that it has not experienced a decline over the last century (see Population trend section). Additional surveys may find that the taxon is more widespread than currently believed. However, it should be remembered that the rarity of a taxon can be particularly difficult to establish. There is the always the possibility that additional surveys would reveal more occurrences. When most information has been collected relatively casually, a criticism with defining a taxon as rare is that there are extensive areas as yet unsurveyed. To some extent this is true, but rarity is also relative and many taxa are regarded as not being rare precisely because casual observation has noted that they occur frequently.

Monitoring known sites is essential in order to understand the implications of existing and new management practices. Where management practices are likely to change, valuable information would be gained from making an inventory to collect baseline data, and then conducting periodic monitoring after the new policy is initiated. In particular, colonies in high disturbance areas, for example areas that receive off-road vehicle, mountain bike, and hiker use need to be monitored because, currently, trend data are not available to determine the long-term survival of plants at high-use sites. The impacts of ungulate grazing are also not clearly understood. Clarifying the levels at which plants may respond, positively or negatively, to browsing or grazing pressure would be very useful in designing management practices. Long-term monitoring would be valuable because the impacts from accelerated soil erosion, disruption of seed bank depletion-replacement cycles, and increased soil compaction may take several decades to become apparent.

Inventory and periodic monitoring of existing sites appear to be important needs, but there are also unanswered questions about the taxon's biology and ecology that would influence its management. Differentiating between whether plants colonize or persist at sites that have experienced disturbance is an important aspect of this species' ecology and may be central to its management. The observation that many individuals appear long-lived suggests that survivorship, as well as reproductive capacity, is critically important to this species' life history. In populations where survivorship is most important, some protections may need to be afforded the adult plants. Alternatively, observations that the taxon grows in areas such as road cuts suggest that it can relatively rapidly colonize such areas and act as a pioneer species. In this case additional studies need to be carried out to determine if the size of the seed bank or fecundity of nearby occurrences is of greater importance. The rate at which *Ipomopsis aggregata* ssp. *weberi* colonizes potential habitat is unknown, and there may be a substantial difference between recolonizing an area from a pre-existing seed bank and colonizing an area through seed dispersal. The spatial dynamics within occurrences are also unknown. It is currently understood that vegetative cover is a primary factor that limits population size and abundance and that contributes to the variable occurrence sizes. This should be confirmed experimentally. The taxon's ability to tolerate interspecific competition is speculated as being low, and non-native invasive species are likely to pose a significant threat.

Understanding the genetic variability and the reproductive system of this taxon would also allow more biologically-informed management decisions to be made. The extent of genetic variability between populations is important when considering the potential genetic losses associated with loss of individual populations. If genetic variability exists between populations, establishing colonies near to the impacted areas using seeds or plants from the impacted populations may conserve genetic resources. In conjunction with such studies research would have to be carried out to determine if transplantation or establishment from seed is feasible.

The degree to which colonies interact also influences the delineation of discrete occurrences if occurrences are equated with populations (see Distribution and abundance section). The species involved in pollination need to be clarified. Management practices, for example grazing policies, may need to be modified if specific pollinators are found to be essential for cross-pollination (see Community ecology section). In addition, prescriptive pesticide applications may need to be reviewed to ensure that the specific pollinators of

Ipomopsis aggregata ssp. *weberi* are not targets of chemicals used to control other species, such as the bark beetle (*Ips* spp. and *Dendroctonus* spp.).

In summary, information needs include:

- ❖ Inventory of occurrences, especially targeting areas that have not been surveyed.
- ❖ Monitoring known occurrences.
- ❖ Reproductive biology studies, especially determining the pollinator species and their vulnerability.
- ❖ Genetic studies to determine the isolation and genetic diversity of disparate occurrences.

Definitions

Diptera — Order of arthropods that consist of flies.

Hermaphrodite — Bisexual; having both stamens and carpels in the same flower (Abercrombie et al. 1973).

Heterosis — Hybrid vigor. "Increased vigor of growth, fertility etc. in a cross between two genetically different lines, as compared with growth etc. in either parental line; associated with increased heterozygosity." (Abercrombie et al. 1973).

Heterozygote — A diploid or polyploid individual that has different forms of a given gene at least one locus.

Homozygote — An individual having the same alles at one or more loci.

Iteroparous — Experiencing several reproductive periods, usually one each year for a number of years, before it dies.

Lepidoptera — Order of arthropods that consist of moths and butterflies.

Loci — Plural of locus. A specific place on a chromosome where a gene is located (Allaby 1992).

Metapopulation — A composite population. That is, a population of populations in discrete patches that are linked by migration and extinction.

Miocene — An epoch of the early Tertiary period - 23.8 to 5.3 million years ago (USGS Cascades Volcano Observatory Internet site).

Monocarpic — Flowering just once in its life (Abercrombie et al. 1973).

Ornithiphilous — Pollinated by birds.

Pleistocene — Also referred to as the Ice Age. An epoch of the Quaternary period, beginning two to three million years ago and lasted until the beginning of the Holocene 8, 000 years ago. (Bates and Jackson 1976).

Polycarpic — Flowering more than once in its life.

Protandrous — The anthers maturing and shedding mature pollen before the style finishes elongating and the stigma becomes receptive to pollen.

> The status of infraspecific taxa (trinomials) are indicated by a "T-rank" following the species' global rank. Rules for assigning T-ranks follow the same principles as those for binomials.
>
> For example, the global rank of a critically imperiled subspecies of an otherwise widespread and common species would be G5T1.
>
> G5T2 indicates *Ipomosis aggregata* (G5) is a widespread and common species, but ssp. *weberi* (T2) is "imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or linear miles (10 to 50)."
>
> S2 indicates it is "imperiled in the nation or subnation because of rarity or because of some factor(s) making it very vulnerable to extirpation from the nation or subnation. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000)."
>
> For further information see NatureServe at internet site: http://www.natureserve.org/explorer/granks.htm

Ranks — NatureServe and the Heritage Programs Ranking system.

Salverform — A corolla with a long slender tube, abruptly flaring into a circular limb (Harrington and Durrell 1979).

Section — A genus may be divided into sections, which can be thought of as "sub-genera."

Semelparous — Reproducing once and then dying.

Withdrawal — "An action that restricts the use of described public lands from operation of certain laws, which are also described in the withdrawal order." (Glossary to the Bureau of Land Management Great Divide Resource Management Plan, Rawlins Field Office, WY). Protective withdrawals are often used to prohibit the staking and development of mining claims.

COMMONLY USED SYNONYMS OF PLANT SPECIES

Commonly used synonyms of plant species (Kartesz 1994) mentioned in this report. The reference in parenthesis refers to a flora in Region 2 in which the synonym is used:

Alnus tenuifolia	*Alnus incana* ssp. *tenuifolia* (Weber and Wittmann 2001)
Oryzopsis hymenoides	*Achnatherum hymenoides* (Dorn 2001, Weber and Wittmann 2001)
Bromus inermis	*Bromopsis inermis* (Weber and Wittmann 2001)
Rubus parviflorum	*Rubacer parviflorum* (Weber and Wittmann 2001)
Stipa comata	*Hesperostipa comata* (Dorn 2001, Weber and Wittmann 2001)
Stipa lettermanii	*Achnatherum lettermanii* (Dorn 2001, Weber and Wittmann 2001)

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LIST OF ERRATA

09/21/05 Changed peer review organization from Society for Conservation Biology to Center for Plant Conservation on the cover and under “Peer Review” heading.