Thelypodiopsis juniperorum (Payson) Rydberg (juniper tumblemustard): A Technical Conservation Assessment

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Author's Biography

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List of Errata

Summary of Key Components for Conservation of *Thelypodiopsis juniperorum*

Status

Thelypodiopsis juniperorum (juniper tumblemustard) is known from 16 occurrences in Gunnison, Delta, and Montrose counties in western Colorado, USA.

It is found primarily in pinyon juniper woodlands and in shrublands dominated by sagebrush, oak, or serviceberry, between 6,200 and 8,200 feet in elevation. *Thelypodiopsis juniperorum* is not currently known from lands administered by the USDA Forest Service (USFS). However, all 16 known occurrences are found in close proximity to the Gunnison National Forest and the probability of finding occurrences on National Forest System land is high. Occurrences of *T. juniperorum* have been documented on private land and on Bureau of Land Management, National Park Service, and Colorado Department of Transportation lands. Seven occurrences are historic and their precise locations and land ownership status are uncertain. At least one, and possibly as many as eight occurrences, resides in part or entirely on private land. *Thelypodiopsis juniperorum* is ranked globally imperiled (G2) by NatureServe, and is likewise considered imperiled (S2) in Colorado (the global and state ranks of *T. juniperorum* were changed from G/S1 to G/S2 due to information obtained for this species assessment). It is not considered sensitive by USFS Region 2 (USDA Forest Service 2003), nor is it included on the Bureau of Land Management Sensitive Species List for Colorado (Bureau of Land Management 2000). It is not listed as threatened or endangered under the Endangered Species Act (U.S.C. 1531-1536, 1538-1540).

Primary Threats

Given the lack of substantive information on *Thelypodiopsis juniperorum*, it is difficult to assess confidently the threats to this species. However, based on information presented in this assessment, there are several threats to *T. juniperorum*. In order of decreasing priority, these are grazing, off-road vehicle use, non-native species invasion, fire suppression, energy development, residential development, pesticide use for range management, hiking, and global climate change. These threats and the hierarchy ascribed to them are speculative due to a lack of information specific to *T. juniperorum*. Assessment of threats to this species will be an important component of future inventory and monitoring work. Because there have not yet been any occurrences documented on lands administered by USFS Region 2, specific threats to this species on National Forest System lands are not known, although two occurrences are within one-half mile of the Gunnison National Forest boundary.

Primary Conservation Elements, Management Implications and Considerations

Its high level of endemism, small number of occurrences, and the vulnerability of its habitat suggest that *Thelypodiopsis juniperorum* is imperiled. It is known from approximately 16 occurrences, seven of which have not been revisited in more than 20 years. The range and abundance of *T. juniperorum* is poorly understood and should be investigated. Understanding the status of *T. juniperorum* is complicated by its high annual variation in population size, making it difficult to ascribe conservation priorities for this species. It is best known from Black Canyon of the Gunnison National Park where it benefits from protected land status. All or portions of at least 13 of the 16 occurrences are located on federal land owned by the Bureau of Land Management and the National Park Service, where they are unlikely to be impacted directly by threats such as residential development. However, occurrences on Bureau of Land Management lands are threatened by energy development (including the construction of infrastructure to support energy development) and grazing. It appears that weed invasion is exacerbated greatly by grazing and other human activities within its habitat. Invasion of its habitat by *Bromus tectorum* appears to be a management concern for *T. juniperorum* because both species are annuals that might compete for limited resources in late spring.

Pursuing conservation easements or other protective land status changes on private properties where occurrences are located would help to ensure the viability of occurrences on private land. Designation of areas of critical environmental concern on Bureau of Land Management lands may also help ensure the viability of some occurrences.

However, at this time further species inventory work is needed to determine the location of suitable sites for these actions. Species inventory work remains a high priority for *Thelypodiopsis juniperorum* and is likely to identify additional occurrences. Research is needed to investigate the population biology and autecology of *T. juniperorum* so that conservation efforts on its behalf can be most effective.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS 2
AUTHOR'S BIOGRAPHY 2
SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *THELYPODIOPSIS JUNIPERORUM* 3
Status 3
Primary Threats 3
Primary Conservation Elements, Management Implications and Considerations 3
LIST OF TABLES AND FIGURES 7
INTRODUCTION 8
Goal of Assessment 8
Scope of Assessment 8
Treatment of Uncertainty in Assessment 9
Publication of Assessment on the World Wide Web 9
Peer Review 9
MANAGEMENT STATUS AND NATURAL HISTORY 9
Management Status 9
Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies 9
Adequacy of current laws and regulations 9
Adequacy of current enforcement of laws and regulations 14
Biology and Ecology 14
Classification and description 14
Distribution and abundance 16
Population trend 17
Habitat 18
Reproductive biology and autecology 19
Demography 21
Community ecology 21
CONSERVATION 27
Threats 27
Influence of management activities or natural disturbances on habitat quality 27
Influence of management activities or natural disturbances on individuals 28
Interaction of the species with exotic species 28
Threats from over-utilization 28
Conservation Status of the Species in USFS Region 2 29
Is distribution or abundance declining in all or part of its range in USFS Region 2? 29
Do habitats vary in their capacity to support this species? 29
Vulnerability due to life history and ecology 29
Evidence of populations in USFS Region 2 at risk 29
Management of the Species in USFS Region 2 29
Implications and potential conservation elements 29
Tools and practices 30
Species and habitat inventory 30
Population monitoring 30
Habitat monitoring 31
Beneficial management actions 32
Seed banking 33
Information Needs 33
Distribution 33
Lifecycle, habitat, and population trend 33
Response to change 33
Metapopulation dynamics 34
Demography 34
Population trend monitoring methods 34

Restoration methods 34
Research priorities for USFS Region 2 34
Additional research and data resources 35
DEFINITIONS 36
REFERENCES 38
LIST OF ERRATA 44

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LIST OF TABLES AND FIGURES

Tables:

Table 1. Summary of specimen label and element occurrence record data for *Thelypodiopsis juniperorum*..... 10

Table 2. Summary of land ownership status of the 16 known occurrences of *Thelypodiopsis juniperorum*. 12

Table 3. Associated species documented with *Thelypodiopsis juniperorum*. 23

Figures:

Figure 1. The distribution of *Thelypodiopsis juniperorum* in the states of USFS Region 2..... 12

Figure 2. The known distribution of *Thelypodiopsis juniperorum*, showing land ownership and proximity of highways, municipalities, reservoirs, and rivers to known occurrences..... 13

Figure 3. *Thelypodiopsis juniperorum* was collected northeast of Crawford, in Delta County, Colorado.... 16

Figure 4. Life cycle diagram for *Thelypodiopsis juniperorum* (after Stern 1994)..... 22

Figure 5. Hypothetical life cycle graph (after Caswell 2001) for *Thelypodiopsis juniperorum*..... 23

Figure 6. Envirogram for *Thelypodiopsis juniperorum*. 24

Figures 7 and 8. Pinyon-juniper woodland along Highway 347, approximately one mile south of the entrance to Black Canyon of the Gunnison National Park..... 26

INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Thelypodiopsis juniperorum* is the focus of an assessment because of its high degree of rarity and endemism, and because of concern for its viability. It is not designated a sensitive species by the USDA Forest Service (USDA Forest Service 2003) or the Bureau of Land Management (Bureau of Land Management 2000). It was considered for sensitive species status, but lack of information precluded listing (USDA Forest Service 2004). Although it is not currently known from lands administered by the USFS Region 2, *T. juniperorum* remains a management concern for USFS Region 2 because of the proximity of all occurrences to National Forest System lands and because of the possibility that it occurs on National Forest System lands.

This assessment addresses the biology of *Thelypodiopsis juniperorum* throughout its range in USFS Region 2. This introduction outlines the scope of the assessment and describes the process used in producing the assessments.

Goal of Assessment

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public a thorough discussion of the biology, ecology, conservation status, and management of certain species based on scientific knowledge accumulated prior to initiating the assessment. 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. However, it does provide the ecological background upon which management must be based, and it focuses on the consequences of changes in the environment that result from management (i.e. management implications). Furthermore, it cites management recommendations proposed outside of USFS Region 2 and examines the success of management plan implementations both within and outside of USFS Region 2.

Scope of Assessment

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

In producing the assessment, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. All known publications, reports, and element occurrence records for *Thelypodiopsis juniperorum* in USFS Region 2 are referenced in this assessment, and all of the available experts on this species were consulted during its synthesis. All available specimens of *T. juniperorum* were viewed to verify occurrences and incorporate specimen label data. Specimens were searched for at COLO (University of Colorado Herbarium), CS (CSU Herbarium), RM (Rocky Mountain Herbarium), SJNM (San Juan College Herbarium), CC (Carter Herbarium), Great Sand Dunes National Park Herbarium, GREE (University of Northern Colorado Herbarium), NMCR (New Mexico State University Range Science Herbarium), and UNM (University of New Mexico Herbarium). This assessment emphasizes refereed literature because this is the accepted standard in science. Nonrefereed publications or reports were regarded with greater skepticism. Some nonrefereed literature was used in the assessment, however, only when information was unavailable elsewhere. Unpublished data (e.g. state natural heritage program records and herbarium specimen labels) were important in estimating the geographic distribution, and contain the vast majority of the useful information known on *T. juniperorum*. However, these data required special attention because of the diversity of persons and methods used to collect the data.

The goal to produce assessments rapidly limited the time available for analysis of existing unpublished data, or attempts to conduct meta-analysis to

synthesize information from published literature. Due to the lack of specific information on *Thelypodiopsis juniperorum*, inferences were made using related taxa whenever possible.

Treatment of Uncertainty in Assessment

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and observations limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, observations, inference, good thinking, and models must be relied on to guide our understanding of ecological relations. Confronting uncertainty then is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

Publication of Assessment on the World Wide Web

To facilitate use of species assessments in the Species Conservation Project, assessments are being published on the USFS Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publication as a book or report. More important, it facilitates 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 Society for Conservation Biology employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Thelypodiopsis juniperorum is not currently listed as a sensitive species in USFS Region 2 (USDA Forest Service 2003), nor is it included on the Bureau of Land Management Sensitive Species List for Colorado (Bureau of Land Management 2000). NatureServe considers *T. juniperorum* to be globally imperiled (G2). Because it is only found in Colorado, it is also considered imperiled (S2) by the Colorado Natural Heritage Program. Its high level of endemism, small number of occurrences, and the vulnerability of its habitat suggest that *T. juniperorum* is imperiled. It is known from approximately 16 occurrences (**Table 1**; **Figure 1**), seven of which have not been revisited in more than 20 years. The global and state ranks of *T. juniperorum* were changed from G/S1 to G/S2 due to information obtained for this species assessment. For explanations of NatureServe's ranking system, see the Definitions section of this document.

Occurrences of *Thelypodiopsis juniperorum* have been documented on private land and on Bureau of Land Management, National Park Service, and Colorado Department of Transportation lands (**Table 2**). *Thelypodiopsis juniperorum* is not currently known from lands administered by the USDA Forest Service. However, known occurrences are found in close proximity to the Gunnison National Forest and the probability of finding occurrences on National Forest System land is high. Two occurrences (at Paonia Reservoir, Taylor 5935 and north-northeast of Crawford, Taylor 4860) are within one-half mile of the Gunnison National Forest (**Figure 2**), and almost all occurrences are within ten miles of National Forest System lands.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Adequacy of current laws and regulations

Thelypodiopsis juniperorum has no legal protection unto itself that would prevent the destruction of habitat or individuals. Because *T. juniperorum* is not

Table 1. Summary of specimen label and element occurrence record data for *Thelypodiopsis juniperorum*. a: Specimens and reports with the same superscript number are considered one occurrence. b: g= general record (exact location cannot be determined), m = minutes record (location known within approximately one square mile) s= seconds record (precise location known). c: RM = Rocky Mountain Herbarium; CS = Colorado State University Herbarium; COLO = University of Colorado Herbarium; KDH = Kalmbach Herbarium (Denver Botanic Garden); GREE = University of Northern Colorado Herbarium; GH = Gray Herbarium, Harvard.

