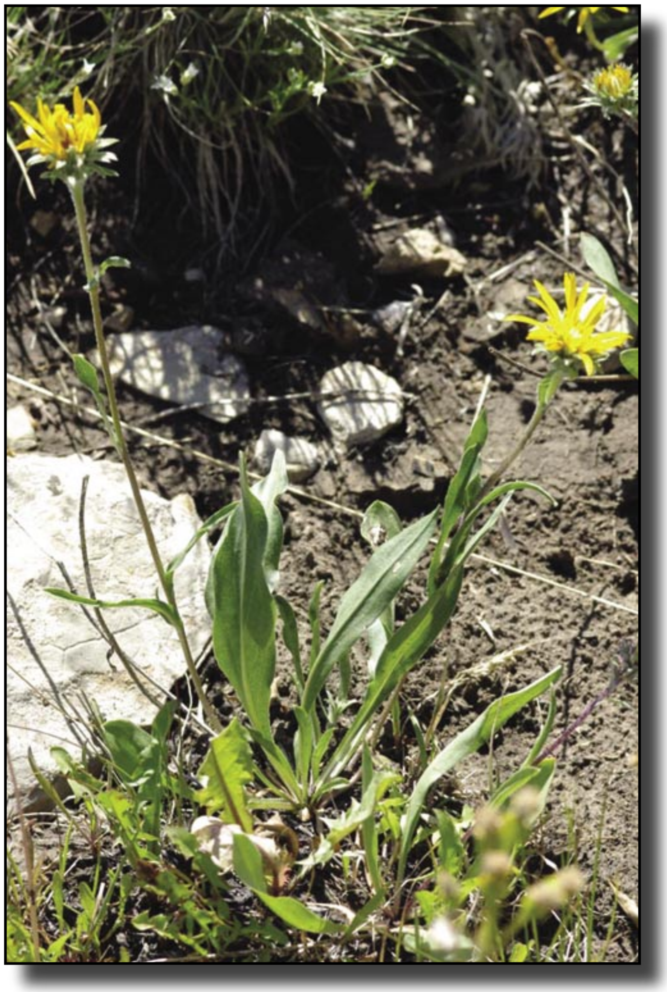
# *Pyrrocoma clementis* var. *villosa* (Rydb.) Mayes ex G.K. Brown & D.J. Keil (tranquil goldenweed): A Technical Conservation Assessment



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## ACKNOWLEDGMENTS

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Juanita A. R. Ladyman received her B.Sc. degree (with First-class honors) in Biochemistry from London University, England. Her first professional position was as plant pathology laboratory technician and, later, as greenhouse research supervisor with the Arid Lands Research Center on Sadiyat Island in the United Arab Emirates. She obtained her Ph.D. degree in Botany and Plant Pathology from Michigan State University where she was also a research assistant with the D.O.E. Plant Research Laboratory. She worked as a plant physiological ecologist and plant scientist for Shell Development Company conducting research on the physiology, ecology, and reproductive biology of economically important plant species and their wild relatives. She then worked for a plant biotechnology company in their Genetic Transformation and Plant Tissue Culture Division. For the last 15 years, she has worked in the area of conservation, particularly on rare, endemic, and sensitive plant species in the southwest United States. For three years of that time, she was the botanist with the New Mexico Natural Heritage Program. She has conducted research and monitoring programs on both non-vascular and vascular species. She currently is a partner in *JnJ Associates* LLC, an environmental consulting company in Colorado.

## COVER PHOTO CREDIT

*Pyrrocoma clementis* var. *villosa* (tranquil goldenweed). Photograph by Earl Jensen; photograph used with permission of the Bighorn National Forest.

# Summary of Key Components for Conservation of *Pyrrocoma clementis* var. *villosa*

## *Status*

*Pyrrocoma clementis* var. *villosa* (tranquil goldenweed) is endemic to north-central Wyoming. Since 1899, nine occurrences have been reported, of which two historic and four extant occurrences are on the Bighorn National Forest. The Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS) has designated *P. clementis* var. *villosa* a sensitive species. The Wyoming Bureau of Land Management (BLM) has not listed it as a sensitive species but does report it as occurring on land they manage and notes that it is a rare species with no federal protection status. The NatureServe Global rank for this variety of an otherwise apparently secure species is critically imperiled (G3G4T1). Likewise, the Wyoming Natural Diversity Database ranks it as critically imperiled (S1). These ranks confer no protection and serve only to indicate its conservation status.

## *Primary Threats*

*Pyrrocoma clementis* var. *villosa* is most vulnerable to habitat loss caused by activities associated with recreation and livestock grazing. An additional threat may come from resource extraction activities, particularly related to oil and gas development and bentonite mining. Habitat encroachment by invasive weeds is a general threat but may specifically threaten the occurrence in the Cedar Creek/Hunt Mountain Road area of the Bighorn National Forest. A variety of historic land uses (e.g., sheep and cattle grazing, fire suppression) may have altered much of this taxon's habitat.

The reproductive biology of *Pyrrocoma clementis* var. *villosa* has not been studied. However, if cross-pollination is important to its reproduction, as it is for other *Pyrrocoma* species, long-term population sustainability may be vulnerable to declines in pollinator abundance and/or changes in pollinator assemblage. As for all plant species, *P. clementis* var. *villosa* may be vulnerable to environmental stochasticity, especially prolonged drought. Elements of demographic and genetic stochasticity may be a threat, particularly if occurrences experience significant long-term declines in size and/or number due to habitat loss, direct destruction, or attrition due to poor reproductive output.

## *Primary Conservation Elements, Management Implications, and Considerations*

*Pyrrocoma clementis* var. *villosa* has only been documented nine times during the last century, and its abundance and range are not well understood. There is no information concerning the taxon's historic abundance. Therefore, it is not possible to estimate whether *P. clementis* var. *villosa* has changed in abundance, distribution, or range within the last century.

*Pyrrocoma clementis* var. *villosa* grows in meadows, grasslands, and big sagebrush communities. Observations made in 2005 suggest that grasslands may be a preferred habitat type. Fire contributes to maintaining grassland habitats; therefore, available *P. clementis* var. *villosa* habitat may have declined during the last century due to fire suppression practices. *Pyrrocoma clementis* var. *villosa* grows with other yellow-flowered species of Asteraceae, some of which may be confused with *P. clementis* var. *villosa* during its seedling and vegetative stages. Casual observation may overlook flowering *P. clementis* var. *villosa* among other yellow-flowered Asteraceae species. However, the flower head of *P. clementis* var. *villosa* is clearly distinguishable from the other species growing within its habitat, and careful observers are unlikely to misidentify it.

Of the nine reported *Pyrrocoma clementis* var. *villosa* occurrences, two are on land managed by the BLM. Another occurrence was found on Wind River Native American tribal land in 1961. The other six occurrences are on the Bighorn National Forest. One of these occurrences extended onto adjacent privately owned land. Two of the six Bighorn National Forest occurrences were reported at the turn of the twentieth century and may no longer be extant. These occurrences have vague location information but appear likely to have been in areas that are now forested. Targeted surveys for *P. clementis* var. *villosa* were conducted in 2004, 2005, and 2006 on the Bighorn National Forest, resulting in two new occurrences found in 2005 and one new occurrence found in 2006. The sixth *P. clementis* var.

*villosa* occurrence on the Bighorn National Forest was first reported in 1955, and the plant distribution was described as sparse. This occurrence was located again in 2004, and in 2005, it was determined to be substantially larger in extent and in number of plants than in 2004. The 2005 surveyors speculated that the wet spring conditions of 2005 might have been conducive to plant development and flowering. In 2004, the environmental conditions were drier and may have been unfavorable.

The four occurrences known to be extant on the Bighorn National Forest are in areas managed primarily for livestock grazing and recreation. Cattle grazing can negatively affect other *Pyrrocoma* species, but the effects on *P. clementis* var. *villosa* are not known. The current levels of livestock grazing appear to be compatible with persistence of *P. clementis* var. *villosa*. Recently implemented restrictions on motorized vehicle traffic in the Bighorn National Forest are expected to reduce disturbance in *P. clementis* var. *villosa* habitat and are likely to benefit the taxon. However, many of the known *P. clementis* var. *villosa* sub-occurrences are within 300 ft. of roads and will still be vulnerable to disturbance since these areas are open to vehicle traffic and camping. A significant decline in *P. clementis* var. *villosa* abundance on the Bighorn National Forest has the potential to impact viability of the species negatively rangewide because this Forest contains the largest known occurrences of the taxon.

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# INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Pyrrocoma clementis* var. *villosa* (Rydb.) Mayes ex G.K. Brown & D.J. Keil (tranquil goldenweed) is the focus of an assessment because it is narrowly endemic to north-central Wyoming and because it is designated a sensitive species by Region 2 (USDA Forest Service 2003b, 2005a). A sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce its distribution (FSM 2670.5 (19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

## *Goal*

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, and conservation status of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

## *Scope*

This *Pyrrocoma clementis* var. *villosa* assessment examines the biology, ecology, conservation status, and management of this species with specific reference to the geographic and ecological characteristics of the Rocky Mountain Region. Because of the limited amount of available information on *P. clementis* var. *villosa*, relevant studies on other *Pyrrocoma* species were also reviewed. Although some of the literature relevant to the species may originate from field investigations outside the region, this document places that literature in the ecological and social context of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive biology, population dynamics, and other characteristics of *P. clementis* var. *villosa* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting this synthesis, but placed in a current context.

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

Occurrence data were compiled from records provided by the Bighorn National Forest (Karow personal communication 2005), the Wyoming Natural Diversity Database (2004), the New York Botanical Garden (2005), the Rocky Mountain Herbarium at the University of Wyoming, and from Hall (1928).

## *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 observations limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference, as described by Platt, suggests that experiments will produce clean results (Hillborn and Mangel 1997), as may be observed in certain physical sciences. The geologist T.C. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (i.e., experiments, modeling, logical inference). Ecological science is, in some ways, more similar to geology than physics because of the difficulty in conducting critical experiments and the reliance on observation, inference, good thinking, and models to guide understanding of the world (Hillborn and Mangel 1997).

Confronting uncertainty, therefore, is not prescriptive. In this assessment, the strength of evidence for hypotheses is noted, and alternative explanations described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted approaches to understanding.

One element of uncertainty is associated with the taxonomic status of *Pyrrocoma clementis* var. *villosa*. Fertig (1999) suggested that additional study was needed to resolve the taxonomic status of the *Pyrrocoma* species that occur in the Big Horn Mountains. *Pyrrocoma clementis* var. *villosa* was described initially as the species *P. villosa* (Hall 1928). More recently, it has been suggested that *P. clementis* var. *villosa* be submerged into *P. integrifolia* (Cronquist 1994, Welp et al. 2000). The Atlas of the Vascular Flora of Wyoming (Chumley et al. 1998) reports *P. clementis*, with no associated varieties, and *P. integrifolia* as occurring in Wyoming. However, the recent edition of the Flora of North America (Nesom personal communication 2005, Bogler 2006) agrees with Mayes (1976) and Brown and Keil (1992) in recognizing *P. clementis* var. *villosa* as a valid taxon.

Another element, not of uncertainty but of caution, especially when reviewing older literature, is that in the past *Pyrrocoma* species were included in the genus *Haplopappus* (Hall 1928). A great deal of research on the ecology and biology of *Haplopappus* species has been reported, some of which may be a appropriate to consider when seeking to gain insights into aspects of *Pyrrocoma* species' biology and ecology. However, it is important to know that there are substantial differences in life form, life history, biology, and ecology among species formerly assigned to *Haplopappus* (Morgan and Simpson 1992, Cronquist 1994). Therefore, discretion must be used when considering the relevance of observations to the taxon of interest.

### *Publication of Assessment on the World Wide Web*

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

### *Peer Review*

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

## MANAGEMENT STATUS AND NATURAL HISTORY

### *Management Status*

*Pyrrocoma clementis* var. *villosa* is endemic to north-central Wyoming. The NatureServe (2006) global[1] rank for this variety is G3G4T1. The rank G3G4 indicates that the status of the full species, *P. clementis*[2], is between vulnerable and apparently secure. The code T1 indicates that the variety *villosa* is critically imperiled (NatureServe 2006). *Pyrrocoma clementis* var. *villosa*

[1]For definitions of G and S ranking see Rank in the **Definitions** section at the end of this document.

[2]*Pyrrocoma clementis* var. *clementis* is more widespread than variety *villosa*, occurring in Wyoming, Utah, and Colorado, and has the NatureServe global rank of between vulnerable and apparently secure (G3G4T3T4). On a state-by-state basis, *P. clementis* var. *clementis* is designated critically imperiled (S1) in Wyoming but is unranked in Utah and Colorado (NatureServe 2006).

is designated critically imperiled (S1) by the Wyoming Natural Diversity Database (2004). USFS Region 2 has designated *P. clementis* var. *villosa* a sensitive species (USDA Forest Service 2003a, 2005b). The Wyoming Bureau of Land Management (BLM) has not listed the taxon as a sensitive species but does report *P. clementis* var. *villosa* as occurring on BLM land, noting that it is a rare species with no conservation status (USDI Bureau of Land Management 2002, USDI Bureau of Land Management Wyoming 2004a). *Pyrrocoma clementis* var. *villosa* is not a candidate for listing under the federal Endangered Species Act of 1973.

## *Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies*

*Pyrrocoma clementis* var. *villosa*'s status as a Region 2 sensitive species indicates that it is "a plant species for which population viability is a concern as evidenced by a significant current or predicted downward trend in population number or density and/or a significant current of predicted downward trend in habitat capability that would reduce a species' existing distribution" (USDA Forest Service 2003a).

Targeted surveys for *Pyrrocoma clementis* var. *villosa* were initiated in 2004 on the Bighorn National Forest because the taxon was listed as a sensitive species in 2003 (Karow personal communication 2005). A management strategy that seeks to reduce threats and impacts to sensitive species and their habitats has been developed for threatened, endangered, sensitive, and other plant species of concern on the Bighorn National Forest (USDA Forest Service 2004a, 2005b). These documents outline survey and inventory procedures and also provide a step-by-step guide for reviewing the vulnerability of occurrences to various projects (e.g., road and trail construction, wildlife habitat improvement) that are undertaken on the forest (USDA Forest Service 2004a, 2005b). The documents also consider actions that can be taken to mitigate the impacts of these projects (USDA Forest Service 2004a, 2005b).

*Pyrrocoma clementis* var. *villosa* is not designated a sensitive species by the BLM in Wyoming (2004). Therefore, the taxon is not considered in management plans, grazing management practices, or during project implementation on lands managed by the BLM. One *P. clementis* var. *villosa* occurrence is likely to be located within the Spanish Point Karst Area of Critical Environmental Concern (ACEC). This ACEC is managed to protect important cave resources, sinking stream segments, and groundwater quantity and quality in a way that is consistent with the Wyoming Standards for Healthy Rangelands (USDI Bureau of Land Management 1999).

