Pyrrocoma carthamoides Hook. var. *subsquarrosa* (Greene) G. Brown & Keil (largeflower goldenweed): A Technical Conservation Assessment

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COVER PHOTO CREDIT

Pyrrocoma carthamoides var. *subsquarrosa.* Photograph by Hollis Marriott and reprinted with permission from: Fertig, W., C. Refsdal, and J. Whipple. 1994 Wyoming Rare Plant Field Guide. Wyoming Rare Plant Technical Committee. Cheyenne, Wyoming.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *PYRROCOMA CARTHAMOIDES* VAR. *SUBSQUARROSA*

Status

Pyrrocoma carthamoides Hook. var. *subsquarrosa* (Greene) G. Brown and Keil (largeflower goldenweed) is a taxon in the aster family occurring from 1,646 to 3,140 meters (m) (5,400 to 10,300 feet [ft]) in grasslands and shrubland communities on limestone, sandstone, or volcanic substrates. This taxon is endemic to the foothills of the Absaroka Mountains of Wyoming, and the Beartooth and Pryor mountains of Montana. At least 17 of the 22 known occurrences of this taxon may occur partly or wholly on USDA Forest Service (USFS) lands, including 13 occurrences on USFS Rocky Mountain Region (Region 2) lands. Some occurrences are located on or extend onto Bureau of Land Management lands, The Nature Conservancy conservation easements, state trust lands, and private lands. This taxon is currently on the USFS Rocky Mountain Region sensitive species list (USDA Forest Service 2003) and was previously listed as a Category 2 taxon under the Endangered Species Act (U.S. Fish and Wildlife Service 1996, 2004). The global heritage status rank for the rangewide status of the variety *P. carthamoides* var. *subsquarrosa* is G4G5T2T3 (between imperiled globally [T2] and vulnerable [T3]) (NatureServe 2003). Because of its small number of occurrences and high endemism, the Wyoming Natural Diversity Database and Montana Natural Heritage Program both rank *P. carthamoides* var. *subsquarrosa* as S2, or imperiled (Fertig and Heidel 2002, Montana Natural Heritage Program 2003a, Wyoming Natural Diversity Database 2004).

Primary Threats

Pyrrocoma carthamoides var. *subsquarrosa* is a taxon of concern because of its restricted geographic range, small number of documented occurrences, and possible vulnerability to human-related and environmental threats. Disturbances and land management activities, such as livestock grazing, may maintain suitable habitat for this taxon or may negatively impact existing occurrences, depending on the intensity, frequency, size, and type of disturbance or activity. Ecological tolerances and ecological dynamics (e.g., competition, succession, fire regime) as related to this taxon have not been studied. Possible human-related threats to *P. carthamoides* var. *subsquarrosa* include changes to natural disturbance patterns (e.g., fire suppression), exotic species invasion and management, grazing and stock water development, road/trail construction, motorized and non-motorized recreation, and energy exploration (Fertig 1995, Lesica 1995, Fertig and Mills 2000, Welp et al. 2000, Reid 2001). Possible environmental and biological threats to occurrences of *P. carthamoides* var. *subsquarrosa* include changes to the natural disturbance regime, succession/ woody encroachment, environmental fluctuations (e.g., drought), global climate changes, and genetic isolation. Of 13 occurrences on USFS Region 2 lands, only four occurrence records provided any assessment of possible threats. These four occurrence records noted that threats for this taxon are generally low, and only two records indicated that proximity to roads or grazing could be a concern.

Primary Conservation Elements, Management Implications and Considerations

The microhabitat needs of *Pyrrocoma carthamoides* var. *subsquarrosa* and the intensity, frequency, size, and type of disturbance optimal for persistence of this taxon are unknown. The lack of information regarding the colonizing ability, adaptability to changing environmental conditions, sexual reproductive potential, and genetic variability of this taxon makes it difficult to predict its vulnerability. Surveying high probability habitat for new occurrences, protecting existing occurrences from any imminent threats, documenting and monitoring the effects of current management activities, and preventing non-native plant invasions are key to determining conservation elements for this taxon. Priorities of future research studies include revisiting and detailed mapping of the extent of existing occurrences, surveying to locate additional occurrences within USFS Region 2, assessing imminent threats from exotic weed invasion or current land management, investigating factors affecting spatial distribution (e.g., microhabitat characteristics and substrate preferences), exploring biological and ecological limitations, and producing information related to demography and genetic structure.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), USDA Forest Service (USFS). *Pyrrocoma carthamoides* var. *subsquarrosa* is the focus of an assessment because it is listed as a sensitive taxon in USFS Region 2 (USDA Forest Service 2003). Within the National Forest System, a sensitive species is a plant or animal species whose population viability is identified as a concern by a regional forester because of significant current or predicted downward trends in population numbers, density, or habitat capability that would reduce the species' existing distribution (USDA Forest Service 1995). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Pyrrocoma carthamoides* var. *subsquarrosa* throughout its range in USFS Region 2 although its range extends outside Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with 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. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Additionally, the assessment cites management recommendations proposed elsewhere, and when management recommendations have been implemented, the assessment examines the success of the implementation.

Scope and Information Sources

The *Pyrrocoma carthamoides* var. *subsquarrosa* assessment examines the biology, ecology, conservation status, and management of this taxon with specific reference to the geographic and ecological characteristics of USFS Region 2. Although some of the literature on the taxon may originate from field investigations outside the region, this document places that literature in the ecological and social context of the central Rocky Mountains. Similarly, this assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of *P. carthamoides* var. *subsquarrosa* in the context of the current environment rather than under historical conditions. The evolutionary environment of the taxon is considered in conducting the synthesis but placed in a current context.

In producing the assessment, we performed an extensive literature search to obtain all material focusing on *Pyrrocoma carthamoides* var. *subsquarrosa*, as well as related information on the geographical and environmental context of this taxon. We reviewed refereed literature (e.g., published journal articles), non-refereed publications (e.g., unpublished status reports), dissertations, data accumulated by resources management agencies (e.g., state natural heritage program [NHP] element occurrence records), and regulatory guidelines (e.g., USFS Manual). We did not obtain Mayes' 1976 cytotaxonomic work on the genus *Pyrrocoma*. We did not visit every herbarium with specimens of this taxon, but we did incorporate specimen label information provided by herbarium staff and available in NHP element occurrence records. While the assessment emphasizes refereed literature because this is the accepted standard in science, non-refereed publications and reports are used extensively in this assessment because they provided information unavailable elsewhere. These unpublished, non-refereed reports were regarded with greater skepticism, and we treated all information with appropriate uncertainty.

Because of a lack of experimental research efforts concerning *Pyrrocoma carthamoides* var. *subsquarrosa*, this assessment report relies heavily on the personal observations of botanists and land management specialists from throughout the taxon's range. When information presented in this assessment is based on our personal communications with a specialist, we cite those sources as "personal communication". Much of the knowledge about the status and ecology of *P. carthamoides* var. *subsquarrosa* is presented in a single, unpublished status report prepared by the Montana NHP (Lesica 1995). Unpublished data (e.g., NHP element occurrence records) were also important in estimating the geographic distribution and describing habitat. These data required special attention because of the diversity of persons and variety of methods used in collection and the inability to verify historical information. Because there is a paucity of knowledge

specific to this taxon, we also incorporated information, where available, from closely related taxa within and outside the region to formulate this assessment. A main source of information is an unpublished report by Mancuso and Moseley (1993) on *P. radiatus* (Snake River goldenweed) known from similar habitats in Idaho. *Pyrrocoma radiatus* is closely related to *P. carthamoides* var. *carthamoides*, and it was historically treated as *Haplopappus carthamoides* var. *maximus*. As a result, conclusions about threats to *P. carthamoides* var. *subsquarrosa* and conservation considerations in USFS Region 2 are based on inference from these published and unpublished sources. We clearly noted when we were making inferences based on the available knowledge to inform our understanding of *P. carthamoides* var. *subsquarrosa*.

Treatment of Uncertainty

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

Publication of Assessment on the World Wide Web

To facilitate the use of species conservation assessments in the Species Conservation Project, they will be published on the USFS Region 2 World Wide Web site. Placing documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More importantly, it facilitates their revision, which will be accomplished based on guidelines established by USFS Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the Web. This assessment was reviewed through a process administered by the Center for Plant Conservation, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Pyrrocoma carthamoides var. *subsquarrosa* is a regional endemic taxon of northwest Wyoming and southwest Montana and is known from 22 occurrences globally (**Figure 1**, **Table 1**; Lesica 1995, Montana Natural Heritage Program 2003b, Wyoming Natural Diversity Database 2004). This section discusses the special management status, existing regulatory mechanisms, and biological characteristics of this taxon.

Management and Conservation Status

Federal status

The Endangered Species Act of 1973 was passed to legally protect plant and animal species placed on the threatened or endangered list. The listing process is based on population data and is maintained and enforced by the U.S. Fish and Wildlife Service (USFWS). In 1993, *Pyrrocoma carthamoides* var. *subsquarrosa* was ranked as a Category 2 species (a taxon for which proposal as endangered or threatened is appropriate, but conclusive data on biological vulnerability and threats are not currently available) (U.S. Fish and Wildlife Service 1993). The USFWS eliminated the Category 2 list in 1996. The USFWS solicits information from agencies (e.g., state NHPs) that continue to monitor *P. carthamoides* var. *subsquarrosa* to determine if there are any changes in the species' current abundance and distribution, or if significant threats exist indicating that elevation to official candidate status is warranted (McKenzie personal communication 2003). Species that meet any of the five listing factors under Section 4 of the Endangered Species Act will be elevated after review and approval. Species added to the candidate list are given a listing priority number and can then be listed pending available funds and completion of actions taken on higher priority species (McKenzie personal communication 2003).

Pyrrocoma carthamoides var. *subsquarrosa* is listed as a sensitive species by USFS Regions 1 and 2 (USDA Forest Service 1999, USDA Forest Service 2003). It is listed as a watch species by the Bureau of Land Management (BLM) in Montana (Montana

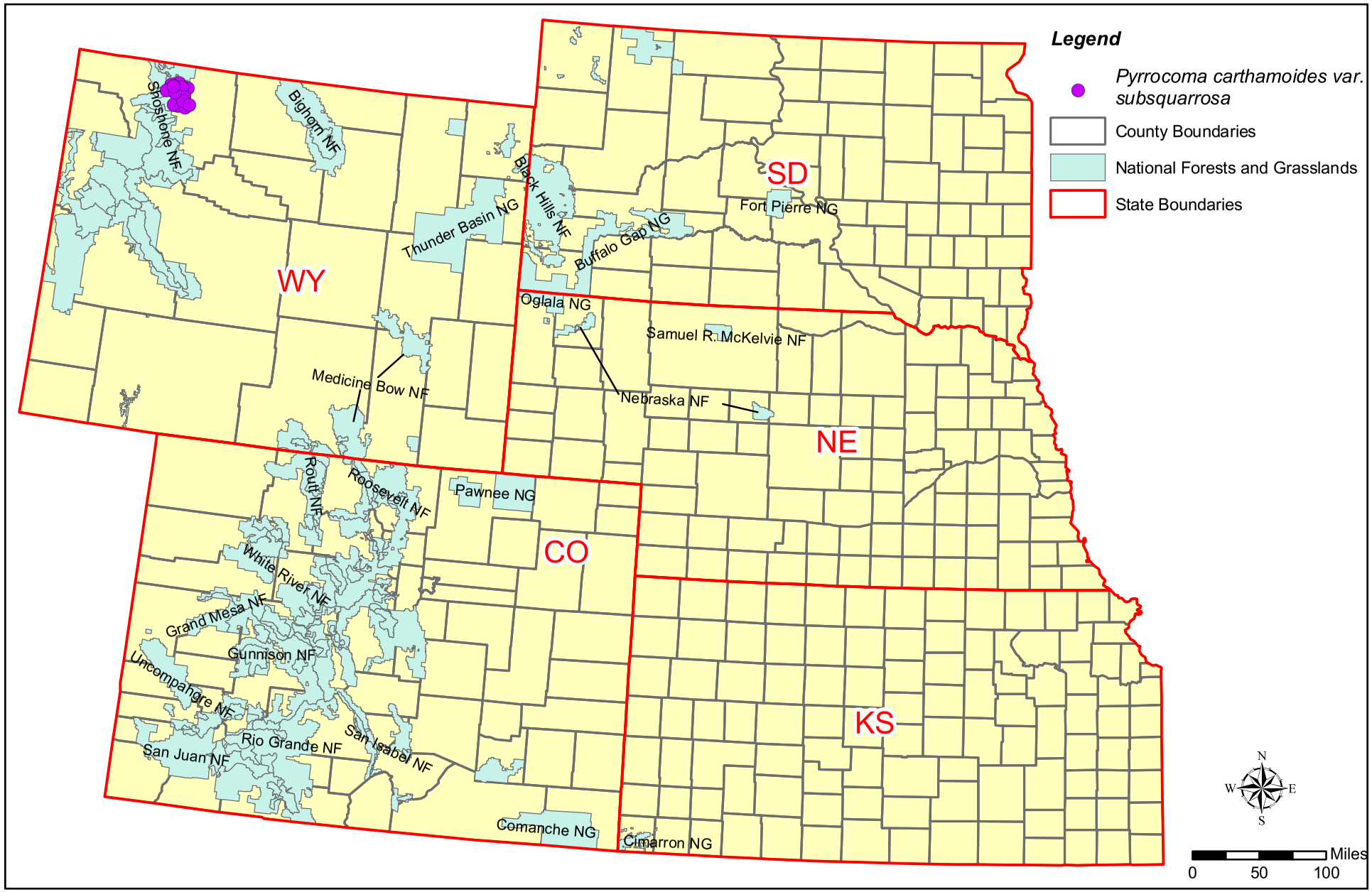


Figure 1. Map of USDA Forest Service (USFS) Region 2 illustrating the distribution of 15 *Pyrrocoma carthamoides* var. *subsquarrosa* occurrences in Park County, Wyoming. There are seven additional occurrences outside USFS Region 2 in adjacent Carbon County, Montana. Refer to document for abundance and distribution information. Sources: Montana Natural Heritage Program (2003); Rocky Mountain Herbarium (2004); Wyoming Natural Diversity Database (2004).

Table 1. *Pyrrocoma carthamoides* var. *subsquarrosa* occurrence information. Includes state, county, occurrence identifier, observation dates, estimated abundance, estimated occurrence area, and land management context. Sources: Lesica (1995); Montana Natural Heritage Program (2003); Rocky Mountain Herbarium (2004); Wyoming Natural Diversity Database (2004).

State/County	Occurrence Identifier	Date of Observations	Estimated Abundance	Estimated Area (acres)	Management Area/ Ownership
Wyoming/Park County (USFS Region 2)	2224	1980, 1985, 1990, 1993, 1996	At least 14 subpopulations; several thousand plants (1990); subarea 1: total population estimated at 1,600 to 2,000 individuals, largest clusters with 50 to 100 plants at a density of 10 to 15 plants per square meter (1996); subarea 2: 1,200 to 1,500 individuals, locally dense but scattered (1996); subarea 3: 50 to 75 plants (1996); subarea 4: 400 to 600 plants (1996), three small to medium-sized subgroups (1993); subarea 5: 1,500 to 2,000 plants conservatively estimated in several subgroups (1996)	250	Shoshone National Forest (Clark's Fork Ranger District, proposed Bald Ridge Research Natural Area); Wyoming BLM (Cody Field Office)
	2225	1983, 1997	Not available (NA)	Not available (NA)	Shoshone National Forest (Wapiti Ranger District)
	2226	1983	NA	NA	Shoshone National Forest (Wapiti Ranger District, North Absaroka Wilderness)
	2227	1985, 1995	Estimated at 500 individuals; in scattered, loose patches (1995)	NA	Shoshone National Forest (Clark's Fork Ranger District, North Absaroka Wilderness)
	2228	1893, 1985, 1995, 1996	18 colonies; 14 colonies observed with estimated total of about 2,500 to 3,000 plants (1995); subarea 1: seven plants (1996); subarea 2: three medium to large colonies observed with 400 to 500 plants (1996)	425	Shoshone National Forest (Clark's Fork Ranger District)
	2229	1985	NA	NA	Shoshone National Forest (Clark's Fork Ranger District)
	2230	1985	NA	NA	Shoshone National Forest (Clark's Fork Ranger District)
	2231	1985	NA	NA	Shoshone National Forest (Clark's Fork Ranger District, North Absaroka Wilderness)
	2232	1985	NA	NA	Shoshone National Forest (Clark's Fork Ranger District)
	2233	1975, 1985, 1997	At least six colonies; four small to medium-sized colonies with estimated 200 to 300 plants total (1997); largest colony with 36 plants (1997)	10	Shoshone National Forest (Wapiti Ranger District, proposed Pat O'Hara Mountain Research Natural Area)
	2234	1994, 1995	At least six small to mid-sized subgroups; four small colonies (1995); largest colony with about 500 plants, and other colonies with four to 50 plants (1995); locally common in three subgroups (1994)	15	Shoshone National Forest (Wapiti Ranger District)

Table 1 (concluded).