County[a]	Elevation (ft)	Date	Precision[b]	Location	Land ownership	Collectors	Collection number	Herbarium[c]	Habitat and notes
Delta	unknown	5/21/1911	g	Paonia	Unknown; possibly private	G.E. Osterhout	4533	RM	Not reported.
Delta	6,200	5/15/1998	s	North-northeast of Crawford	BLM: Uncompahgre Field Office	Kevin J. Taylor	4860	KDH, RM	Pinyon pine and juniper forest; *Cercocarpus* spp. and *Amelanchier* spp.
Delta[1]	7,300 to 7,850	5/17/1997	s	Jumbo Mountain	BLM: Uncompahgre Field Office	R.L. Hartman, Kevin J. Taylor	56360	COLO, RM	Squaw-apple and serviceberry zone and pinyon-juniper slopes above with sandstone and shales.
Delta[1]	6,400 to 6,550	6/7/1998	s	North-northwest of Paonia	Private	Kevin J. Taylor	6054	RM	Pinyon/ juniper forest; *Amelanchier* spp., *Cercocarpus* spp., *Peraphyllum* spp., *Bromus tectorum*, and *Thermopsis* spp.
Delta[2]	6,250 to 6,350	5/14/1998	s	Northwest of Crawford	BLM: Uncompahgre Field Office	Kevin J. Taylor	4807	RM	Pinyon pine and juniper mesa; *Cercocarpus* spp., *Amelanchier* spp., *Atriplex* spp., and *Quercus* spp.
Delta[2]	6,720	5/19/1998	s	Northeast of Crawford	BLM: Uncompahgre Field Office	Kevin J. Taylor	5090	RM	Sagebrush and juniper/pinyon.
Delta[2]	6,700	5/19/1998	s	East of Youngs Peak	BLM: Uncompahgre Field Office	Kevin J. Taylor	5069	RM, GREE	Pinyon/juniper forest.
Gunnison	7,000	5/23/1939	m	Sapinero	NPS: Curecanti National Recreation Area	Reed C. Rollins	2110	RM	Dry granitic hillside, three miles east of Sapinero, Gunnison County. Flowers lavender to white. [from Gray Herbarium on Exchange].
Gunnison	6,400 to 6,900	6/7/1998	s	Paonia Reservoir	BLM: Uncompahgre Field Office	Kevin J. Taylor	5935	RM, CS	Southeast-facing drainage; *Quercus* spp., juniper, *Symphoricarpos* spp., *Prunus* spp., and Douglas fir.
Montrose	7,000	5/31/1913	g	Near Red Rock	BLM: Uncompahgre Field Office or private	Edwin Payson	97	RM, GH	Dry hillside under cedar, near Red Rock. [2 copies of this specimen at RM].
Montrose	~6,300	7/15/1915	g	East of Montrose	Private or Colorado Department of Transportation	Edwin Payson	688	RM, GH	Flower and fruit. [Isotype specimen is housed at GH; Holotype at RM].
Montrose	~8,150	5/27/1979	m	East of Cerro Summit	NPS: Curecanti National Recreation Area or Private	Reed C. Rollins and Kathryn W. Rollins	7975	COLO, RM, GH	Annual. Stems one or few from base; sepals and petals bright purple. Sagebrush and juniper area below granitic cliffs.
Montrose	7,050 to 7,350	5/19/1998	s	North edge of Gould Reservoir	BLM: Uncompahgre Field Office	Kevin J. Taylor	5019	RM	Along edge of reservoir; *Juniperus* spp., pinyon pine, *Amelanchier* spp., and *Symphoricarpos* spp.
Montrose[3]	7,700	5/31/1942	m	Near entrance to Black Canyon of the Gunnison National Park	Private or NPS: Black Canyon of the Gunnison National Park	C. William and T. Penland	1810	COLO	Cedar- pinyon slope.

Table 1 (concluded).

County[a]	Elevation (ft)	Date	Precision[b]	Location	Land ownership	Collectors	Collection number	Herbarium[c]	Habitat and notes
Montrose[3]	6,500	6/13/1953	g	Highway 347	BLM: Uncompahgre Field Office, private, or Colorado Department of Transportation	W.E. Liggett	2040	CS	Not reported.
Montrose[3]	~8,000	5/21/1962	g	Highway 347	NPS: Black Canyon of the Gunnison National Park	W.A. Weber	11373	COLO	On roadside banks, *Juniperus osteosperma* woodland along entrance highway.
Montrose[3]	~8,200	5/28/1979	m	Highway 347	NPS: Black Canyon of the Gunnison National Park	Reed C. Rollins and Kathryn W. Rollins	7994	GH	Not reported.
Montrose[4]	~7,350	7/24/1969	m	Highway 347	BLM: Uncompahgre Field Office or Colorado Department of Transportation	I. & M. Al-Shehbaz	6902	GH	Not reported.
Montrose[4]	~7,130	5/28/1979	m	Highway 347	Private or Colorado Department of Transportation	Reed C. Rollins and Kathryn W. Rollins	7987	COLO, RM, GH	Annual. Buds purple; sepals erect during anthesis; petals brilliant purple; leaves fleshy. Abundant.
Montrose[5]	~7,725	6/3/1961	m	Serpent's Point Road	NPS: Black Canyon of the Gunnison National Park	Carol Miller	3	COLO	Shallow rocky soil.
Montrose[5]	7,800	6/6/2000	s	North Vista Trail	NPS: Black Canyon of the Gunnison National Park	Observed by Peggy Lyon	N/A	N/A	Two plants along the North Vista Trail in a dry, disturbed site. In pinyon-juniper woodland on a steep south-facing slope.
Montrose[5]	7,800	6/14/2003	s	North Vista Trail	NPS: Black Canyon of the Gunnison National Park	Tim Hogan, Nan Lederer, Dina Clark	4061b	COLO	Dry pinyon-juniper uplands with oak and serviceberry; mostly in the shade of pinyons or junipers. On canyon rim on volcanics. Perhaps ten groups of 20 plants.
Montrose	~8,130	5/9/2004	s	Warner Point	NPS: Black Canyon of the Gunnison National Park	Tim Hogan	4232	COLO	Rocky pinyon-juniper woodland; plants scattered.
Montrose	~7,260	5/23/2004	s	West boundary of Black Canyon of the Gunnison National Park	NPS: Black Canyon of the Gunnison National Park	Tim Hogan	4290	COLO	Sandstone slopes proximate to Mancos Shale. With *Juniperus osteosperma*, *Pinus edulis*, *Sarcobatus vermiculatus*, and *Atriplex canescens*. Was seen regularly in this area but was not abundant.
Montrose	7,950	6/14/2003	s	North Rim of Black Canyon of the Gunnison National Park	NPS: Black Canyon of the Gunnison National Park	Observed by Nan Lederer, Dina Clark, and Tim Hogan	N/A	Not available	Numerous plants growing on a dry, sunny roadcut.

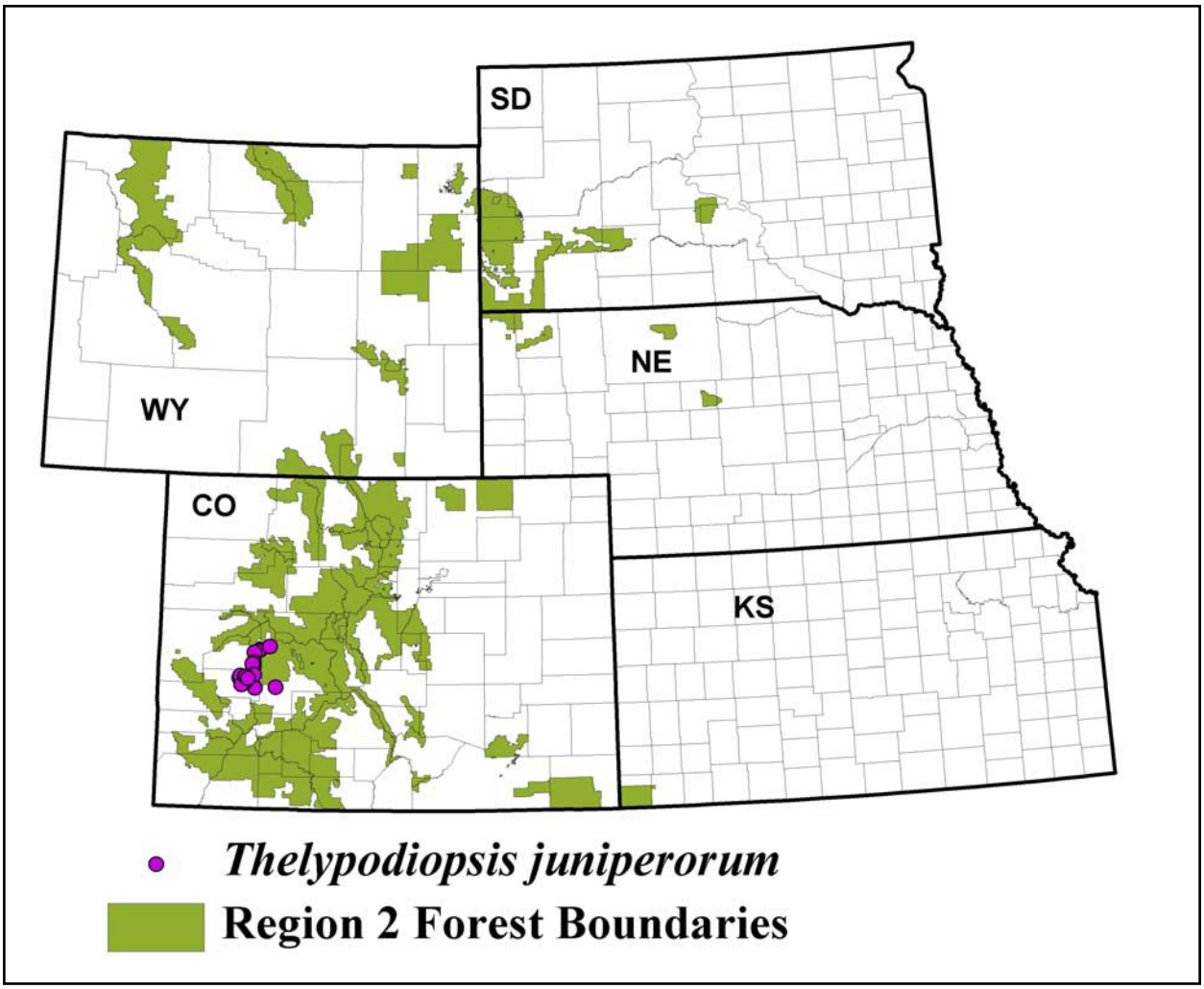

Figure 1. The distribution of *Thelypodiopsis juniperorum* in the states of USFS Region 2.

Table 2. Summary of land ownership status of the 16 known occurrences of *Thelypodiopsis juniperorum*. Because some occurrences may be found on more than one land ownership type, the total number of occurrences is less than the sum of the rows in this table. Numbers in parentheses are possible additional occurrences, but because their precise location is uncertain the land ownership status is also uncertain. Please see **Table 1** for land ownership of specific occurrences.

Land Ownership Status	Number of Occurrences	Subtotals
USDA Forest Service	0	
Bureau of Land Management	5 (3)	
National Park Service	6 (2)	
Curecanti National Recreation Area		1 (1)
Black Canyon of the Gunnison NP		5 (1)
Colorado Department of Transportation	(3)	
Private	1 (7)	
Unknown	8	
Total	**16**	

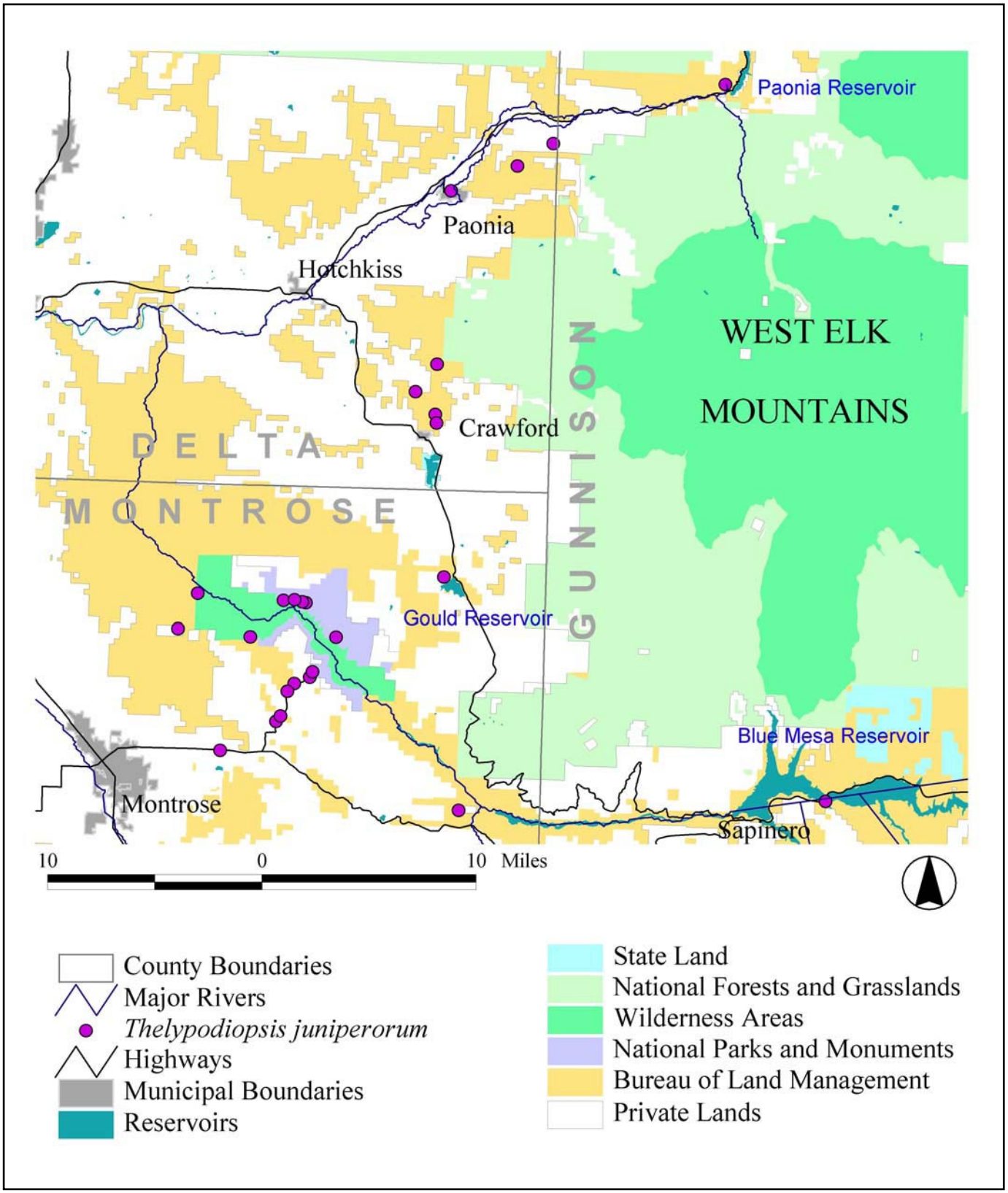

Figure 2. The known distribution of *Thelypodiopsis juniperorum*, showing land ownership and proximity of highways, municipalities, reservoirs, and rivers to known occurrences.

a designated sensitive species in USFS Region 2, it would not receive protection as such on National Forest System lands. As of this writing, a conservation strategy has not been written for this species at a national or regional level by the USFS or any other federal agency. Some occurrences are found in areas where they are likely to have been impacted by land management, although the extent to which these occurrences have been subjected to human impacts is unknown.