## *Biology and Ecology*

### Classification and description

#### *Systematics and synonymy*

*Pyrrocoma* is a genus of the Asteraceae, commonly known as the daisy, sunflower, or thistle family. *Pyrrocoma* is a member of the tribe *Astereae* and subtribe *Machaerantherinae* (Nesom 2000). The scientific taxonomic classification of *P. clementis* var. *villosa* is shown in **Figure 1**. Nesom (1994) estimated that at least 189 genera and approximately

| | |
|---|---|
| Kingdom | Plantae – Plants |
| Subkingdom | Tracheobionta – Vascular plants |
| Superdivision | Spermatophyta – Seed plants |
| Division | Magnoliophyta – Flowering plants |
| Class | Magnoliopsida – Dicotyledons |
| Subclass | Asteridae |
| Order | Asterales |
| Family | Asteraceae |
| Tribe | *Asteraea* |
| Subtribe | *Machaerantherinae* |
| Genus | *Pyrrocoma* |
| Species | *Pyrrocoma clementis* |
| Variety | *Pyrrocoma clementis* var. *villosa* |

**Figure 1.** Scientific taxonomic classification of *Pyrrocoma clementis* var. *villosa* (after Bogler 2006, Integrated Taxonomic Information System 2006).

3,020 species constitute the *Astereae*. The subtribe *Machaerantherinae* is currently reported to include the following genera: *Benitoa*, *Corethrogyne*, *Grindelia*, *Hazardia*, *Isocoma*, *Lessingia*, *Machaeranthera*, *Olivaea*, *Oonopsis*, *Rayjacksonia*, *Stephanodoria*, *Xanthisma*, *Xanthocephalum*, and *Xylorhiza*, as well as *Pyrrocoma* (Nesom 2000). The phylogenetic relationships among these taxa have been the subject of research (e.g., Hartman 1976, Mayes 1976, Hartman 1990, Lane and Hartman 1994, Morgan 1997).

Hooker (1833) first described the genus *Pyrrocoma* based on one specimen and initially remarked that the single specimen that he examined appeared to be related to species of the genera *Carthamus* (tribe *Cardueae*) and *Liatris* (tribe *Eupatorieae*). In 1894, E.L. Greene extended *Pyrrocoma* to include the genus *Homopappus* (Rydberg 1900). Recently, *Pyrrocoma* has been recognized as being closely related to several other genera including *Oonopsis* and *Rayjacksonia* (Lane and Hartman 1996), which some researchers consider as belonging in the *Machaeranthera* group (Bremer 1994). In a wider concept, *Oonopsis*, *Pyrrocoma*, and *Rayjacksonia* have also been included with many others to constitute the "*Haplopappus* group" (Hall 1928, Bremer 1994). Hall (1928) believed that generic segregates of the *Haplopappus* group were more effectively treated as sections of one inclusive genus, the oldest name of which was *Haplopappus*, first described by Alexandre Henri Gabriel Compte de Cassini in 1828. From the time that Hall (1928) published his treatment, many researchers included species of *Pyrrocoma* in *Haplopappus* until Mayes (1976) revised *Pyrrocoma* in a cytotaxonomic and chemosystematic study for his dissertation. Mayes (1976) did not validate any of the nomenclatural changes that he proposed in his dissertation, but many were formalized in a publication by Brown and Keil (1992).

One aspect to consider when discussing relatedness is that some taxa may appear to be closely related using methods of genetic analysis but share few morphological or cytological characters. Using chloroplast restriction site DNA analysis, Morgan and Simpson (1992) found that a close relationship existed between species of *Pyrrocoma* and species of *Machaeranthera* (section *Arida*), suggesting that they both arose from a common ancestor. However, the latter have a different morphology, life history, and ecological niche than *Pyrrocoma* species (Morgan and Simpson 1992). In addition, the sequence data from the internal transcribed spacers (ITS) of nuclear ribosomal DNA do not support the purported relationship (Morgan 1997). The commonality of specific restriction sites in the chloroplast genome raises questions as to their physiological significance and to the potential adaptations that *Pyrrocoma* and *Machaeranthera* might share with respect to their ostensibly different environments. Chloroplast DNA encodes for genes involved in photosynthesis and changes in these genes can have ecologically important consequences (Steinback et al. 1981). These genetic commonalities ("relatedness") between *Machaeranthera* and *Pyrrocoma* species might provide insights into the potential response of individual taxa, such as *P. clementis* var. *villosa*, to future environmental changes (e.g., elevated carbon dioxide levels), even though the species appear to be very different.

There are approximately 10 to 14 species of *Pyrrocoma*, several with infraspecific varieties; all are distributed within the western United States and Canada (Bremer 1994, Nesom 2000). Several of these taxa are narrow endemics in the western United States (Mancuso 1991, Mancuso 1997, Urie and van Zuuk 2000, Kaye 2002, Beatty et al. 2004). Two varieties of *P. clementis* are recognized: *P. clementis* var. *clementis*[3] and var. *villosa* (Kartesz 1994, Nesom personal communication 2005, Bogler 2006, Integrated Taxonomic Information System 2006).

It is widely accepted that many taxa within the Machaerantherinae pose a taxonomic challenge, and *Pyrrocoma clementis* var. *villosa* is apparently no exception (Morgan and Simpson 1992). The affinities of *P. clementis* var. *villosa* have been subject to various interpretations. Rydberg (1900) considered it to be related to *P. uniflora*, and Coulter and Nelson (1909) reduced *P. villosa* to a synonymy with this taxon. There is also a suggestion that *P. clementis* var. *villosa* might be appropriately submerged into *P. integrifolia* (Welp et al. 2000). Rather than being a variety of *P. clementis*, Cronquist (1994) stated that *P. clementis* var. *villosa* was "better included in *Haplopappus* [*Pyrrocoma*] *integrifolius*." Hall (1928) viewed *P. integrifolia* as being closely related to *P. clementis* but reported that it differed by consistently having "smaller parts" and especially by having wholly herbaceous involucral bracts. Hall (1928) also noted that the variation observed in *P. clementis*, named by Greene as *P. calendulaceae*

[3]Synonyms for *Pyrrocoma clementis* var. *clementis* include *Haplopappus clementis* (Hall 1928), *Aplopappus clementis* (Tidestrom 1925), *P. calendulaceae* (Greene 1909), *P. subcaesia* (Greene 1909), and *P. cheiranthifolia* (Greene 1910, Hall 1928).

(Greene 1910), *P. subcaesia* (Greene 1909), and *P. villosa* (Rydberg 1900), was unlikely to represent actual subspecies, except in the case of *P. villosa*, which he thought might be worthy of specific rank. He noted that "field studies of this form may lead to its acceptance as a full species, in which case its provisional reduction to sub-specific rank would only cause confusion." No detailed studies of *P. clementis* var. *villosa* have been published since Hall (1928). Mayes (1976) suggested that *P. villosa* was closely related to *P. clementis* in his unpublished dissertation, which was subsequently supported by Brown and Keil (1992).

### *History of species*

*Pyrrocoma clementis* var. *villosa* was apparently first collected at the end of nineteenth century in the Big Horn Mountains of Wyoming (occurrence 2 in **Table 1**). In his original description of the species in 1900, Rydberg characterized *P. villosa* as a unique taxon, "easily distinguished by the larger head and the foliaceous bracts in several series." Rydberg (1900) cited a specimen collected by Frank Tweedy, *#2063*, from Willow Creek in the Big Horn Mountains as the holotype, which is deposited at the New York Botanical Garden Herbarium. Infrequent collections of *P. clementis* var. *villosa* have been made since the turn of the twentieth century (occurrences 2 and 3 in **Table 1**). Two collections were made in 1950s (occurrences 1 and 4 in **Table 1**), and one each in 1961 (occurrence 6 in **Table 1**), 1981 (occurrence 5 in **Table 1**), and 2004 (occurrence 1 in **Table 1**). Three collections of *P. clementis* var. *villosa* were made in 2005 (occurrences 1, 7, and 8 in **Table 1**) and two in 2006 (occurrences 1 and 9 in **Table 1**).

Hooker (1833) derived the name *Pyrrocoma* from the Greek words *pyrrhos* ("tawny") and *kome* ("hair" [of the head]), in reference to the reddish pappus of the seed. The name can have a similarly appropriate derivation from the Latin words for "bronze" (*pyropus*) and "hair" (*coma*). The epithet *villosa* refers to long, shaggy hairs (Stearn 1998). The varietal name might be considered a slight misnomer for this taxon because var. *villosa* has smooth achenes while those of var. *clementis* are hairy (Dorn 2001).

### *Non-technical description*

*Pyrrocoma clementis* var. *villosa* is a perennial plant with a thick, woody taproot. It has one to three stems from a branched caudex. The stems are 3 to 15 cm tall, rarely up to 30 cm tall, and loosely white-hairy to hairless (glabrous). The stems are also described as purplish (Rydberg 1900). The basal leaves are oblanceolate to narrowly elliptic, 2 to 12 cm long, and sparsely hairy (pubescent) to hairless (glabrate) on the surface. Stem leaves are progressively smaller and sessile to clasping. Flower heads are solitary or may number up to four per stem. The flower head involucres are 10 to 20 mm high and woolly to smooth (glabrous). The involucral bracts are green (herbaceous) throughout and lanceolate to oblanceolate in shape, tapering at the tip. The ray flowers are yellow and 10 to 15 mm long, while the central disk flowers are 6 to 8.5 mm long. The fruits are smooth, hairless, four-sided achenes with tawny to brown bristles (Rydberg 1900, Dorn 2001, Fertig 2003). An illustration of *P. clementis* is shown in **Figure 2**, and photographs of *P. clementis* var. *villosa* are shown in **Figure 3**.

*Pyrrocoma clementis* var. *clementis*, *P. clementis* var. *villosa*, *P. uniflora*, *P. lanceolatus* and *P. integrifolia* are all morphologically similar taxa. Mature flower heads are required for definitive identification of *P. clementis* var. *villosa*. Features of flower head and the achene that distinguish it from other species are outlined in **Table 2**.

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

Detailed technical descriptions of *Pyrrocoma clementis* var. *villosa* appear in Hall (1928) and Bogler (2006). Other comprehensive technical descriptions are published in Rydberg (1900) and Dorn (1988, 2001). A photograph and collection details of the holotype specimen collected by Frank Tweedy in 1899 (occurrence 2 in **Table 1**) are on the Internet site of the New York Botanical Garden Herbarium (2005).

## Distribution and abundance

*Pyrrocoma clementis* var. *villosa* is endemic to north-central Wyoming (**Figure 4**). Approximately nine occurrences have been reported within the last century, and six are from land managed by the Bighorn National Forest. Four of the Bighorn National Forest occurrences (occurrences 1, 7, 8, and 9 in **Table 1**) have been observed within the last two years while two (occurrences 2 and 3 in **Table 1**) may no longer be extant.

In 2004, an occurrence composed of two sub-occurrences about 0.25 miles (0.4 km) apart was found on the Bighorn National Forest in the same vicinity as the occurrence reported in 1955 (occurrence 1 in

**Table 1.** Information describing occurrences of *Pyrrocoma clementis* var. *villosa*.

| Occurrence number | County | Land management | Dates observed | Location | Habitat description provided with occurrence report [geological formation from Love and Christiansen (1985)] | Abundance, reproductive status, and distribution | Sources of information |
|---|---|---|---|---|---|---|---|
| **1** | Big Horn | USDA Forest Service (USFS) Region 2 Bighorn National Forest | 04-Aug-1955<br>26-Jul-2004<br>27-Jul-2005<br>13-Jul-2006 | Within the Hunt Mountain Management Area, Medicine Wheel/Paintrock Ranger District.<br>1955: Bighorn Mountains, Cedar Creek.<br>2004: Cedar Creek; approximately 2 miles northeast of Granite Pass on US Highway 14.<br>2005: From Spring Creek Road, USFS road 221 along the Hunt Mountain Road [USFS road 10].<br>2006: Along USFS road 10 till fence line/district boundary; area to the south between the ridgeline and USFS road 10 | 1955: "Grassland on limestone loam soil and southwest slope of 10 degrees. Occurs with *Festuca idahoensis*, *Poa*, and *Carex*."<br>2004: In sagebrush grassland with *Artemisia tridentata*, *Pinus flexilis*, and *Poa* spp. in sites with high light exposure and low moisture. "Nathrop-Passcreek-Starley soil association" at 9,200 feet elevation."<br>2005: *Pyrrocoma clementis* var. *villosa* plants were most common in the forb and grass association. Plants grew in limestone "ruble" and slight washes. In north part of occurrence, plants were mostly in open gravelly areas with some sagebrush on gentle slopes. Associated species: *Agoseris*, *Arnica*, *Aster*, *Taraxacum*, *Lupinus*, and *Sedum* species. Plants in high light exposure, moist soil. 9,300 - 9,600 ft.<br>2006: Open park with *Agoseris*, *Arnica*, *Aster*, *Taraxacum*, *Lupinus*, spp., *Phlox* spp., and *Lupinus* spp. at 9,400-9,600 ft. Plants in all aspects on slopes of approximately 40%, in full sun, dry conditions and loam soils of Nathrop-Passcreek-Starley series [Madison limestone and Darby formation; landslide and glacial deposits in the vicinity] | 1955: In flower. "Sparse" abundance.<br>2004: "Approximately 100 individuals: 80% flowering and 20% vegetative."<br>2005: Several thousand plants scattered individually and in patches along roads and trails along approximately 9 miles crossing over 5 sections. Plants were most abundant at the center of the area in which plants were found. To the south of the area with the highest number of plants there were at least 9 sub-occurrences ranging in size from approximately 15 individuals to several thousand. On average reproductive status was: 86% flowering; 1% fruiting; 13% vegetative. To the north of the area with the highest number of plants there were at least six main sub-occurrences with plants in between. Depending upon the sub-occurrence: 85-90% flowering plants; 0-5% fruiting; 5-40% vegetative (Only one site had 40% vegetative plants in all other cases number of vegetative plants were <12%).<br>2006: Dozens of plants: 70 % flowering; 30% vegetative | *T.W. Galloway #2004-010* Big Horn National Forest Herbarium; Wyoming Natural Diversity Database (2004); Rocky Mountain Herbarium; Big Horn National Forest (2005), Big Horn National Forest (2006) |