State/County	Occurrence Identifier	Date of Observations	Estimated Abundance	Estimated Area (acres)	Management Area/ Ownership
Wyoming/Park County (USFS Region 2)	2235	1995	250 flowering or vegetative plants observed in three small subgroups	5	Shoshone National Forest (Wapiti Ranger District)
	2236	1994	Three colonies; subarea 1: density of plants about two to four per square foot (although clusters of plants themselves may be patchy); subarea 2: population conservatively estimated at 200 to 400 plants widely scattered	35	Wyoming BLM (Cody Field Office)
	2237	1997	Four small subgroups; subarea 1: 12 plants, in clumps of two to three per square meter; subarea 2: about 50 to 100 plants in about 18 square meters of habitat, more densely clustered; subarea 3: 12 plants; subarea 4: about 25 plants	2 to 5	Private land (?)
	2238	1989	NA	NA	Shoshone National Forest (Clark's Fork Ranger District)
Montana/Carbon County (USFS Region 1)	001	1995	1,000 to 10,000 plants	50	Montana BLM (Billings Field Office, Meeteetse Spires Area of Critical Environmental Concern); private land
	002	1993, 1995	100,000 plants in at least seven subgroups (1995); 100 or more plants (1993)	4,000	Montana BLM (Billings Field Office); Custer National Forest (Beartooth Ranger District); private land
	004	1995	1,000 to 10,000 plants; 100 to 500 plants in the smaller sub-group	400	Custer National Forest (Beartooth Ranger District); private land
	005	1995	500 to 1,000 plants	10	Custer National Forest (Beartooth Ranger District); private land
	006	1995	100 to 500 plants	5	Custer National Forest (Beartooth Ranger District); private land; road right-of-way
	007	1995, 1999	Several subgroups, may be additional plants on adjacent private land; subarea 1: 500 to 1,000 plants (1995); subarea 2: 100 or more plants (1999)	10	Montana BLM (Billings Field Office, Meeteetse Spires Area of Critical Environmental Concern)
	008	1995	500 to 1,000 plants	10	Montana State Trust land

Natural Heritage Program 2003a), but it is not listed by the BLM in Wyoming (U.S. Bureau of Land Management 2001).

Heritage program ranks

The global heritage status rank for the rangewide status of *Pyrrocoma carthamoides* var. *subsquarrosa* is G4G5T2T3 and the rounded rank is T2 (NatureServe 2003). A range of ranks (i.e., G4G5 or T2T3) is used to indicate uncertainty about the exact status of a taxon, and the rounded rank summarizes those ranks into the most imperiled one. Global (G) ranks refer to the rangewide status of the species as a whole, while trinomial (T) ranks refer to the rangewide status of the subspecies or variety. The global rank of *P. carthamoides* is between apparently secure (G4) and demonstrably widespread, abundant, and secure (G5). The trinomial rank of *P. carthamoides* var. *subsquarrosa* is between imperiled (T2) and vulnerable (T3) globally as a result of the limited abundance and distribution of this variety. The heritage ranks draw attention to species potentially requiring conservation strategies for future success. However, identification is not associated with specific legal constraints, such as limiting plant harvesting or restricting damage to critical habitats.

State natural heritage programs collect information about the biological diversity of their respective states and maintain databases of species of special concern. Because of its small number of occurrences, *Pyrrocoma carthamoides* var. *subsquarrosa* has been ranked by Wyoming Natural Diversity Database and Montana NHP as imperiled (S2) in those states (vulnerable to extirpation; endangered or threatened in the state) (Fertig and Heidel 2002, Montana Natural Heritage Program 2003a). This taxon is not known from Colorado, Kansas, Nebraska, or South Dakota and is thus not currently listed or ranked in those states (Kansas Natural Heritage Inventory 2002, Nebraska Natural Heritage Program 2002, South Dakota Natural Heritage Program 2002, Colorado Natural Heritage Program 2003).

Existing Regulatory Mechanisms, Management Plans, and Conservation Practices

Known occurrences of *Pyrrocoma carthamoides* var. *subsquarrosa* are located in a variety of land ownership and management contexts (**Table 1**). In Wyoming, 13 out of 15 known occurrences are in the Shoshone National Forest (USFS Region 2), with three occurrences within the North Absaroka Wilderness Area, one occurrence in the proposed Pat O'Hara Mountain Research Natural Area (RNA), and one occurrence in the proposed Bald Ridge RNA (Jones 1991, Fertig and Bynum 1994, Jones and Fertig 1999, Wyoming Natural Diversity Database 2004). Thus, the majority of plants in Wyoming are on USFS Region 2 lands. One to three occurrences may also partially occur on The Nature Conservancy (TNC) conservation easements in the Clark's Fork and North Fork Shoshone River valley areas (Fertig and Mills 2000).

Of seven known occurrences of *Pyrrocoma carthamoides* var. *subsquarrosa* in Montana, four occurrences are wholly or partly on Custer National Forest (USFS Region 1) lands. These occurrences include the two largest occurrences; thus, the majority of plants in Montana are on USFS Region 1 lands (Lesica 1995). In addition, two occurrences are found on BLM Montana lands, including one occurrence within the Meeteetse Spires Area of Critical Environmental Concern (ACEC) (Montana Natural Heritage Program 2003b). One occurrence is on State of Montana lands (Lesica 1995). Some occurrences also extend onto private lands (**Table 1**).

Although *Pyrrocoma carthamoides* var. *subsquarrosa* has been identified as a taxon of special concern, there are few specific regulatory mechanisms at the federal or state level to regulate its conservation. This taxon may obtain protection from various general conservation strategies designed to protect plants and animals on federal lands. USFS and BLM lands are managed for multiple use (unless a special management designation is made [e.g., RNA, ACEC]), with an effort to prevent damage to occurrences of species of special concern. The USFS is directed to develop and implement management practices to ensure that sensitive species do not become threatened and endangered; biological evaluations are required to determine impacts of USFS projects to *P. carthamoides* var. *subsquarrosa* and suitable habitat (USDA Forest Service 1995). The National Environmental Policy Act (U.S. Congress 1982) requires assessment of the impacts of any significant USFS project to natural environments. In addition, the USFS prohibits the collection of any sensitive plants without a permit (USDA Forest Service 1995), and wilderness areas have restrictions on motorized travel (Office of the Secretary of the Interior 1964). Occurrences of *P. carthamoides* var. *subsquarrosa* on proposed RNAs on USFS Region 2 lands would be protected as part of a national network to preserve representative areas for research, education, and maintenance of biological diversity (USDA Forest Service 1997) if these areas have been approved as

RNAs in the next planning cycle (Houston personal communication 2003). Although the Pat O'Hara Mountain and Bald Ridge areas are only proposed RNAs at this time, Shoshone National Forest resource specialists are still managing that land for conservation by restricting land uses (e.g., cattle grazing) and minimizing new projects (e.g., trail construction) (Houston personal communication 2003).

Existing regulations may not be adequate to conserve *Pyrrocoma carthamoides* var. *subsquarrosa* over the long term, considering that the current abundance and distribution of this taxon is not well known and specific occurrences may be threatened by a variety of human-related and ecological threats.

Biology and Ecology

Classification and description

Systematics and synonymy

Pyrrocoma carthamoides Hook. var. *subsquarrosa* (Greene) G. Brown and Keil is in the genus *Pyrrocoma* of family Asteraceae (aster family), order Asterales, and group Dicotyledonae (dicots) of phylum Anthophyta (flowering plants) (NatureServe 2003). Synonyms for *P. carthamoides* var. *subsquarrosa* include *Haplopappus carthamoides* (Hook.) Gray var. *subsquarrosus* (Greene) Dorn, *H. carthamoides* (Hook) Gray ssp. *subsquarrosus* (Greene) Hall, and *P. subsquarrosa* Greene. Common names include largeflower goldenweed, Beartooth large-flowered goldenweed, and Absaroka goldenweed (Lesica 1995, Montana Natural Heritage Program 2003b, Wyoming Natural Diversity Database 2004).

Pyrrocoma carthamoides comprises three varieties: var. *carthamoides*, var. *cusickii*, and var. *subsquarrosa*. *Pyrrocoma carthamoides* var. *subsquarrosa* was originally described as *P. subsquarrosa* by E.L. Greene (Greene 1895) after Hooker's creation of the *Pyrrocoma* genus in 1840 based on *P. carthamoides* (Rydberg 1900). Hall (1928) produced a monograph of the genus *Haplopappus* with this taxon included as *H. carthamoides* ssp. *subsquarrosus*. Dorn (1988) treated this taxon as a variety within the *Haplopappus* genus: *H. carthamoides* var. *subsquarrosa*. The most recent treatment of these genera by Brown and Keil (1992) separates *Pyrrocoma* from *Haplopappus* based on cytotaxonomic work by Mayes (1976). Cronquist et al. (1997) do not recognize the genus *Pyrrocoma* or the var. *subsquarrosa* and use a taxonomic treatment similar to that in Hall (1928). They noted that a spiny-leaved form of var. *carthamoides* occurs at the east end of the Columbia Basin, and they chose to include the specimens from Wyoming and Montana in var. *carthamoides*. Overall, there are blurred relationships within the *Pyrrocoma* (*Haplopappus*) group, and further studies may be necessary to address taxonomic uncertainties (Mancuso and Moseley 1993). Refer to Mayes (1976) for a further discussion on the systematics of *Pyrrocoma*.

Pyrrocoma carthamoides Hook. var. *subsquarrosa* (Greene) G. Brown & Keil is the name used by the PLANTS (Natural Resources Conservation Service 2002) database, WYNDD database in USFS Region 2 (Wyoming Natural Diversity Database 2004), and Dorn (2001). The Montana NHP lists this plant as *Haplopappus carthamoides* var. *subsquarrosus* (Greene) Dorn (Montana Natural Heritage Program 2003a).

History of taxon

The holotype specimen for *Pyrrocoma carthamoides* var. *subsquarrosa* was collected in Sunlight Basin of Park County, Wyoming, on 5 September 1893 (Rose 334) and is housed at the U.S. National Herbarium (Washington, D.C.). Isotypes are housed at the University of California Herbarium (Berkeley, California) and the University of Montana herbarium (Helena, Montana) (Lesica 1995). *Pyrrocoma carthamoides* var. *subsquarrosa* was listed as a Category 2 species with the USFWS in 1993 (U.S. Fish and Wildlife Service 1993), but the category program was eliminated by the USFWS in 1996 (U.S. Fish and Wildlife Service 1996). This variety was the subject of a status assessment in 1995 (Lesica 1995). No detailed demographic, ecological, or biological studies of this species or variety have been undertaken.

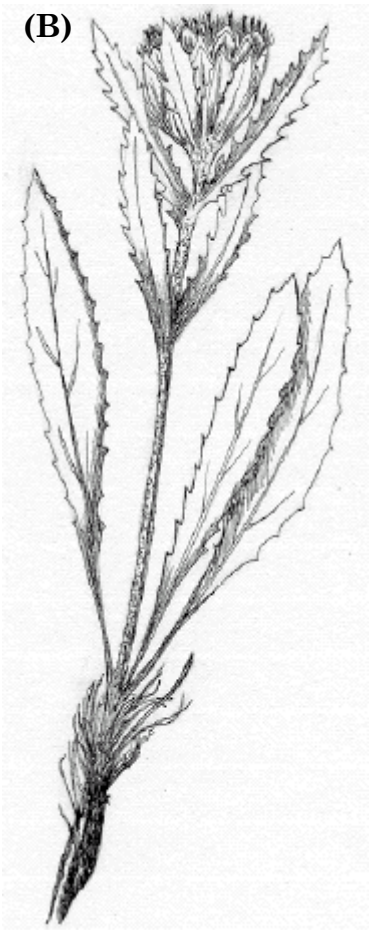
Morphological characteristics

Members of the family Asteraceae are characterized by a head (capitulum inflorescence) with many tiny flowers (florets) crowded onto the receptacle. In many cases, the inflorescence is a radiate head comprised of both "ray" florets (with strap-like corolla) arranged on the head margin and "disc" florets (with tubular corolla) in the center of the head. In addition, the heads are subtended by numerous bracts that protect the bud or close over the flower in cold weather (Zomlefer 1994). The genus *Pyrrocoma* is comprised of roughly 14 species from the western United States and southwestern Canada (Natural Resources Conservation Service 2002). These species are characterized by an

herbaceous perennial habitat, production of flavones, and a base chromosome number of n=6 (Mancuso and Moseley 1993).

Pyrrocoma carthamoides var. *subsquarrosa* is a perennial, tap-rooted herb with one to a few stems arising from a simple or branched woody root crown (**Figure 2**; Fertig and Mills 2000). The leafy stems grow erect or curved, ascending from 10 to 30 centimeters (cm) tall. The foliage is comprised of lanceolate, glabrous leaves with spiny margins. The petioled basal leaves are up to 20 cm long and 25 millimeters (mm) wide, and the mostly sessile, alternate cauline leaves are smaller and decrease in size upward. The narrowly hemispheric flowerheads are solitary and terminal on each stem, or in a sessile or racemose group of two to four heads. The flowerheads are subtended by three to four series of overlapping, broadly lance-shaped, involucral bracts, 10 to 25 mm long. The outermost bracts have spiny margins. Disc flowers are numerous, light-yellow, and 8 to 12 mm long. Ray flowers are absent or less numerous (8 to 25), inconspicuous, and less than 8 mm long. The seeds are 4-angled achenes, with a pappus of 35 to 45 pale brown, stiff bristles that are as long as or longer than the disk corollas.

The three varieties of *Pyrrocoma carthamoides* differ slightly in morphology. *Pyrrocoma carthamoides* var. *subsquarrosa* has a narrowly hemispheric flowerhead with broadly lance-shaped,



Photograph by Hollis Marriott and illustration by Walter Fertig. Reprinted with permission from: Fertig, W., C. Refsdal, and J. Whipple. 1994 Wyoming Rare Plant Field Guide. Wyoming Rare Plant Technical Committee. Cheyenne, Wyoming.

Figure 2. *Pyrrocoma carthamoides* var. *subsquarrosa* **(A)** photograph in its natural habitat in Wyoming, and **(B)** illustration of the vegetative and reproductive structures.

spiny involucral bracts. *Pyrrocoma carthamoides* var. *cusickii* has a cylindrical head with narrowly lance-shaped, spineless involucral bracts. *Pyrrocoma carthamoides* var. *carthamoides* generally has a broader hemispheric head with scarious-margined involucral bracts (Lesica 1995).

Pyrrocoma carthamoides var. *subsquarrosa* can generally be distinguished from other co-occurring members of the Asteraceae family by its large heads and inconspicuous rays in combination with its spiny-margined leaves and involucral bracts (Lesica 1995). For example, *P. clementis* and *P. integrifolia* have prominent yellow flowers with rays over 10 mm long (Fertig and Mills 2000). *Pyrrocoma uniflora* and *P. lanceolata* have smaller heads and shorter disk flowers than *P. carthamoides* var. *subsquarrosa* (Fertig and Mills 2000).

Technical descriptions of *Pyrrocoma carthamoides* var. *subsquarrosa* are presented in Greene (1895) and Lesica (1995). Photographs and illustrations are available in Lesica (1995) and Fertig and Mills (2000).

Distribution and abundance

Pyrrocoma carthamoides var. *subsquarrosa* is a regional endemic taxon found in a 50-mile stretch between Cody in northwest Wyoming and Red Lodge in southwest Montana (**Figure 1**). The range of this goldenweed includes the east side of the Absaroka Range in Park County, Wyoming in USFS Region 2 and the east side of the Beartooth Mountains and Pryor Mountains in adjacent Carbon County, Montana in USFS Region 1 (Lesica 1995). The two main mountain valleys in this range are the Clark's Fork of the Yellowstone River (Wyoming) and Rock Creek (Montana) (Lesica 1995).

The other two varieties of *Pyrrocoma carthamoides* occur farther west than *P. carthamoides* var. *subsquarrosa*. *Pyrrocoma carthamoides* var. *carthamoides* occurs mainly in the Columbia Basin from British Columbia south to Oregon and east to northwest Montana. *Pyrrocoma carthamoides* var. *cusickii* is mainly an intermountain species and is present in southeastern Washington, eastern Oregon, central Idaho, Nevada, and California (Lesica 1995, NatureServe 2003).