Adequacy of current enforcement of laws and regulations

There have been no documented cases in which an occurrence of *Thelypodiopsis juniperorum* was extirpated due to human activities or the failure to enforce any existing regulations. However, this does not necessarily indicate that current regulations or their enforcement are adequate for its protection. Human impacts such as reservoir creation may have diminished the abundance of this species.

Biology and Ecology

Classification and description

Thelypodiopsis juniperorum is a member of the Brassicaceae (Cruciferae) family. Members of the Brassicaceae are found on all continents except Antarctica (Rollins 1993). It is a large family that includes approximately 3,350 species worldwide (Al-Shehbaz 1984), although new taxa continue to be recognized (Rollins 1993). North America is an important center of diversification for this family, with 778 recognized species (Rollins 1993). However, the centers of diversity for the family are undoubtedly southwestern Asia and the Mediterranean (Heywood 1993, Rollins 1993). Unlike some other families, the boundaries between many genera of the Brassicaceae (*Thelypodiopsis* included) are often poorly defined. This suggests that the Brassicaceae are a relatively recently evolved family, since wide gaps exist between the genera of more ancient families (Rollins 1982). There are many narrowly endemic genera and species within the Brassicaceae (Heywood 1993). The family Brassicaceae is in the class Magnoliopsida (dicots), subclass Dilleniidae, order Capparales (Mabberley 1997, Natural Resources Conservation Service 2002). The Brassicaceae are closely related to the Capparaceae. Recent cladistic analysis has shown that the Brassicaceae are a monophyletic group nested within the paraphyletic Capparadaceae. Thus it has been proposed to lump the Brassicaceae within the Capparadaceae (Judd et al. 1994; see the Preface to Mabberley (1997) for an interesting discussion of this issue). The genus *Thelypodiopsis* is included within the tribe Thelypodieae (Heywood 1993). All members of *Thelypodiopsis* are native to North or Central America, with more than half in Mexico and Guatemala (Rollins 1993).

The taxonomy of *Thelypodiopsis* and its relatives has been in constant turmoil for more than 100 years. The genus *Thelypodiopsis* was first described in 1907 by Per Axel Rydberg (Rydberg 1907). *Thelypodiopsis juniperorum* was first recognized as a species in 1922 by Edwin Payson, who described it as "*Sisymbrium juniperorum*" in his North American revision of that genus (Payson 1922). Payson did not recognize several segregate genera such as *Thelypodiopsis*, and felt that species within them were better treated within other genera such as *Sisymbrium*. In 1923 Rydberg included this taxon in his "Flora of the Rocky Mountains and Adjacent Plains" as *T. juniperorum*, a name by which it is most commonly known today, especially following the monumental treatment of the Brassicaceae by Rollins (Rollins 1993). Harrington (1954) treated *T. juniperorum* as a variety under *T. elegans*. Rollins (1982) cited growing evidence that *Sisymbrium* ought to be considered a strictly Old World genus, but in Rollins (1993) he included one North American species of *Sisymbrium*. A recent phylogenetic study using nuclear ribosomal DNA by Warwick et al. (2002) circumscribed *Sisymbrium* with 41 Old World species and 53 New World species, reversing the balance of Old World versus New World taxa in the genus. In this study, *Sisymbrium* as described by Schulz (1924, 1936) was shown to be highly polyphyletic, and the cladistic analysis in this study includes members of *Thelypodiopsis* scattered among the New World members of *Sisymbrium*. The persistent taxonomic difficulties within this group of the Brassicaceae suggest that it may be some time before the phylogeny of these taxa is resolved and the nomenclature is stabilized.

It appears that *Thelypodiopsis juniperorum* was first collected by G.E. Osterhout in 1911, before it was formally described. Osterhout had labeled this specimen (collected in Delta County) as "*Thelypodium elegans*," from which *T. juniperorum* was segregated by Edwin Payson (Payson 1922). However, this specimen was not identified as *T. juniperorum* until it was annotated by Reed Rollins in 1981 and it is not the type specimen for this species. Edwin Payson collected *T. juniperorum* in 1913 and in 1915 in Montrose County. His 1915 specimen (collection 688) is the type collection for his description of the species and is housed at the Gray Herbarium at Harvard (Payson 1922). Reed Rollins collected it in Gunnison County in 1938, and

twice with Kathryn Rollins in 1979. Other collections were made by William Penland, William Weber, Carol Miller, W.E. Liggett, and I.A. Al-Shehbaz, but overall *T. juniperorum* remained poorly collected and understood. In 1997 and 1998 Kevin Taylor, a graduate student at the University of Wyoming, made eight collections from four occurrences as a part of his master's thesis research (Taylor 2000). These collections and thorough label data greatly expanded our understanding of its range and habitat. It was most recently collected by Tim Hogan, Nan Lederer, and Dina Clark in 2003 and 2004 at Black Canyon of the Gunnison National Park.

Three specimens housed at the Colorado State University Herbarium (CS), one at Mesa State College Herbarium, and two at the University of Northern Colorado Herbarium are labeled as *Thelypodiopsis juniperorum*, but their identity as such is somewhat questionable. Two of the specimens at CS are probably those referred to by Rollins (1982, p. 77) as being the "type of material that probably misled Harrington (1954) into believing that *T. juniperorum* is only a variety of *T. elegans*." One of the questionable specimens was collected in Routt County by Dr. Harrington in 1948 and labeled "*Arabis*." This specimen was annotated that year by Reed Rollins as "*Sisymbrium juniperorum* (Payson) (?)." The question mark suggests that Rollins himself was perplexed by this specimen. Rollins' 1982 revision of *Thelypodiopsis* suggests that this specimen and two other specimens from Garfield County at CS are probably *T. elegans* rather than *T. juniperorum*. *Thelypodiopsis elegans* is a highly variable species with a broad distribution that overlaps with that of *T. juniperorum*. The specimen from Mesa County at Mesa State College Herbarium (Austin 33) appears to be misidentified and is probably also *T. elegans* (Lyon personal communication 2002). Similarly, two specimens at the UNC Herbarium (Grey 1245 from Gunnison County and Morris, Dunn, and Conrad 107 from Mesa County) are probably *T. elegans*.

Thelypodiopsis juniperorum is a slender annual, three to ten decimeters tall, with a single erect stem or with several branches arising from the base (Rollins 1993; **Figure 3**). Payson (1922) wrote that *T. juniperorum* is an annual or perennial, but all subsequent descriptions have stated that it is only an annual. However, some specimens have rather stout roots and many dead leaves giving them the appearance of a biennial, or perhaps a winter annual. The basal leaves are five to 15 centimeters long (sometimes smaller), entire or irregularly dentate, with a winged petiole (Rollins 1993). The fruit of *T. juniperorum* is a silique, which in the Brassicaceae is a long, slender, almost terete (round) structure. The ascending siliques of *T. juniperorum* are approximately one millimeter in diameter and five to nine centimeters long.

The most commonly used diagnostic characteristic is the presence of flattened hairs near the base of the stem and at the nodes. This character is useful for distinguishing *Thelypodiopsis juniperorum* from *T. ambigua*, which is glabrous throughout. One of Payson's specimens (97) had been labeled *T. ambigua* before his annotation as *Sisymbrium* (*Thelypodiopsis*) *juniperorum.*

It can be difficult to distinguish *Thelypodiopsis juniperorum* from *T. elegans*. The ranges of these species overlap, and *T. elegans* is highly polymorphic (Rollins 1982, Rollins 1993). Weber and Wittmann (2001) use flower color to distinguish *T. juniperorum* from *T. elegans*, noting that *T. juniperorum* has purple flowers while *T. elegans* has white to pink flowers. Rollins (1982 and 1993) and Rydberg (1923) also mention only purple flowers for *T. juniperorum*, but two specimens of *T. juniperorum* at the Rocky Mountain Herbarium (Payson 97 and Rollins 2110) have purple sepals and white petals. Payson (1922), in describing the species, noted that flowers could be white or purple.

The length and thickness of the stipe, a stalk that attaches the fruit to the receptacle, is highly diagnostic in members of the genus *Thelypodiopsis*, and is used by Rollins (1993) to separate *T. juniperorum* from *T. elegans*. The stipe of members of the genus *Thelypodiopsis* is similar to those seen in members of the genus *Stanleya* and distinguishes it from many other species in the Brassicaceae. The stipe of *T. juniperorum* is slender and exceeds two millimeters in length, while that of *T. elegans* is less than two millimeters or absent, and stout (Rollins 1993). There is often considerable variation in stipe characteristics on single plants of both *T. juniperorum* and *T. elegans*, which can make it difficult to identify this species confidently.

Payson (1922) notes that *Thelypodiopsis elegans* can sometimes be found within 100 yards of *T. juniperorum*, but *T. elegans* is found on barren gypsiferous or "adobe" substrates while *T. juniperorum* is found in more densely vegetated sites. Thus fine-scale edaphic characteristics are also useful in distinguishing *T. juniperorum* and *T. elegans*.

Thelypodiopsis juniperorum has not yet been photographed in the wild or rendered by a botanical illustrator. Technical descriptions are available from several sources, but the best and most readily available is that of Rollins (1993). However, in his 1982 revision

Figure 3. *Thelypodiopsis juniperorum*. This specimen was collected by Kevin Taylor on May 19, 1998 (5069 at GREE) northeast of Crawford, in Delta County, Colorado. This individual is approximately 25 centimeters tall.

of *Thelypodiopsis* and *Schoenocrambe*, Rollins offers additional notes on *T. juniperorum* that are very helpful. These descriptions are complemented well by those of Payson (1922) and Rydberg (1923). Weber and Wittmann (2001) include *T. juniperorum* in their key but do not offer descriptive notes. Although it has been documented in the Gunnison Basin, *T. juniperorum* was not included in Barrell's Flora of the Gunnison Basin (Barrell 1969). Please see **Figure 3** for a photograph of a specimen of *T. juniperorum*.

Distribution and abundance

Thelypodiopsis juniperorum is narrowly endemic to three counties (Montrose, Delta, and Gunnison) in western Colorado. Most of the known occurrences have been documented through herbarium specimens. However, because Lyon (2000) observed only two individuals at the North Vista Trail occurrence in Montrose County, a specimen was not collected from this occurrence.

Thelypodiopsis juniperorum is currently known from 23 specimens in five herbaria (University of Colorado, Rocky Mountain, Kalmbach, Colorado State University, and Grey) and two observations (**Table 1**; **Figure 1** and **Figure 2**). These collectively represent 16 occurrences. It was most recently collected in 2004 by Tim Hogan, Nan Lederer, and Dina Clark at Black Canyon of the Gunnison National Park (Hogan personal communication 2004, Lederer personal communication 2004). It was collected by Kevin Taylor in 1997 and 1998 in Gunnison, Montrose, and Delta counties. Seven of the 16 occurrences have not been seen in more than 20 years.

The documented locations are all found in the vicinity of the mainstem and North Fork of the Gunnison River. The occupied area is a crescent embracing the area west of the West Elk Mountains, extending in the northeast from Paonia and Paonia Reservoir south through Crawford and Black Canyon of the Gunnison National Park, and back to the southeast along the

mainstem Gunnison River as far as Sapinero (**Figure 2**). A number of these locations have not been revisited in several decades, adding considerable uncertainty as to whether these occurrences remain extant.

Collections of this species from Routt, Garfield, and Mesa counties housed at the Colorado State University, Mesa State College, and University of Northern Colorado herbaria are probably misidentified, but warrant assessment by experts (see the Classification and Description section of this document for details).

Information on the abundance of *Thelypodiopsis juniperorum* is extremely sparse, with almost no quantitative data from which to assess population sizes. Reed Rollins noted on a collection label (7987 from 1979) in Montrose County (near the junction of Highway 50 and State Route 347) that *T. juniperorum* was "abundant" at this location. At an occurrence discovered by Lyon (2000) in Black Canyon of the Gunnison National Park, only two individuals were observed. However, Weber and Wittmann (2001, p. 128) write that *T. juniperorum* is "very common at Black Canyon." Dr. William Weber (personal communication 2002) added that he has seen large occurrences on the north and south rims of the Black Canyon of the Gunnison, but could not speculate any further on population sizes. Vegetation mapping in Black Canyon of the Gunnison and Curecanti National Parks in 2002 did not yield any new occurrences of *T. juniperorum*, although crews were made aware of this species (Bockus personal communication 2002). However, these projects did not start in 2002 until after *T. juniperorum* is typically finished flowering, and it is likely that the extreme drought conditions of 2002 resulted in a poor year for *T. juniperorum*. In 2003 and 2004, which were moister years, *T. juniperorum* was observed at Black Canyon of the Gunnison National Park (Hogan personal communication 2004, Lederer personal communication 2004). The observations of Hogan and Lederer support to some extent Dr. Weber's observations of this species. Hogan (personal communication 2004) described *T. juniperorum* as "common" on the North Rim of the Black Canyon, where approximately 10 groups of 20 plants were observed in 2004. It was also commonly seen on the South Rim of the Black Canyon, where "hundreds of plants" were observed (Hogan personal communication 2004). **Table 1** is a summary of all collections and element occurrence records of *T. juniperorum*.