**Table 1 (cont.).**

| Occurrence number | County | Land management | Dates observed | Location | Habitat description provided with occurrence report [geological formation from Love and Christiansen (1985)] | Abundance, reproductive status, and distribution | Sources of information |
|---|---|---|---|---|---|---|---|
| 2 | Sheridan | USFS<br>Region 2<br>Bighorn National Forest | Aug-1899 | Bighorn Range, "Willow Creek" [probably in the vicinity of Park Reservoir on Willow Creek, a tributary of Little Goose Creek]; Tongue Ranger District | Meadow. (Meadows, Willow Creek 9,200 feet on specimen sheet). [Largely granite gneiss - contains diorite and quartz diorite facies which are neutral pH; glacial deposits - till & outwash of sand & boulders in the vicinity] | No information | *F. Tweedy #2063* 1899 NY[1]; Wyoming Natural Diversity Database (2004), Mayes (1976) |
| 3 | Johnson | USFS<br>Region 2<br>Bighorn National Forest | Jul-1900<br>Aug-1900 | East slope Bighorn Range, "headwaters of Clear Creek and Crazy Woman River". Powder River Ranger District | No information associated with specimen. [Gneiss complex with glacial deposits -till and outwash of sand & boulders in the vicinity] | Aug-1900: In flower | Wyoming Natural Diversity Database (2004); Rocky Mountain Herbarium |
| 4 | Big Horn | Bureau of Land Management (BLM) Worland Field Office<br>Spanish Point Karst Area of Critical Environmental Concern | 01-Jul-1952 | West slope Bighorn Mountains, "2 miles west of Forest Boundary, 6 miles south of Shell Ranger Station" [vicinity of Trapper Canyon] | No information associated with specimen. [Madison limestone and Darby formation or Whitewood dolomite and Winnipeg and Deadwood formations or Tensleep sandstone | In flower | Wyoming Natural Diversity Database (2004); Rocky Mountain Herbarium |
| 5 | Washakie | BLM Worland Field Office | 15-Jul-1981 | Bighorn Range, Middle Fork Powder River, approximately 17 miles southeast of Big Trails, and 28 miles southeast of Ten Sleep [near the confluence of Rock Creek and the Middle Fork Powder River] | Grassy sagebrush slope with scattered limber pine at 7,300 feet [Cambrian limestone rocks with old gneiss complex in the vicinity] | In flower | Wyoming Natural Diversity Database (2004); B.E. Nelson, Rocky Mountain Herbarium; Karow personal communication (2005) |

**Table 1 (concluded).**

| Occurrence number | County | Land management | Dates observed | Location | Habitat description provided with occurrence report [geological formation from Love and Christiansen (1985)] | Abundance, reproductive status, and distribution | Sources of information |
|---|---|---|---|---|---|---|---|
| 6 | Fremont | Wind River Native American tribal lands | 29-Jul-1961 | East slope Wind River Range, “about 25 miles west of Lander on the Moccasin Lake Road” [probably on slopes of Bald Mountain east of Moccasin Lake] | Mountain meadow with scattered big sagebrush. [Madison limestone and Darby formation or Whitewood dolomite and Winnipeg and Deadwood formations] | In flower | Wyoming Natural Diversity Database (2004); Rocky Mountain Herbarium |
| 7 | Big Horn | USFS Region 2 Bighorn National Forest | 01-Aug-2005 | Along open ridge above Johnny Creek and just north of USFS road 374112 | On open slope with forbs (*Agoseris*, *Arnica*, *Senecio* and *Taraxacum* species) and grasses. West aspect, good moisture, 0 to 1% slope and high light exposure | “Too many [individuals] to count in some spots and scattered in others.” 50% flowering, 50% fruiting | Big Horn National Forest (2005) |
| 8 | Big Horn | USFS Region 2 Bighorn National Forest; private land | 01-Aug-2005 | Along USFS road 17 about 1.5 miles south from the National Forest boundary | Open forb-dominated area with some grasses along a road and into open, slight slope areas with gravel. Predominantly *Agoseris* and *Arnica* species with abundant *Senecio* and *Taraxacum*. East to west aspect, 0 to 10% slope, high light exposure, good spring moisture. | At least four main sub-occurrences. Individuals were scattered over a distance of 3 to 4 miles. The “number of individuals in the area were probably in the hundreds, there were a lot of them on both sides of the road” 50% flowering, 50% fruiting. Occurrence mostly on private land used for livestock grazing. | Big Horn National Forest (2005) |
| 9 | Big Horn | USFS Region 2 Bighorn National Forest | 13-Jul-2006 | Approximately 15 miles south on USFS road 17 from Hwy 14, north east of Spanish Point | Open sites within sagebrush; associated species include *Artemisia* spp., *Carex* spp., *Taraxacum officinale*, *Potentilla paradoxa*, Poa spp., *Penstemon* spp., *Zigadenus paniculatus*, *Aster* spp., and *Lupinus* spp. Plants with north, northwest, and northeast aspect on slopes <16 %, in full sun, with “dry-moist” conditions and loam soil of series Nathrop-Passcreek-Starley [Limestone] | Total number of individuals were less than 100; 100% flowering | Big Horn National Forest (2006) |

[1] Abbreviation: NY: New York Botanical Garden Herbarium, New York.

**Figure 2.** Illustration of *Pyrrocoma clementis* from Hall (1928). Used courtesy of the Carnegie Institution of Washington D.C.

**Figure 3.** Photographs of *Pyrrocoma clementis* var. *villosa* taken from (left) above and (right) from the side. Both photographs are used with permission of the Bighorn National Forest. Earl Jensen is the photographer of right photograph. The photographer of left is unknown.

**Table 2.** Achene and floral characteristics that distinguish *Pyrrocoma clementis* var. *villosa* from *P. clementis* var. *clementis*, *P. uniflora*, *P. lanceolata*, and *P. integrifolia* (after Bogler 2006). See **Definitions** section for explanation of technical terms.

| Species | Achene | Flowers per stem | Involucre | Phyllaries | Floret |
|---|---|---|---|---|---|
| *P. clementis* var. *villosa* | Hairless | Usually 1 terminal flower per stem; sometimes with 2 or three smaller flowers down the stem | Broadly campanulate, 8-15 x approximately 20 mm wide | In 3 or 4 series, green with white margins, sometimes yellowish, narrowly lanceolate, 6-12 mm long, margins ciliate, faces usually hairy, apices attenuate | Ray florets 21 to 55; corollas 10 to 18 mm long; disc florets 100+; corollas 6 to 8 mm long |
| *P. clementis* var. *clementis* | Covered with long, silky hairs. | Usually 1 terminal flower per stem; sometimes with 2 or three smaller flowers down the stem | Broadly campanulate, 8-15 x 20 - 44 mm wide | In 3 or 4 series, green with white margins, sometimes yellowish, narrowly obovate, 6-12 mm long, apices abruptly acute | Ray florets 21 to 55; corollas 10 to 18 mm long; disc florets 100+; corollas 6 to 8 mm long |
| *P. uniflora* | Covered with long, silky hairs. | Usually 1 per stem; sometimes 2 to 4 per stem in racemiform arrays | Hemispheric, 6-13 x 10-20 mm | In 2 series, appressed or loose, linear-lanceolate, 6-11mm long, sub-equal or unequal, margins ciliate, faces usually hairy to woolly, rarely hairless, outer phyllaries sometimes green throughout | Ray florets 18 to 50; corollas 7 to 11 mm long; disc florets 35 to 60; corollas 5 to 8 mm long |
| *P. lanceolata* | Covered with long, silky hairs. | Usually 2 to 20 (sometimes 1 to 50) per stem in corymbiform or paniculiform arrays | Hemispheric, 7-10 x 10-18 mm | In 3 or 4 series, linear-lanceolate to lanceolate, 3-11 mm long, unequal, margins eciliate, faces hairless or slightly tomentulose, and sometimes stipitate glandular, apices conspicuously green, bases white-chartaceous | Ray florets 18 to 45; corollas 6 to 11 mm long; disc florets 20 to 100; corollas 5 to 7 mm long |
| *P. integrifolia* | Hairless | Usually 2 to 4 per stem in racemiform arrays or sometimes 1 per stem | Hemispheric, 11-17 x 20-30 mm | In 2 or 3 series, oblanceolate to oblong, 7-13 mm long, unequal, margins densely ciliate, faces hairless, apices green and acuminate, bases chartaceous | Ray florets 18 to 45; corollas 10 to 20 mm long; disc florets 80 to 100; corollas 6.5 to 10 mm long. |

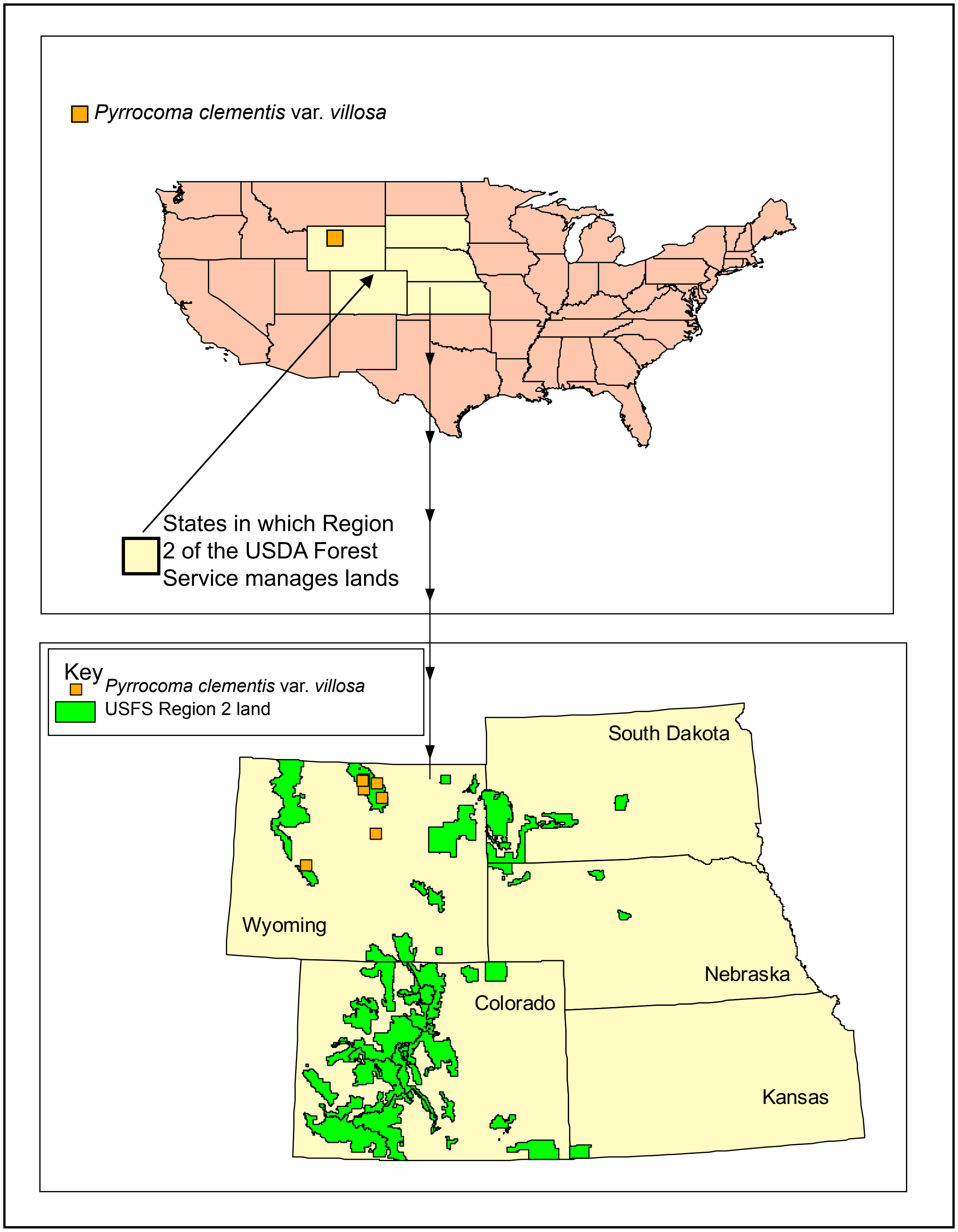


**Figure 4.** Global range of *Pyrrocoma clementis* var. *villosa* (above), and distribution of occurrences within USDA Forest Service Region 2 (below).

**Table 1**); this occurrence contained an estimated 100 individuals within an area of approximately 1 acre (Karow personal communication 2005). In 2005, the area and number of individuals that comprised occurrence 1 had increased considerably. Several thousand individuals were distributed in patches and as single individual plants between the patches along approximately 9 consecutive miles of roads and trails. At least 36 isolated individuals and 16 sub-occurrences ranging in size from 15 to several thousand individuals were reported (Karow personal communication 2005). In 2006, dozens of individuals were again found in the vicinity of occurrence 1, and the area covered by this occurrence was extended further west by approximately 0.5 miles (Karow personal communication 2006).

The range of occurrence 1 (**Table 1**) includes areas along Cedar Creek and is within 1 mile of the area nominated as the Elephant Head Research Natural Area (RNA) (Welp et al. 1998). *Pyrrocoma clementis* var. *villosa* was not observed within the proposed RNA during surveys conducted in late July and early August 1997, when *P. clementis* var. *villosa* was likely to be in flower. However, the participants in the survey suggested that *P. clementis* var. *villosa* may occur in the northern half of the proposed RNA where there is limestone grassland that appears to be suitable habitat for the taxon (Welp et al. 1998). The Elephant Head site was not recommended for RNA status in 2005, and most of the area is now being managed for deer and elk winter range, with a small portion managed for rangeland vegetation (Bornong personal communication 2006).

Two other *Pyrrocoma clementis* var. *villosa* occurrences on the Bighorn National Forest (occurrences 7 and 8 in **Table 1**) were first located in 2005. Occurrence 7 was found approximately 13 miles southwest of the southern boundary of occurrence 1, and occurrence 8 was located approximately 9 miles south of occurrence 1. Most of the area covered by occurrence 8 is on private land. In 2006, another occurrence (occurrence 9 in **Table 1**) was found approximately 3 miles south of occurrence 7.

Two occurrences of *Pyrrocoma clementis* var. *villosa* (occurrences 4 and 5 in **Table 1**) are likely to be on land managed by the BLM. Occurrence 4, first located in 1952, may be in the BLM Spanish Point Karst ACEC, but the location information is too vague to be certain. There is private land in the vicinity. Occurrence 5 dates from 1981 and definitely is on BLM managed land. One additional occurrence, reported in 1961, is most likely on Eastern Shoshone and Northern Arapahoe tribal lands. The status of *P. clementis* var. *villosa* at occurrences 2, 3, 4, 5, and 6 and the rangewide abundance of the taxon are unknown.

### Population trend

*Pyrrocoma clementis* var. *villosa* appears to be restricted to a few areas in north-central Wyoming (**Figure 4**). The taxon has been documented infrequently since the first collection in 1899 (**Table 1**). Prior to 2004, all occurrence information for *P. clementis* var. *villosa* was derived from herbarium specimens or relatively casual incidental observations by botanists and does not provide quantitative information on the abundance or spatial extent of the taxon.