Pyrrocoma carthamoides var. *subsquarrosa* is known from 15 occurrences in Wyoming (USFS Region 2) and seven occurrences in Montana (USFS Region 1). Based on field surveys by NHP staff as of 1998, there was an estimated total of approximately 100,000 individuals in Wyoming (Fertig and Bynum 1994, Fertig 1998) and approximately 100,000 individuals in Montana (Lesica 1995). Refer to **Table 1** for abundance estimates by occurrence, as available in NHP element occurrence records (Montana Natural Heritage Program 2003b, Wyoming Natural Diversity Database 2004). *Pyrrocoma carthamoides* var. *subsquarrosa* is often locally abundant, numbering in the low hundreds to thousands of individuals (Handley and Laursen 2002). The occurrences in Wyoming, the majority of which are on USFS Region 2 lands, range in size from several hundred to several thousand individuals (**Table 1**; Wyoming Natural Diversity Database 2004). Within these occurrences, multiple sub-occurrences have been noted (Wyoming Natural Diversity Database 2004). There are seven occurrences in Wyoming that lack abundance information. Of the seven occurrences in Montana, one occurrence has 100 to 500 plants, three occurrences range in size from 500 to 1,000 individuals, two occurrences have 1,000 to 10,000 individuals, and one occurrence has up to 100,000 individuals (Montana Natural Heritage Program 2003b).

Population trends

There are no data on population trends for *Pyrrocoma carthamoides* var. *subsquarrosa*. Although population sizes have been estimated in some cases, multi-year demographic monitoring has not been initiated for any site. Of 15 occurrences in Wyoming (USFS Region 2), only six have records of multiple observations. All of the occurrences in Wyoming have been discovered or relocated since 1983, and nine have been observed since 1994. All seven of the Montana occurrences have been observed since 1995. Fertig and Mills (2000) suggest that population trends for *P. carthamoides* var. *subsquarrosa* are probably stable. The authors do not state how they reach this conclusion, presumably because they have not observed large decreases or increases in population sizes over some period of time. Element occurrences in Wyoming were ranked based on observer judgment of *P. carthamoides* var. *subsquarrosa* occurrence size and landscape context (Wyoming Natural Diversity Database 2004). Six occurrences were deemed to have excellent or good estimated viability (i.e., moderate sized occurrences, habitat in mostly good condition, threats fairly low or large-sized occurrences with good habitat and some threats). Two occurrences were determined to have fair or fair to good estimated viability due to slightly

smaller abundances compared to other occurrences. Seven occurrences were verified as extant, but viability has not yet been assessed.

Habitat characteristics

Pyrrocoma carthamoides var. *subsquarrosa* is a perennial plant found growing in bunchgrass and sagebrush/bunchgrass habitat on limestone, sandstone, or volcanic substrates in Wyoming (USFS Region 2) and Montana (USFS Region 1). Refer to **Table 2** for descriptions of habitat characteristics and associated plant species for each *P. carthamoides* var. *subsquarrosa* occurrence, if available (Montana Natural Heritage Program 2003b, Wyoming Natural Diversity Database 2004). These descriptions are presented as they are in the element occurrence records, and therefore, plant species nomenclature may not be consistent from one observation to the next.

Habitat within USFS Region 2

In Wyoming, *Pyrrocoma carthamoides* var. *subsquarrosa* grows in open rocky meadows, in sagebrush-grasslands, and on bare slopes and ridges on sandstone, limestone, or volcanic substrates in the Absaroka Mountains at elevations ranging from 1,646 to 3,140 meters (m) (5,400 to 10,300 feet [ft]) (**Table 2**; Jones and Fertig 1999, Wyoming Natural Diversity Database). The eastern flank of the Absaroka Mountains is mainly comprised of Paleozoic and Mesozoic sedimentary strata on Precambrian granite gneiss and granite; some areas are overlain by Tertiary-age andesitic volcaniclastic rocks (Fertig and Bynum 1994, Jones and Fertig 1999). *Pyrrocoma carthamoides* var. *subsquarrosa* occurrences are mainly found on limestones and dolomites of the Misissippian Madison and Amsden formations, although they occur on shale, sandstone, and volcanic substrates as well (Fertig and Bynum 1994, Jones and Fertig 1999). Although *P. carthamoides* var. *subsquarrosa* often occurs on limestone substrates, this species is not considered an obligate calceophile, like *Shoshonea pulvinata*, by WYNDD (Jones 1991). An occurrence area can include a matrix of different substrates, i.e., limestone-derived substrates may occur in close proximity to volcanic-derived substrates. Element occurrence records do not provide sufficiently detailed suboccurrence information to determine if less abundant or less dense suboccurrences may be correlated with one type of substrate or another.

Pyrrocoma carthamoides var. *subsquarrosa* is recorded from 10 habitat types in Wyoming, as presented in element occurrence records (**Table 2**; Jones and Fertig 1999, Wyoming Natural Diversity Database 2004):

- *Elymus spicatus*/*Poa secunda* meadows with scattered *Potentilla fruticosa* on calcareous soils of semi-rocky slopes;
- meadows dominated by *Poa cusickii*, *P. secunda*, *Elymus spicatus*, *Koeleria macrantha*, and *Carex* spp. with little to no *Festuca idahoensis* on humus-clay soil with much organic matter and thin rock cover of scattered limestone gravel and cobbles on upper slopes and broad ridgelines. Soils may have well-developed cryptogam crusts (with cover of *Selaginella densa* as high as 50 percent)
- *Festuca hallii-Poa secunda* community on gentle slopes on dry to moist lime-humus soil with sparse limestone gravel
- *Frasera speciosa*-bunchgrass meadows on calcareous soils on gentle slopes and ridgetops
- *Artemisia frigida-Festuca idahoensis* or *Artemisia frigida-Poa* spp. grasslands on gentle slopes with thin, dry limestone soils and significant lichen cover
- *Carex* spp.-cushion plant communities with *Poa secunda* and *Selaginella densa*
- open *Pinus flexilis* woods with *Leucopoa kingii* and *Koeleria macrantha*. Substrates are thin and dry, mostly limestone-derived, but sometimes mixed with volcanic-derived soils
- *Artemisia tridentata-Elymus spicatus* communities on volcanic soils in forest openings
- muddy roadcuts and roadsides in sparsely vegetated volcanic clays and muds
- talus slopes on reddish, fine-textured volcanic soil and pea-gravel.

Suitable slopes for *Pyrrocoma carthamoides* var. *subsquarrosa* range from 0 to 30 percent of all aspects and exposures. Depending on habitat type, ground

Table 2. *Pyrrocoma carthamoides* var. *subsquarrosa* habitat characteristics. Includes occurrence identifier, elevation range, general habitat description, and associated plant species. Sources: Lesica (1995); Reid (2001); Montana Natural Heritage Program (2003); Rocky Mountain Herbarium (2004); Wyoming Natural Diversity Database 2004).

State/County	Occurrence Identifier	Elevation Range (ft)	General Habitat Description	Associated Plant Species
Wyoming/Park County (USFS Region 2)	2224	5,400 to 8,700	Occurs in four main habitat types: (1) *Elymus spicatus/ Poa secunda* meadows with scattered *Potentilla fruticosa* on calcareous soils of semi-rocky slopes; (2) meadows dominated by *Poa cusickii*, *P. secunda*, and *Koeleria macrantha* with little to no *Festuca idahoensis* on humus-clay soil with much organic matter and thin rock cover of scattered limestone gravel on upper slopes and broad ridgelines. Woody shrubs conspicuously absent. Vegetative cover often 85 to 90 percent and usually 4 to 12 inches tall. Soils may have well-developed cryptogam crusts (with cover of *Selaginella densa* as high as 50 percent); (3) *Festuca hallii-Poa secunda* community on gentle east and west-facing slopes on dry to moist lime-humus soil with sparse limestone gravel; (4) *Frasera speciosa*-bunchgrass meadows on calcareous soils on gentle slopes and ridgetops; Highest densities of this species typically occur in areas with low cover of *Festuca idahoensis* and on drier microsites with well-developed cryptogam crusts. Many colonies occur in habitats with few to no woody shrubs. Often absent from semi-mesic sites, areas with freshly disturbed soil (from gopher activity), sites with tall cover of grass (over 12 inches tall), and areas with dense cover of *Pinus flexilis*.	*Agoseris glauca* var. *dasycephala*, *Arenaria congesta*, *Artemisia frigida*, *Astragalus miser*, *Castilleja longispica*, *C. nivea*, *Cymopterus terebinthinus*, *Festuca hallii*, *Frasera speciosa*, *Gaillardia aristata*, *Gentiana affinis*, *Heterotheca* spp., *Hymenoxys acaulis*, *Ipomopsis spicata* var. *orchidacea*, *Koeleria macrantha*, *Linum lewisii*, *Lupinus argenteus*, *Poa cusickii*, *P. secunda*, *Potentilla* spp., *P. fruticosa*, *Selaginella densa*, *Zigadenus venenosus*
	2225	7,500 to 8,245	Occurs in two main habitats: (1) sagebrush-grassland on limestone; (2) north-facing ridges with rocky outcrops and montane meadows.	Not available (NA)
	2226	10,000 to 10,600	Tundra.	NA
	2227	6,900 to 7,800	Occurs in three vegetation types: (1) *Artemisia frigida-Festuca idahoensis* grasslands; (2) *Carex nardina* - cushion plant communities; and (3) open *Pinus flexilis* woods with *Leucopoa kingii* and *Koeleria macrantha*. Substrates thin and dry, mostly derived from limestone, but sometimes mixed with volcanic-derived soils. Found on slopes and ridges of 0 to 22 percent and various aspects. Ground cover averages are: rock: 5 to 15 percent, gravel: 15 to 25 percent, bare soil: 35 to 45 percent, litter: 15 to 25 percent, and basal vegetation: 5 to 15 percent.	*Anemone patens*, *Antennaria corymbosa*, *Artemisia frigida*, *Astragalus miser*, *Carex nardina*, *Elymus spicata*, *Erigeron caespitosus*, *Eritrichium nanum*, *Festuca idahoensis*, *Hymenoxys acaulis*, *Koeleria macrantha*, *Leucopoa kingii*, *Oxytropis lagopus*, *Pinus flexilis*
	2228	6,000 to 8,592	Occurs in three main vegetation types: (1) *Artemisia frigida-Poa* spp. and *Artemisia frigida-Festuca* spp. communities on gentle slopes (0 to 15 percent) with thin, dry limestone soils and significant lichen cover; (2) *Artemisia tridentata-Elymus spicatus* community on volcanic soils in forest openings; (3) *Elymus spicatus-Koeleria macrantha* meadow community on gentle east to southwest-facing slopes on thin, dry, humus-clay-limestone soil with scattered dolomitic gravel. Vegetative cover ca 60 to 70 percent. Typically absent from meadows with high cover of *Festuca idahoensis*, limestone bedrock flats with dense cryptogam cover, *Pinus flexilis* savannas with deep needle duff soil, and calcareous areas with high cover of *Artemisia tridentata*.	*Achillea millefolium*, *Agoseris glauca*, *Astragalus adsurgens* var. *robustior*, *A. miser*, *Arenaria congesta*, *Artemisia frigida*, *A. tridentata*, *Castilleja linariifolia*, *Crepis acuminata*, *Elymus spicatus*, *Erigeron caespitosus*, *Festuca hallii*, *F. idahoensis*, *Koeleria macrantha*, *Leucopa kingii*, *Lithospermum ruderale*, *Mertensia viridis*, *Oxytropis lagopus*, *Poa* spp., *Senecio canus*, *Solidago multiradiata*
	2229	6,800	Calcareous substrate, grassy plains.	NA

Table 2 (cont.).

State/County	Occurrence Identifier	Elevation Range (ft)	General Habitat Description	Associated Plant Species
	2230	7,200 to 8,200	Roadside.	NA
	2231	7,400 to 10,000	Open ridge with adjacent conifer woodland.	NA
	2232	6,400 to 6,600	Meadows back from the first rim.	NA
Wyoming/Park County (USFS Region 2)	2233	8,600 to 9,300	Occurs in three main habitats: (1) sparsely vegetated summits and slopes of south-southwest trending ridges of volcanic deposits in *Poa secunda*-*Carex* spp. grassland with scattered cushion plants. Vegetative cover about 25 to 35 percent and locally rich in cryptogams and *Selaginella densa*; (2) roadsides and roadcuts in sparsely vegetated volcanic clays and muds; (3) uncommon in calcareous meadows dominated by *Festuca idahoensis* and *P. secunda* on south-dipping slopes. Vegetative cover about 75 to 80 percent.	*Agoseris glauca*, *Arenaria hookeri*, *Besseya wyomingensis*, *Carex* spp., *Erigeron compositus*, *Lesquerella alpina*, *Minuartia obtusiloba*, *Poa secunda*, *Selaginella densa*
	2234	7,280 to 8,000	Occurs in two main vegetation types: (1) dry, west-facing grassland slopes dominated by *Elymus spicatus*, *Festuca idahoensis*, and *Leucopoa kingii* with scattered pockets of cushion plant communities at the edge of limber pine savanna on limestone gravel and bedrock; (2) dry meadows and talus slopes on reddish, fine textured volcanic soil and pea-gravel.	*Antennaria microphylla*, *Artemisia frigida*, *Castilleja nivea*, *Elymus spicatus*, *Festuca idahoensis*, *Koeleria macrantha*, *Leucopoa kingii*, *Poa secunda*, *Shoshonea pulvinata*
	2235	6,920	Observed in two main vegetation types: (1) *Elymus spicatus*/*Carex filifolia* grassland on east and west-facing slopes of 9 to 30 degrees in full sun. Soil derived from limestone with high cover of cobbles and gravel on the surface; (2) draw with *Artemisia tridentata* var. *wyomingensis*.	*Artemisia tridentata* var. *wyomingensis*, *Carex filifolia*, *Elymus spicatus*, *Erigeron* spp., *Koeleria macrantha*, *Orthocarpus* spp., *Parmelia* spp., *Poa secunda*
	2236	8,300 to 8,900	Open meadows on slopes and summits of low knolls on pockets of deep, dark, calcareous soil with rich organic matter. May occur in areas of high grass cover (90 to 100 percent), or in sites with more exposed gravels (vegetative cover 60 to 70 percent). Meadows dominated by *Festuca idahoensis*, *Koeleria macrantha*, or locally by *F. halli*. May also be found at edges of burned groves of *Pinus contorta*, but absent from rim sites dominated by conifer or *Artemisia tridentata* var. *vaseyana* communities.	*Agoseris glauca*, *Antennaria umbrinella*, *Campanula rotundifolia*, *Elymus trachycaulus*, *Danthonia intermedia*, *Delphinium* spp., *Festuca halli*, *F. idahoensis*, *Gentiana affinis*, *Geum triflorum*, *Helictotrichon hookeri*, *Koeleria macrantha*, *Minuartia obtusiloba*, *Saxifraga rhomboidea*, *Shoshonea pulvinata*
	2237	6,800 to 6,900	Occurs in two main vegetation types: (1) *Elymus spicatus*-*Koeleria macrantha*-*Carex filifolia* meadow at edge of *Artemisia tridentata* thickets on fine-textured calcareous clay with abundant surface cover of white limestone fragments, chips, and rock; (2) cushion plant-bunchgrass community with occasional *Pinus flexilis* and scattered *Chrysothamnus nauseous* on semi-bare clay limey soils with abundant cover of rounded cobbles.	*Allium geyeri*, *Arenaria hookeri*, *Astragalus miser*, *Balsamorhiza sagittata*, *Carex filifolia*, *Chrysothamnus nauseous*, *Comandra umbellata*, *Elymus spicatus*, *Hymenoxys acaulis*, *Ipomopsis spicatus* var. *orchidaceus*, *Koeleria macrantha*, *Lupinus argenteus*, *Oxytropis besseyi*, *Pinus flexilis*
	2238	8,100 to 8,200	Open, stony volcanic ridge.	NA

Table 2 (concluded).