As an annual species that probably capitalizes on snowmelt moisture, the abundance and reproductive output of *Thelypodiopsis juniperorum* probably fluctuates greatly from year to year. This is likely to complicate the assessment of population trends. *Thelypodiopsis juniperorum* sets seed and senesces very early in the spring before many collectors have begun field work in earnest, which may partially explain why it has not been collected often.

Following the typology of Rabinowitz (1981, "the seven forms of rarity"), *Thelypodiopsis juniperorum* probably falls into the category of small geographic range, narrow habitat specificity, and small local population size. However, the current lack of information on habitat specificity and abundance leaves a great deal of uncertainty in this assessment.

The degree to which occurrences are physically and genetically isolated is not known. If there are indeed occurrences of *Thelypodiopsis juniperorum* in Garfield, Routt, and Mesa counties, then its distribution pattern is disjunct. If not, then there is no occurrence separated from another by more than 16 miles.

Population trend

There are insufficient data to make any inferences regarding population trend for *Thelypodiopsis juniperorum*, and there are no quantitative data available from which trends can be determined. Observations at Black Canyon of the Gunnison suggest that population size fluctuates greatly from year to year. Population size probably varies in response to edaphic and climatic conditions, as well as the seed crop from the preceding season, size of the seed bank, and recruitment from the seed bank. Determining population status and trend can be extremely difficult for species with highly variable population sizes. These difficulties are discussed by U.S. Fish and Wildlife Service (2003) regarding *Lesquerella filiformis*, an annual mustard in which population size at a single site has varied between zero and 303,446 individuals. It is very likely that other occurrences of *T. juniperorum* remain to be discovered, so more species inventory work is needed before the population trends can be accurately assessed.

The impoundment of rivers throughout the northern Gunnison Basin has probably impacted occurrences of *Thelypodiopsis juniperorum*. Filling Blue Mesa Reservoir in 1965 is likely to have impacted at least one occurrence. Part or all of the occurrence from which Reed Rollins collected it in 1938 ("3 miles east of Sapinero") may be inundated now by Blue Mesa Reservoir, which was completed in 1966. No attempts have been made to revisit this occurrence to verify this. The filling of Paonia Reservoir in 1962

also may have impacted an occurrence discovered by Kevin Taylor (collection 5935), as did Gould Reservoir (Kevin Taylor collection 5019), which was filled in 1910 (Cocker 2004). The degree to which these impacts have diminished the population size of *T. juniperorum* is unknown.

Habitat

Information on the habitat of *Thelypodiopsis juniperorum* is sparse and limited almost entirely to herbarium specimen label data. Rollins (1993, p. 871) reports the habitat as "dry hillsides, sagebrush and juniper areas, below granitic cliffs, rock slides, pinyon-juniper woodlands; western Colorado." Payson (1922, p. 13) reports it from "dry hillsides with a scattering growth of *Juniperus utahensis* [= *J. osteosperma*]." Lyon (2000) reported it from a steep, xeric, south-facing slope in pinyon-juniper woodland. Although Rollins (1993) reports *T. juniperorum* from sagebrush areas, only one specimen (Rollins and Rollins 7975) reports the presence of sagebrush. However, shrublands dominated by big sagebrush (*Artemisia tridentata* ssp. *tridentata*) are common throughout the area inhabited by *T. juniperorum* (Colorado Division of Wildlife 1998). Most specimens where plant associates are reported were collected in pinyon-juniper woodlands. It is reported most often from xeric sites including hillsides and mesa tops. It is reported more often from south-facing hillsides and drainages. These sites are probably snow-free early in the spring. The elevation range documented for *T. juniperorum* is 6,200 to 7,850 feet.

Although habitat descriptions are lacking for *Thelypodiopsis juniperorum*, some inferences can be drawn from available vegetation maps and literature. *Thelypodiopsis juniperorum* is known from three vegetation types (after West and Young 2000) or ecological systems (as defined by Anderson et al. 1999), based on the intersection of GIS vegetation data (Colorado Division of Wildlife 1998) with known occurrences. These are sagebrush shrubland (Simons and Johnston 1999, Rondeau 2000a), pinyon-juniper woodland (Rondeau 2000b), and oak/serviceberry shrubland (Rondeau 2001) (equivalent to mountain mahogany-oak scrub of West and Young 2000, and some community types within the non-riparian tall shrublands of Johnston et al. 2001). Included in this category is the "squaw-apple and serviceberry zone" in which it was collected by Hartman and Taylor (Hartman collection 56360). For detailed descriptions of these vegetation types, their geographic extent, and perturbations caused by human impacts, please see the Community Ecology section of this document.

Thelypodiopsis juniperorum does not appear to be restricted to a particular geologic substrate. The exact geologic composition of the known occurrences has not been determined, but overlaying the known locations (some of these are only known to within five miles of their actual location) with the Geologic Map of Colorado (Tweto 1979) shows occurrences on both sedimentary and igneous substrates from many different formations. Sedimentary rocks deposited in the early Cretaceous underlie most of the area inhabited by *T. juniperorum*. The area northeast of Paonia to Paonia reservoir in Gunnison County includes sandstone outcrops of the Mesa Verde Formation, where Hartman and Taylor (Hartman 56360) note the presence of sandstone and shale parent materials. Several specimens collected along State Route 347 south of Black Canyon of the Gunnison National Park are probably underlain by sandstone of the Dakota/ Burro Formation. Occurrences around Crawford and east of Montrose may be underlain by shales of the Mancos Formation that weather easily into fine-particled soils. The occurrence near Serpent's Point in Black Canyon of the Gunnison National Park is probably underlain by Precambrian granite, but this is overlain by Jurassic sandstones directly upslope of the occurrence and is probably influenced by these nearby sedimentary strata. Two specimen labels (Rollins 2110 and Rollins and Rollins 7975) report it from granitic substrates ("granitic hillside" and "below granitic cliffs") near U.S. Highway 50 between Montrose and Sapinero.

Detailed soil surveys apparently have not been conducted for much of the occupied habitat for *Thelypodiopsis juniperorum*, particularly for areas immediately to the west of the West Elk Mountains. The area around Blue Mesa Reservoir is underlain by soils in the Parlin-Lucky association (Soil Conservation Service 1975). These soils are calcareous, often sloping, well-drained loams and gravelly sandy loams, found primarily on ridges, benches, and hills. Soils east of Montrose along U.S. Highway 50 are mostly included within the Billings-Christianburg and Chipeta-Persayo associations (Soil Conservation Service 1967). These are fine textured soils of alluvial origin (Billings-Christianburg) or derived from shale (Chipeta-Persayo). Along Route 347, soils fall primarily into the Rock outcrop-Transvessilla and Bostwick-Cerro associations, which differ significantly from one another. The Rock outcrop-Transvessilla soils are shallow and coarse-textured, and are found on slopes, hills, and the sides of mesas. The information available from herbarium specimen labels suggests that *T. juniperorum* is likely to be found on these soils in this area. One specimen label (Miller 3) notes that the plants were growing

in "shallow rocky soil." Soils associated with big sagebrush, oak/serviceberry shrublands, and *Juniperus scopulorum* (juniper) woodlands in the Gunnison Basin are most commonly Argiborolls and Haploborolls, often very stony, cobbly, or gravelly (Johnston et al. 2001).

Thelypodiopsis juniperorum is usually found on slopes, mesa tops, or canyon rims, in sites that tend to be xeric and well-drained. It has been reported growing below cliffs twice. However, it has also been collected in bottomlands near Sapinero, Paonia, Montrose, and Crawford. Xeric, south-facing slopes are probably snow-free earlier in the spring. These sites might be favorable to *T. juniperorum* if the microclimate of these sites allows an early onset of spring growth. By starting growth as early as possible, *T. juniperorum* might complete its annual lifecycle before temperatures rise sharply in June, and before vapor pressure gradients steepen and cause rapid desiccation and water stress.

Because a precise definition of appropriate habitat is not known for *Thelypodiopsis juniperorum*, the geographic extent of its appropriate habitat is also not known. Sagebrush shrublands, pinyon-juniper woodlands, and oak/serviceberry shrublands cover millions of acres in the Intermountain West from Colorado west to California and Oregon (West and Young 2000).

Reproductive biology and autecology

In the CSR (Competitive/Stress-Tolerant/Ruderal) model of Grime (2001), the life history characteristics of *Thelypodiopsis juniperorum* are typical of ruderal species. Some of the characteristics shared by *T. juniperorum* and other ruderal species are an annual life history, herbaceous life form and small stature, and a large proportion of annual production devoted to reproduction. The most consistent feature of ruderal species in the CSR model is an annual or short-lived perennial life history (Grime 2001).

There is some evidence that *Thelypodiopsis juniperorum* has some affinity for, or at least a tolerance of, disturbance. Lyon (2000) reported it from a disturbed site downslope of a trail, where trampling and runoff are likely to maintain a moderate disturbance regime. It has been collected at least five times from roadside and road berms. It has also been collected adjacent to Gould and Paonia Reservoirs, where it may also have been subject to periodic inundation or disturbance from trampling. It is not known if plants or seedlings can survive periodic inundation.

As an annual with relatively large amounts of biomass allocated to the production of propagules, the life history pattern of *Thelypodiopsis juniperorum* is best classified as r-selected (using the classification scheme of MacArthur and Wilson 1967). A possible role for disturbance in the autecology of *T. juniperorum* also typifies *T. juniperorum* as r-selected.

As an annual, *Thelypodiopsis juniperorum* reproduces exclusively by seed and does not propagate itself vegetatively. It is not known to what extent it is dependent on outcrossing. Varying degrees of self-compatibility and self-incompatibility are found among members of the Brassicaceae (Rollins and Shaw 1973, Rollins 1993). Most members of the Brassicaceae possess a sporophytic multiple allele incompatibility system that encourages outcrossing (Bateman 1955). In this system, which has been studied extensively in the Brassicaceae, pollen grains will not germinate on the stigma if either of the two alleles from the parent plant are present (Kimball 2002). The federally listed plant *Thelypodium howellii* ssp. *spectabilis* is self-compatible but is primarily pollinated by insects including bumblebees (*Bombus* spp.) (U.S. Fish and Wildlife Service 2002).

Chromosome numbers among members of the Brassicaceae vary widely. There are some cases where the haploid chromosome number even varies between populations of the same species, which is highly unusual (Rollins 1993). Polyploidy is also common within the family. There have been no cytological studies of members of the genus *Thelypodiopsis* from which to attempt to deduce a chromosome number or ploidy of *T. juniperorum*.

Apomixis is a common phenomenon in some groups in the Brassicaceae, but its role in the reproductive biology of most taxa is unknown (Böcher 1951, Rollins 1993). The presence of multiple ploidy levels and erratic chromosome numbers in some taxa suggests that populations of these taxa are maintained through apomixis (Rollins 1993).

There has been no investigation of the pollinators, pollination ecology, and floral biology of *Thelypodiopsis juniperorum*. In general, members of the Brassicaceae have unspecialized flowers and tend to be pollinated by generalists (Mabberley 1997). Bees and flies are the most common visitors to members of the genus *Lesquerella* (Rollins and Shaw 1973). *Thelypodium howellii* ssp. *spectabilis* is pollinated by insects including bumblebees (*Bombus* spp.; U.S. Fish

and Wildlife Service 2002). Thrips are also frequently observed on and in the flowers of some species in the Brassicaceae (Davis et al. 1998). Failure to set seed resulting from low population density was observed in experimental arrays of *Brassica kaber*, a self-incompatible annual pollinated by bees and syrphid flies (Kunin 1993). It might be expected that in low-density populations, *T. juniperorum* may incur similar difficulties in seed set if it is an obligate outcrosser.

Thelypodiopsis juniperorum completes its life cycle very early in the growing season. It has been collected in flower as early as May 15, and has only been collected twice in July. All specimens in the herbaria searched are also in fruit, so the timing of fruiting cannot now be distinguished from that of flowering. In spring and early summer the siliques dehisce and seeds are dispersed. Like many other members of the Brassicaceae (e.g., *Descurainia sophia*) (Whitson et al. 2000), *T. juniperorum* may function as a winter annual, germinating in late fall, overwintering as a rosette, and bolting in the early spring. The viability of seeds of *T. juniperorum* is not known.

Siliques dehisce and release numerous seeds, which are probably dispersed by wind or surface water runoff. The seeds are not winged (Payson 1922, Rollins 1982, Rollins 1993), and thus have no obvious adaptations to wind dispersal. There have been no observations to document the seed dispersal vectors for *Thelypodiopsis juniperorum*. Seeds of the federally listed species *Thelypodium stenopetalum* do not appear to disperse very far from the plant (U.S. Fish and Wildlife Service 1997).

As an annual, seed bank dynamics are of particular practical interest in *Thelypodiopsis juniperorum*. Annual species without a persistent seed bank live a tenuous existence, dependent on successful colonization of new sites (Silvertown and Doust 1993). However, observations at Black Canyon of the Gunnison National Park suggest that *T. juniperorum* has a persistent seed bank that allows for recruitment of individuals during favorable years. A persistent seed bank also typifies ruderals in the conceptual framework of Grime (2001).