*Pyrrocoma clementis* var. *villosa* was reported to be "sparse" at Cedar Creek in 1955 (occurrence 1 in **Table 1**). Targeted surveys for *P. clementis* var. *villosa* were initiated on the Bighorn National Forest in 2004 when approximately 100 individuals were observed in the vicinity of the 1955 report (Karow personal communication 2005). Targeted surveys continued in 2005, and the numbers of *P. clementis* var. *villosa* plants and the area they covered increased considerably. Several thousand individuals were reported, both in patches and singly across 4 to 5 square miles at occurrence 1 (**Table 1**). Two new *P. clementis* var. *villosa* locations were discovered south of occurrence 1: one divided between the Bighorn National Forest and private land, and one wholly on the Bighorn National Forest (occurrences 7 and 8 in **Table 1**). Early reports from the 2006 surveys indicate that plants were found within the area covered by occurrence 1 and an additional occurrence (occurrence 9 in **Table 1**) was located.

The increase in number of *Pyrrocoma clementis* var. *villosa* plants reported in 2005 and 2006 cannot be interpreted as an increase in abundance over historical levels. The observations in 2004, 2005, and 2006 likely represent an increase in botanist awareness and reflect the effectiveness of targeted surveys for *P. clementis* var. *villosa* since it was designated a sensitive species. Observations during recent surveys on the Bighorn National Forest suggest that *P. clementis* var. *villosa* could be overlooked because the taxon superficially looks like many other yellow Asteraceae species (e.g., species of *Arnica*, *Agoseris*, *Senecio*, and *Taraxacum*) growing in the same area (Bighorn National Forest 2005). However, when targeted for survey, *P. clementis* var. *villosa* is easy to recognize because it is the only yellow member of the Asteraceae with central disk florets in the flower head and alternate leaves growing in open areas (Bighorn National Forest 2005).

The fact that considerably more *Pyrrocoma clementis* var. *villosa* plants were found on the Bighorn National Forest in 2005 than in 2004 is probably due to more than just increased efforts to find it. Targeted surveys were made both years. Even though search intensity may have been different between the two years, the order of magnitude difference in the number of individuals is striking. One explanation is that considerably more plants were vegetative in 2004 than in 2005 and were overlooked in 2004. Alternatively or additionally, plants may have been dormant (underground) in 2004. These hypotheses suggest that growth and development of *P. clementis* var. *villosa* is sensitive to environmental conditions, and abundance may vary greatly depending on the year. The wet spring of 2005 may have been particularly favorable for *P. clementis* var. *villosa* growth and flowering (Karow personal communication 2005). The final results of the 2006 surveys had not been determined as this assessment was being written, and it is unknown whether *P. clementis* var. *villosa* plants will be as abundant as in 2005. Surveys need to be conducted over several consecutive years to determine if the annual abundance of *P. clementis* var. *villosa* experiences large fluctuations.

## Habitat

*Pyrrocoma clementis* var. *villosa* has been reported to grow at elevations between approximately 7,300 and 9,200 ft. (2,200 and 2,805 m). The elevation range may actually be wider than that reported because *P. clementis* var. *clementis*, which appears to have similar habitat affinities, grows at elevations up to 12,000 ft. (3,660 m) in Utah (Welsh et al. 2003). *Pyrrocoma clementis* var. *villosa* plants grow on gentle slopes and in shallow washes. Plants do not appear to favor any particular aspect.

*Pyrrocoma clementis* var. *villosa* grows in montane meadows and sagebrush grasslands (**Table 1**, **Figure 5**). Observations in 2005 suggested that *P. clementis* var. *villosa* grew in the spaces between widely spaced *Artemisia tridentata* (big sagebrush) shrubs and were most abundant in grasslands devoid of this shrub. Widely scattered *Pinus flexilis* (limber pine) were reported at occurrence 5 and at one of the sub-occurrences of occurrence 1 (**Table 1**). Occurrence 3 (**Table 1**), which was reported in 1900, is now in a *P. contorta* (lodgepole pine) community (USDA Forest Service 2003a). This occurrence might have been in a meadow or shrub-grassland surrounded by forest, and conifers may have now replaced the open habitat that was present more than 100 years ago (Knight 1994).

*Pyrrocoma clementis* var. *villosa* appears to favor neutral to alkaline loam soils (**Table 1**, USDA Forest Service 2005b). Although the location descriptions associated with some of the occurrences are rather

**Figure 5.** Photograph of *Pyrrocoma clementis* var. *villosa* plants in a big sagebrush-grassland community on the Bighorn National Forest, Wyoming. *Pyrrocoma clementis* var. *villosa* plants are among several other yellowed-flowered species. Photograph used with permission of the Bighorn National Forest.

vague, the available information indicates that seven of the nine occurrences are most likely associated with soils derived from limestone or dolomite. Occurrences 1, 4, and 6 in **Table 1** are most likely on soils derived from the Madison Limestone and Darby formations (Love and Christiansen 1985). Occurrence 2 appears to be most likely on a formation of largely granite gneiss that contains diorite and quartz diorite facies, which have neutral pH (Bates and Jackson 1984, Love and Christiansen 1985).

### Reproductive biology and autecology

*Pyrrocoma clementis* var. *villosa* is a perennial species with a persistent basal rosette (Nesom 2000). Other than the branching caudex that permits restricted lateral spread, the taxon is unlikely to be able to propagate vegetatively. *Pyrrocoma clementis* var. *villosa* therefore relies on reproduction by seed for long-term sustainability. Observations indicate that flowering is from July 1st through August 4th (**Table 1**). It is possible that flowering extends over a longer period since *P. clementis* var. *clementis* flowers from late June into early September (Cronquist 1994).

The ploidy level of *Pyrrocoma clementis* var. *villosa* has not been determined (Mayes 1976). The base chromosome number of *Pyrrocoma* species is n = 6, but *Pyrrocoma* species can be polyploid (Nesom 2000). Polyploidization can contribute to speciation in angiosperms, and closely related pairs of species often differ in their degree of ploidy. For example, some populations of *P. carthamoides* and *P. radiatus*[4] are tetraploid (n = 12) or hexaploid (n = 18), respectively (Kaye 2002).

*Pyrrocoma* species' flowers are hermaphroditic, having both male and female organs. No specific studies have been made on reproductive biology of *P. clementis* var. *villosa*. *Pyrrocoma* species can be self- and cross-pollinated, although maximum levels of seed set in *P. radiata* required cross-pollination (Kaye et al. 1990, Kaye and Meinke 1992, Mancuso and Moseley 1993). A level of within-flower self-pollination (autogamy) is likely to be advantageous, since it can provide reproductive assurance (Eckert 2000). On the other hand, self-pollination forced by factors such as small population size or paucity of pollinators can lead to inbreeding depression in a primarily out-breeding species (Herlihy and Eckert 2002). Reproductive assurance may therefore be of only limited use for long-term sustainability.

Extensive data that relate flower shape to pollinator species among members of the Asteraceae have been collected (Leppik 1977). *Pyrrocoma clementis* var. *villosa* flowers are actinomorphic, or radially symmetrical, and are therefore likely pollinated by a wide assemblage of arthropods that include members of the Hymenoptera (bumblebees and solitary bees), Diptera (flies), Lepidoptera (butterflies), and to a lesser extent Coleoptera (beetles) (Leppik 1977). Bees are likely to be the primary pollinator of *P. clementis* var. *villosa* (Leppik 1977).

The pollen exine of members of the *Haplopappus* group has an elaborate architecture of pyramidal-shaped spines that facilitates transport by hairy arthropod species. *Pyrrocoma* species are a little different from other members of the subtribe *Machaerantherinae* by having five rows of the pyramidal spines between colpi and, often having larger-sized pollen with equatorial diameters up to 49 µm (Clark et al. 1980). Like all members of the Asteraceae, *Pyrrocoma* pollen is trinucleate (Gegick and Ladyman 1999).

There are no details known of the quantity or viability of seed produced by *Pyrrocoma clementis* var. *villosa*. Climatic conditions may influence both flower head production and seed set. The total number of *P. radiata* seeds produced per flower head was positively correlated with summer precipitation, and the number of seed heads produced was positively correlated with the amount of winter precipitation (Kaye 2002). Timing of seed germination is also unknown. *Pyrrocoma radiata* seed germination trials indicated that seeds were able to germinate within a few weeks of dispersal, at temperatures at least as low as 7 °C, and some seeds continued to germinate through fall, winter, and spring if kept moist (Kaye 2002). In the field, most germination appeared to occur in the spring, which was likely to be due to dry fall conditions coupled with freezing temperatures (Mancuso and Moseley 1993). *Pyrrocoma clementis* var. *villosa* grows at higher elevations than *P. radiata*. At higher elevations, some type of seed dormancy mechanism may be advantageous in order to avoid germinating in unfavorable conditions (Kaye 1997). In addition, there may be variation among occurrences of *P. clementis* var. *villosa*. In many plant families, populations of the same species that are adapted to different elevations can have different seed dormancy characteristics (Meyer et al. 1989, Lesica and Shelley 1995, Allen and Meyer 2002). The size and longevity of the soil seed bank of *P. clementis* var. *villosa* have not been studied.

[4]Synonyms: *P. carthamoides* ssp. *maximus*, *Haplopappus carthamoides* ssp. *maximus*.

*Pyrrocoma clementis* var. *villosa* seed dispersal mechanisms are not documented. Water may disperse seeds across the ground surface, especially during intense downpours. The bristle-like pappus at the top of each fruit (achene) suggests that wind may also assist in dispersal. The seed otherwise does not appear to have structural features, such as barbs to catch on animal fur, that would aid other types of dispersal. If the seed is edible, seed caching and dispersal by rodents and other animals such as ants may contribute to dispersal.

### Demography

There have been no studies of the demographics of *Pyrrocoma clementis* var. *villosa*. Since it is a perennial, plants are probably iteroparous, reproducing for a number of years before they die. The number of years a single individual can live is unknown. Observations made in 2004, 2005, and 2006 at occurrence 1 (**Table 1**) indicate that 20 to 40 percent of an occurrence might remain vegetative in a given year and suggesting that plants do not necessarily flower and produce seed every year. However, rather than having reverted to a vegetative state after being reproductive in previous years, it is possible that the vegetative individuals were juveniles or had not yet reached the necessary size for reproduction to begin. It is also unknown if plants can remain dormant for one or more years in response to environmental stress, such as drought. The fact that thousands of plants were counted in 2005 in the same area where only approximately 100 individuals had been seen in 2004 (occurrence 1 in **Table 1**) suggests that the plants can remain dormant (underground) for at least one growing season. This type of extended dormancy is termed "prolonged dormancy."

*Pyrrocoma clementis* var. *villosa* is a perennial plant with a thick, woody taproot and branched caudex. The phenomenon of prolonged dormancy has been most often studied in plant species that possess bulbs, rhizomes, or tubers (Lesica 1994, Kèry and Gregg 2004, Miller et al. 2004). However, a few species with thick woody taproots in disparate plant families have been documented to exhibit prolonged dormancy under unfavorable environmental conditions (e.g., drought) (Lesica 1994). *Silene spaldingii* (Caryophyllaceae) is a perennial herb, arising from a simple or branched caudex surmounting a long, slender taproot (Lesica 1999). *Silene spaldingii* (Spalding's silene) plants may go undetected for one or more years, and prolonged dormancy of the taproot has been inferred for this species (Lesica and Steele 1994, Lesica 1997, 1999). Other species with a compact taproot that apparently exhibit prolonged dormancy include *Cymopterus deserticola* (desert cymopterus) and *Lomatium attenuatum* (tapertip desertparsley) in Apiaceae, *Astragalus scaphoides* (Bitterroot milkvetch) in Fabaceae, and *Gentiana pneumonanthe* (marsh gentian) in Gentianaceae (Lesica 1994, Vanderhorst and Heidel 1998, U.S. Fish and Wildlife Service 2004). The life history of all these species was studied because they are rare. Detailed studies of other vascular plant species might reveal that prolonged dormancy is more widespread than is currently appreciated (Lesica 1994).

**Figure 6** is a simple life cycle diagram for *Pyrrocoma clementis* var. *villosa*, based on Kaye's (2002) demographic studies of *P. radiata* in Idaho and Oregon. *Pyrrocoma radiata* shares several attributes with *P. clementis* var. *villosa*. They both have a perennial growth habit and do not spread by vegetative reproduction. Both are rare species that occur in shrub-steppe rangeland. *Pyrrocoma radiata* is endemic to a region that straddles eastern Oregon and western Idaho, whereas *P. clementis* var. *villosa* is endemic to north-central Wyoming. A notable difference is that although both grow in *Artemisia tridentata*-grassland communities, *P. radiata* grows at lower elevations (650 to 1,500 m) than *P. clementis* var. *villosa*. The implications of these differences on life history are unknown but might be sufficient to invalidate this extrapolation. However, in the absence of specific studies on *P. clementis* var. *villosa*, the conclusions made by the authors of the studies on *P. radiata* are useful to consider, especially in designing future studies for *P. clementis* var. *villosa*.

Kaye (2002) analyzed information collected for more than 16,000 *Pyrrocoma radiata* individuals over an eleven-year period. The results indicated that mortality was highest for seedlings, followed by juvenile, vegetative, and reproductive plants, and a plant's chance of survival improves as it increases in size, and perhaps with age (Kaye 2002). Other than those generalities, populations differed from site to site and even from year to year in terms of density, plant size, and fecundity. The differences were ascribed to different environmental conditions, especially precipitation and impacts from livestock grazing (Kaye 2002). Plant size and age were not directly correlated because environmental conditions and the extent to which plants were protected from grazing also affected plant size (Kaye 2002).