State/County	Occurrence Identifier	Elevation Range (ft)	General Habitat Description	Associated Plant Species
Montana/ Carbon County (USFS Region 1)	001	6,000 to 6,280	Dry, open residual mountain midslope. Limestone parent material, stony soil.	*Agropyron spicatum*, *Antennaria microphylla*, *Astragalus miser*, *Chrysothamnus nauseosus*, *Erigeron caespitosus*, *Haplopappus acaulis*, *Koeleria cristata*, *Phlox hoodii*
Montana/ Carbon County (USFS Region 1)	002	5,640 to 7,200	Dry, open lowerslope foothills of glaciated mountains. Limestone parent material.	*Agropyron spicatum*, *A. dasystachyum*, *Antenniaria microphylla*, *Artemisia frigida*, *A. nova*, *A. tridentata* (burned), *Astragalus adsurgens*, *A. miser*, *Carex filifolia*, *Chrysothamnus nauseosus*, *Erigeron caespitosus*, *Festuca idahoensis*, *Hesperocloa kingii*, *Hymenoxys acaulis*, *Koeleria cristata*, *Lupinus sericeus*, *Oxytropis sericea*, *Phlox hoodii*, *Pinus flexilis*, *Pseudotsuga menziesii*, *Stipa comata*
	004	5,600 to 6,400	Dry, open residual mountain midslope. Limestone parent material, stony soil.	*Agropyron spicatum*, *Antennaria microphylla*, *Artemisia tridentata* var. *vaseyana*, *Chrysopsis villosa*, *Chrysothamnus nauseosus*, *Erigeron caespitosus*, *Festuca idahoensis*, *Hymenoxys acaulis*, *Phlox hoodii*, *Selaginella densa*, *Senecio canus*
	005	6,600 to 6,880	Dry, open glaciated mountain midslope. Granitic talus parent material, stony soil.	*Agropyron spicatum*, *Artemisia tridentata* var. *vaseyana*, *Festuca idahoensis*
	006	6,600 to 6,880	Dry, open short glacial mountain slope. Granitic talus parent material, stony soil. Site characterized by 5 to 20 percent slopes of varying aspects (mostly west and northwest). Canopy cover of 15 percent shrub, <5 percent forbs, 70 percent grass, and 5 percent bare ground. Site was rocky and bare ground was greater in areas with rodent activity.	*Achillea* spp., *Agropyron spicatum*, *Amelanchier* spp., *Anemone* spp., *Antennaria microphylla*, *Artemisia frigida*, *A. tridentata* ssp. *vaseyana*, *A. tridentata* ssp. *wyomingensis*, *Carex filifolia*, *Chrysopsis villosa*, *Comandra* spp., *Erigeron caespitosus*, *Erigeron* spp., *Eriogonum* spp., *Festuca idahoensis*, *Geum* spp., *Heterotheca villosa*, *Juniperus* spp., *Koeleria* spp., *Leucopoa kingii*, *Lomatium* spp., *Phlox hoodii*, *Poa pratensis*, *P. secunda*, *Prunus* spp., *Ribes* spp., *Rosa woodsii*, *Selaginella* spp., *Stipa comata*
	007	5,880 to 7,240	Dry, open foothills and mountain grassland openings. Limestone/sandstone parent material, stony soil. Extending across blister rust-infected pine parkland with *Shoshonea pulvinata*.	*Agropyron spicatum*, *Astragalus adsurgens*, *Carex filifolia*, *Chrysothamnus nauseosus*, *Erigeron caespitosus*, *Gutierrezia sarothrae*, *Shoshonea pulvinata*
	008	5,520 to 5,760	Dry, open mid-to-upper residual mountain slope. Limestone parent material, stony soil.	*Agropyron spicatum*, *Artemisia frigida*, *A.a nova*, *Erigeron caespitosus*, *Gutierrezia sarothrae*, *Hymenoxys acaulis*, *Koeleria cristata*, *Phlox hoodii*, *Pinus flexilis*

cover can include varying percentages of rock, gravel, bare soil, litter, and basal vegetation, and vegetative cover can range from 10 to 90 percent (**Table 2**).

Within these habitat types, *Pyrrocoma carthamoides* var. *subsquarrosa* is typically absent from meadows with high cover of *Festuca idahoensis* or other grasses over 12 inches tall, limestone bedrock flats with dense cryptogam cover, *Pinus flexilis* savannas with deep needle duff soil, calcareous areas with dense cover of *Artemisia tridentata* or other woody shrubs, semi-mesic sites, highly disturbed roadsides, or areas with freshly disturbed soil (from gopher activity) (**Table 2**; Wyoming Natural Diversity Database 2004).

Habitat outside USFS Region 2

In Montana (USFS Region 1), *Pyrrocoma carthamoides* var. *subsquarrosa* grows in relatively mesic grassland on calcareous substrates at elevations ranging from 1,677 to 2,195 m (5,500 to 7,200 ft). It is most commonly found from 1,829 to 1,981 m (6,000 to 6,500 ft) (**Table 2**; Lesica 1995).

This taxon is recorded from three main habitat types in Montana (Lesica 1995):

- *Festuca idahoensis/Agropyron spicatum* grasslands
- *Artemisia tridentata/Festuca idahoensis* grasslands
- *Artemisia arbuscula/Agropyron spicatum* grasslands.

In these habitats, shrub cover is generally low (1 to 5 percent), grass cover is generally moderate (20 to 50 percent), forb cover is generally high (30 to 75 percent), and bare ground is low to moderate (0 to 30 percent) (**Table 2**; Lesica 1995, Montana Natural Heritage Program 2004).

Soils in these habitats are moderately deep with high coarse fragment content, and they are derived exclusively from Madison limestone, from gravels of limestone and granitic origins, or entirely granitic soils (**Table 2**). The topography is generally moderate to steep slopes (10 to 50 percent) with a cool aspect (i.e., north, northwest, northeast, and east). While *Pyrrocoma carthamoides* var. *subsquarrosa* can be found on south facing, more gentle slopes, it tends to be sparser in those areas (Lesica 1995, Montana Natural Heritage Program 2004).

Reproductive biology and autecology

The biology of *Pyrrocoma carthamoides* var. *subsquarrosa* has not been studied, and details concerning its reproductive system are largely unknown. In this and subsequent sections, we summarize available observations of *P. carthamoides* var. *subsquarrosa* as well as present information, where available, from other *Pyrrocoma* species endemic to USFS Region 2 or adjacent states. These comparisons are not meant to imply that *P. carthamoides* var. *subsquarrosa* necessarily reproduces in a similar manner, but they represent an effort to elucidate *potential* reproductive mechanisms for this species and suggest avenues for future research.

Reproduction

Members of the family Asteraceae produce an inflorescence (head, capitulum) with many small flowers (florets). An inflorescence is a radiate head comprised of both "ray" florets (with strap-like corolla) arranged on the head margin and "disc" florets (with tubular corolla) in the center of the head. The ray florets are either pistillate (female) or sterile, and the disc florets are staminate (male) or perfect (male and female) (Zomlefer 1994).

Pyrrocoma carthamoides var. *subsquarrosa* begins to flower in late July and continues flowering throughout August (Lesica 1995, Fertig and Mills 2000). Mature fruit can be found from late August through September. Plants appear to flower earlier on the Beartooth front compared to north slopes of the Pryor Mountains (Lesica 1995). Reproduction is entirely by seed; there is no evidence of vegetative reproduction (Lesica 1995). Mancuso and Moseley (1993) also discovered that *P. radiatus*, a closely related goldenweed from similar habitats in Idaho, reproduces solely by seed. Element occurrence observations of *P. carthamoides* var. *subsquarrosa* noted that reproductive success was high, with high proportions of the occurrences producing flowers and fruits (Wyoming Natural Diversity Database 2004). Refer to the following sections for further information: Life history and strategy, Pollinators and pollination ecology, and Dispersal mechanisms.

Life history and strategy

There have been no studies on the life history, demographic rates, fecundity, or longevity of *Pyrrocoma carthamoides* var. *subsquarrosa* (Lesica 1995). It is a perennial forb growing with a stout,

woody rootcrown in dry grasslands. The competitive relationships, ecological limitations, and reproductive biology of *P. carthamoides* var. *subsquarrosa* are really not adequately known to assess the life history and strategy of this species based on vegetation strategies described by Grime (1979). Stress-tolerant or "S-selected" species have a perennial life history, an ability to withstand harsh or unproductive environments, and a capability to access resources with well-developed roots (Grime 1979, Barbour et al. 1987). Ruderal or "R-selected" species can exploit low stress, high disturbance environments by minimizing vegetative growth and maximizing reproductive output (Grime 1979, Barbour et al. 1987). Good competitors, or "C-selected" species, tend to be robust, perennial plants that can maximize resource capture in relatively undisturbed conditions and allocate resources to growth (Grime 1979, Barbour et al. 1987). It is possible that *P. carthamoides* var. *subsquarrosa* could be considered an S-selected, or stress-tolerant, species because of its perennial life history, ability to withstand relatively unproductive conditions, and capability to access resources with a taproot (Grime 1979, Barbour et al. 1987). The hypothesized life cycle of this perennial plant is depicted in **Figure 3**.

Pollinators and pollination ecology

Pollination biology and specific pollination mechanisms for *Pyrrocoma carthamoides* var. *subsquarrosa* have not been studied. Members of the Asteraceae family are well equipped to attract pollinators and to disperse pollen. The showy inflorescences attract pollinators and allow many flowers to be visited in

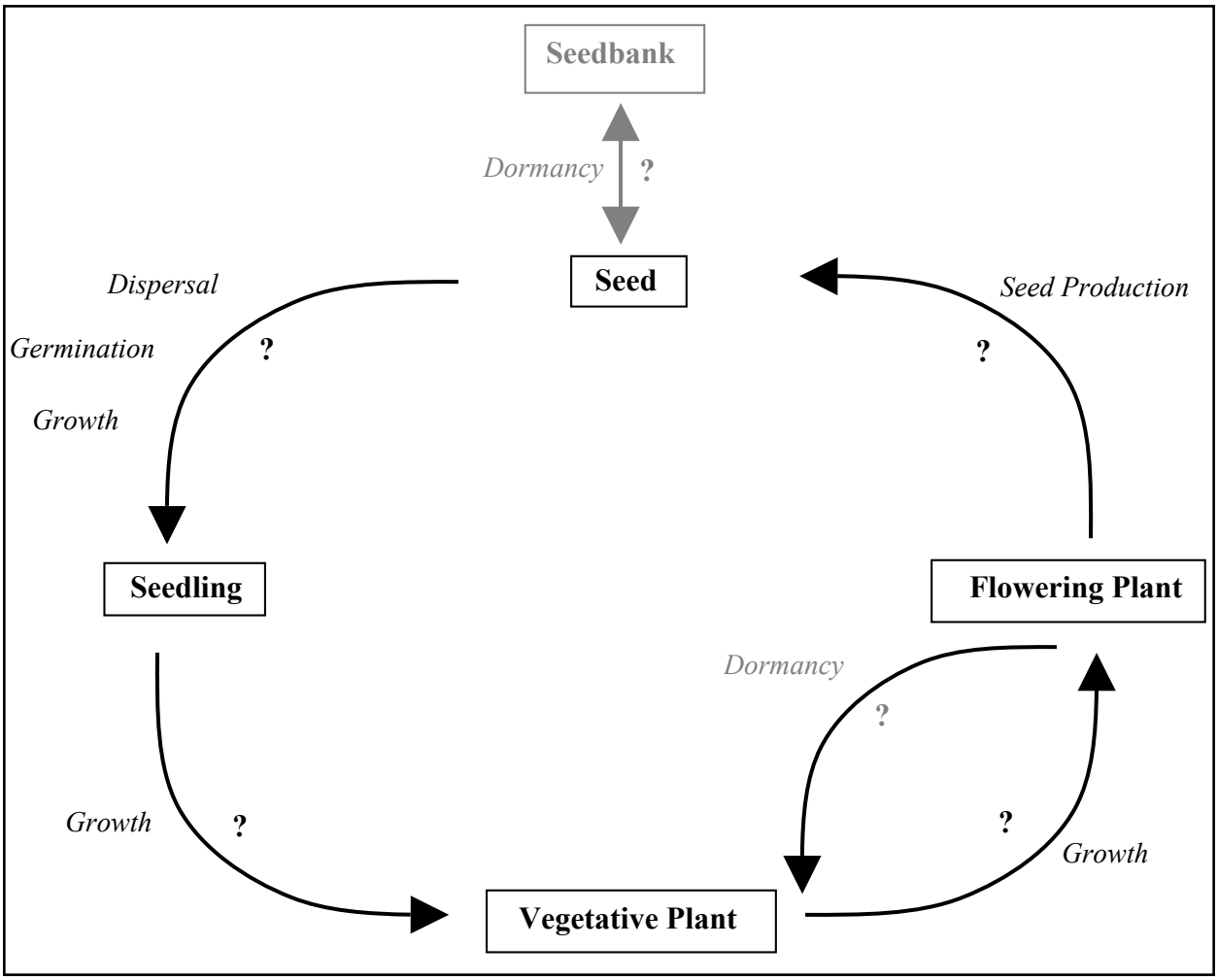


Figure 3. Schematic representation of the hypothesized life cycle of *Pyrrocoma carthamoides* var. *subsquarrosa*. Rates of recruitment, growth, dormancy, fecundity, and dispersal are unknown and are indicated by "?". The presence of a seedbank is also unknown for this species. There is no evidence of vegetative reproduction in this species. Death at each stage and mortality rates are not indicated on this figure. Figure adapted from Grime (1979).

a short time. In addition, unique flower adaptations cause nectar and pollen to be easily accessed and dispersed by pollinators (Zomlefer 1994). Bumblebees (Apidae, *Bombus* spp.) and sulphur butterflies (Pieridae, *Colias* spp.) were seen visiting *P. carthamoides* var. *subsquarrosa* in Montana (Lesica 1995, Montana Natural Heritage Program 2004). Moseley and Mancuso (1993) recorded a diverse assemblage of bumblebees, solitary bees, flies, and butterflies visiting *P. radiatus* plants in Idaho. Lesica (1995) believed that pollination for *P. carthamoides* var. *subsquarrosa* is unlikely to be a limiting factor because pollinators are abundant in August, and there are not many other flowering species competing for pollination in that habitat at that time.

Important issues related to the pollination of rare plants that have yet to be researched for *Pyrrocoma carthamoides* var. *subsquarrosa* include the extent of self-pollination (if any), the identity of effective pollinators, the effect of plant density on pollination, the genetic implications of pollination, the presence of pollinators at different sites, and the effects of environmental fluctuations on pollinators or pollination. *Pyrrocoma radiatus* in Idaho can self-pollinate but requires insect pollinators for maximum seed set (Mancuso and Moseley 1993).

Dispersal Mechanisms

Details of seed dispersal mechanisms in *Pyrrocoma carthamoides* var. *subsquarrosa* are not known. This taxon has numerous bristles on the achenes, which presumably act like a small parachute during wind dispersal (Zomlefer 1994, Lesica 1995, Handley and Laursen 2002). Achenes are shed in the late summer and fall, when windy weather is common (Lesica 1995). Animal dispersal by seeds sticking to the fur of deer or elk is also possible (Lesica 1995, Montana Natural Heritage Program 2004). Mancuso and Moseley (1993) hypothesized that *P. radiatus* seeds fall to the ground, where wind, sheets of rain, and animal vectors may move them. Presumably, dispersal success of *P. carthamoides* var. *subsquarrosa* depends on wind and precipitation patterns, animal activities, topographic heterogeneity, and availability of suitable "safe" sites.

Seed viability and germination requirements

No information is available concerning the fertility, seed viability, and germination requirements of *Pyrrocoma carthamoides* var. *subsquarrosa* (Lesica 1995). The seeds of *P. radiatus* in Idaho appear to have few germination requirements; seeds will germinate readily under a range of temperatures throughout the fall, winter, and spring. Most germination occurs in the spring, perhaps as a result of winter freezing and spring moisture (Mancuso and Moseley 1993).

Phenotypic plasticity

Phenotypic plasticity is demonstrated when members of a species vary in height, leaf size, flowering time, or other attributes, with change in light intensity, latitude, elevation, or other site characteristics. Lesica (1995) noted that a greater proportion of plants were flowering at sites in the Beartooth Mountains compared to those in the Pryor Mountains, perhaps as a result of elevation, climate differences, or differences in site quality.

Cryptic phases

No information regarding cryptic phases of *Pyrrocoma carthamoides* var. *subsquarrosa* is available. Seed dormancy can be an important adaptation for plant populations to exploit favorable conditions in a harsh environment (Kaye 1997). It is not known whether a persistent seed bank exists or what the extent of seed dormancy is for *P. carthamoides* var. *subsquarrosa*. Details of seed longevity, patterns of seed dormancy, and factors controlling seed germination for *P. carthamoides* var. *subsquarrosa* have not been studied.

Mycorrhizal relationships

The existence of mycorrhizal relationships with *Pyrrocoma carthamoides* var. *subsquarrosa* or related species was not reported in the reviewed literature.

Hybridization

There was no evidence of hybridization with *Pyrrocoma carthamoides* var. *subsquarrosa* in Montana (Lesica 1995), nor any reported occurrences in Wyoming. Some species in the Asteraceae are known to hybridize with congeners, as well as with species from other genera (e.g. *Aster*, *Haplopappus*, *Machaeranthera*) (Hartman 1976).