There has been much research on dormancy, seed bank dynamics and seed longevity of weedy members of the Brassicaceae and other annual species. Members of this family range widely with respect to these variables. In particular, *Sisymbrium officinale* has been the focus of research on the physiology of dormancy and germination, and is regarded as a model species for such studies (Hilhorst 1997). Dormancy in *S. officinale* is broken by a combination of light, temperature, and nitrate level (Bouwmeester and Karssen 1993, Bouwmeester et al. 1994). However, dormancy is not broken by short-duration light exposure in other genera of Brassicaceae (Milberg et al. 1996). *Arabidopsis thaliana* germination is promoted by gibberellin (Debeaujon and Koornneef 2000). Gibberellin and scarification promote germination in members of the genus *Draba* (Brochmann et al. 1992). Because there is no clear pattern of germination promoters among relatives of *Thelypodiopsis juniperorum*, it is not possible to draw inferences regarding its germination cues at this time.

Ruderal species tend to have greater seed longevity than other species (Rees 1994). Some annual plants are seed limited, while others have a sufficiently large seed bank to make up for any shortfalls in years where productivity is low (Crawley 2000).

The range of phenotypic plasticity of *Thelypodiopsis juniperorum* is not known, but mature specimens vary greatly in size and stature. Small specimens are 20 to 30 centimeters tall and have leaves that do not exceed three or four centimeters in length, while large specimens approach one meter in height with leaves approaching 15 centimeters in length (Rollins 1993). This magnitude of variability is not unusual among annuals and is controlled by the availability and plentitude of resources (Harper 1977, Grime 2001). Flower color also may be variable in *T. juniperorum*, although the descriptions of Rollins (1982, 1993) do not include individuals with light-colored flowers within *T. juniperorum*. Although most specimens have deep purple or lavender flowers, white-flowered plants have been observed and collected, as represented by two specimens housed at the Rocky Mountain Herbarium (Payson 97 and Rollins 2110).

Arbuscular mycorrhizal (AM) fungi belong to a group of nondescript soil fungi (Glomales) that are difficult to identify because they seldom sporulate (Fernando and Currah 1996). They are the most abundant type of soil fungi (Harley 1991) and infect up to 90 percent of all angiosperms (Law 1985). Unlike most land plants, members of the Brassicaceae do not typically form mycorrhizal symbioses (Barbour et al. 1987) and have often shown decreased fitness in the presence of AM fungi (Lewis 1985; Read 1999). *Sisymbrium altissimum*, an annual Eurasian weed, is not a host plant for AM fungi (Fontenla et al. 1999).

Hybridization occurs between some taxa in the Brassicaceae, and is responsible for causing some of the

most difficult taxonomic problems in the family (Rollins 1993). Rollins (1983) notes a case within the genus *Arabis* where a common, widely distributed taxon, hybridizes with other, more narrowly distributed taxa at different places within its range. It is thus plausible to suspect that interspecific hybridization might occur in sympatric populations of *Thelypodiopsis juniperorum* and *T. elegans*.

Demography

Maintaining genetic integrity and eliminating inbreeding and outbreeding depression are important management considerations for *Thelypodiopsis juniperorum*. *Thelypodiopsis juniperorum* is more vulnerable to genetic concerns if it is heavily dependent on outcrossing. Maintaining distinct genetic populations (if there are any) and natural levels of gene flow are also important for its conservation. Studies of other taxa have shown that hybridization can lead to extinction by outbreeding depression (swamping) in naturally small populations (Ellstrand 1992). Signs of inbreeding depression were observed in small populations (less than 100 individuals) of *Ipomopsis aggregata* (Heschel and Paige 1995, Paige and Heschel 1996).

Vital rates (recruitment, survival, and proportion of populations reproducing) have not been measured for *Thelypodiopsis juniperorum*. As stated previously, *T. juniperorum* is an annual (although Payson (1922) described it as an annual or a perennial). The lifespan of *T. juniperorum* has not yet been verified through demographic studies or observations in the greenhouse. The number of individuals that break dormancy and mature in a given year is almost certainly highly correlated with the quality of the growing season. As an annual, individuals will most likely adjust the allocation of resources such that they achieve at least some reproductive output, even in a poor year (Grime 2001). It is likely that reproductive output varies greatly from year to year depending on growing conditions and the availability of limited resources such as moisture. See **Figure 4** for a diagrammatic representation of the life cycle of *T. juniperorum*, and **Figure 5** for a lifecycle graph after Caswell (2001).

Population Viability Analysis (PVA) has not been performed for *Thelypodiopsis juniperorum*. Apparently there has never been a PVA of any member of the genus *Thelypodiopsis* or other members of the Brassicaceae from which inferences could be drawn for this report. Several other species of Brassicaceae are listed as endangered (U.S. Fish and Wildlife Service 1999) but there has been no PVA performed on any of them. Monitoring and preliminary quantitative assessment of population viability have been conducted for at least four federally listed taxa in the Brassicaceae: *Arabis serotina* (U.S. Fish and Wildlife Service 1991), *Lesquerella filiformis* (U.S. Fish and Wildlife Service 1988), *Thelypodium howellii* ssp. *spectabilis* (U.S. Fish and Wildlife Service 2002), and *T. stenopetalum* (U.S. Fish and Wildlife Service 1997). Conducting a minimum viable population study is among the recovery steps cited for the federally listed species *Lepidium barnebyanum* (U.S. Fish and Wildlife Service 1993).

Identifying critical life history stages that contribute most to population or metapopulation dynamics is crucial to developing recovery strategies for rare plants (Schemske et al. 1994). However, these have not been identified for *Thelypodiopsis juniperorum*. In a study of the population dynamics of the winter annual *Collinsia verna*, the seed bank was determined to be critical to the demography of the species (Kalisz and McPeek 1992). This may also be the case with *T. juniperorum* given the probable nature of its population dynamics.

Community ecology

Detailed lists of species associated with *Thelypodiopsis juniperorum* have not been written. The known associated species (**Table 3**) are those included on herbarium specimen labels and brief descriptive notes (i.e., Payson 1922). The known associated species are mostly woody dominant or subdominant species. An envirogram is presented in **Figure 6** that portrays the generalized interactions between *T. juniperorum* and its environment.

Thelypodiopsis juniperorum has been documented in three broadly defined vegetation types. These are described here using the typology developed by Rondeau (2000a, 2000b, 2001) and Neely et al. (2001). Included within the description of each type is a brief overview of human impacts on these systems. More detailed treatments of these impacts are offered in the excellent references cited below.

Thelypodiopsis juniperorum has been reported in association with sagebrush twice (in Delta County by Taylor 5090 and in Montrose County by Rollins and Rollins 7975), and this vegetation type is common in the area inhabited by *T. juniperorum*. Sagebrush shrublands are widely distributed, occupying nearly 10 percent of the Southern Rocky Mountain Ecoregion (as circumscribed by Bailey 1995; Rondeau 2000a). Sagebrush shrublands are widely distributed in the

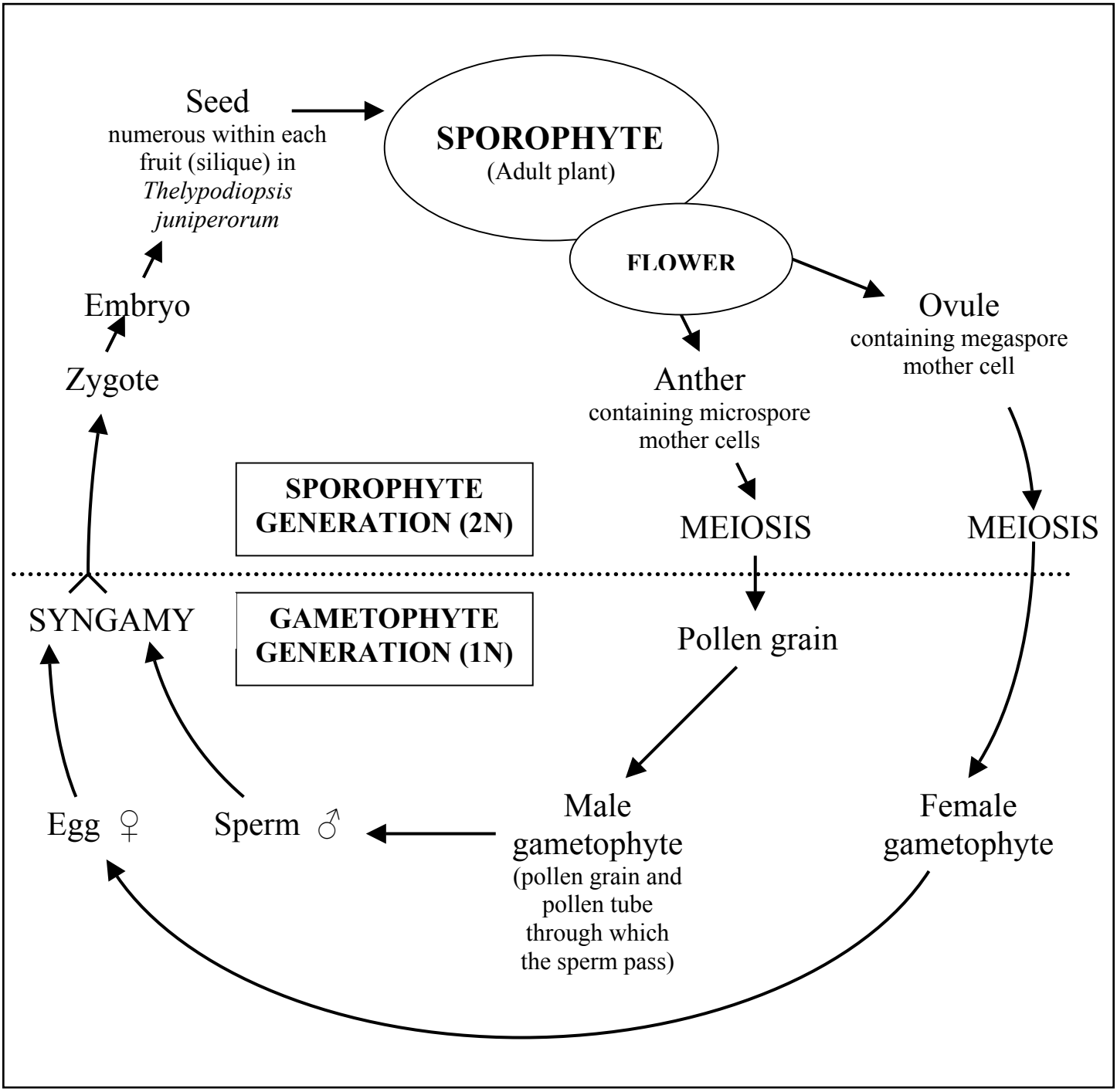

Figure 4. Life cycle diagram for *Thelypodiopsis juniperorum* (after Stern 1994).

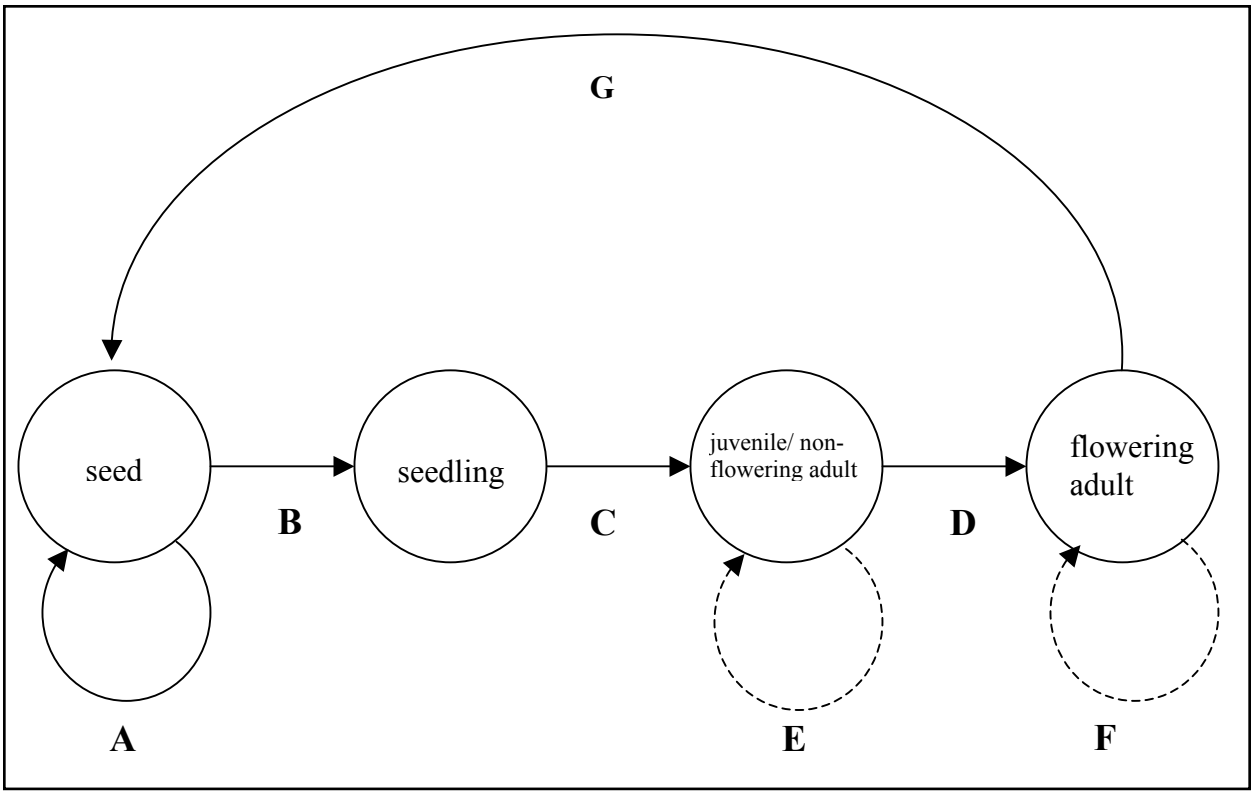

Figure 5. Hypothetical life cycle graph (after Caswell 2001) for *Thelypodiopsis juniperorum*. There has been no investigation of the life history stages of this species. No transition probabilities are known for *T. juniperorum*, and there has been no demographic monitoring from which valuable inferences can be drawn. The values of B through D probably vary from year to year depending on climatic variables. It is likely that seeds remain dormant in poor years (A). Seed production per plant has not been quantified (G). No seedlings have ever been observed, so there are no data from which to infer the values of B and C. If *T. juniperorum* can survive more than one year, then arrows E and F are possible; if it is indeed a true annual then individuals do not return to those stages in subsequent years.