No seedlings have been reported at *Pyrrocoma clementis* var. *villosa* occurrences. This might be due to their inconspicuous nature, lack of surveys, or, considering the *P. radiata* results (Kaye 2002), high

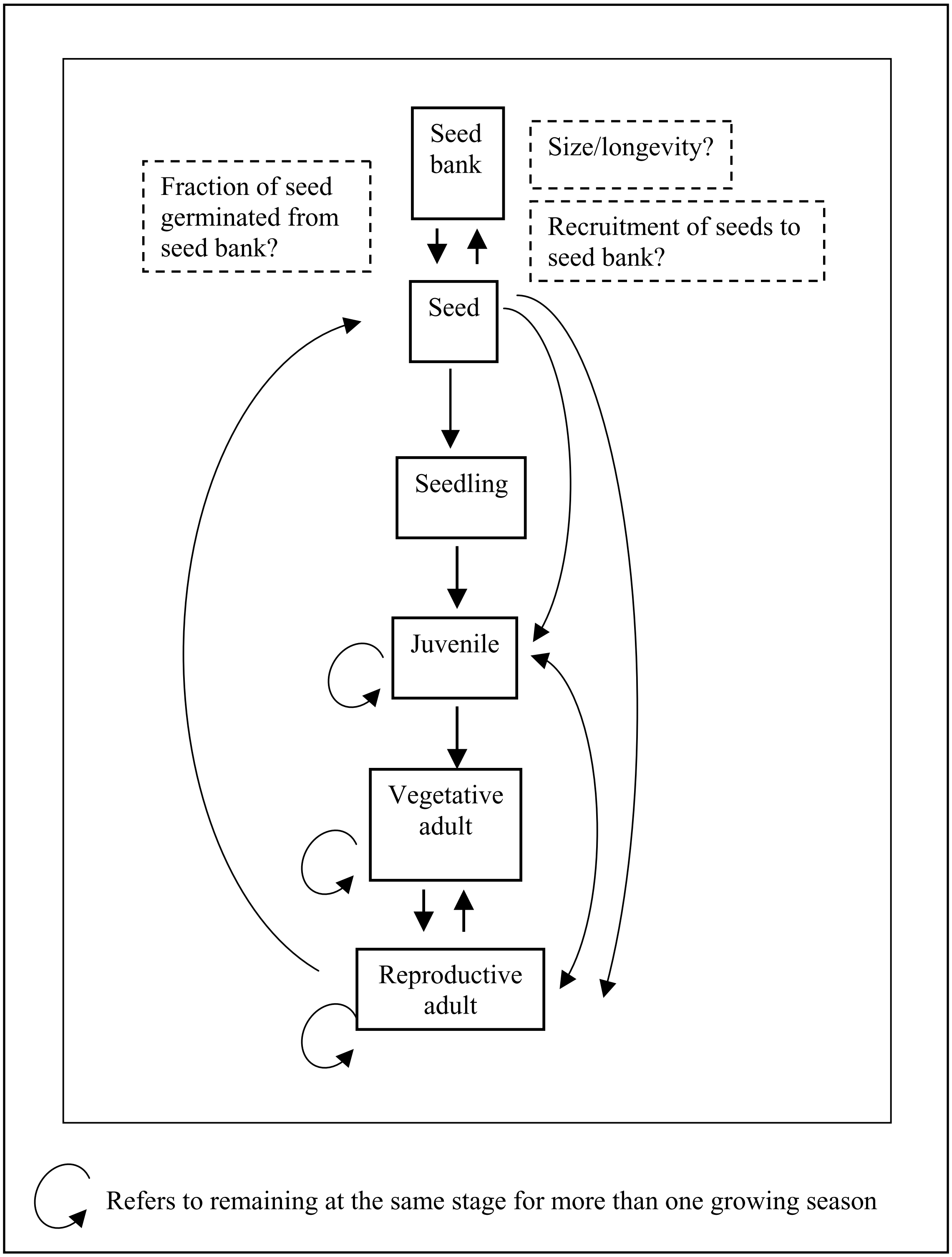


**Figure 6.** Proposed life cycle of *Pyrrocoma clementis* var. *villosa* (after Kaye 2002).

rates of mortality early in the season before the surveys were conducted. If *P. clementis* var. *villosa* shares life history traits with *P. radiata*, the survival of the adult plant, not annual seedling recruitment, may be a more critical stage in its life history.

The equilibrium growth rate, λ, which integrates the effects of survival, growth, and fecundity of the different life history stages into a single parameter, is very useful in evaluating the stability of a population (Caswell 1989, Silvertown et al. 1993). When $\lambda = 1$, the population is stable; when it is less than 1, the population is in decline; and when it is greater than 1, the population is growing (Mills et al. 1999). Herbaceous perennials tend to have λ greater than 1 (Silvertown et al. 1993). For example, λ for populations of *Senecio integrifolius*, a rare perennial similar to *Pyrrocoma clementis* var. *villosa* in both habitat and morphology, was calculated to be 1.46 (Widén 1987, Silvertown et al. 1993). Over the 11 years of the study of four *P. radiata* populations, λ averaged 0.97 (0.82 to 1.11 and 0.86 to 1.08 for protected and grazed populations respectively), suggesting that the populations were stable but not growing (Kaye 2002). Habitat conditions might influence the potential for growth. *Pyrrocoma radiata*'s habitat is apparently significantly modified and degraded from how it was more than a century ago (Moseley and Mancuso 1994, Kaye 2002). The results from a similar study of *P. clementis* var. *villosa* would be very informative.

*Pyrrocoma clementis* var. *villosa* has a short stature and little lateral spread, and it appears to grow slowly. Species having a similar life form and regenerative strategy were characterized as stress-tolerant by Grime et al. (1988), and as *K*-selected species (i.e., species that have a long life span in relatively stable habitats) by MacArthur and Wilson (1967). Disturbance above some as yet unknown level may be detrimental to the sustainability of *P. clementis* var. *villosa* populations.

### Community ecology

Due to the small number of occurrences and the absence of detailed studies of the taxon, there is little information on the community ecology of *Pyrrocoma clementis* var. *villosa*. Observations indicate that it is a member of montane meadow and sagebrush grassland communities. At occurrence 1 (**Table 1**), *P. clementis* var. *villosa* plants appeared to be most common in the forb and grass association and were not closely associated with *Artemisia* shrubs (Bighorn National Forest 2005). In 2006, *Artemisia* (sagebrush) shrubs and species of *Carex* (sedge) dominated the community at a new occurrence located that year (occurrence 9 in **Table 1**). Grassland is included in the habitat description for most occurrences, but few grass species have been identified (see occurrences 1 and 9 in **Table 1**). *Festuca idahoensis* (Idaho fescue) and species of *Poa* (bluegrass) are common grasses in both meadow and sagebrush grassland communities (Knight 1994). Forb species reported at *P. clementis* var. *villosa* occurrences are listed in **Table 3**.

There is no information for microbiotic or mycorrhizal associations with *Pyrrocoma clementis* var. *villosa*. Therefore, it is unknown if they play a critical role in this taxon's ecology. However, mycorrhizal associations are apparently important to other members of the community. Vesicular-arbuscular mycorrhizal (VAM) fungi are commonly associated with members of the Asteraceae and are important to the establishment and persistence of *Artemisia tridentata* ssp. *wyomingensis* (Wyoming big sagebrush; Bethlenfalvay and Dakessian 1984, Stahl et al. 1998). Mycorrhizal fungi are also documented with *Festuca idahoensis* (Molina et al. 1978, Goodwin 1992). Therefore, *P. clementis* var. *villosa* is likely to be exposed to mycorrhizal soils and may have an active association with mycorrhizal fungi.

Since fire historically may have helped maintain the taxon's meadow and sagebrush-grassland habitat, *Pyrrocoma clementis* var. *villosa* may be adapted to periodic fire (Knight 1994). However, its response to fire is unknown. The caudex's survival or re-sprouting rate after fire has not been documented. After fire, the relative importance of seed in the seed bank or from seed rain in recolonizing sites is also not known. In

**Table 3.** Forb species observed with *Pyrrocoma clementis* var. *villosa* on the Bighorn National Forest.

| | |
|---|---|
| *Agoseris* spp. | *Phlox* spp. |
| *Pulsatilla* sp. [reported as "*Anemone* (*Pulsatilla*)"] | *Potentilla paradoxa* |
| *Antennaria* spp. | *Potentilla* spp. |
| *Arnica* spp. | *Sedum* spp. |
| *Artemisia* spp. | *Senecio* spp. |
| *Aster* spp. | *Taraxacum officinale* |
| *Cerastium* spp. | *Taraxacum* sp. |
| *Geum triflorum* | *Zigadenus paniculatus* |
| *Lupinus* spp. | *Zigadenus elegans* |
| *Penstemon* spp. | *Zigadenus* spp. |

some cases, a species' response to fire does not match what would be expected based on its natural habitat type. *Hazardia squarrosa* is a shrub of fire-prone habitats in coastal sage scrub, chaparral, and foothill woodland occurring at relatively low elevations in California. Unlike most matorral plant species, the presence of charred wood or its aqueous extracts decreased seed germination of *H. squarrosa* (Baskin and Baskin 2001). Like *P. clementis* var. *villosa*, *H. squarrosa* is in the subtribe *Machaerantherinae* and was once placed in the broad genus *Haplopappus* (Nesom 2000).

Animals find plant species palatable through a combination of morphological, structural, and chemical characteristics not restricted to taste and smell (Dayton 1931, Lusk et al. 1961, Hanks et al. 1975, Moghaddam 1977, Nemati 1977, Sheehy and Winward 1981). These characteristics can change during the growing season, and many plant species may be desirable early in the season when the herbage is tender and/or has low concentrations of certain chemicals but provide unappealing forage and browse later in the growing season (Williams and James 1978, Berg et al. 1997). Using information from other *Pyrrocoma* or *Haplopappus* species to estimate palatability are dubious because there is a wide range of secondary plant products among members of the tribe *Astereae* and even within a single genus (Hegnauer 1977). Some members of the *Haplopappus* group are unpalatable and may even be injurious to livestock, while other species provide acceptable forage, especially for sheep (Dayton 1931, USDA Forest Service 1988). There is some knowledge of the secondary plant compounds of *P. clementis* var. *villosa* (Mayes 1976). However, the chemistry of this taxon has been studied for taxonomic purposes rather than to estimate livestock palatability, and the palatability of *P. clementis* var. *villosa* to livestock is not documented. Cattle use has been shown to have a significant negative impact on flower head production in *P. radiata* (Kaye 2002). Wild animals (e.g., deer, lagomorphs) are also likely to use *P. clementis* var. *villosa* to some extent. Caching and dispersal of *P. clementis* var. *villosa* seed by animals (e.g., rodents, insects) have not been reported.

Arthropods also use *Pyrrocoma* species as food, and the consequences of their herbivory can be reflected by lower reproduction or damage to vegetative tissue (Mancuso 1997, Kaye 2002). Mean seed production of *P. radiata* was negatively correlated to the intensity of tissue damage by grasshoppers (Kaye 2002). Bud and fruit herbivory have been reported to decrease seed production directly in several species (Adler et al. 2001a). Some butterflies (e.g., checkerspots (*Chlosyne* species)) use members of the Asteraceae as larval host plants (Scott 1997). The pearly or sagebrush checkerspot (*C. gabbii acastus*[5]) may use *P. clementis* var. *villosa* because this species overlaps the plant's range and appears to use a relatively broad selection of Asteraceae as host plants, including species of *Haplopappus* and *Machaeranthera* (Scott 1997, Opler et al. 2006). Direct seed predation by insects is also likely. Weevils, gelechiid moths, and the larvae of cecidomyiid midges were the primary insects that damaged seed in the flower heads of *P. radiata* (Kaye 2002). The insect larvae in the flower heads of *P. radiata* damaged or consumed a substantial proportion of ovules in some years, and average seed predation varied from a low of 15 percent to a high of 67 percent (Kaye 2002). The degree of *P. radiata* seed predation by insect larvae was influenced by winter precipitation, with more seed damage occurring after dry winters (Kaye 2002). Insects also caused significant damage to developing flowers and seeds of *H. venetus* and *Hazardia squarrosa* (Louda 1982, 1983). In some circumstances, insect predation was a critical factor in limiting recruitment of both species (Louda 1982, 1983).

*Pyrrocoma clementis* var. *villosa* flowers may be self- and/or cross-pollinated (see Reproductive biology and autecology section). Flower color, size, shape, and odor influence the type of pollinator species (Bond 1995). If *P. clementis* var. *villosa* follows the pattern set by *P. radiata*, then *P. clementis* var. *villosa* might be cross-pollinated by a wide assemblage of arthropods that include bumblebees, solitary bees, flies, and butterflies (Kaye 2002).

### *Resources envirogram*

An envirogram is a graphic representation of the components that influence the condition of a species and reflects its probability of reproduction and survival. Envirograms have often been used to describe the condition of animals (Andrewartha and Birch 1984), but they may also be used to describe the condition of plant species. Those components that directly impact *Pyrrocoma clementis* var. *villosa* make up the centrum, and the indirectly acting components comprise the web (**Figure 7**, **Figure 8**). Information to make a

[5] Some regard this group as *Chlosyne* while others as *Charidryas*. There is also some disagreement regarding the specific name and grouping: *gabbii acastus* vs. *acastus* vs. *acastus acastus* (Scott 1997, Savela 2005, Opler et al. 2006)

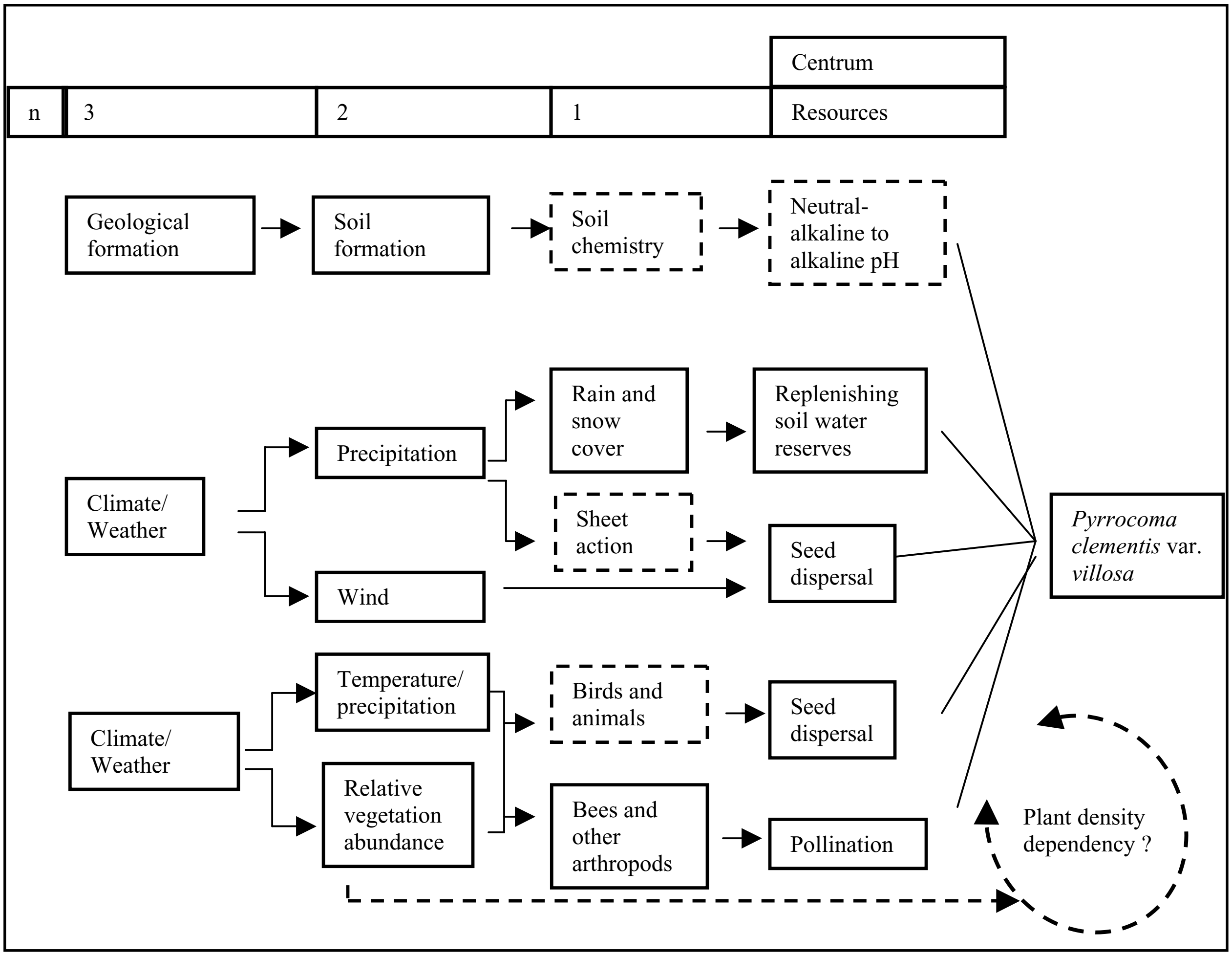


**Figure 7.** Envirogram outlining the resources of *Pyrrocoma clementis* var. *villosa*. The dashed-lines indicate that the relationships need to be confirmed.

comprehensive envirogram for *P. clementis* var. *villosa* is unavailable. The envirogram in **Figure 7** is constructed to outline some of the resources that are known or that are likely to affect the species directly. Resources include soil properties, pollinators, and agents of seed dispersal, namely water, wind, rodents, and arthropods. Of all the components of climate, precipitation appears most likely to influence the reproductive success of *P. clementis* var. *villosa*. Precipitation is also likely to influence the abundance of potential pollinators. Fire has not been included as a resource because, although it may be necessary to maintain habitat, its direct impacts on *P. clementis* var. *villosa* are unknown.