Demography

Life history characteristics

There is no information regarding population parameters or demographic features of *Pyrrocoma carthamoides* var. *subsquarrosa*, such as metapopulation dynamics, life span, age at maturity, recruitment, and survival. Refer to **Figure 4** and **Figure 5** for

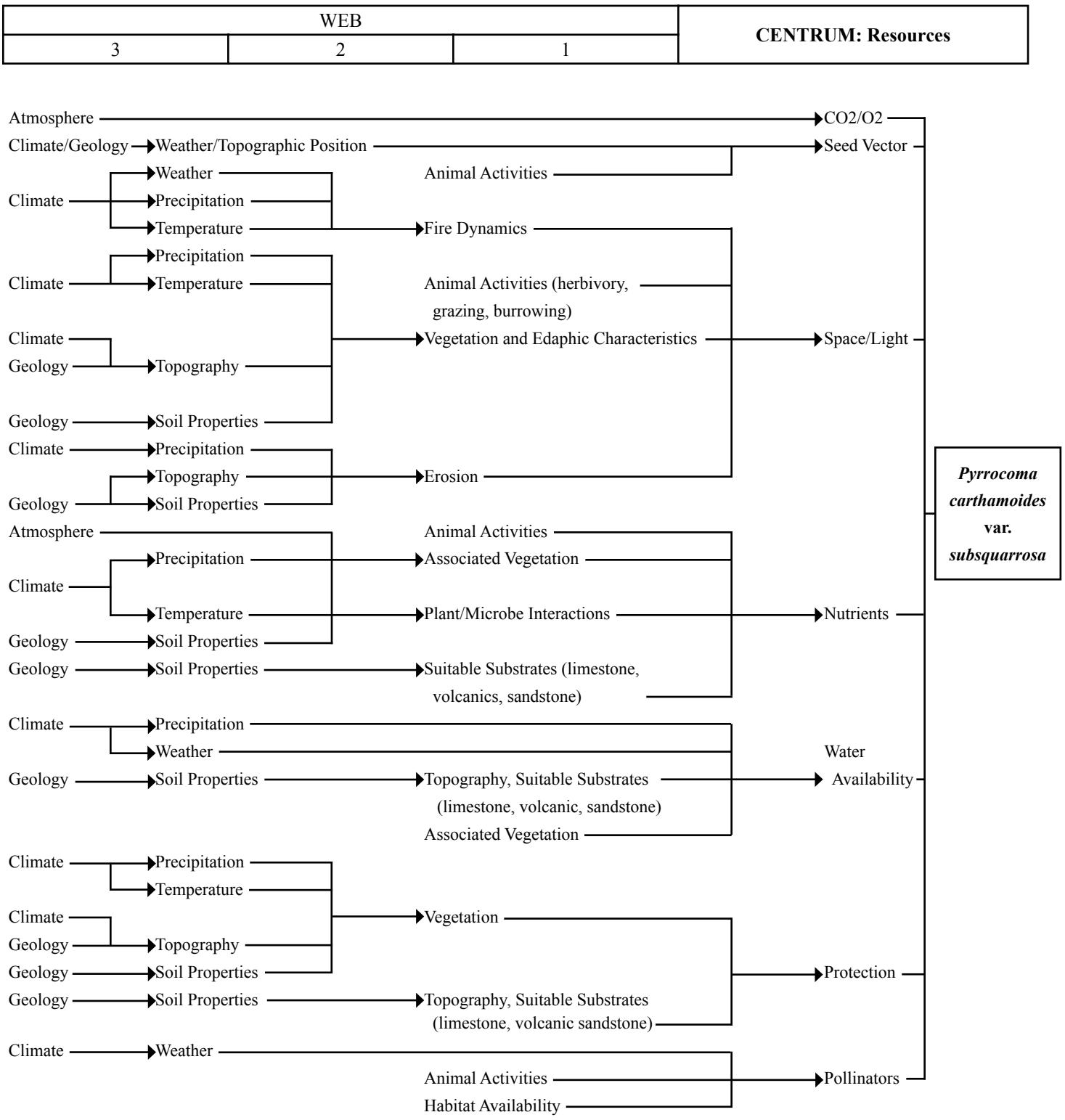


Figure 4. Envirogram outlining resources for *Pyrrocoma carthamoides* var. *subsquarrosa*.

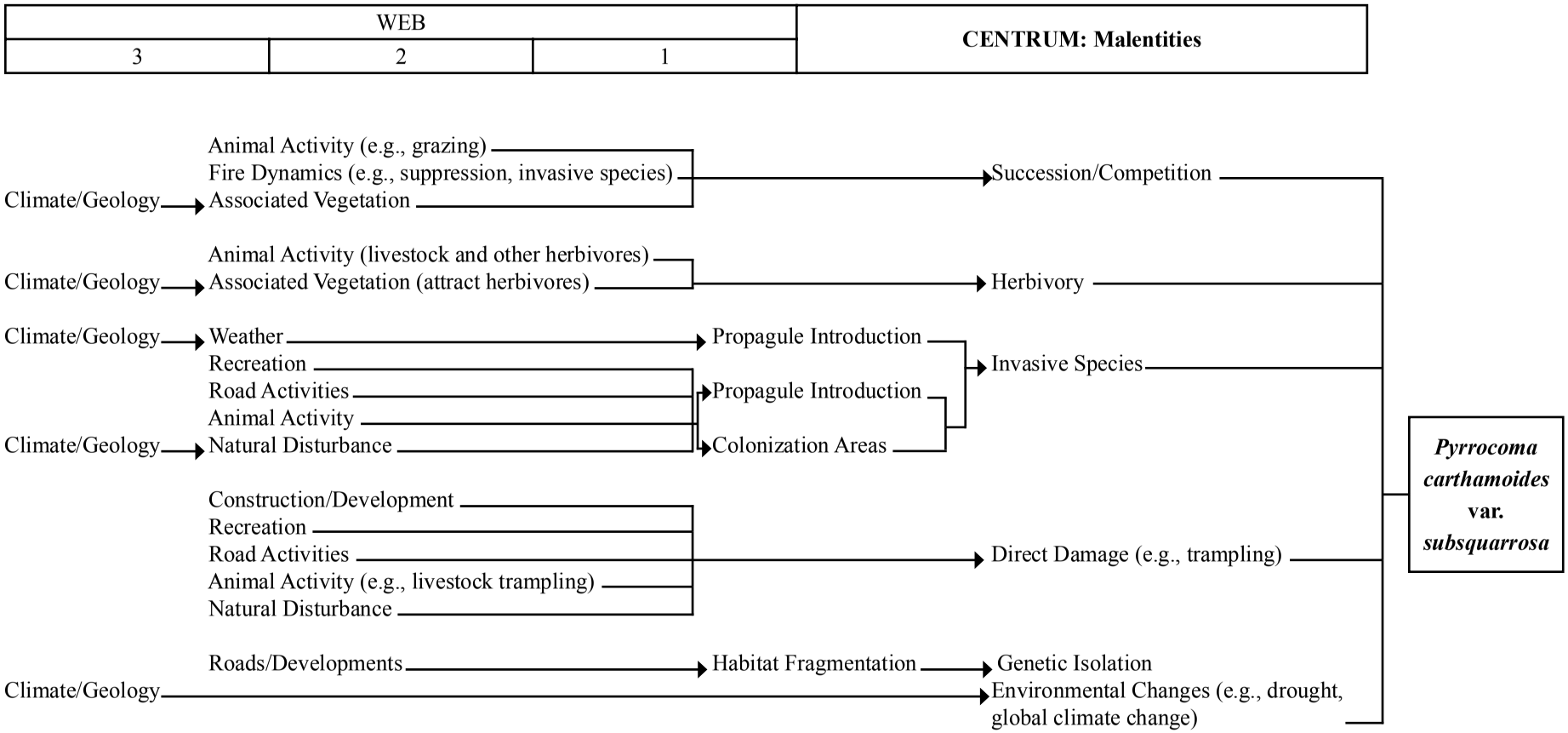


Figure 5. Envirogram outlining malentities to *Pyrrocoma carthamoides* var. *subsquarrosa*.

envirograms outlining resources and malentities important to *P. carthamoides* var. *subsquarrosa*. First introduced by Andrewartha and Birch (1984) for animal species, an envirogram is a schematic diagram that depicts relationships between a target organism and environmental conditions. The centra are the main categories (i.e., resources and malentities) that directly affect the target species, and the web outlines factors that indirectly influence the centra. The web depicts the most distal to most proximal factors using linear, one-way branches. Because there is a paucity of ecological information about this species, the envirograms outline hypothesized resources and malentities that are *potentially* important for *P. carthamoides* var. *subsquarrosa*. Additional information would be needed to create more comprehensive and specific envirograms.

Life cycle diagram and demographic matrix. A life cycle diagram is a graphical model representing the dominant life history stages for a species and the transitions between those stages or vital rates. The diagram consists of a series of nodes that represent the different life stages connected by various arrows for vital rates (i.e., survival rate, fecundity). Demographic parameters, such as recruitment and survival rates, are not currently available for *Pyrrocoma carthamoides* var. *subsquarrosa*, and so there are no definitive data regarding the vital rates that contribute to species fitness. Although stage-based models based on population matrices and transition probabilities can be used to assess population viability (Caswell 2001), adequate quantitative demographic data are needed for input into the model. For *P. carthamoides* var. *subsquarrosa*, the stages that could potentially be incorporated into a demographic matrix include seed, seedling, vegetative individuals, and reproductive adults (**Figure 3**).

Presumably, seeds of *Pyrrocoma carthamoides* var. *subsquarrosa* are dispersed to suitable locations. The probability of germination and subsequent establishment depends on the longevity of these propagules and whether appropriate environmental conditions exist for germination and growth. Seeds that germinate will grow into seedlings, assimilate resources, and mature into reproductive individuals. Growth rates may be influenced by the intensity and frequency of disturbance and the availability of resources, such as space, light, moisture, and nutrients. Successful seed set will depend on the rate of pollen and ovule formation, pollination, fertilization, and embryo development. Fecundity rates depend on the production of seeds and the percentage of those seeds that survive to germination in subsequent years.

Population viability analysis. In order to initiate a population viability assessment for *Pyrrocoma carthamoides* var. *subsquarrosa*, the rates of germination, fecundity, survival, and other important parameters require additional study.

Ecological influences on survival and reproduction

Germination, growth, seed production, and long-term persistence of *Pyrrocoma carthamoides* var. *subsquarrosa* most likely depend on a range of ecological influences over many years, including climatic fluctuations, microsite conditions, grazing levels, disturbance patterns, interspecific competition, seed predation, and pollinator activities. Refer to **Figure 4** for an envirogram outlining resources important to *P. carthamoides* var. *subsquarrosa*. There is little information on the capabilities of *P. carthamoides* var. *subsquarrosa* to disperse, colonize, and establish new occurrences around the landscape. The establishment of new occurrences most likely depends on barriers to dispersal and the availability of suitable germination sites and conditions. The rate of population growth is also influenced by factors that affect sexual reproduction, such as pollinator limitations.

It is also unclear what type, size, intensity, or frequency of disturbance regime is important for *Pyrrocoma carthamoides* var. *subsquarrosa*. Several observations suggest that *P. carthamoides* var. *subsquarrosa* relies on periodic or moderate disturbances to keep habitats relatively open (Fertig 1995, Lesica 1995, Evert personal communication 2003, Wyoming Natural Diversity Database 2004). Disturbances in these environments can include grazing/herbivory, erosion, fire, blowdowns, wind-scouring, small mammal activity, environmental fluctuations, and human influences. In Wyoming, *P. carthamoides* var. *subsquarrosa* appears to thrive in areas with low competition from dense grass, shrubs, or trees. Fertig (1995) suggested that periodic disturbances or edaphic features may be important factors in determining species distributions. Evert (personal communication 2003) also added that many of the sites with *P. carthamoides* var. *subsquarrosa* are dry and wind-scoured with rocky substrates, and these somewhat harsh conditions probably prevent overcompetition by other species. In Montana, *P. carthamoides* var. *subsquarrosa* grows on cool, slightly mesic slopes where grass vegetation is relatively dense (Lesica 1995). However, this taxon was absent or sparsely distributed where shrub or tree cover was greater than 10 percent. Lesica (1995) suggested

that fire and grazing are important forces shaping this landscape (Montana Natural Heritage Program 2004). The relationships between *P. carthamoides* var. *subsquarrosa*, other vegetation, and fire dynamics have not been studied. However, if *P. carthamoides* var. *subsquarrosa* does not tolerate the shade in a dense stand of sagebrush or limber pine, then fire could play a role in thinning the dominant overstory species and maintaining open habitat for this taxon in areas where succession would tend toward dense shrubs or trees (Montana Natural Heritage Program 2004). It is possible that *P. carthamoides* var. *subsquarrosa* will only occur on sites that do not support dense stands of sagebrush or trees or where they are burned frequently enough to prevent dominance (Montana Natural Heritage Program 2004). Lesica (1995) noted that a large occurrence of *P. carthamoides* var. *subsquarrosa* was found at the site of a 1992 wildfire that reduced dominance by *Artemisia tridentata*. Presumably this fire facilitated the colonization by *P. carthamoides* var. *subsquarrosa* at this site or existing *P. carthamoides* var. *subsquarrosa* individuals survived and flourished after the fire. The effect of high-intensity or low-intensity fires on the survivorship of individuals is unknown; *P. carthamoides* var. *subsquarrosa* is somewhat resinous and may possibly burn hot during a fire. Refer to the Competitors and relationship to habitat section for more discussion about fire dynamics.

Pyrrocoma carthamoides var. *subsquarrosa* appeared to be most common where it was coexisting with other unpalatable forbs, suggesting that moderate cattle grazing facilitated the growth of unpalatable forbs, including *P. carthamoides* var. *subsquarrosa*, by reducing competition with palatable grasses and forbs (Lesica 1995). However, it is also possible that heavy grazing could shift a community from grassland to shrubland, eventually leading to an unsuitable community for *P. carthamoides* var. *subsquarrosa* (Lesica 1995). Refer to the Herbivores and relationship to habitat section for more discussion about grazing dynamics.

These disturbances could either create suitable habitat throughout a landscape or directly impact an existing occurrence, depending on the intensity and location of the disturbance. For example, WYNDD (2004) records noted that *Pyrrocoma carthamoides* var. *subsquarrosa* was absent from areas with freshly disturbed soil from small mammal activity. However, small mammal activities likely open up spaces in dense vegetation where potential future colonization could take place by *P. carthamoides* var. *subsquarrosa* or other species. The type, size, frequency, and intensity of disturbances that define the natural disturbance regime and would affect colonization and extirpation events are unknown. The spatial relationships between edaphic characteristics, competition with other species, disturbance factors, and *P. carthamoides* var. *subsquarrosa* are likely important issues for understanding this taxon and warrant further study.

Spatial characteristics

The factors governing the spatial distribution of *Pyrrocoma carthamoides* var. *subsquarrosa* have not been studied. This taxon ranges from dense and locally common to sparsely-distributed with scattered colonies (Montana Natural Heritage Program 2003b, Wyoming Natural Diversity Database 2004). One occurrence is described as covering an area of several square miles, comprised of up to 14 different suboccurrences (colonies) with plants in large clusters of 50 to 100 plants at a density of 10 to 15 plants per square meter (Wyoming Natural Diversity Database 2004). In the case of sparsely distributed occurrences, the occurrence area is often extensive, but large portions of the area are unoccupied (Lesica 1995). In harsh environments especially (e.g., wind swept ridges), Evert (personal communication 2003) observed *P. carthamoides* var. *subsquarrosa* distributed as small colonies with fewer than 12 individuals with several miles in between colonies. Metapopulations likely occur where *P. carthamoides* var. *subsquarrosa* occupies several suitable sites on a ridge or slope, for example. The spatial configuration of metapopulations or the extent to which gene flow occurs between local and distant populations is unknown for this taxon. Characteristics that could influence the spatial distribution of this rare taxon may include habitat availability (e.g., edaphic characteristics), seed dispersal patterns, competition with other vegetation, landscape and microsite heterogeneity, and disturbance patterns. As discussed above, the relationships between edaphic characteristics, competition with other species, disturbance factors, and *P. carthamoides* var. *subsquarrosa* have not been studied.

Genetic characteristics and concerns

Genetic concerns, such as the amount of genetic variability between and within populations, have not been studied for *Pyrrocoma carthamoides* var. *subsquarrosa*. Issues related to gene flow, inbreeding, and genetic isolation could affect the demography, ecology, management considerations, and long-term persistence for this taxon. Assessing the genetic variability of populations is also important for establishing conservation plans to protect genetic diversity and to design reintroduction plans (Hollingsworth et al. 1998).