Table 3. Associated species documented with *Thelypodiopsis juniperorum*. For taxa not identified to species by the source, probable specific epithets are offered where indicated.

Associated Species
Amelanchier c.f. *utahensis* (and/or *A. alnifolia*)
Artemisia c.f. *tridentata*
Atriplex c.f. *confertifolia*
Bromus tectorum
Cercocarpus c.f. *montanus*
Juniperus osteosperma
Peraphyllum ramosissimum
Pinus edulis
Prunus c.f. *virginiana*
Pseudotsuga menziesii
Quercus gambelii
Symphoricarpos c.f. *rotundifolius*
Thermopsis c.f. *montana*

INDIRECT ENVIRONMENT		DIRECT ENVIRONMENT
2	1	
		RESOURCES
	Canopy openness	Light energy
	Slope, aspect, albedo	Thermal energy (climate)
Local geology	Soil texture	Soil moisture
	Climate	
		Oxygen, carbon dioxide
		Nutrients
		REPRODUCTION
	Other food resources	Pollinators
	Nest sites	
	Other *T. juniperorum* individuals	Genetic diversity
	Microsite attributes	Safe sites
	Wind	
	Seed dispersal vectors	
		PREDATORS/ HERBIVORES
		Fungal rust?
		Viruses?
	Other food resources	Herbivores
	Site accessibility	Humans (collectors)
		Seed predators
		MALENTITIES
	Industrial complex	Airborne pollutants
		Thermal energy (climate)
Economic variables	Human population density	Humans (off-road vehicle users)
	Site/microsite attributes	Competitors
	Drought	Soil moisture

Thelypodiopsis juniperorum

Figure 6. Envirogram for *Thelypodiopsis juniperorum*, showing resources, reproduction, predators/herbivores, and malentities (after Niven and Liddle 1994).

broad valleys and lower foothills of the intermountain region (Cronquist et al. 1986). Big sagebrush (*Artemisia tridentata* ssp. *tridentata*) and mountain sagebrush (*A. tridentata* ssp. *vaseyana*) are the most common dominant species in the Gunnison Basin and the area to the west of the West Elk Mountains (Colorado Division of Wildlife 1998). Agriculture has greatly diminished the extent of sagebrush shrublands (Cronquist et al. 1986). Invasion of sagebrush shrublands by *Bromus tectorum* increases the likelihood of fire, after which sagebrush must resprout from seed. This can lead to dominance by *B. tectorum* and other non-natives rather than sagebrush (Bunting et al. 1987 as cited in Johnston et al. 2001). Grazing reduces the availability of water in these systems (Johnston et al. 2001, Rondeau 2000a).

Thelypodiopsis juniperorum is most commonly documented from pinyon-juniper woodlands. Pinyon-juniper woodlands are widely distributed throughout the Intermountain West (West and Young 2000), and comprise approximately 11 percent of the Southern Rocky Mountain Ecoregion (Rondeau 2000b). In the pinyon-juniper woodlands of Western Colorado and the Colorado Plateau, *Pinus edulis* and *Juniperus osteosperma* are the dominant overstory species. These woodlands are found at elevations slightly higher than many shrubland and grassland types including saltbush-greasewood shrublands (West and Young 2000). In Colorado, pinyon-juniper woodlands are found roughly between 4,000 to 9,000 feet in elevation (Rondeau 2000b). At approximately 6,500 feet, the relative abundance of pinyon and juniper is roughly equal, but as elevation increases the relative cover of juniper decreases and pinyon increases (Tueller et al. 1979). Grazing and fire suppression have greatly altered this vegetation type in many ways throughout its range, and very little of it remains unaltered (West and Young 2000). While grazing in many areas was much heavier in the early and mid 20th century than it is today, the legacy of this overgrazing persists in many areas. Grazing reduces the cover of perennial bunchgrasses and forbs in pinyon-juniper woodlands, opening them for invasion by *Bromus tectorum* and other exotic species (**Figures 7 and 8**). Erosion increases when the native understory species are gone, sometimes evinced by trees growing on small hills where the soil has washed away around them (West and Young 2000).

Shrublands dominated by *Quercus gambelii* (scrub oak) with *Amelanchier utahensis* (Utah serviceberry) and/or *Cercocarpus montanus* (alderleaf mountain mahogany) are also widespread on the lower slopes of mountains in western Colorado. Approximately three percent of the Southern Rocky Mountain Ecoregion is composed of this vegetation type (Rondeau 2001). In western Colorado these shrublands typically occur at higher elevations than pinyon-juniper woodlands, from roughly 5,000 to 9,500 feet (Rondeau 2001). However, because these vegetation types have broad elevation ranges, this vegetation type may be found below stands of pinyon-juniper woodland as noted by Hartman and Taylor (Hartman collection 56360). This vegetation type usually occurs as large or small patches rather than as zones or a matrix community (Johnston et al. 2001, Rondeau 2001). Fire is frequent in this chaparral-like vegetation, and scrub oak is capable of resprouting after fire. Like pinyon-juniper woodlands, grazing and other human influences have caused changes in the structure and fire periodicity in this vegetation type (West and Young 2000). Increased fire frequency causes relative density of *Q. gambelii* to increase, which can lead to stand closure (Komárková et al. 1988). *Quercus gambelii* also increases with grazing and browsing by elk and deer, while serviceberry (a favorite browse for elk) decreases (Johnston et al. 2001).

As a ruderal annual, *Thelypodiopsis juniperorum* probably capitalizes on abundant ephemeral resources to complete its lifecycle quickly, thus avoiding competition. Grime (2001) includes an interesting summary of research on the reproductive output of annuals when subjected to resource limitation (stress) resulting from competition. These studies show that ruderal annuals will allocate resources such that they sustain some level of seed production even under severe stress. This is not surprising when considered from an evolutionary perspective, since annuals that fail to produce offspring are quickly removed from the gene pool. Under ideal conditions, an individual of the annual species *Chenopodium album* can produce 50,000 times more seed than a stressed individual (Harper 1977).

There have been no reports in the literature or other observations of parasite or disease attack on *Thelypodiopsis juniperorum* or other members of the genus *Thelypodiopsis*. Herbarium specimens show some indications of insect attack. Basal leaves of some plants have numerous small holes and areas where the parenchymatous tissue has been eaten, leaving the vascular tissue. Other specimens have numerous leaves throughout the plant with holes that are two to seven mm in diameter. No plants have been observed where the impacts of such herbivory appear severe. No evidence of herbivore attack on flowers has been observed. Two non-native mustard species (*Sisymbrium altissimum* and *Capsella bursa-pastoris*) were infected with potato leafroll virus in a greenhouse experiment, with green peach aphids as the vector (Fox

Figures 7 and 8. Pinyon-juniper woodland along Highway 347, approximately one mile south of the entrance to Black Canyon of the Gunnison National Park, May 19, 2003. Photographs by the author. The dominant species in the foreground of both photos is *Bromus tectorum*. This area is heavily grazed. Rangeland deterioration such as this is likely to be detrimental to *Thelypodiopsis juniperorum*. An attempt by the author to find *T. juniperorum* in this area was unsuccessful.

et al. 1993). The rust species *Puccinia monoica* and *P. thlaspeos* are known to attack members of *Arabis* and other genera in the Brassicaceae (Roy 1993). The life cycle of *P. monoica* involves members of three grass genera (*Trisetum*, *Koeleria*, and *Stipa*) in addition to members of Brassicaceae. However, there has been no documentation of rust attack in *T. juniperorum*.

CONSERVATION

Threats

Given the lack of substantive information on *Thelypodiopsis juniperorum*, it is difficult to assess confidently the threats to this species. However, based on information presented in this assessment, there are several threats to *T. juniperorum*. In order of decreasing priority, these are grazing, off-road vehicle use, non-native species invasion, fire suppression, energy development, residential development, pesticide use for range management, hiking, and global climate change. These threats and the hierarchy ascribed to them are speculative due to a lack of information specific to *T. juniperorum*. The significance of a given threat to particular occurrences is contingent largely on land ownership status. Assessment of threats to this species will be an important component of future inventory and monitoring work. Because there have not yet been any occurrences documented on lands administered by USFS Region 2, specific threats to this species on National Forest System lands are not known. However, the threats discussed in this section that pertain to federal, state, and private lands on which *T. juniperorum* is found are also likely to threaten any occurrences that might reside on USFS lands.

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

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

Influence of management activities or natural disturbances on habitat quality

Much of the public land in western Colorado has active grazing allotments, and *Thelypodiopsis juniperorum* is exposed to grazing on Bureau of Land Management lands. Grazing is probably the primary threat to *T. juniperorum* because of the broad impacts it has on habitat quality and ecosystem processes in the plant communities it occupies. These are summarized in the Community Ecology section of this assessment. Indirect impacts of grazing via habitat degradation are well documented in West and Young (2000).

Some level of natural disturbance might be beneficial to *Thelypodiopsis juniperorum*. However, most anthropogenic disturbances that might occur in habitat for *T. juniperorum* are likely to result in habitat degradation. Off-road vehicle (ORV) use is widespread and difficult to regulate in the area inhabited by *T. juniperorum*, and has resulted in degradation of rare plant habitat on large areas of the Gunnison Gorge National Conservation Area (Lyon and Deslow 2001). Disturbance associated with energy development is likely to degrade habitat, alter natural disturbance regimes, and hasten the spread of weeds in occurrences of *T. juniperorum*. Natural gas drilling and exploration are ongoing within the range of *T. juniperorum* (Bureau of Land Management 2003). Residential development is proceeding rapidly along Colorado's Western Slope and could threaten occurrences on private land (as many as eight of the known occurrences may occur on private land). The municipalities of Montrose, Delta, and Crawford are likely to expand greatly in coming decades. The human population of Montrose County grew by 36.9 percent between 1990 and 2000 (Montrose County 2001). Subdivision of property into ranchettes and construction of second homes are perhaps greater threats to *T. juniperorum* than suburban development at the periphery of metropolitan areas. This type of low density development fragments large areas of natural habitat (Knight et al. 2002). The proliferation of roads and disturbance from construction is likely to encourage the spread of weeds into *T. juniperorum* habitat. Horse grazing on ranchettes often results in serious degradation and erosion resulting from overgrazing. A natural fire regime is incompatible with

dispersed development, resulting in fire suppression at the expense of the functional needs of the ecosystem. Please see the Community Ecology section of this assessment for details regarding fire suppression.

Influence of management activities or natural disturbances on individuals

Grazing is likely to have direct negative impacts on individuals when cattle graze in occurrences of *Thelypodiopsis juniperorum* in spring and early summer. Spring grazing is cited as a threat to the federally listed endangered species *Thelypodium howellii* ssp. *spectabilis*, which is palatable to livestock (U.S. Fish and Wildlife Service 2002). *Thelypodiopsis juniperorum* is also likely to be palatable to livestock, but even if it is not, it is unlikely to withstand trampling since it is a somewhat delicate plant. Grazing in the late summer and fall is far less likely to impact *T. juniperorum* than spring and early summer grazing, when the plants are growing.

A variety of human activities and infrastructure pose likely threats to *Thelypodiopsis juniperorum*. Herbicides and pesticides used for right-of-way management and for range management are likely to impact occurrences of *T. juniperorum* and its pollinators when used in their proximity. Other right-of-way management practices such as mowing might also affect roadside occurrences. If *T. juniperorum* is a highly outcrossing species, roads and trails might act as barriers to pollinators and prevent effective geneflow by disrupting their traplines. Hikers along the North Vista Trail in Black Canyon of the Gunnison National Park may impact the occurrence in this vicinity by trampling. Hydrological alterations such as reservoir creation have impacted habitat for *T. juniperorum*, and are likely to have impacted occurrences as well. Impoundments in the Gunnison River watershed have reduced the extent of available habitat within the known range of *T. juniperorum*. Several reservoirs have been filled within the range of *T. juniperorum*, including Blue Mesa, Crawford, Gould, and Paonia reservoirs. Other factors that may have reduced the extent of available habitat for *T. juniperorum* include agricultural development, road construction, residential development, chaining and other range management practices, and noxious weed invasion (Cronquist et al. 1986, West and Young 2000).

Interaction of the species with exotic species

Cheatgrass (*Bromus tectorum*) probably presents the greatest threat to *Thelypodiopsis juniperorum* from exotic species for several reasons. *Bromus tectorum* aggressively invades native plant habitat (**Figures 7 and 8**), and its spread throughout the intermountain west has been well documented (Young and Blank 1995). As a winter annual, *B. tectorum* is likely to compete with *T. juniperorum* by utilizing water and nutrients on which *T. juniperorum* depends. It has been documented with *T. juniperorum* (Taylor collection 6054), and is common throughout its range. Efforts to manage *B. tectorum* often employ early season burning, but this is likely to injure *T. juniperorum* as well. The dramatic changes wrought by *B. tectorum* on the fire ecology of woodland ecosystems are also likely to affect the habitat of *T. juniperorum*. *Bromus tectorum* has spread through sagebrush shrublands and pinyon-juniper woodlands throughout the Intermountain West, resulting in increased erosion as perennial understory species are outcompeted (West and Young 2000). Invasion of its habitat by *B. tectorum* is among the principal threats to the federally listed *Lesquerella filiformis*, another annual mustard (U.S. Fish and Wildlife Service 1988).