# CONSERVATION

## *Threats*

Identifying and ranking the threats to *Pyrrocoma clementis* var. *villosa* is difficult because relatively little is known about its biology and ecology. Current information suggests that threats are primarily associated with habitat loss, which is principally caused by human recreation, livestock grazing, and energy and mineral development. The extent to which energy and mineral development currently affects occurrences on the Bighorn National Forest is not documented, but it is a potential threat since most of the land on which *P. clementis* var. *villosa* occurs is open to resource extraction. High intensity fire is a potential threat because it may prevent *P. clementis* var. *villosa* plant regeneration and negatively impact its seed bank. Fire suppression may pose a threat since the grassland habitat of *P. clementis* var. *villosa* is maintained by fire. Invasive non-native plant species are potential threats since they contribute to habitat loss and may provide interspecific competition for resources. Changes in pollinator assemblage and/or a decline in their abundance are potential threats if *P. clementis* var. *villosa* is predominantly an out-crossing species. As with all species that are relatively rare with a restricted range, demographic stochasticity, genetic stochasticity,

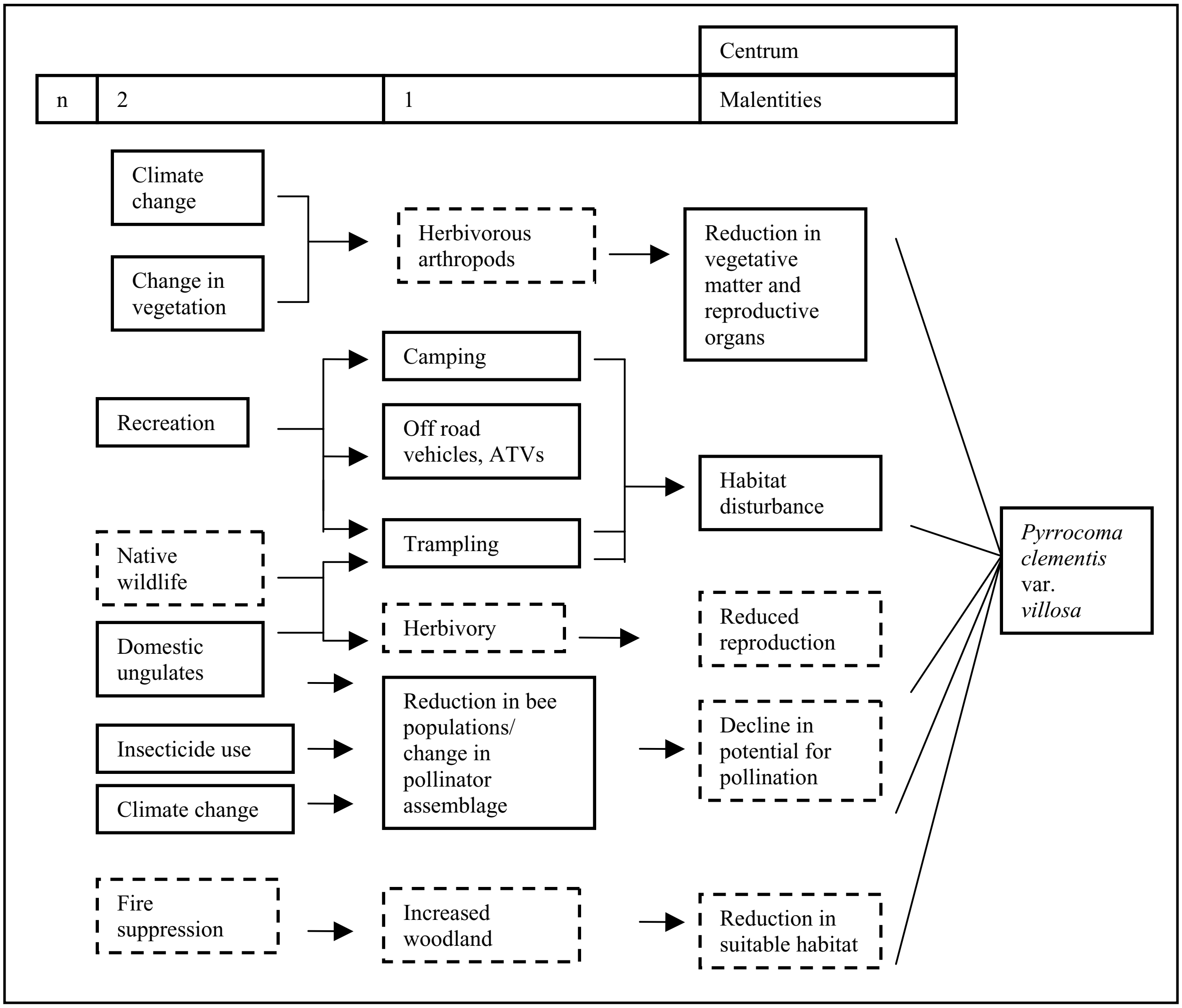


**Figure 8.** Envirogram outlining the threats and malentities of *Pyrrocoma clementis* var. *villosa*. The dashed-lines indicate that the relationships need to be confirmed.

environmental stochasticity, and natural catastrophe pose potential threats to the persistence of occurrences. Threats, limiting factors, and vulnerabilities to management activities that have been listed by the USFS (2005b) for *P. clementis* var. *villosa* include heavy grazing, prescribed burns, development, road and trail construction, and invasion of its habitat by noxious weeds. No specific details about any of these factors were provided in the document (USDA Forest Service 2005b).

### Recreation

The range of *Pyrrocoma clementis* var. *villosa* in Region 2 is heavily used for human recreation activities (e.g., camping, off-road vehicle travel, horseback riding, hiking, and snowmobiling). All of these activities can lead to disturbance and change the structure and assemblage of the plant community (Chaneton and Facelli 1991, van der Maarel 1996, Zabinski et al. 2000).

Prior to 2005, most of the areas in which *Pyrrocoma clementis* var. *villosa* occurs on the Bighorn National Forest were open to off-road motorized vehicle recreation. A small portion of occurrence 1 (**Table 1**) appears to be within the eastern edge of a management area that is closed to all motorized vehicle traffic and that only permits saddle, draft, and pack animals, such as horses and mules (USDA Forest Service 2001). Motorized recreation is a significant management issue on the Bighorn National Forest. Motorized recreation-related offenses were the most frequently cited category of law enforcement offenses on the forest, accounting for 39 percent of total violations in 2004 (USDA Forest Service 2005b). Recently implemented Bighorn

National Forest travel management regulations require that all motorized users stay on designated and signed motorized routes in restricted areas, which will include most of the known *P. clementis* var. *villosa* occurrences (USDA Forest Service 2005b, 2005c). However, motorized travel is allowed up to 300 ft. (91 m) off of a designated route "for the purpose of camping, game retrieval, and firewood collecting providing no resource damage will occur by doing so" (USDA Forest Service 2005b, 2005c). In 2005, the majority of the sub-occurrences and scattered individuals that comprised occurrence 1 (**Table 1**) were within 300 ft. (91 m) of designated roads and trails (**Figure 9**). In part of *P. clementis* var. *villosa* occurrence 1 (**Table 1**), some of the motorized routes are closed and signed seasonally to protect elk calving areas and/or to minimize seasonal damage to the roads (USDA Forest Service 2001, USDA Forest Service 2005b, 2005c). In these areas, threats from direct impact and habitat disturbance from motorized vehicles will likely be principally from illegal travel away from managed roads and trails, which remains a concern on the Bighorn National Forest (USDA Forest Service 2005b, 2005c). Several informal routes, created by repeated off-road and off-trail use, have been established in the northwestern part of occurrence 1, and these have damaged the area (USDA Forest Service 2005c).

The potential adverse environmental impacts of snowmobiling within *Pyrrocoma clementis* var. *villosa* occurrences also need to be considered. Snowmobiling is permitted from November 16 to May 15 in several areas on the Bighorn National Forest where *P. clementis* var. *villosa* grows (USDA Forest Service 2001). Roadside patches of plants away from sagebrush stands, such as most of the sub-occurrences in occurrence 1 (**Table 1**), might be the most vulnerable. Snow compaction can cause considerable below-surface vegetation damage (Neumann and Merriam 1972). Significant reductions in soil temperatures, which retard soil microbial activity and seed germination, may also result from snow compaction (Keddy et al. 1979, Aasheim 1980). All forms of motorized vehicle recreation can severely disturb vegetation, cause accelerated soil erosion, increase soil compaction, and add to pollution (Ryerson et al. 1977, Keddy et al. 1979, Aasheim 1980, Fahey and Wardle 1998, Belnap 2002, Misak et al. 2002, Gelbard and Harrison 2003, Durbin et al. 2004).

### Livestock grazing

All *Pyrrocoma clementis* var. *villosa* occurrences known to be extant on the Bighorn National Forest are within active cattle grazing allotments and may be affected by livestock grazing. Cattle herbivory has


**Figure 9.** *Pyrrocoma clementis* var. *villosa* plants were often found on each side of roads and trails in grassland and big sagebrush-grassland communities on the Bighorn National Forest in 2005.

been shown to reduce the reproductive output of a related *Pyrrocoma* species, *P. radiata* (see Community ecology section). Kaye (2002) tested for the effects of cattle grazing on *P. radiata* over a ten-year period using three general metrics: plant size, population viability, and annual population growth rate. Fencing *P. radiata* to exclude livestock over the ten-year period resulted in an increase in plant size and reproduction compared to unfenced plants, but these effects were only detectable after several years (Kaye 2002). *Pyrrocoma radiata* leaves were significantly longer inside exclosures than outside after five years of protection, and plants were taller after seven years. Flower head production was significantly higher inside exclosures than outside seven and nine years after fencing (Kaye 2002). The effects of excluding cattle were not detected in the population growth rate until the eighth year after fencing. Therefore, although relieving *P. radiata* from livestock grazing clearly resulted in an increase in plant size and reproduction, the measures had only weak effects on population growth rate even after nine years of fencing. It is not unusual for vegetation to be very slow to recover from grazing pressures, especially in regions with low or uneven precipitation (Fuhlendorf et al. 2002, Guo 2004).

In studies of *Pyrrocoma radiata*, Kaye (2002) discerned a relationship between climate and grazing frequency. In plots exposed to livestock use, increases in grazing frequency were associated with reductions in the population growth rate of *P. radiata*. However, in both grazed and protected *P. radiata* populations, fall precipitation increased population growth rate significantly. Kaye (2002) suggested that the effects of high grazing frequency may be partially offset in years when there is high fall precipitation. The levels of grazing and environmental conditions are also likely to interact and influence the net response of *P. clementis* var. *villosa* occurrences.

Direct trampling by large mammalian herbivores is likely to disturb *Pyrrocoma clementis* var. *villosa* plants, soils, and habitat (USDA Forest Service 2005b). If *P. clementis* var. *villosa* seeds disperse only short distances, then the seed bank might have substantial value for sustained populations and may be directly affected by direct soil compaction and disturbance. The seed bank may also be affected by accelerated erosion that frequently accompanies direct disturbance.

### Mineral and energy resource extraction

*Pyrrocoma clementis* var. *villosa* occurs on land in the Bighorn National Forest that is open to mineral and energy resource development (USDA Forest Service 2005b). However, the stipulations concerning development differ within and among occurrences. For example, in parts of occurrence 1 (**Table 1**), ground disturbance must be minimized (USDA Forest Service 2005b).

*Pyrrocoma clementis* var. *villosa* occurs on land managed by the BLM that might be subject to oil and gas extraction and bentonite mining (USDI Bureau of Land Management Wyoming 2004b). At the present time, any occurrences within the Spanish Point Karst ACEC are protected from resource development (USDI Bureau of Land Management 1999). Protests[6] associated with legal precedence were made in response to the plan to withdraw the Spanish Point Karst ACEC from mineral development (USDI Bureau of Land Management 1999). These protests suggest that there is dissatisfaction with the current situation and that land management conditions may change in the future.

Potential threats from resource extraction arise from disturbance directly caused by well site establishment and mine installations and from support activities such as road, pipeline, power line, and borrow pit construction. Significant disturbance arises from temporary equipment storage and the informal tracks and turn-around sites made by individual vehicles (author's personal observations).

### Fire and fire suppression

The effect of other types of disturbance, such as fire, on *Pyrrocoma clementis* var. *villosa* is unknown (see Community ecology section). Prescribed burning may present some risks for this taxon although its historic presence in fire-adapted ecosystems would suggest that it survives fire (USDA Forest Service 2005b). The temperature of the burn may be important (Whelan 1997). High intensity burns are likely to be detrimental, especially if the seed bank, not seed rain, is critical to population recovery after fire (see Reproductive biology and autecology section). Limited seed dispersal distances are likely to make recovery via seed rain a slow process.

[6] "A protest was received from the Rocky Mountain Oil and Gas Association (RMOGA) on …. the BLM's apparent failure to use its withdrawal authority instead of a leasing closure to preclude the issuing of oil and gas leases in the Spanish Point Karst ACEC. The protest was resolved and had no affect on the Washakie RMP decisions" (USDI Bureau of Land Management 1999).