At this time, no extirpated sites have been identified for *P. carthamoides* var. *subsquarrosa*.

To elucidate phylogenetic relationships of closely related genera within Asteraceae, Morgan and Simpson (1992) analyzed chloroplastic genomes. They verified that *Pyrrocoma* is characterized by a base chromosome count of n=6. In addition, they found that *Pyrrocoma* is closely allied to *Machaeranthera* section *Arida* and may share a common ancestor despite widely differing habit, habitat, and morphology. These observations suggest that further phylogenetic work is warranted on closely related genera of Asteraceae, including *Pyrrocoma* and *Machaeranthera*. Mayes (1976) indicates that there is significant morphological variation in *Haplopappus carthamoides*. In their study of the *P. radiatus* (*H. radiatus*), Mancuso and Moseley (1993) noted that there are blurred relationships within the genus *Haplopappus* (*Pyrrocoma*), resulting in some taxonomic uncertainties (e.g., in the *radiatus-carthamoides* group). Further studies could help to resolve some of these taxonomic uncertainties. Studying the taxonomic status of *P. carthamoides* var. *subsquarrosa* and its relationship to other closely-related taxa (i.e., *P. carthamoides* var. *carthamoides*, *P. carthamoides* var. *cusickii*) may help to determine if this taxon is distinct enough to consider as a species or whether it should continue to be treated as a variety of a more widespread species. Refer to Mayes (1976) for a further discussion of *Pyrrocoma* systematics.

Factors limiting population growth

Based on the information presented in the preceding sections, population growth or establishment of *Pyrrocoma carthamoides* var. *subsquarrosa* could be limited by competition with other species (e.g., grasses, shrubs, trees, invasive species), inadequate dispersal, ineffective pollination, insufficient genetic variability for long-term persistence, or reduced habitat availability as a result of changes to the natural disturbance regime. The rate at which colonization and establishment of new populations occurs is unknown.

Community ecology

Herbivores and relationship to habitat

Cattle grazing, at a range of intensities, occurs on many sites with *Pyrrocoma carthamoides* var. *subsquarrosa* (Montana Natural Heritage Program 2003b, Wyoming Natural Diversity Database 2004); the number of sites in USFS Region 2 with grazing has not been quantified. At one site in Montana, evidence of heavy grazing was clear (i.e., many cowpies and closely grazed grasses), but *P. carthamoides* var. *subsquarrosa* appeared untouched, perhaps due to its tough, spiny tissues and resinous chemicals (Lesica 1995). Reid (2001) observed an occurrence of *P. carthamoides* var. *subsquarrosa* on a grazing allotment on the Custer National Forest in USFS Region 1. The allotment is managed as part of a deferred grazing system, and livestock use on the allotment was estimated at 70 to 75 percent at the time of observations. The researcher did not see foraging on the species and hypothesized that this forb is coarse and spiny and thus unpalatable to cattle. However, trampling on several individuals of *P. carthamoides* var. *subsquarrosa* was photographed. In addition, Reid (2001) observed an area outside the grazed allotment for comparison. She concluded that *P. carthamoides* var. *subsquarrosa* was more robust and had more flowering stalks and vegetative composition was better in the ungrazed plot compared to the grazed plot. Fertig's (1995) analysis of livestock grazing on the Shoshone National Forest also concluded that *P. carthamoides* var. *subsquarrosa* is probably not palatable and thus has low vulnerability to grazing. In addition, many of the Wyoming sites where *P. carthamoides* var. *subsquarrosa* occurs are probably not attractive to cattle because of low availability of forage and water (Fertig 1995). However, as discussed previously, cattle grazing may play an important role in successional and competition-related dynamics in these landscapes by potentially minimizing competition from palatable species (Lesica 1995, Montana Natural Heritage Program 2004). On the other hand, if overgrazing facilitated shrubby growth or exotic grasses, it is possible that those species would compete with *P. carthamoides* var. *subsquarrosa* and effectively eliminate it by creating unfavorable habitat. In addition, cattle grazing at high intensities is associated with heavy trampling, which can directly impact plants by knocking over or crushing flowering stalks and by compacting the soil. In Montana, Lesica (1995) concluded that *P. carthamoides* var. *subsquarrosa* populations would likely remain stable or increase in areas with moderate cattle grazing. However, Lesica (1995) did not extend that same conclusion to sheep grazing, as sheep often browse on forbs that are unpalatable to cattle. Reid (personal communication 2003) noted that sheep grazing does not occur on *P. carthamoides* var. *subsquarrosa* habitat in Montana. Elk and deer also graze in these habitats, but the palatability of *P. carthamoides* var. *subsquarrosa* to native herbivores is probably minimal as well (Welp et al. 2000).

The extent or effect of insect herbivory on *Pyrrocoma carthamoides* var. *subsquarrosa* is

unknown. Lesica (1995) observed evidence of insect herbivory, with small holes and mine tunnels in the basal leaves. No seed head predation was observed, but this may take place after observations were made (Lesica 1995). Reid (2001) also observed insect damage on a *P. carthamoides* var. *subsquarrosa* individual. *Pyrrocoma radiatus* in Idaho is subject to intense insect predation on flowerheads, and seed production can be reduced up to 100 percent (Mancuso and Moseley 1993). The researchers believed that reproductive success of *P. radiatus* can be severely affected in populations with intense insect flowerhead predation. Heavy seed predation of *Haplopappus venetus* and *H. squarrosus* is also noted as reducing seedling recruitment and even limiting the geographic ranges of these species in California (Mancuso and Moseley 1993).

Competitors and relationship to habitat

Habitats with *Pyrrocoma carthamoides* var. *subsquarrosa* include open rocky meadows, sagebrush grasslands, and bare slopes and ridges (Fertig 1995). It is unclear what ecological processes drive successional patterns and competition dynamics at these sites, especially as some of these habitats may be at an early to mid-seral successional stage (Fertig 1995) and others may represent a later stage. This taxon grows in open areas and in areas with fairly dense cover of short grasses, but it appears to prefer areas lacking dense cover by tall grasses, shrubs, or trees (Montana Natural Heritage Program 2003b, Wyoming Natural Diversity Database 2004). Although *P. carthamoides* var. *subsquarrosa* appears to be a sun-loving taxon, it has been observed with 5 to 20 percent sagebrush (e.g., *Artemisia tridentata* ssp. *vaseyana*, *A. tridentata* ssp. *wyomingensis*) cover, within the sagebrush canopy as well as in the spaces between the sagebrush (Lesica 1995, Reid 2001, Reid personal communication 2003). "These observations suggest that [*P. carthamoides* var. *subsquarrosa*] may be able to persist in communities with relatively high levels of competitive pressure, but that establishment may be facilitated by moderate disturbances that produce small-scale safe sites…" (Lesica 1995). The successional or competition dynamics in these habitats and the full range of *P. carthamoides* var. *subsquarrosa*'s tolerances have not been studied. It is important to note that the following discussion concerning issues related to competition and ecological interactions are based on observations during field work and hypotheses. Ecological dynamics in habitats with *P. carthamoides* var. *subsquarrosa* need further study.

It has been hypothesized that grazing and fire may play important roles in maintaining suitable colonization sites for *Pyrrocoma carthamoides* var. *subsquarrosa* (Lesica 1995, Reid 2001). Grazing may help to minimize competition from palatable species and to open up "safe sites" for unpalatable species like *P. carthamoides* var. *subsquarrosa* (Lesica 1995). In addition, fire may play a role in maintaining grasslands and preventing encroachment from woody species such as *Artemisia* spp. and *Pinus flexilis* (Lesica 1995, Reid 2001). In those cases, fire suppression may possibly threaten *P. carthamoides* var. *subsquarrosa* (Lesica 1995). Despite fire suppression activities, recent fires have occurred in *P. carthamoides* var. *subsquarrosa* habitat in the last 10 years (Lesica 1995, Welp et al. 2000, Reid 2001) and have likely created suitable habitat for this taxon (Lesica 1995, Reid 2001), by either creating colonization areas or allowing existing individuals to flourish. Houston (personal communication 2003) also pointed out that *P. carthamoides* var. *subsquarrosa* grows in a range of grassland habitats, some with a significant encroachment threat from woody species and others with minimal encroachment threat. In the latter case, fire (and fire suppression) may be less important than other site factors in controlling communities. It must be stressed that the characteristics of the natural fire regime, especially in grassland sites and forest/grassland ecotones with *P. carthamoides* var. *subsquarrosa*, and the specific response of *P. carthamoides* var. *subsquarrosa* to fire have not been studied.

The introduction of exotic species can be a secondary effect of disturbances such as trails, roads, and cattle activity. In some instances, exotic species can outcompete or replace native plants by using space, nutrients, and water. Fertig and Mills (2000) noted that some *Pyrrocoma carthamoides* var. *subsquarrosa* habitat areas in Wyoming (USFS Region 2) have been disturbed by highway construction and competition with weeds, although they did not mention which weeds or how many sites. Other sites with *P. carthamoides* var. *subsquarrosa*, such as the proposed Pat O'Hara Mountain RNA, have a low complement of exotic species (Jones and Fertig 1999). Houston (personal communication 2003) pointed out that spotted knapweed (*Centaurea maculosa*), diffuse knapweed (*C. diffusa*), houndstongue (*Cynoglossum officinale*), and leafy spurge (*Euphorbia esula*) are potential invaders in the Absaroka Mountains, although the level of infestation near *P. carthamoides* var. *subsquarrosa* occurrences is not known. In USFS Region 1, spotted

knapweed and leafy spurge have invaded road corridors and grasslands along the Beartooth Mountains and considerably threaten occurrences of *P. carthamoides* var. *subsquarrosa* and other native plants (Lesica 1995). Reid (2001) suggested that spotted knapweed invasion along a road right-of-way is one of the largest threats to a nearby occurrence of *P. carthamoides* var. *subsquarrosa*. She also noted that care needs to be taken to treat only target species when using herbicides. One element occurrence record from Wyoming suggested that some potential (but unsurveyed) habitat along a road right-of-way may have been altered by the planting of tall grasses after road construction (Wyoming Natural Diversity Database 2004). Mancuso and Moseley (1993) found that years of intense grazing pressure in bunchgrass and sagebrush/bunchgrass habitats in Idaho have facilitated a change from native plant communities to communities dominated by exotic annual grasses. This habitat degradation is significantly threatening *P. radiatus*.

Parasites and disease

Evidence for parasites or diseases on *Pyrrocoma carthamoides* var. *subsquarrosa* or related species was not reported in the reviewed literature.

Symbiotic interactions

Insect pollination of flowering plants is an example of an important symbiotic interaction. Plants lure insects to a pollen or nectar reward and the insects carry pollen to other flowers, thus, helping to cross-fertilize. Specific details concerning pollination ecology of *Pyrrocoma carthamoides* var. *subsquarrosa* are largely unknown.

The positive interactions between other associated plant or microbial species and *Pyrrocoma carthamoides* var. *subsquarrosa* are also unknown. This taxon tends to occur in areas with well-developed cryptogamic crusts, but the role of these organisms (if any) in facilitating the growth of *P. carthamoides* var. *subsquarrosa* through soil stabilization or nitrogen fixation has not been studied.

Habitat influences

Pyrrocoma carthamoides var. *subsquarrosa* appears to be commonly associated with calcareous soils, thus possibly exhibiting a pattern of edaphic preference (Lesica 1995). Welp et al. (2000) noted that locations with exposed calcareous bedrock in the eastern Absarokas are unique because most of the sedimentary bedrock was buried in volcanic deposits 50 million years ago. However, this taxon is also found growing in smaller, satellite occurrences on adjacent soils derived from granitic or volcanic parent material (Lesica 1995). Element occurrence records do not provide sufficiently detailed suboccurrence information to determine if less abundant or less dense suboccurrences may be correlated with one type of substrate or another. Also, the amount of available habitat was not quantified in any status report. Handley and Laursen (2002) suggested that the habitat for this species is locally extensive in the Northern Absarokas although it is restricted to a small range in Wyoming. Lesica (1995) searched several areas of apparently appropriate habitat and failed to find *P. carthamoides* var. *subsquarrosa*. Lesica (1995) also noted several areas where appropriate habitat exists but has not been surveyed. The availability and quality of suitable habitat most likely varies from area to area, depending on heterogeneity in edaphic factors, microhabitat, topography, environmental fluctuations, disturbance factors, and competition with other species.

CONSERVATION

Threats

Pyrrocoma carthamoides var. *subsquarrosa* occurrences and habitat throughout its range, including USFS Region 2, are potentially threatened by human-related actions, environmental changes, and biological vulnerabilities. The information presented in this section is primarily based on observations in occurrence records (Montana Natural Heritage Program 2003b, Wyoming Natural Diversity Database 2004), status reports (Fertig 1995, Lesica 1995, Reid 2001), and personal communications with resource management specialists and botanists (Evert personal communication 2003, Houston personal communication 2003, Reid personal communication 2003). These factors are summarized in an envirogram outlining the malentities potentially important to *P. carthamoides* var. *subsquarrosa* (centrum) and the indirect variables affecting those centrum factors (**Figure 5**). It is important to note that the malentities outlined on the envirogram represent possible threats to be researched and not definite threats that have been identified as causing population declines.

Occurrences of *Pyrrocoma carthamoides* var. *subsquarrosa* could potentially be threatened by a variety of human-related activities (e.g., road-related impacts, grazing-related impacts) or ecological changes (e.g., global climate changes, invasive species introduction). The specific threats will likely vary

for each occurrence or suboccurrence, depending on the landscape context. For example, *P. carthamoides* var. *subsquarrosa* individuals near roads could suffer impacts from road-related activities (e.g., road maintenance) or competition with non-native species, whereas individuals located a distance away from roads may not experience the same threats. In addition, human-related activities and other disturbances can either create suitable habitat throughout a landscape or directly impact an existing occurrence, depending on frequency, intensity, size, and location. For example, livestock grazing at low to moderate intensities may play an important role in maintaining suitable habitat for this taxon, while grazing at heavy intensities could possibly extirpate an occurrence. Direct impacts could either damage the existing individuals or reduce reproductive success, available habitat, establishment of new populations, or other factors important for long-term persistence of the species.

Possible human-related threats to *Pyrrocoma carthamoides* var. *subsquarrosa* include changes to natural disturbance patterns (e.g., fire suppression), exotic species invasion and management, grazing and stock water development, road/trail construction, motorized and non-motorized recreation, or energy exploration (Fertig 1995, Lesica 1995, Fertig and Mills 2000, Welp et al. 2000, Reid 2001). As discussed previously, evidence suggests that this taxon may possibly benefit from periodic or light disturbance and that it appears to be negatively correlated with areas characterized by a dense overstory. Fire may play an important role in maintaining open grassland habitat for *P. carthamoides* var. *subsquarrosa*, and fire suppression in these habitats could facilitate woody encroachment onto suitable sites (Lesica 1995). Some areas are likely more prone to woody encroachment, and thus more affected by fire, than other sites (Houston personal communication 2003). Aggressive exotic species, such as spotted knapweed (*Centaurea maculosa*), also have the potential to encroach onto *P. carthamoides* var. *subsquarrosa* habitat and outcompete native species (Lesica 1995, Reid 2001). Leafy spurge (*Euphorbia esula*) is an aggressive exotic that has been found in the burned area along the road leading to Robertson Draw, the site of the largest occurrence of *P. carthamoides* var. *subsquarrosa* in Montana (Lesica 1995). Mancuso and Moseley (1993) have found that *P. radiatus* is absent or much sparser where weedy species have invaded the grasslands. In addition, management of exotic species, such as herbicide use, also poses a threat to *P. carthamoides* var. *subsquarrosa* and other native plants (Reid 2001). Currently, knapweed occurs in small occurrences near at least one *P. carthamoides* var. *subsquarrosa* site in Montana, and these clumps are being spot treated with herbicides in an effort to reduce the impact to *P. carthamoides* var. *subsquarrosa* (Reid personal communication 2003). Exotic weeds and extensive weed control activities pose the greatest threat to *P. carthamoides* var. *subsquarrosa* occurrences near sources of weed seed, such as roads and trails (Lesica 1995). Off-highway vehicle use, non-motorized recreation, and maintenance and construction activities near roads and trails have the potential to directly trample *P. carthamoides* var. *subsquarrosa* as well as facilitate the spread of exotic plants (Lesica 1995). As discussed previously, cattle probably avoid *P. carthamoides* var. *subsquarrosa* when grazing, but this taxon could still be affected by heavy trampling and import of weed seeds by cattle, especially at high use areas (i.e., cattle watering sites) (Reid 2001, Houston personal communication 2003, Reid personal communication 2003).