Yellow starthistle (*Centaurea solstitialis*) has been found in Montrose and Delta Counties (Dillon 1999), and it poses a threat to *Thelypodiopsis juniperorum* and many other native plant species if ongoing efforts to contain it fail. It has a wide ecological range and has the potential to spread widely in Colorado. It currently infests ten million acres in California (Colorado Weed Management Association 2002).

Other exotic species of concern for *Thelypodiopsis juniperorum* include halogeton (*Halogeton glomeratus*) and Russian knapweed (*Acroptilon repens*) (Colorado Weed Management Association 2004), which are aggressive invaders on the Western Slope of Colorado.

Threats from over-utilization

As one of the first plant families to be recognized, members of the Brassicaceae have a long history of human use (Rollins 1993). Members of this family include some of our most familiar food crops and seasonings (Heywood 1993), and have numerous medicinal applications (Texas A&M Bioinformatics Working Group 2002). However, there are very few New World Brassicaceae for which there is any culinary usage (Rollins 1993), and no such uses are reported for *Thelypodiopsis juniperorum* or its close relatives. Currently there is little reason to suspect that over-utilization of this species for commercial purposes poses a significant threat. Care should be taken by collectors not to remove plants from small occurrences (Wagner

1991, Pavlovic et al. 1992). *Sisymbrium altissimum* has been noted to cause digestive tract irritation when grazed (Burrows and Tyrl 2001).

Conservation Status of the Species in USFS Region 2

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

There are no data on population trend for *Thelypodiopsis juniperorum*. If occurrences have been extirpated as a result of human alterations of the landscape (such as grazing, ORV use, reservoir creation) then *T. juniperorum* has declined. Further focused inventory and monitoring work will help to determine the population trend of this species.

Do habitats vary in their capacity to support this species?

The dearth of information on *Thelypodiopsis juniperorum* makes it impossible to speculate on the capacity of habitats to support it. It is likely that key environmental variables and year-to-year variation in temperature and precipitation have significant effects on the ability of different locations to support *T. juniperorum*, but until research is conducted to understand the relationships between *T. juniperorum* and its habitat this cannot be satisfactorily assessed.

Vulnerability due to life history and ecology

The minimum viable population size is not known for *Thelypodiopsis juniperorum*, but even small populations may still be viable and of conservation importance by the standards of the 50/500 rule of Soulé (1980). Somewhat arbitrarily, the Colorado Natural Heritage Program considers occurrences of *T. juniperorum* containing ten or more plants as viable, but this threshold will be revised when a minimum viable population size is determined. No reports are known in which signs of inbreeding depression were observed in small populations of related taxa.

Evidence of populations in USFS Region 2 at risk

There is much evidence to suggest that occurrences of *Thelypodiopsis juniperorum* are at risk. Its high level of endemism, small number of occurrences, and the vulnerability of its habitat suggest that *T. juniperorum* is imperiled. *Thelypodiopsis juniperorum* is very poorly understood, which is a liability because well-intended conservation actions cannot be as effective when basic information is not available. Better data are needed regarding its range and abundance to accurately assess the risk of extirpation of the known occurrences. Seven of the 16 known occurrences have not been reassessed in more than 20 years. Because the precise location is not known for six occurrences, they are at risk because no protective efforts on their behalf can begin as long as their location is uncertain. This underscores the importance of further inventory work to document the distribution of this species. *Thelypodiopsis juniperorum* appears to be naturally rare, but increased recruitment of individuals during favorable years suggests that large dormant populations may occur at some locations.

Six (and possibly eight) occurrences are known from lands administered by the National Park Service within the Black Canyon of the Gunnison National Park and Curecanti National Recreation Area (**Table 1** and **Table 2**), where they are protected from some impacts that are possible on private land. It appears that these protected areas support the bulk of the known occurrences of *Thelypodiopsis juniperorum*, so direct impacts of development and grazing are unlikely to result in extinction of this species. However, these occurrences remain vulnerable to impacts from weeds and recreational use, some of which are likely to be difficult to mitigate.

Management of the Species in USFS Region 2

Implications and potential conservation elements

Currently available data suggest that *Thelypodiopsis juniperorum* is a narrowly endemic species imperiled due to a small number of occurrences, high level of endemism, and threats to its habitat. Thus, the loss of any occurrence is significant and will probably result in the loss of important components of the genetic diversity of the species. Further research is needed before meaningful inference can be offered regarding restoration policy. Please see the Tools and Practices and Threats sections of this assessment for information on mitigating threats resulting from management.

Desired environmental conditions for *Thelypodiopsis juniperorum* include sufficiently large areas where the natural ecosystem processes on which *T. juniperorum* depends can occur, permitting it to persist unimpeded by human activities and their secondary effects, such as weeds. This includes a satisfactory

degree of ecological connectivity between occurrences to provide corridors and other nectar and pollen resources for pollinators if necessary. Given the current paucity of detailed information on this species, it is unknown how far this ideal is from being achieved. It is possible that most or all of the ecosystem processes on which *T. juniperorum* depends are functioning properly at many or most of the occurrences of this species. Further research on the ecology and distribution of *T. juniperorum* will help develop effective approaches to management and conservation. Until we have a more complete picture of the distribution and ecology of this species, priorities lie with conserving the known occurrences.

It is likely that a thoughtful assessment of current management practices on lands occupied by *Thelypodiopsis juniperorum* would identify some opportunities for change that would be inexpensive and have minimal impacts on the livelihood and routines of local ranchers, managers, stewards, and recreationists while conferring substantial benefits to *T. juniperorum*.

Tools and practices

Species and habitat inventory

Species inventory work is among the highest priorities for research on *Thelypodiopsis juniperorum*. Recent floristic inventory work has identified previously unknown occurrences, contributing greatly to our basic knowledge of the distribution and habitat for this species and suggesting that more await discovery. Species inventories are simple, inexpensive, and effective. At present, species inventory work for *T. juniperorum* is complicated by the lack of habitat specificity information. Difficulty in identifying this species in the field may further hamper species inventory efforts. However, it is likely that with experience it will be possible to develop a search image for *T. juniperorum* if sites are visited at phenologically appropriate times. Contracting experts on this species to search for more occurrences and update historic records would contribute greatly to our knowledge of *T. juniperorum*.

Thelypodiopsis juniperorum could benefit greatly from inventory and mapping using GPS to precisely mark occurrence boundaries. This would provide land managers with useful data for generating land use plans and evaluating permit applications, for example. The value of such a project would be greatly augmented by the collection of quantitative census data with ecological data.

Aerial photography, topographic maps, soil maps, and geology maps can be used to refine surveys of large areas, and could be highly effective for refining survey areas for *Thelypodiopsis juniperorum*. This technique is most effective for species about which we have basic knowledge of the substrate and habitat specificity from which distribution patterns and potential search areas can be deduced. In the case of *T. juniperorum*, searching apparently suitable habitat in the vicinity of known occurrences is an effective starting point for species inventory work.

Searches for *Thelypodiopsis juniperorum* could be aided by modeling habitat based on the habitat of known occurrences. The intersection of topography, geologic substrate, and vegetation could be used to generate a map of a probabilistic surface showing the likelihood of the presence of *T. juniperorum* in given locations. This would be a valuable tool for guiding and focusing future searches. Techniques for predicting species occurrences are reviewed extensively by Scott et al. (2002). Habitat modeling has been done for other sensitive plant species in Wyoming (Fertig and Thurston 2003) and these methods are applicable to *T. juniperorum* as well. Generating such a map for *T. juniperorum* is contingent on the refinement of the definition of suitable habitat for *T. juniperorum*.

Population monitoring

Monitoring selected occurrences of *Thelypodiopsis juniperorum* could answer many important questions. A monitoring program that addresses recruitment, seed production, seed and plant longevity, population variability, and pollinators would generate data useful to managers and the scientific community. Collecting baseline information and developing a detailed baseline map of the known occurrences will provide a starting point from which population trend can be assessed. It will be important to define *a priori* the changes the sampling regime intends to detect, and the management actions that will follow from the results (Schemske et al. 1994, Elzinga et al. 1998).

Plant species with high annual variability in population size such as annuals present special monitoring challenges (Elzinga et al. 1998). Elzinga et al. (1998, p. 55) offer an excellent discussion of some of these problems, which are summarized here. Monitoring annual species that appear aboveground only once every few years is complicated by the fact that most of the population resides in the seed bank,

only expressing itself in favorable years. Because the distribution of seeds in the seed bank is highly clustered, sampling the seed bank with soil cores usually results in many soil cores with no seeds, and a few with many seeds. For annual species that only appear above ground once every few years, habitat monitoring may be an alternative to monitoring the species itself. Because many annuals are sensitive to disturbance, Elzinga et al. (1998) recommend paying special attention to changes in the habitat that result in disturbance.

Occurrences of close relatives of *Thelypodiopsis juniperorum* have been monitored as a result of federal- and state-instituted recovery plans for these species. These species are *Thelypodium stenopetalum* (U.S. Fish and Wildlife Service 1997), *T. howellii* ssp. *spectabilis* (U.S. Fish and Wildlife Service 2002), and *Lesquerella filiformis* (U.S. Fish and Wildlife Service 1988, U.S. Fish and Wildlife Service 2003). Of particular interest is the monitoring of *L. filiformis*, since it is also an annual species. Methods that have been employed for monitoring *L. filiformis* are reviewed in Morgan (1980) and Morgan (1983). A protocol for long-term monitoring of *L. filiformis* at Wilson Creek National Battlefield is under development by Michael Kelrick at Truman State University in Missouri (Center for Plant Conservation 2004).

Selecting monitoring sites throughout the range of *Thelypodiopsis juniperorum* from a variety of substrates, elevations, vegetation types, and human usage patterns would provide the best assessment of the relative performance of populations in these scenarios. These sites should be sampled between mid-May and mid-June, when the species is most likely to be observable. Following up with searches in the fall for seedlings will help determine if *T. juniperorum* is a winter annual, although seedlings may be difficult to find and identify.

Because it is an annual species, resampling of monitoring plots will be necessary every year for *Thelypodiopsis juniperorum*. Obtaining a measure of reproductive output will permit the use of demographic modeling techniques to analyze the population biology of *T. juniperorum*. Making note of insect visitors while conducting population monitoring will generate valuable preliminary data on the pollination ecology of *T. juniperorum*. Monitoring sites should be selected carefully, and a sufficient number of sites selected if the data are intended to detect population trends.

Estimating cover and/or abundance of associated species within the plots described above could permit the investigation of interspecific relationships through ordination or other statistical techniques. Understanding environmental constraints on *Thelypodiopsis juniperorum* would facilitate the management of this species. Gathering data on edaphic characteristics (moisture, texture, and soil chemistry) from the permanent plots described above would permit the canonical analysis of species-environment relationships. These data would facilitate hypothesis generation for further studies of the distribution and ecology of this species.

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

To address the hypothetical metapopulation structure of *Thelypodiopsis juniperorum*, one approach might be to select highly suitable but unoccupied sites and attempt to observe colonization events. Selection of such sites would require more *a priori* research on the habitat requirements of *T. juniperorum*. Concurrent observations of local extinctions (which are fairly likely to occur in the smaller known occurrences) would also add to our understanding of the metapopulation structure of *T. juniperorum*. Looking at relative reproductive success of different occurrences would be useful in understanding possible metapopulation structure and in assessing viability of occurrences. Even for plants in which metapopulation dynamics can be successfully inferred from regional extinction and colonization data, focusing efforts on monitoring of individual occurrences is more likely to provide an accurate assessment of the species (Harrison and Ray 2002).

Habitat monitoring

Currently, habitat monitoring in the absence of *Thelypodiopsis juniperorum* individuals cannot be effectively conducted due to the lack of specific, detailed information on habitat requirements.

For sites that are occupied by *Thelypodiopsis juniperorum*, habitat monitoring should be conducted concurrently with population monitoring if population monitoring is conducted. Descriptions of habitat during all population monitoring efforts will greatly augment our present understanding of its habitat requirements. This could be incorporated into the field forms used for the quantitative sampling regimen described above.

If carefully selected environmental variables are quantified during monitoring activities, they will help explain observations of population change. Habitat monitoring of known occurrences will alert managers of new impacts such as weed infestations and damage from human disturbance and grazing. Making special note of abundance, distribution, and any detectable impacts of cheatgrass (*Bromus tectorum*) is important to include in a habitat monitoring program for *T. juniperorum*. Documenting changes in amount of stand closure, erosion, cover of perennial grasses and other perennial understory species, and other signs of degradation from overgrazing may help managers prevent serious degradation proactively by implementing changes in the grazing regime. Change in environmental variables might not cause observable demographic repercussions for several years, so resampling the chosen variables may help to identify underlying causes of population trends. Evidence of current land use practices and management are important to document while monitoring occurrences.

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

The use of photo points for habitat monitoring is described in Elzinga et al. (1998) and Hall (2002). This is a powerful technique that can be done quickly in the field. Though it does not provide detailed cover or abundance data, it can help to elucidate patterns observed in quantitative data.