The impacts of long-term fire suppression on the distribution and abundance of *Pyrrocoma clementis* var. *villosa* are difficult to assess. Some loss of habitat may have occurred because the communities in which *P. clementis* var. *villosa* has been found are to varying extents maintained by periodic burns (Knight 1994, Whelan 1997).

### Invasive, non-native plant species

Weeds, defined as invasive, non-native plant species, may be a substantial threat because *Pyrrocoma clementis* var. *villosa* does not have the characteristics of a good competitor. That is, it is not rhizomatous, does not appear to spread rapidly, and has a relatively small stature. In addition, several noxious weed species secrete allelopathic chemicals into the soil that can contribute to habitat loss (Sheley and Petroff 1999, Inderjit 2005). Weed seeds are spread by recreational activities, especially by motorized off-road vehicles and livestock (Sheley and Petroff 1999, USDA Forest Service 2005b). Overspray and drift of herbicides that may be applied to control the spread of dicot weed species can directly affect *Pyrrocoma* species as well as the target plants (Fletcher et al.1996, Kleijn and Snoeijing 1997). *Pyrrocoma clementis* var. *villosa* plants near roads that are subject to highway right-of-way management practices are likely to be most vulnerable to accidental herbicide exposure. No weed species have been reported at any of the known occurrences, but concentrations of non-native species were found less than 1 mile away from occurrence 1 (Welp et al. 1998, USDA Forest Service 2004a; see Distribution and abundance section). The weed species observed in this area include cheatgrass (*Bromus tectorum*), crested wheatgrass (*Agropyron cristatum* var. *cristatum*), Japanese brome (*B. japonicus*), thistle (*Cirsium arvense* and *C. vulgare*), African mustard (*Malcolmia africana*), field morning glory (*Convolvulus arvensis*), mullein (*Verbascum thapsus*), tumbling mustard (*Sisymbrium altissimum*), alfalfa (*Medicago sativa*), and common yellow sweetclover (*Melilotus officinalis*).

### Changes in pollinator assemblage and/or abundance

*Pyrrocoma clementis* var. *villosa* may be vulnerable to decline or changes in species composition of pollinator populations. Pollinators are essential if a certain level of cross-pollination is important for maximum seed set and healthy populations (see Reproductive biology and autecology and Demography sections; Kaye 2002). Habitat alteration and fragmentation, and the introduction of non-native plant and animal species all contribute to reducing pollinator populations as well as causing the extirpation or extinction of individual pollinator species (Bond 1995, Kearns et al. 1998). Pesticide applications to control arthropod pests related to other management issues may have a negative effect on pollinator assemblage and abundance nearby (Kevan 1975, Johansen 1977, Tepedino 1979, Thomson and Plowright 1985).

### Stochasticity and natural catastrophe

Uncertainties that include elements of demographic stochasticity, genetic stochasticity, environmental stochasticity, and natural catastrophes may also affect the sustainability of plant species (Shaffer 1981, Menges 1991). Small occurrences of rare plants are particularly at risk to stochasticity. Vulnerability to stochasticities is typically addressed in a population viability analysis, which has not been conducted for *Pyrrocoma clementis* var. *villosa*.

A minimum viable population size cannot be estimated from available data for this taxon. The minimum viable population size depends upon the differences in inherent variability among species, demographic constraints, and the evolutionary history of a population's structure (Frankham 1999). When considering minimum viable population size, it is useful to remember that from a genetic perspective, natural populations often behave as if they were smaller than a direct count of individuals would suggest and the effective population size needs to be considered (Barrett and Kohn 1991). Studies suggest that, depending upon the species, an effective population size of between 500 and 5,000 individuals can be sufficient to maintain evolutionary potential in quantitative characters under a balance between mutation and random genetic drift (Franklin 1980, Lande and Barrowclough 1987, Lande 1995, Franklin and Frankham 1998, Frankham 1999).

Demographic stochasticity relates to the random variation in survival and fecundity of individuals within a fixed population. Chance events independent of the environment may affect the reproductive success and survival of individuals that, in small populations, have a proportionally more important influence on survival of the whole population. For example, seeds may be aborted by a certain percentage of the population, the percentage becoming bigger and perhaps reaching 100 percent as the population shrinks. Demographic stochasticity may be important in smaller occurrences of *Pyrrocoma clementis* var. *villosa* (Pollard 1966, Keiding 1975).

Genetic stochasticities are associated with random changes in the genetic structure of populations such as inbreeding and founder effects. The likelihood that genetic stochasticity is a threat to *Pyrrocoma clementis* var. *villosa* occurrences is unknown. In some cases, particularly in self-pollinating species, inbreeding can purge deleterious genes (Byers and Waller 1999), although the fitness of species is more often compromised by inbreeding depression (Soulé 1980). Many rare species that have evolved in isolated small populations do not show the ill effects of inbreeding depression experienced by some fragmented, naturally abundant species (Barrett and Kohn 1991). Prior to 2005, the few, small occurrences suggested that *P. clementis* var. *villosa* was a naturally rare and infrequent species. However, inventories in 2005 and 2006 indicated that the taxon can be locally abundant within its range, at least in some years. The potential for inbreeding depression appears to be most likely if *P. clementis* var. *villosa* is primarily an outcrossing species and if its occurrences experience significant long-term declines in size and/or number due to habitat loss, direct destruction, or attrition due to poor reproductive output (Soulé 1987).

The potential for genetic loss in *Pyrrocoma clementis* var. *villosa* from hybridization or introgression is unknown and cannot be estimated with the available information. More data on the frequency of hybridization and on the specifics of its pollination system are needed. Several mechanisms (e.g., pollinator specificity, temporal differences in pollinator activity or flowering phenology, dominance of self-pollination) exist that keep sympatric taxa genetically isolated from each other and from any hybrids (Grant 1981). However, information on other species within the subtribe Machaerantherinae suggests that there is the potential for interspecific and intraspecific hybridization (Jackson 1985, Hauber 1986). Hauber (1986) remarked that the observed hybridization and introgression among subspecies of *Haplopappus spinulosus*[7] was mainly caused by man-made disturbances that allowed ecologically and geographically isolated taxa to come into contact. When formulating restoration seed mixes for areas where *P. clementis* var. *villosa* might occur, it is probably best to avoid using *P. clementis* var. *villosa* seed collected outside the local area or the seed of species with which it could hybridize.

Environmental stochasticity includes random climatic events (e.g., periods of drought) and biological events (e.g., arthropod infestations), while natural catastrophes include floods and landslides. Compared to related species, *Pyrrocoma clementis* var. *villosa* appears to be vulnerable to both drought and infestations of several arthropod species (see Community ecology section). The area in which this taxon occurs in the Bighorn National Forest does not appear to be particularly vulnerable to any specific natural catastrophe, except catastrophic wildfire.

Environmental stochasticity includes elements of global climate change. Wyoming has experienced slightly warmer and drier conditions over the last century. In the last one hundred years, the average temperature in Laramie, Wyoming, has increased 1.5 °F (0.84 °C), and precipitation has decreased between 10 and 20 percent in the north-central part of the state (U.S. Environmental Protection Agency 1998). Some climate change models such as the United Kingdom Hadley Centre's climate model (HadCM2) have indicated that by 2100, temperatures in Wyoming could increase by 2 to 7 °F (1.1 to 3.9 °C) in spring and fall, 2 to 8 °F (1.1 to 4.5 °C) in summer, and 3 to 11 °F (1.7 to 6.2 °C) in winter (Johns et al. 1997, U.S. Environmental Protection Agency 1998). The same HadCM2 model estimates that precipitation will decrease up to 10 percent in summer, increase by 5 to 20 percent in spring and fall, and increase by 10 to 50 percent in winter (U.S. Environmental Protection Agency 1998). The majority opinion appears to be that weather will become more extreme so that the amount of precipitation on extreme wet or snowy days in winter is likely to increase, as is the frequency of extreme hot days in summer (U.S. Global Climate Change Research Program 2006).

The potential impact of changing weather patterns and environmental stochasticity on *Pyrrocoma clementis* var. *villosa* is difficult to estimate. Global climate change that is associated with hotter, drier conditions and extended drought periods may adversely affect the seed germination, vegetative growth, and reproduction of *P. clementis* var. *villosa*. On the other hand, drier conditions are likely to reduce the range and health of conifer forests, while grasslands and rangeland might expand into previously forested areas in the western part of the state (U.S. Environmental Protection Agency 1998). This change might increase the amount of habitat suitable for *P. clementis* var. *villosa*. Decreases in summer precipitation or warmer temperatures may significantly affect seed production, but this potential threat may be partially mitigated by

[7]Currently accepted name is *Xanthisma spinulosum* and another synonym is *Machaeranthera pinnatifida* (Hartman 2006).

higher winter precipitation that may promote flower head production (see Reproductive biology and autecology and Demography sections). Another possibility is that milder winters could increase the frequency of insect outbreaks and of wildfires in the dead fuel left after an outbreak, which might be detrimental to *P. clementis* var. *villosa* occurrences.

### Malentities envirogram

Threats and potential threats to *Pyrrocoma clementis* var. *villosa* tend to be interrelated, and one may exacerbate the effects of another. The potential threats and malentities of *P. clementis* var. *villosa* are outlined in the envirogram in **Figure 8**. Habitat modification or loss appears to be, and perhaps has been, the greatest threat. Occurrences are vulnerable to disturbance from activities associated with recreation, livestock grazing, and resource extraction and to invasive weeds encroaching on habitat. Livestock and vehicles also contribute to the spread of invasive weeds. Direct trampling and herbivory by livestock are threats to occurrences in all parts of its range, including the Bighorn National Forest. Fire suppression and livestock grazing, which can reduce competition for herbaceous plants, may have led to a reduction in meadows and grasslands with concomitant increase in forested areas during the last 150 years (Dunwiddie 1977, Knight 1994; see Habitat section). Certain environmental conditions, including above-average temperature and prolonged drought, appear to be potentially detrimental to *P. clementis* var. *villosa* (see Demography section). Although there is little on a local level that can be done to avoid unfavorable environmental conditions, control of additional pressures (e.g., loss of reproductive organs from livestock herbivory, invasion of habitat by weeds) may mitigate their impacts.

## Conservation Status of *Pyrrocoma clementis* var. *villosa* in Region 2

Nine *Pyrrocoma clementis* var. *villosa* occurrences are known, all in Wyoming, of which six are on the Bighorn National Forest (occurrences 1, 2, 3, 7, 8, and 9 in **Table 1**). Four of the National Forest System occurrences are known to be extant (occurrences 1, 7, 8, and 9 in **Table 1**). *Pyrrocoma clementis* var. *villosa* individuals can be locally common, numbering several thousand at one occurrence on National Forest System land. The status of the two historic occurrences needs to be confirmed (occurrences 2 and 3 in **Table 1**). The location information for these historic occurrences is somewhat vague, but they appear to be located within areas that are now forested (Karow personal communication 2005). Habitat for *P. clementis* var. *villosa* has yet to be critically defined, but current information suggests that occurrences are unlikely to persist under forest canopy. Therefore, these occurrences are unlikely to be extant.

In 2004 and 2005, *Pyrrocoma clementis* var. *villosa* plants were found in the same vicinity as an occurrence reported in 1955 (occurrence 1 in **Table 1**). The 2005 survey greatly expanded the area of the 1955 report and increased the estimated number of plants there by several thousand (occurrence 1 in **Table 1**). Two additional occurrences (occurrences 7 and 8 in **Table 1**) were found on the Bighorn National Forest in 2005, and another new occurrence (occurrence 9 in **Table 1**) was found in 2006.

The apparent large increase in number of individuals and area occupied might suggest that the abundance of *Pyrrocoma clementis* var. *villosa* has increased. However, there is no historical information with which to evaluate whether *P. clementis* var. *villosa* has experienced a change in abundance or range since the mid 19th century. The taxon might have actually experienced loss of habitat since meadow, grassland, and big sagebrush-grassland habitat has been subject to alteration and destruction (Knight 1994). The impact of changes in habitat availability on the distribution and abundance of *P. clementis* var. *villosa* on the Bighorn National Forest is unknown.

## Management of *Pyrrocoma clementis* var. *villosa* in Region 2

A revised management plan for the Bighorn National Forest was completed in September 2005 (Karow personal communication 2005, USDA Forest Service 2005b, Bornong personal communication 2006). In the plan, *Pyrrocoma clementis* var. *villosa* was identified as a sensitive species and as an "emphasis species." Emphasis species were selected as surrogates for addressing the viability of all species that may inhabit the forest (USDA Forest Service 2005b). In the Final Environmental Impact Statement, a Biological Evaluation that describes the effects of alternative management strategies considered in the revised management plan was reported for all USFS sensitive species. With regard to *P. clementis* var. *villosa*, it was concluded that all of the alternatives in the revised management plan "may adversely impact individuals or habitat, but [are] not likely to result in a loss of viability in the planning area nor cause a trend toward federal listing or a loss of species viability rangewide."

A management strategy that seeks to reduce threats and impacts to sensitive species and their habitats was developed for all threatened, endangered, sensitive, and other plant species of concern on the Bighorn National Forest (USDA Forest Service 2004a, 2004b). In accordance with the management strategy recommendations, targeted surveys for *Pyrrocoma clementis* var. *villosa* were initiated in 2004 and continued in 2005 and 2006 on the Bighorn National Forest (Karow personal communication 2005, 2006). These surveys succeeded in finding additional *P. clementis* var. *villosa* plants at one previously known occurrence (occurrence 1 in **Table 1**), as well as three new occurrences (occurrences 7, 8, and 9 in **Table 1**) (Karow personal communication 2005, 2006).

*Pyrrocoma clementis* var. *villosa* occurrences 7 and 9 (**Table 1**) are within grazing allotments on the Bighorn National Forest and within areas designated as management area (MA) 5.11 - Forest Vegetation Emphasis. A portion of occurrence 8 is on the Bighorn National Forest and is within a livestock grazing allotment that extends across areas designated MA 3.31 - Backcountry Recreation, Year-round Motorized Use and MA 5.11. The western portion of occurrence 8 is on private land, which is also grazed. Occurrence 1 (**Table 1**) is within a region designated as the "Hunt Mountain Area." The majority of sub-occurrences in occurrence 1 are within MA 5.12 - Rangeland Vegetation Emphasis, but a few are also within MA 4.2 – Scenery. The latter area is within a "C" travel area designation, which permits unrestricted off-road travel. "C" travel area designation, which permits unrestricted off-road travel. Travel management of the Hunt Mountain Area may change when the Hunt Mountain Travel Management Area Environmental Assessment is completed. The Hunt Mountain Animal Management Plan and the Hunt Mountain Travel Management Plan respectively include analyses of the effects of grazing and travel on *P. clementis* var. *villosa*, and both will be completed at the end of 2006 (Karow personal communication 2006). These analyses could also provide direction for the management of other *P. clementis* var. *villosa* occurrences. **Table 4** provides brief descriptions of each MA category.