An exploratory natural gas well was drilled in the mid-1990s in similar habitat "two draws away" from a *Pyrrocoma carthamoides* var. *subsquarrosa* site in Montana. Although energy exploration is not currently ongoing at *P. carthamoides* var. *subsquarrosa* sites in Montana, *P. carthamoides* var. *subsquarrosa* does occur on land leasable for energy exploration and development, and these lands could be considered in the future (Reid personal communication 2003). Oil and gas leasing has been proposed for at least one area with a *P. carthamoides* var. *subsquarrosa* occurrence in the Shoshone National Forest in Wyoming (Welp et al. 2000). *Pyrrocoma carthamoides* var. *subsquarrosa* occurrences on steep slopes would probably not be at risk for oil and gas drilling. Even if occurrences were not directly impacted by these activities, they could still be affected by the introduction of non-native invasive species through such disturbances (Lesica 1995).

Possible environmental and biological threats to occurrences of *Pyrrocoma carthamoides* var. *subsquarrosa* include changes to the natural disturbance regime, succession/woody encroachment, environmental fluctuations (e.g., drought), global climate changes, and genetic isolation. Disturbances can either create suitable habitat throughout a landscape or directly impact an existing occurrence, depending on frequency, intensity, size, and location. It is possible that if natural fire, erosion, or successional patterns were altered, then appropriate habitat for *P. carthamoides* var. *subsquarrosa* might not exist. The ecological tolerances of *P. carthamoides* var. *subsquarrosa* or ecological

dynamics (e.g., competition, succession, fire return interval, edaphic characteristics) as they relate to this taxon have not been studied.

The metapopulation structure or gene flow between *Pyrrocoma carthamoides* var. *subsquarrosa* populations is unknown, but fragmentation or population extirpation could potentially decrease genetic resources of this taxon.

Changes to existing climatic and precipitation patterns, perhaps as a result of global climate change, could also possibly impact *Pyrrocoma carthamoides* var. *subsquarrosa*. For example, average temperatures are projected to increase, and precipitation is generally expected to increase over western North America (U.S. Environmental Protection Agency 1997, Watson et al. 2001). An Environmental Protection Agency (1997) document about regional climate changes in Colorado reports that average temperatures have increased by 4.1 ºF and precipitation has decreased by up to 20 percent in some areas of Colorado over the last century. Over the next century, climate models predict that temperatures in Colorado could increase by 3 to 4 ºF (with a range of 1 to 8 ºF) in the spring and fall and by 5 to 6 ºF (with a range of 2 to 12 ºF) in the summer and winter. Precipitation is estimated to increase by 10 percent in the spring and fall and increase by 20 to 70 percent in the winter; more summer thunderstorms are predicted, without a significant change in precipitation total (U.S. Environmental Protection Agency 1997). Although this study focused on Colorado, it is possible that similar changes may occur in Wyoming. Climate change and other potential changes to a suite of environmental variables have the potential to affect plant community composition by altering establishment, growth, reproduction, and death of plants. For example, model projections predict that tree lines could shift upslope in alpine ecosystems (U.S. Environmental Protection Agency 1997). In addition, environmental stochasticity can also affect pollinator activity and behavior.

Although much of the information concerning threats to *Pyrrocoma carthamoides* var. *subsquarrosa* are based on observations of occurrences in Montana (USFS Region 1), many of the same issues are potentially important for occurrences in Wyoming (USFS Region 2). Possible threats to *P. carthamoides* var. *subsquarrosa* occurrences on USFS Region 2 lands in Wyoming include non-native plant invasion, weed control activities, fire suppression, woody encroachment, livestock grazing and stock water development, trail construction, climate change, motorized and non-motorized recreation, and oil/gas development (Fertig 1995, Lesica 1995, Fertig and Mills 2000, Welp et al. 2000). Of 13 occurrences on USFS Region 2 lands, only four occurrence records provided any assessment of possible threats. These four occurrence records noted that threats for this taxon are generally low, and only two records indicated that proximity to roads or grazing could be a concern. Thus, any imminent threats to this taxon on USFS Region 2 lands appear to pertain to individuals existing near roads or in heavily-grazed areas. However, as recreational use of National Forest System lands increases and the spread of exotic plants increases, the risks to *P. carthamoides* var. *subsquarrosa* also increase (Lesica 1995).

Conservation Status of the Taxon in USFS Region 2

Pyrrocoma carthamoides var. *subsquarrosa* is a taxon of concern because it is a geographically limited plant with a small number of occurrences and potential threats to existing occurrences and habitat. The viability of this taxon within USFS Region 2 is difficult to ascertain because much information is lacking on its abundance, distribution, and biology. The ecological tolerances of *P. carthamoides* var. *subsquarrosa* or ecological dynamics (e.g., competition, succession, fire return interval, edaphic characteristics) as they relate to this taxon have not been studied. The viability of seven of the 13 occurrences on USFS Region 2 lands has not been assessed (Wyoming Natural Diversity Database 2004). Any imminent threats to occurrences of *P. carthamoides* var. *subsquarrosa* appear to be related to the proximity of those occurrences to roads and heavily-grazed areas. However, potential threats such as fire suppression, exotic species invasion, and global climate changes could potentially threaten other occurrences. It is difficult to predict the ability of this taxon to tolerate environmental stochasticity and any future environmental or management changes.

Population declines

Based on the existing estimates of abundance, we are unable to conclude that the distribution or abundance of *Pyrrocoma carthamoides* var. *subsquarrosa* is declining or expanding throughout its range. Abundance estimates for *P. carthamoides* var. *subsquarrosa* approximate that there are over 100,000 individuals in Wyoming; the majority of these individuals are on USFS Region 2 lands. Fertig and Mills (2000) suggest that population trends for *P. carthamoides* var. *subsquarrosa* are probably stable. The authors do not state how they reach this conclusion, presumably because they have not observed

large decreases or increases in population sizes. Of 13 occurrences on USFS Region 2 lands, the viability of five occurrences was estimated as good to excellent by botanists as a result of moderate to large sizes, one occurrence was rated as having fair viability as a result of a smaller abundance, and seven occurrences were not rated (Wyoming Natural Diversity Database 2004).

Habitat variation and risk

Pyrrocoma carthamoides var. *subsquarrosa* appears to prefer open grasslands on calcareous substrates with gentle slopes. However, this taxon has been recorded to inhabit a wide range of elevations (1,646 to 3,140 m), slopes (0 to 30 percent), aspects (all), percent vegetation cover (0 to 90 percent), substrate types (e.g., calcareous, granitic, volcanic), community types and associated plant species (e.g., bunchgrass meadows, open limber pine woods, cryptogamic crusts), and microhabitats (e.g., grasslands, ridgetops, and talus fields). This taxon ranges from dense and locally abundant to sparsely distributed with scattered colonies (Montana Natural Heritage Program 2003b, Wyoming Natural Diversity Database 2004). Handley and Laursen (2002) suggested that the habitat for this species is locally extensive although it is restricted to a small range in the state. In Montana, Lesica (1995) searched several areas of apparently appropriate habitat and failed to find *P. carthamoides* var. *subsquarrosa*. The microhabitat requirements for *P. carthamoides* var. *subsquarrosa* are largely undefined, and the distribution of this taxon likely depends on edaphic characteristics, competition with other species, disturbances, and other ecological factors.

While inhabiting different microhabitats over a range of elevations may insulate *Pyrrocoma carthamoides* var. *subsquarrosa* from complete extinction by one particular factor (e.g., road construction or trampling), this taxon is still only known from a relatively small geographic area. Potential risks within the habitat could include competition from surrounding vegetation, lack of suitable germination sites, inadequate pollinator habitat, barriers to gene flow, unsuitable conditions for adequate growth and development, and other fluctuations in disturbance processes that could affect existing occurrences or creation of habitat. Although many of these factors are also part of the natural habitat to which the species has adapted through evolutionary time, environmental changes such as global climate change, land management activities, or non-native plant invasion can alter natural processes. The optimal type, size, frequency, and intensity of disturbances required to sustain occurrences of *P. carthamoides* var. *subsquarrosa* are not known. It is difficult to predict the spread of non-native invasive plants and the potential risk of alteration to plant communities. As recreational use of National Forest System lands increases and the spread of exotic plants increases, the risks to *P. carthamoides* var. *subsquarrosa* also increase (Lesica 1995). Specific occurrences could be at a greater risk than other occurrences, depending on the landscape context and characteristics of the natural and human disturbance regimes. *Pyrrocoma carthamoides* var. *subsquarrosa* occurrences are likely less susceptible to human-related threats where land uses are restricted by wilderness area or RNA policies.

Potential Management of the Taxon in USFS Region 2

Quantitative demographic monitoring and detailed biological and ecological studies of *Pyrrocoma carthamoides* var. *subsquarrosa* occurrences and its habitat have not occurred. Based on the available information, we can only hypothesize how changes in the environment may affect the abundance, distribution, and long-term persistence of this taxon.

Management implications

Pyrrocoma carthamoides var. *subsquarrosa* occurrences and habitat in USFS Region 2 may possibly be at risk as a result of human-related activities within the range. Possible human-related threats to existing individuals of this taxon include livestock grazing, off-road (or off-trail) motorized and non-motorized activities, road maintenance, and introduction of non-native species. Only two (Wyoming occurrences 2224 and 2233 from **Table 1** and **Table 2**) of 13 element occurrence records for occurrences on USFS Region 2 lands stated that the occurrence may potentially be affected by grazing or road-related disturbances; definite threats have not been identified, or threats have not been assessed for the other occurrences. The long-term persistence of *P. carthamoides* var. *subsquarrosa* may rely on monitoring the effects of current USFS Region 2 land-use practices in order to reduce any possible human-related threats to existing occurrences and to learn about the effects of these actions to help inform future management decisions. For example, livestock grazing may have positive, negative, or neutral effects on *P. carthamoides* var. *subsquarrosa* and its habitats, depending on timing and intensity. In general, this taxon may not require specific management actions but will benefit from management tactics that reduce any degradation of its habitats.

Livestock grazing occurs at locations in USFS Region 2 with this taxon, although the number of sites with grazing has not been quantified. The relationship between cattle grazing and *Pyrrocoma carthamoides* var. *subsquarrosa* occurrences and habitats is not fully understood. Observations of *P. carthamoides* var. *subsquarrosa* in Montana (USFS Region 1) may provide insight about possible relationships between grazing and *P. carthamoides* var. *subsquarrosa*. Lesica (1995) hypothesized that cattle grazing may reduce the abundance of palatable forbs that compete with *P. carthamoides* var. *subsquarrosa* and open up suitable sites for colonization. On the other hand, cattle grazing can also shift the balance from grasses to shrubs, import weed seeds, and directly trample *P. carthamoides* var. *subsquarrosa* (Lesica 1995). Reid (2001) suggested that future management options at a site with heavy grazing in Montana (USFS Region 1) could include improvement of site conditions and more protection of *P. carthamoides* var. *subsquarrosa* through stocking rate adjustments, more deferment in sequence, rest, or grazing removal. These changes may reduce intense trampling and maintain bunchgrass habitat at that impacted site. However, these observations are from one site in USFS Region 1 and may or may not apply to habitats in USFS Region 2. For example, Fertig (1995) hypothesized that some microsites where *P. carthamoides* var. *subsquarrosa* occurs in USFS Region 2 are not attractive to cattle because of low availability of forage and water (Fertig 1995). The effects of grazing at sites in USFS Region 2 would need to be studied to determine the effects of this land use on *P. carthamoides* var. *subsquarrosa* individuals and habitat.

The role of fire or fire suppression in *Pyrrocoma carthamoides* var. *subsquarrosa* habitats is also not well known. Observational evidence from wildfires and prescribed burns suggests that *P. carthamoides* var. *subsquarrosa* occurrences may benefit from moderate disturbances, like fire, to reduce woody encroachment from sagebrush or limber pine and to create suitable sites for colonization (Lesica 1995, Reid 2001, Houston personal communication 2003, Reid personal communication 2003). However, the timing and frequency of fire optimal for the persistence of this taxon are not known. Reid (personal communication 2003) is considering using prescribed burns to enhance *P. carthamoides* var. *subsquarrosa* habitat in Montana (USFS Region 1) and assessing the effects of this management practice through pre- and post-burn monitoring. While the results of these experiments will provide useful information for land managers in USFS Region 2, the effects of wildfire, fire suppression, and prescribed burns in habitats in Region 2 should be studied.

The invasion of non-native plant species is a significant potential threat to *Pyrrocoma carthamoides* var. *subsquarrosa* habitats in both USFS Region 1 and USFS Region 2. Efforts to reduce the spread of these species would likely benefit this taxon (Lesica 1995). Reid (personal communication 2003) reported that there are weed control efforts (e.g., herbicide spot-application) in Montana to minimize the spread of invasive species into *P. carthamoides* var. *subsquarrosa* areas. Lesica (1995) suggested that, in Montana, weed control activities should target roads and trails, as weeds are mostly found in those corridors. The extent and effects of non-native plant species invasions near occurrences of *P. carthamoides* var. *subsquarrosa* in USFS Region 2 need to be assessed.

Pyrrocoma carthamoides var. *subsquarrosa* may possibly be affected by land management activities in USFS Region 2, such as livestock grazing, fire suppression, prescribed burns, non-native plant species control, stock water development, and road maintenance. The effects may be positive, negative, or neutral; insufficient evidence exists at this time to adequately assess specific management implications. This taxon would benefit from studies assessing the impacts of those activities. From existing information about this taxon, it is possible that this taxon may benefit from policies such as encouraging forest users to minimize the spread of invasive species, reducing intense livestock trampling during flowering periods, and other activities that would minimize habitat degradation.

Potential conservation elements

Pyrrocoma carthamoides var. *subsquarrosa* is a taxon endemic to one region with a small number of recorded populations and potentially high vulnerability of some individuals to human-related activities and environmental changes. The microhabitat needs of this taxon and the intensity, frequency, size, and type of disturbance optimal for persistence of this taxon are unknown. The lack of information regarding the colonizing ability, adaptability to changing environmental conditions, sexual reproductive potential, or genetic variability of this taxon makes it difficult to predict its long-term vulnerability. Features of *P. carthamoides* var. *subsquarrosa* biology that may be important to consider when addressing conservation of this species (i.e., key conservation elements) include its possible edaphic preference for limestone substrates, its apparent preference for sites lacking a dense overstory of woody species or grasses, its possible unpalatability to cattle, and its possible reliance on periodic or low-intensity disturbances. Further study on this species

would help to verify these observations and to identify other key conservation elements in USFS Region 2. Surveying high probability habitat for new occurrences, protecting existing occurrences from any imminent threats, documenting and monitoring the effects of current management activities, and preventing non-native plant invasions are key conservation tools for this taxon on USFS Region 2 lands.

Tools and practices

There are no existing population monitoring protocols for *Pyrrocoma carthamoides* var. *subsquarrosa*, and very little is known about its biology, ecology, or spatial distribution. Thus, additional habitat surveys, quantitative species monitoring, and ecological studies are priorities for constructing a current status assessment and conservation plan.

Taxon inventory and habitat surveys

Reports of existing *Pyrrocoma carthamoides* var. *subsquarrosa* occurrences provide a useful base of information, but the distribution and total abundance of this taxon are not sufficiently known to formulate regional conservation strategies. Most occurrences in USFS Region 2 have not been revisited since the mid-1990s, and updated census data on the known sites would be helpful (Welp et al. 2000). At least one of the known occurrences (i.e., Bald Ridge) is located at the site of a fire in 1996, and the current status of *P. carthamoides* var. *subsquarrosa* in that area is not known (Welp et al. 2000). In addition, surveys of potential habitat are needed to discover any additional occurrences and to document the full spatial extent of this taxon. For example, Jones and Fertig (1999) mentioned that much unsurveyed habitat exists in the vicinity of the Pat O'Hara Mountain proposed RNA. As a result, the actual distribution and abundance of *P. carthamoides* var. *subsquarrosa* may be underestimated. The Northern Absaroka area was the focus of floristic surveys by associates of the Rocky Mountain Herbarium from 1985 to 1997 (i.e., Rosenthal 1998), but it is unlikely that continued work will occur by herbarium staff in that area (Nelson personal communication 2003). Because the Absaroka Range is a hotspot for rare, endemic species (Rosenthal 1998), surveys could be conducted for several species simultaneously. For example, there are six calceophile species of special concern (i.e., *Androsace chamaejasme*, *Antennaria aromatica*, *Aquilegia jonesii*, *Eritrichium howardii*, *Kelseya uniflora*, and *Shoshonea pulvinata*) that inhabit slightly different habitat than *P. carthamoides* var. *subsquarrosa* but are often found in the same vicinity (e.g., Bald Ridge) (Jones 1991). Jones (1991) suggested walking regular survey routes every five years to note numbers and locations of plants. He also suggested dividing an area into parts, using a simple quantitative scale to score the plant abundance in each part, and comparing the results from successive surveys to document changes in distribution and abundance over time.