Beneficial management actions

Because there have not yet been any occurrences of *Thelypodiopsis juniperorum* documented on National Forest System lands, it is not possible to identify specific management actions that the Forest Service can take on behalf of known occurrences. However, land management practices discussed below are likely to increase the likelihood that any occurrences that remain undiscovered on National Forest System lands (most likely on the Gunnison National Forest) will remain extant. Because of the close proximity of all the known occurrences of *T. juniperorum* to National Forest System lands, management actions by the USDA Forest Service have the potential to impact them, particularly those at Paonia Reservoir and north-northeast of Crawford (**Table 1**).

Management practices that reduce the impacts from grazing on occurrences of *Thelypodiopsis juniperorum* are likely to contribute greatly to the achievement of conservation goals for this species. The most effective change in grazing regime is likely to be the elimination of grazing in May and June, when *T. juniperorum* is growing. This was among the recommendations for recovery of *Thelypodium howellii* ssp. *spectabilis*, a close relative of *Thelypodiopsis juniperorum* on the endangered species list with a similar phenology (U.S. Fish and Wildlife Service 2002). The authors of the recovery plan speculate that fall grazing might not cause heavy impacts, since *Thelypodium howellii* ssp. *spectabilis* is dormant then. Other approaches that might be considered on a site-by-site basis include the use of exclosures and reducing stocking rates.

Johnston et al. (1999) offer a detailed treatment of range management strategies for sagebrush-dominated systems and for tall non-riparian shrublands such as the oak/serviceberry shrublands. Please see West and Young (2000) for recommendations on the management of pinyon-juniper woodlands. There have been no active population or habitat management efforts on behalf of *Thelypodiopsis juniperorum*.

Given the threats to *Thelypodiopsis juniperorum* and its habitat from exotic species, particularly *Bromus tectorum*, aggressive management of weeds in and near *T. juniperorum* occurrences is a high priority for its conservation. Unfortunately it will probably be difficult to remove *B. tectorum* from *T. juniperorum* occurrences without harming *T. juniperorum* as well. Early season burning is one management tool used to reduce *B. tectorum* cover, but it is extremely risky to use this tool where *T. juniperorum* co-occurs with *B. tectorum* because of their phenological overlap. Any management strategies that work to prevent the infestation of uninfested occurrences of *T. juniperorum* are likely to confer the greatest benefits.

Occurrences of *Thelypodiopsis juniperorum* need to be evaluated for negative impacts resulting from recreational use of its habitat, particularly ORV activity. Where ORV use is causing mortality or habitat degradation, efforts to route activity around occurrences will probably procure substantial benefits to *T. juniperorum*. Mitigating trampling impacts from

hikers in occurrences adjacent to trails, including the North Vista Trail in Black Canyon of the Gunnison National Park, may also benefit *T. juniperorum*.

Identifying high quality occurrences of *Thelypodiopsis juniperorum* in which the population size, condition, and the landscape context are excellent will help managers prioritize conservation efforts for *T. juniperorum*. Delineating special management areas for these locations will help ensure the long-term viability of this species. Because many occurrences probably reside on land owned by the Bureau of Land Management, designation of selected areas as areas of critical environmental concern is one option for protecting occurrences of high conservation value.

Seed banking

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

Information Needs

Distribution

Further species inventory work is among the top priorities for research on *Thelypodiopsis juniperorum*. To be effective, it will be important to search for *T. juniperorum* at phenologically appropriate times, because its early phenology may be partly responsible for the infrequency with which it is observed. Often when a species thought to be rare is actively sought and inventoried, it is found that the species is not as rare as previously believed. Much suitable habitat between known occurrences remains to be searched. Recent floristic inventory work has resulted in the discovery of new occurrences, and it is likely that others remain to be discovered. Revisiting and assessing all the known occurrences, but particularly those that have not been visited in more than 20 years, is also needed. More detailed habitat specificity information will help to refine future search efforts. Also, careful annotation is needed for questionable specimens to confirm the distribution of *T. juniperorum*. It is likely that specimens not included in this report are housed in herbaria not searched as a part of this project. Until we have a better picture of its distribution and population size, it will not be possible to accurately assess the conservation needs and priorities for this species.

Lifecycle, habitat, and population trend

The lifecycle, habitat, and population trend of *Thelypodiopsis juniperorum* remain very poorly understood. However, understanding the population biology of *T. juniperorum* is important for appropriate stewardship and management of this species. Only the most basic information is known about the lifecycle of *T. juniperorum*. Almost all the available data on habitat for *T. juniperorum* have come from herbarium specimen labels and are thus very coarse. Because *T. juniperorum* is an annual species that is not easily found most of the year, understanding its habitat and being able to identify suitable habitat is particularly important for its conservation and management. There have been no baseline studies that might provide insight into the population trend of *T. juniperorum*. Autecological research is needed to help refine our definition of appropriate habitat and facilitate effective habitat monitoring and conservation stewardship of *T. juniperorum*. The definitions of high quality and marginal habitat are not known for *T. juniperorum*. It is not known to what extent *T. juniperorum* is dispersal-limited. Given the current paucity of information on the habitat specificity of *T. juniperorum*, unoccupied sites might be suitable but unoccupied, or may be unsuitable for reasons we do not yet understand.

Response to change

Rates of reproduction, dispersal, and establishment and the effects of environmental variation on these parameters have not been investigated in *Thelypodiopsis juniperorum*. The sensitivity of *T. juniperorum* to habitat alteration and degradation is also not known. Thus, the effects of various management options cannot be assessed during project planning. *Thelypodiopsis juniperorum* occurrences could be expected to respond quickly to environmental impacts since it is an annual species and populations turn over rapidly.

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

The specific responses of *Thelypodiopsis juniperorum* to disturbance are not clear and warrant further investigation. *Thelypodiopsis juniperorum* may

be tolerant of some disturbance. However, anthropogenic disturbance is unlikely to benefit *T. juniperorum* in natural settings because it is likely to cause erosion and exacerbate problems from weeds. Information on the effects of the invasion of its habitat by cheatgrass and other exotic species is needed to properly manage occurrences of *T. juniperorum*. The effects of grazing on the survival and population ecology of *T. juniperorum* warrant careful study.

Metapopulation dynamics

Research on the population ecology of *Thelypodiopsis juniperorum* has not been done to determine the importance of metapopulation structure and dynamics to its long-term persistence at local or regional scales. The number of populations required to ensure the persistence of *T. juniperorum* is not known. Migration, extinction, and colonization rates are also unknown for *T. juniperorum*, and baseline population dynamics and viability need to be assessed.

It is unlikely that metapopulation dynamics are important for the conservation of *T. juniperorum* as they are for other species such as *Pedicularis furbishiae* (Furbish's lousewort; Menges and Gawler 1986). There are no plausible means by which *T. juniperorum* might effectively disperse itself long distances to other sites, and its habitat is not seral or particularly facile. The primary natural arbiter of successional change in the vegetation types occupied by *T. juniperorum* is fire, but there is no information suggesting that *T. juniperorum* colonizes burned areas.

Demography

Only the broadest generalizations can be made at present regarding the demography of *Thelypodiopsis juniperorum*. Population size has not been assessed for occurrences of *T. juniperorum*. Growth, survival, and reproduction rates are also unknown. Our knowledge of the distribution of the species is incomplete. Therefore much work is needed in the field before local and range-wide persistence can be assessed with demographic modeling techniques. Short-term demographic studies often provide misleading guidance for conservation purposes, so complementary information, such as historical data and experimental manipulations should be included whenever possible (Lindborg and Ehrlén 2002). However, the value of demographic data for conservation planning and species management cannot be overstated.

Population trend monitoring methods

Although methods are available to monitor population trend, it is difficult to assess population trend meaningfully in annual species such as *Thelypodiopsis juniperorum* (Elzinga et al. 1998). *Thelypodiopsis juniperorum* probably has highly variable above-ground population numbers, which better reflect the quality of growing conditions in a given year than the effective population size. Assessing population trend is further complicated by our incomplete knowledge of the number of occurrences of *T. juniperorum*. The available methods cannot be effective for understanding range-wide trends unless most of the occurrences of the species are known and incorporated into the monitoring program. Observations at known sites may or may not reflect real population trends. Multiple seasons and large sample sizes will be required to detect meaningful change.

Restoration methods

Because no attempts have been made to restore occurrences of *Thelypodiopsis juniperorum*, there is no applied research to draw from in developing a potential restoration program. It is possible that *T. juniperorum* may be readily propagated in a greenhouse environment, but it may be difficult to transfer plants successfully into a natural or quasi-natural (restored) setting. Efforts to restore populations of native annuals to tracts of coastal sage scrub in California have been met with varying levels of success, largely due to competition with annual grasses (Allen et al. in press). These efforts have used seed mixes to restore populations. Given (1994) offers case studies and excellent guidance on the translocation and reestablishment of plant populations.

Research priorities for USFS Region 2

Species inventory work is the first step towards developing a better understanding of *Thelypodiopsis juniperorum*. Targeted search efforts at phenologically appropriate times (mid May to early June) in suitable habitat throughout the area west of the West Elk Mountains will yield much information on the distribution and abundance of *T. juniperorum*. Collecting detailed notes on associated species, habitat, geology, soil, and other natural history observations at all locations will be extremely useful. Documentation of any threats, particularly evidence of negative impacts from cheatgrass (*Bromus tectorum*), will help to develop conservation strategies, and will help managers act to mitigate these threats.

Demographic studies are needed for *Thelypodiopsis juniperorum*. Demographic data are far more useful for assessing status and developing recovery efforts than genetic information (Schemske et al. 1994). Determining the critical life history stages of *T. juniperorum* will allow managers to focus efforts on implementing management protocols that benefit those stages. A monitoring program that determines effective population sizes and investigates the growth, survival, and reproduction of individuals within occurrences will have considerable practical value and will help determine the conservation status of *T. juniperorum*. Because herbivory of fruits by caterpillars and other insects impacts members of the genus *Arabis* and other members of the Brassicaceae, the role of insect herbivory on *T. juniperorum* also needs to be investigated (Inouye personal communication 2003).

Reaching a better understanding of the influence of grazing and human activities on individuals and habitat of *Thelypodiopsis juniperorum* will confer substantial practical benefits for land managers. All of the threats cited in this assessment including grazing are somewhat speculative and are not based on direct evidence. Documentation of the impacts of grazing on *T. juniperorum* is needed to mitigate threats from grazing and to prescribe alternatives.

The role of disturbance in the autecology of *Thelypodiopsis juniperorum* is unknown. An understanding of the disturbance regime to which *T. juniperorum* is adapted will assist with developing conservation strategies and management plans by determining the types of disturbance most likely to impact it negatively.

Understanding the breeding systems employed by *Thelypodiopsis juniperorum* is another research priority for this species due to the practical and scientific value of such studies. Answers to questions about whether *T. juniperorum* reproduces mostly by asexual means or is instead an obligate or frequent outcrosser will provide needed guidance for developing appropriate management practices. If *T. juniperorum* is heavily dependent on self-pollination, the genetic population structure is more stable than if the species is an obligate outcrosser. Thus, a trail near a primarily asexual population will not be as detrimental as one near a population of obligate outcrossers. Identifying the pollinators of *T. juniperorum* is important for determining whether they are common species or need to be addressed in management planning.

Information gleaned from studies of the physiological ecology of *Thelypodiopsis juniperorum* will be valuable in the event that an occurrence needs to be restored, and will help determine biotic and abiotic factors that contribute to its survival. Understanding the plant-environment relationship for *T. juniperorum* will be insightful in understanding the coping strategies employed by this species, and will help to model its potential distribution.

Additional research and data resources

There are likely to be other specimens of *Thelypodiopsis juniperorum* in herbaria that were not searched for this assessment. These include Brigham Young University, Colorado College, and USDA Forest Service and BLM herbaria at district and field offices. Annotation of mislabeled specimens is also likely to yield further data; checking specimens labeled *T. elegans* is the best first step in searching for other specimens of *T. juniperorum*.

Definitions

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

Apomixis: Reproduction that involves structures commonly concerned in sexual reproduction but in which there is no actual fusion of male and female gametes (Gould and Shaw 1983).

Cladistics: A classification system that expresses the branching relationships between species through a phylogenetic tree with ancestral forms at the bottom and recently diverged ones at the top (Art 1993).

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

Cytological: The study of the cell, including its structure and function (Allaby 1998).

Dehisce: Opening at maturity by fruits and anthers (Harris and Harris 1999).

Edaphic: Of the soil, or influenced by the soil (Allaby 1998).

Haploid: Describes a cell nucleus that contains one set of chromosomes, designated *n*, as in the gametophyte generation of plants (Allaby 1998).

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

Phylogenetic: Based on evolutionary history and relationships (Art 1993).

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

Polyploid: Having three or more sets of chromosomes (Art 1993).

Stipe: a stalk that attaches the fruit to the receptacle in some members of the Brassicaceae (Harris and Harris 1999).

Sympatric: Describes two populations or species that live in the same region without merging into one population through interbreeding (Art 1993)

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

Global imperilment (G) ranks are based on the range-wide status of a species. State-province imperilment (S) ranks are based on the status of a species in an individual state or province. State-province and Global ranks are denoted, respectively, with an "S" or a "G" followed by a character. **These ranks should not be interpreted as legal designations.**

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

Notes: Where two numbers appear in a G or S rank (e.g., S2S3), the actual rank of the element falls between the two numbers.

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LIST OF ERRATA

09/22/05 Changed peer review organization from Center for Plant Conservation to Society for Conservation Biology on the cover and under "Peer Review" heading.

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