The distribution of *Pyrrocoma carthamoides* var. *subsquarrosa* is widely scattered, with occurrences or groups of occurrences spread over the range (Evert personal communication 2003). This pattern is probably a combination of edaphic endemism, preference for open habitat, disturbance patterns, and/or undocumented occurrences. Because *P. carthamoides* var. *subsquarrosa* appears to grow on specific substrates and topographies throughout its range, researchers could identify areas of potential habitat using topographic maps, geologic maps, and aerial or satellite images. Jones (1991) mapped existing occurrences on U.S. Geological Survey 7.5-minute topographic maps. New surveys could use these maps and reports of existing occurrences as a starting point because similar habitats may extend along topographic lines. In addition, locations downslope, downwind, or downstream from existing occurrences should be surveyed because *P. carthamoides* var. *subsquarrosa* seeds are most likely wind, water, and gravity dispersed.

Once located, the size and extent of occurrences could be mapped, labeled, and recorded using global positioning system (GPS) and geographic information systems (GIS) technology. Mapping the extent of and providing a unique label for each known occurrence of *Pyrrocoma carthamoides* var. *subsquarrosa* will maintain consistency for future observations and help in making estimates of density and abundance. Mapping exercises will also elucidate the spatial distribution of occurrences at the local and regional levels and provide a framework for creating a metapopulation study. Occurrences in areas slated for various management, maintenance, or disturbance activities could be readily identified. A detailed assessment should be undertaken before activities such as trail construction or natural resource exploration occur.

Population monitoring and demographic studies

Additional information is needed to gain an understanding of the life cycle, demography, and population trends of *Pyrrocoma carthamoides* var. *subsquarrosa*. Information is lacking on longevity, germination requirements, seed survival, factors

affecting flower development, pollination ecology, role of a seed bank, and gene flow between populations. This type of species-specific information would be useful in assessing threats to this taxon and in estimating viability. For example, studies of germination needs in the field might elucidate potential limiting factors for the establishment of new individuals.

No data are available on population trends for *Pyrrocoma carthamoides* var. *subsquarrosa*, and no long-term demographic monitoring has been initiated. Long-term monitoring studies could yield helpful information, such as temporal and spatial patterns of abundance and dormancy; environmental factors that influence abundance; whether occurrences are increasing, decreasing, or remaining stable; and the vulnerability of this taxon to environmental fluctuations. In addition, further studies on the genetic differences between and among occurrences will clarify metapopulation dynamics. Also, studying the taxonomic status of this taxon and its relationship to other closely-related taxa (i.e., *P. carthamoides* var. *carthamoides*, *P. carthamoides* var. *cusickii*) may help to determine if this taxon is distinct enough to consider as a species or whether it should continue to be treated as a variety of a more widespread species.

Understanding certain aspects of demography is a priority in order to provide basic population information and is indicated by these questions:

- What are the rates of survival, longevity, and recruitment?
- What are the population/occurrence fluctuations from year to year?
- What are the effects of disturbances on demographics?
- What are the factors affecting dispersal and germination?
- What are the role, status, and longevity of the seed bank?
- What is the age structure of the population?
- What is the age at which individuals become reproductive?
- What is the gene flow between populations?

Several groups have developed protocols for monitoring population and demographic trends of rare plant species. These protocols can be easily accessed and used to develop specific monitoring plans for use in USFS Region 2. For example, *Measuring and Monitoring Plant Populations* (Elzinga et al. 1998) and *Monitoring for Conservation and Ecology* (Hutchings 1994) are general references that provide concrete guidance on designing and implementing quantitative monitoring plans for rare plant species. *USDA Forest Service Region 2 TES Plant Management Strategy* (Austin et al. 1999) and *Protocols and Models for Inventory, Monitoring, and Management of Threatened and Endangered Plants* (Bonham et al. 2001) provide helpful protocols specifically designed for federal agencies monitoring plants on public lands. Mancuso (2001) used permanent belt transects (i.e., Lesica 1987) to monitor rare plants in Idaho to gauge population density, changes in age classes over time, and effects of wildfires. To monitor *Pyrrocoma liatriformis* (Palouse goldenweed) in Idaho, Mancuso (1997) used permanently marked monitoring plots to collect population information as well as general vegetation and site characteristics. In addition, population matrix models that measure individual fitness and population growth provide flexible and powerful metrics for evaluating habitat quality and identifying the most critical feature of the species' life history (Hayward and McDonald 1997). Deterministic demographic models of single populations are the simplest analyses and are used as powerful tools in making decisions for managing threatened and endangered species (Beissinger and Westphal 1998).

Habitat monitoring and management

The general habitats of *Pyrrocoma carthamoides* var. *subsquarrosa* have been identified, but there are too many unknowns regarding microhabitat requirements and basic population dynamics to know which factors are critical in maintaining or restoring habitat for this taxon. For example, it is currently not known what types, intensities, or frequencies of disturbance create and maintain habitat and are tolerated by existing populations of this taxon. Land management techniques, such as prescribed burns, cattle grazing, and fire suppression, are used in some habitats with *P. carthamoides* var. *subsquarrosa* and could influence the persistence of this taxon. The cumulative beneficial or detrimental effects of these activities on *P. carthamoides* var. *subsquarrosa* and its habitats have not been quantitatively studied or monitored. Documenting

land management and monitoring habitat could occur in conjunction with population monitoring efforts in order to associate population trends with environmental conditions. Simple, periodic surveys of the largest *P. carthamoides* var. *subsquarrosa* occurrences, such as photographs and "walk throughs," would help to assess weed encroachment, successional processes, and wildfire activity (Lesica 1995).

Biological and ecological studies

Much of the information regarding habitat requirements, establishment, reproduction, dispersal, relationship with herbivores, competition with other species, and overall persistence has not been studied for *Pyrrocoma carthamoides* var. *subsquarrosa*. This taxon appears to prefer calcareous substrates, but it is also found on adjacent granitic- or volcanic-derived substrates. The full ecological range and habitat preferences of this taxon and the potential resulting differences in growth and reproductive success warrant study. In addition, the response of *P. carthamoides* var. *subsquarrosa* to habitat changes is not known in sufficient detail to evaluate the effects of changes in disturbance patterns. Research studies to evaluate the effects of erosion, succession, and fire at several scales (local and regional) would provide valuable input to the development of conservation strategies and management programs. The types of monitoring studies required to understand how this taxon responds to environmental fluctuations, changes in the disturbance regime, or natural succession would be complex and could take decades. For example, precipitation fluctuations have the potential to affect erosion rates, germination success, pollinator population trends, timing of flowering, and/or growth of surrounding vegetation. It will be difficult to determine to what extent disturbances are necessary to create habitat and/or maintain an occurrence, what disturbance intensity and frequency may be most appropriate, and what factors would result in local extirpation.

Availability of reliable restoration methods

There are too many unknowns regarding habitat preferences and basic population dynamics to know what factors are critical in restoring habitat for *Pyrrocoma carthamoides* var. *subsquarrosa*. Reid (personal communication 2003) may be initiating prescribed burns and changes to the grazing regime at one impacted site to try to restore suitable habitat for this taxon. However, it is important to note that there are no detailed studies concerning this taxon and fire and grazing. Thus, using grazing and fire to restore habitats needs further study. No information was found regarding the germination of this taxon in a greenhouse setting or the availability of propagules for use in a restoration program. *Pyrrocoma radiatus* has been cultivated in greenhouses in Oregon, but the authors did not provide details on the techniques used or the results gained (Mancuso and Moseley 1993).

Information Needs and Research Priorities

Based on our current understanding of *Pyrrocoma carthamoides* var. *subsquarrosa*, we can identify research priorities where additional information will help to develop management objectives, to initiate monitoring and research programs, and to inform a conservation plan. To address these data gaps, information can be obtained through surveys, long-term monitoring plans, and extended research programs. There is so little known about the biology and ecology of this taxon that there are a large number of research projects that could be implemented.

The following types of studies are priorities to supplement our basic knowledge and further our understanding of this taxon in USFS Region 2:

- Revisiting and detailed mapping of existing occurrences
- Surveying for new occurrences
- Addressing imminent threats to known occurrences
- Characterizing and measuring microhabitat attributes
- Documenting and monitoring current land management practices
- Studying reproductive biology, including pollinator surveys, germination trials, dispersal capabilities, mycorrhizal associations, and seedbank analyses
- Conducting genetic analyses to assess gene flow and variability throughout range
- Conducting taxonomic studies to assess relationship to other varieties of *Pyrrocoma carthamoides*.

Additional research and data that may be useful but are not incorporated into this assessment include aspects related to managing data for efficient use. Data acquired during surveys, inventories, monitoring programs, and research projects are most easily accessible if they are entered into an automated relational database. State natural heritage programs and NatureServe have developed databases and GIS components to assist in information storage and habitat modeling (Anderson personal communication 2004). Such a database should be integrated with GIS and allow queries and activities such as the following:

- Efficient incorporation of data in the field
- Generation of location and habitat maps
- Identification of occurrence locations
- Characterization of associated habitat types
- Identification of population trends over time
- Identification of data gaps that require further information gathering
- Simple modification of database, as additional information becomes available.

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Definitions

Achene — Small, dry fruit with a close-fitting wall surrounding a single seed.

Andesite — Volcanic rock usually medium dark in color and containing 54 to 62 percent silica and moderate amounts of iron and magnesium.

Annual — A plant that completes its entire life cycle in one growing season.

Anther — Part of the flower reproductive structure (stamen) that bears pollen.

Asexual reproduction — Any form of reproduction not involving the union of gametes.

Bract — Reduced, modified leaf associated with flowers.

Calcareous — Composed of, containing, or characteristic of calcium carbonate, calcium, or limestone; chalky.

Calceophile — Found on calcareous substrates.

Capitulum — Inflorescence with many small flowers clustered on the receptacle.

Carpel — The plant organ that bears the ovules.

Cauline — On or pertaining to a stem.

Congener — A member of the same genus.

Corolla — Portion of flower comprised of petals.

Cryptogamic crust — Tightly bound mesh of various cyanobacteria, lichens, algae, mosses, liverworts, and fungi on soil surface.

Dehisce — To split or open, discharging seeds, pollen, or other contents, as the ripe capsules or pods of some plants.

Demographics — The study of fecundity and mortality parameters that are used to predict population changes.

Disc floret — A flower with a tubular corolla (petals), present in Asteraceae. (Tubular floret).

Disjunct — A geographically isolated population or species outside of the range of other similar populations or species.

Dormancy — A period of growth inactivity in seeds, buds, bulbs, and other plant organs even when environmental conditions normally required for growth are met.

Ecotone — A transitional zone between two plant communities or regions.

Endangered — Defined in the Endangered Species Act as a species, subspecies, or variety likely to become extinct in the foreseeable future throughout all or a significant portion of its range.

Endemic — A population or species with narrow physiological constraints or other restrictions, which limit it to a special habitat or a very restricted geographic range, or both.

Fertility — Reproductive capacity of an organism.

Fitness — Success in producing viable and fertile offspring.

Floret — Small, individual flowers.

Fruit — The ripened, seed-containing reproductive structure of a plant.

G1 ranking — Critically imperiled globally because of extreme rarity (five or fewer occurrences or very few remaining individuals) or because of some factor making it especially vulnerable to extinction (NatureServe).

G2 ranking — Imperiled globally because of rarity (6 to 20 occurrences) or because of factors demonstrably making a species vulnerable to extinction (NatureServe).

G3 ranking — Vulnerable throughout its range or found locally in a restricted range (21 to 100 occurrences) or because of other factors making it vulnerable to extinction (NatureServe).

G4 ranking — Apparently secure, though it may be quite rare in parts of its range, especially at the periphery (NatureServe).

G5 ranking — Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery (NatureServe).

Genotype — Genetic constitution of an organism.

Habitat fragmentation — The breakup of a continuous landscape containing large patches into smaller, usually more numerous, and less connected patches. Can result in genetic isolation.

Habitat isolation — When two or more habitats are separated (i.e., geographically) to an extent to prevent cross breeding, thereby genetically isolating two parts of a once continuous population.

Herbaceous — Characteristic of an herb (plant with no aboveground persistent woody stem).

Hybridization — The result of a cross between two interspecific taxa.

Inflorescence — The flowering part of a plant, usually referring to a cluster of flowers.

Interspecific competition — Competition for resources between individuals of different species.

Intraspecific competition — Competition for resources among individuals of one species.

Involucre — Series of bracts (phyllaries) surrounding or subtending a flower or inflorescence.

Lanceolate — Lance-shaped; much longer than broad, widening above the base and then tapering to the tip.

Mesic — Characteristic of an environment that is neither extremely wet, nor extremely dry.

Metapopulation — Group of populations that are linked through migration of individuals.

Mycorrhiza — Symbiotic association between a fungus and the root of a higher plant.

Ovary — The enlarged portion of the female reproductive structure (pistil) that contains the ovules and develops into the fruit.

Pappus — The crown of hairs, bristles, awns, or scales on the ovary (and achene) of Asteraceae.

Perennial — A plant that lives for 3 or more years and can grow, flower, and set seed for many years; underground parts may regrow new stems in the case of herbaceous plants.

Perfect flower — Flower with both "male" (stamens) and "female" (pistils) reproductive organs.

Petiole — Leaf stalk.

Phenotype — The external visible appearance of an organism.

Phenotypic plasticity — When members of a species vary in height, leaf size or shape, flowering (or spore-producing time), or other attributes, with changes in light intensity, latitude, elevation, or other site characteristics.

Phyllaries — Bracts associated with the involucre of Asteraceae.

Pistil — The seed-producing organ of a flower, consisting of a stigma, style, and ovary.

Pistillate flower — A flower with "female" reproductive organs (pistils) and lacking "male" reproductive organs (stamens).

Pollen — The male spores in an anther.

Polyploidy — Having more than two complete sets of chromosomes per cell.

Population Viability Analysis — An evaluation to determine the minimum number of plants needed to perpetuate a species into the future, the factors that affect that number, and current population trends for the species being evaluated.

Propagule — A reproductive body, usually produced through asexual or vegetative reproduction.

Radiate head — Inflorescence of Asteraceae with "ray" florets arranged on the head margin and "disc" florets in the center of the head.

Ray floret — Flower with a strap-like corolla (petals), present in Asteraceae. (Ligulate floret)

Recruitment — The addition of new individuals to a population by reproduction.

Ruderal habitat — Temporary or frequently disturbed habitats.

Ruderal species — Species that can exploit low stress, high disturbance environments.

S1 ranking — Critically imperiled globally because of extreme rarity (five or fewer occurrences or very few remaining individuals) or because of some factor making it especially vulnerable to extinction (NatureServe).

S2 ranking — Imperiled globally because of rarity (6 to 20 occurrences) or because of factors demonstrably making a species vulnerable to extinction (NatureServe).

S3 ranking — Vulnerable throughout its range or found locally in a restricted range (21 to 100 occurrences) or because of other factors making it vulnerable to extinction (NatureServe).

S4 ranking — Apparently secure, though it may be quite rare in parts of its range, especially at the periphery (NatureServe).

S5 ranking — Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery (NatureServe).

Scarious — Thin, dry, non-green, and membranous.

Scree — Accumulation of small rock debris (generally smaller than talus), often at base of cliff or steep slope.

Sensitive species — A species whose population viability is a concern due to downward trends in population numbers, density, or habitat capability, as identified by a regional forester.

Sessile — Lacking a stalk.

Sexual reproduction — Reproduction involving the union of gametes.

Stamen — The pollen-producing structures of a flower; the "male" part of a flower.

Staminate flower — A flower with "male" reproductive organs (stamens) and lacking "female" reproductive organs (pistils).

Succession — The orderly process of one plant community replacing another.

Symbiosis — An intimate association between two dissimilar organisms that benefits both of them.

Sympatric — Occupying the same geographic region.

Talus — Accumulation of coarse rock debris (generally larger than scree), often at base of cliff or steep slope.

Taproot — Main, central root growing straight down, often stouter than other roots.

Threatened — Defined in the Endangered Species Act as a species, subspecies, or variety in danger of becoming endangered throughout all or a significant portion of its range.

Vegetative reproduction — A form of asexual propagation whereby new individuals develop from specialized multicellular structures that often detach from the mother plant.

Viability — The capability of a species to persist over time. A viable species consists of self-sustaining and interacting populations that have sufficient abundance and diversity to persist and adapt over time.

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