### Implications and potential conservation elements

At the present time, most of the National Forest System land on which *Pyrrocoma clementis* var. *villosa* is known to occur is managed primarily for livestock grazing and to maintain forage for livestock and wildlife. This is similar to past management when these areas were designated "6B - Livestock Grazing, Maintain Forage Condition" (USDA Forest Service 1985). *Pyrrocoma clementis* var. *villosa* occurrences are currently stocked at a rate of 1 animal unit per month (AUM - a cow and a calf/month) for every 5 acres (Karow personal communication 2005). *Pyrrocoma clementis* var. *villosa* may not be entirely resilient to the impacts of cattle grazing. An 11-year study of another *Pyrrocoma* species found that cattle grazing resulted in negative impacts (Kaye 2002; see Community ecology and Threats sections).

Sheep grazed the allotment that includes occurrence 1 (**Table 1**) for about 75 years prior to approximately 1978, when it was converted to cattle grazing. The impacts that sheep grazing had on *P. clementis* var. *villosa* abundance and distribution are not known. Cattle and sheep grazing may have different effects on individual plant species. Sheep tend to eat vegetation closer to the ground surface than cattle (Strasia et al. 1970, Adler et al. 2001b). Loss of the aerial parts of *P. clementis* var. *villosa* may prevent the plants from recovering sufficiently during the growing season to produce seed. In general, sheep prefer forbs rather than grasses and shrubs, but they also tend to be selective in their choice of plant species, and predicting the preferred species is difficult (Vogel and Van Dyne 1966, Strasia et al. 1970). Sheep preferences can be important in shaping plant community composition because plant species that are selected by sheep are documented to be more abundant on un-grazed land, indicating that grazing negatively affects their abundance (Strasia et al. 1970, Bonham 1972). Release from sheep grazing in 1978 may have benefited *P. clementis* var. *villosa*, since it is likely to be a palatable forb and vulnerable to sheep grazing behavior.

The different management unit guidelines suggest that impacts from recreational activities on *Pyrrocoma clementis* var. *villosa* are likely to be variable within and among the known occurrences on the Bighorn National Forest. However, the close proximity of *P. clementis* var. *villosa* plants to open roads and trails increases the chance of trespass use or unintentional disturbance, even in areas with restricted travel. Encroachment by non-native invasive species may be a special concern since roads and trails are common conduits for weed seed dispersal (Sheley and Petroff 1999).

Observations made in 2004, 2005, and 2006 on the Bighorn National Forest indicate that the number of plants flowering in *Pyrrocoma clementis* var. *villosa* occurrences in a given year can fluctuate widely. These limited observations suggest that environmental

**Table 4.** Brief descriptions of the designated Management Areas (MA) where *Pyrrocoma clementis* var. *villosa* is known to occur on the Bighorn National Forest. The descriptions are excerpted from USDA Forest Service (2005b).

**MA 3.31 – Backcountry Recreation, Year-round Motorized Use:** These backcountry areas provide motorized and nonmotorized recreation opportunities on primitive roads and trails. The landscape has a predominantly natural appearance and is relatively undisturbed by human activity. Vegetation may be altered through timber harvest or fire (prescribed or wildland fire use) to enhance recreation opportunities, to provide vistas for people to view surrounding areas, or to meet objectives for wildlife habitat.

**MA 4.2 – Scenery:** These areas occur where scenic features are a management focus: They are scenic byways, high quality scenic areas, travel corridors, vistas, or other areas noted for outstanding physical features. The landscape provides high quality scenery, through time, incorporating management activities such as timber harvest, prescribed fire, recreation, and livestock use. Developments such as roads, recreation facilities, and rangeland improvements may be evident, but appear to be in harmony with the natural environment. Recreation facilities such as scenic overlooks, interpretive signing, trailheads, campgrounds, and rest areas may occur. Evidence of human activities or habitation due to mining or grazing may be present now and in the future. Frequent contact with other users is acceptable in most cases. Both motorized and nonmotorized recreation opportunities occur. Many uses and their interactions are interpreted for the visitor.

**5.11 – Forest Vegetation Emphasis:** These areas are characterized by forest and grassland communities. The major vegetation type is coniferous forest, with open parks, meadows, shrub communities and aspen. Uses in these areas include grazing, wood production, mineral exploration and development, hunting, driving for pleasure, wildlife viewing, and winter sports. Management emphasis is on a balance of resource uses. Thinning is commonly encountered, except in lynx habitat. Visitors to this area can expect to find a full range of improvements. Road quality varies from primitive roads to hard-surfaced. There may be fences, corrals, water developments, trails, timber harvest operations, rangeland revegetation projects, or evidence of other human activities or improvements. Visitors can expect dispersed recreation opportunities including both motorized and non-motorized. Access may be restricted, at times, through the use of seasonal or year-long road closures. There may be developed camping opportunities. Opportunities for multiple-use trails exist. Existing facilities (roads, primitive roads, trails, bridges, fences, shelters, signs or water diversions) blend into the landscape where feasible or are removed if no longer need.

**MA 5.12 – Open grasslands and areas of woody vegetation dominate this management area:** Many of these areas produce substantial forage for wildlife and livestock needs. The areas also provide resource values such as wildlife habitat and recreation. A variety of management options are available, including wildlife habitat, livestock grazing, dispersed recreation, minerals management, and timber harvest. Management emphasis is on a balance of resource uses. Thinning is commonly encountered, except in lynx habitat. Vegetative diversity includes grassland species, shrubs, aspen, and conifers. Signs of motorized travel, hunting, hiking, timber harvest, mining, and livestock grazing may be evident. Recreation facilities may be present and coordinated with rangeland vegetation and other management activities of the area. Dispersed camping opportunities are plentiful. Structural and nonstructural forage improvement practices, livestock management, and integrated resource management are used to maintain desired condition. Structural improvements benefit, or at least do not adversely affect, wildlife. Livestock and related rangeland improvements such as ponds, fences, developed springs, stock tanks and stock pipelines are designed to improve livestock distribution. Nonstructural restoration and forage improvement practices such as seeding, planting, burning, fertilizing, and spraying may be used. Cutting of encroaching trees may also occur. Roads vary from primitive to gravel surfaced. Some roads are closed seasonally to protect road surfaces, reduce maintenance, and reduce disturbance to wildlife.

conditions influence the number of plants that flower per year (see Demography section). This hypothesis needs to be tested by monitoring occurrences through multiple years.

In general, the management of areas in which *Pyrrocoma clementis* var. *villosa* occurs on the Bighorn National Forest appears to be compatible with the taxon's persistence. Since so little is known about the biology and habitat requirements of *P. clementis* var. *villosa*, the impacts of livestock grazing, recreational activities, and resource development need to be evaluated periodically to ensure that the current management strategy does not need to be adjusted to maintain viable occurrences.

### Tools and practices

Well-documented inventories and monitoring studies will help to clarify the status and vulnerability of *Pyrrocoma clementis* var. *villosa* on National Forest System land. Recent surveys on the Bighorn National Forest have been important in advancing understanding of this taxon's abundance and distribution. The first collection on National Forest System land since 1955, and the only rangewide collection since 1981, was made during the 2004 survey. In 2005 and 2006, three new occurrences were found, and the extent and number of individuals in occurrence 1 (**Table 1**) were greatly expanded.

*Species inventory*

Inventory protocols for threatened, endangered, and sensitive plant species have been outlined in the Five-year Action Plan for Bighorn National Forest rare species management strategy (USDA Forest Service 2004a). This document includes examples of survey forms, collection protocols, and survey methods; it is an excellent reference for inventory and monitoring work.

As indicated in the Five-year Action Plan (USDA Forest Service 2004a), the numbers of *Pyrrocoma clementis* var. *villosa* individuals, the area they occupy, and the amounts of apparently suitable but unoccupied habitat are important data for comparing occurrences. The easiest way to describe *P. clementis* var. *villosa* occurrences covering a large area may be to count patches, make note of their extent, and estimate or count the numbers of individuals within each patch. If specific counts cannot be made, then a numerical estimate such as "fewer than 10 individuals" or "between 20 to 30 individuals" within a certain area is more helpful in estimating trends in abundance than are subjective evaluations such as "sparse" or "frequent." Collecting information on plant size or life stage (i.e., flowering plant, vegetative plant, seedling) is also valuable in assessing the potential sustainability of an occurrence. Observations of habitat are important additions to the inventory record (USDA Forest Service 2004a). Recording specific geographic information on where plants occur provides the means for precisely relocating occurrences. With the advent of low cost global positioning systems (GPS), this information is relatively easy to collect.

The potential for mis-identification needs to be considered during field studies (Beauvais et al. 2000). *Pyrrocoma clementis* var. *villosa* can be mistaken in the field for other *Pyrrocoma* species (Beauvais et al. 2000). Early in the season, the basal leaves of other Asteraceae species, such as in the genus *Agrostis*, may be mistaken for vegetative *Pyrrocoma* species (Mancuso 1997). For definitive field identification purposes, surveying for *P. clementis* var. *villosa* during July and early August when the plants are flowering and fruiting is recommended (**Table 1**).

*Habitat inventory*

Available habitat descriptions suggest that, within the restrictions of the eco-climate zones in which it exists, *Pyrrocoma clementis* var. *villosa* can grow in a variety of meadow and shrub-grassland habitats. The hypothesis that *P. clementis* var. *villosa* is most abundant in areas where big sagebrush is absent needs to be confirmed. Potential habitat for *P. clementis* var. *villosa* can best be described as meadow and sagebrush-grassland habitat that, from casual observation, appears suitable for the species but is not occupied by it. The information currently available for *P. clementis* var. *villosa* habitat is insufficient in detail to make accurate analyses or preditions of which areas that might be occupied in the future.

*Population monitoring*

No census or demographic monitoring studies have been reported for *Pyrrocoma clementis* var. *villosa*. Monitoring methods for sensitive and rare species were discussed in the Bighorn National Forest Five-year Action Plan (USDA Forest Service 2004a). Monitoring data may be collected at several levels of detail. A simple repeated census of the individuals can provide an estimate of population stability over time. If information on the number of reproductive individuals is included, trends in population stability may be estimated. Full demographic monitoring of the recruitment and death rates within occurrences allows development of population matrix models to project population trends and to identify life stages that most affect the growth rate of the population (Bonham et al. 2001).

Permanent transects may be the most accurate way to census occurrences of *Pyrrocoma clementis* var. *villosa*. Lesica (1987) discussed a technique for monitoring non-rhizomatous, perennial plant species using permanent belt transects. Elzinga et al. (1998, 2001) and Goldsmith (1991) have discussed using rectangular quadrat frames along transect lines to monitor patchy plant distributions. Given the short distances over which seeds probably disperse and that adult plants are understood to be relatively long-lived perennials, it might be expected that patches of *P. clementis* var. *villosa* plants are persistent. However, this has not been confirmed. Colonizations and local extirpations of patches may take place over time. There was a substantial change in the number of *P. clementis* var. *villosa* individuals and the area they covered between 2004 and 2005. These observations suggest that the abundance of flowering plants, and possibly vegetative plants, is temporally variable. It is important to consider the areas between sub-occurrences when designing a monitoring program because the demographics and population dynamics of *P. clementis* var. *villosa* are not known.

Lesica and Steele (1994) discussed the monitoring implications of prolonged dormancy in vascular plants (see Demography section). They concluded that population estimates of plants with prolonged dormancy based on random sampling methods will often underestimate density. They also concluded that demographic monitoring studies of species with prolonged dormancy would require longer studies to obtain useful information. In order to monitor change in population density with a reduced risk of bias, establishing permanent monitoring plots with repeated measure analysis may be most effective (Lesica and Steele 1994).

It is very important to define the goals of any monitoring plan and to identify the methods of data analyses before the beginning of the project. The time commitment per year will depend on the design adopted, the skill of the surveyors, and the distance between monitoring plots. Annual monitoring is very useful if population size and/or vigor exhibits a high degree of year-to-year variation. This is particularly true for many annual species or herbaceous perennial species that undergo prolonged underground dormancy. For species that exhibit more stable aboveground populations, monitoring at longer intervals may be most time- and cost-effective, although the potential loss of information due to less frequent observations needs to be recognized. The appropriate interval will be most successfully determined after an initial period of annual monitoring. A resampling interval of five years was suggested for *Pyrrocoma liatrifomis* (Mancuso 1997), and Kaye (2002) suggested an interval of three to five years for *P. radiata*.

A monitoring scheme needs to be robust over time and with respect to differing levels of operator expertise. Monitoring protocols also need to include specific observations of habitat characteristics (e.g., disturbance, land use, abundance of noxious weeds), so that changes in abundance or status of the target species can be evaluated in the context of its environment. Photo points and photo plots are very useful in illustrating changes over time. They should augment, not replace, quantitative monitoring data. Even though digital photographs are convenient and easy to store, many museums and researchers suggest storing slides or even prints, because in 50 years, the technology to read current digital media may be difficult to obtain or unavailable.

Demographic and populations dynamic studies for *Pyrrocoma clementis* var. *villosa* will take several years, and the time commitment each year will be substantial. If these studies are considered, developing a stage projection model for *P. clementis* var. *villosa* after the method of Lefkovitch (1965) may be useful for estimating transition probabilities between the different stages in its life history and calculating an equilibrium growth rate. A combination of age and size classes and life-history stages were used in developing a matrix model of the population dynamics of *P. radiata* (Greenlee and Kaye 1997, Kaye 2002). The stages were seedling, juvenile (≤ three leaves), vegetative (≥ four leaves and not reproductive), and reproductive (**Figure 6**).

### *Habitat monitoring*

The relative lack of information on *Pyrrocoma clementis* var. *villosa* habitat requirements makes it premature to consider that habitat monitoring in unoccupied habitat can be effective. An exception would be when surveys for non-native plant species and weed management programs are part of a "habitat monitoring" plan.

Habitat monitoring within occurrences of a target species is customarily associated with population monitoring protocols. Important observations include the presence of associated species (both flora and fauna), the micro-environment (e.g., moist or xeric, shaded or sunny, aspect, slope), and the substrate conditions (e.g., moist or xeric, sand or clay). Land use and its intensity (e.g., livestock stocking rates) and whether or not there is evidence of these uses are important facts to include with the monitoring data. Habitat data collected during population monitoring can explain how environmental conditions influence target species' abundance and condition over the long-term. Conditions several years prior to the onset of a decrease or increase in population size may be as important as the conditions existing during the year the change is observed. An easily accessible, documented history of this information may be valuable when management plans are revised.

### *Population or habitat management approaches*

A first step in determining which management practices are the most appropriate for *Pyrrocoma clementis* var. *villosa* is to complete an inventory to determine the location and size of all occurrences of the taxon. Inventories were initiated on the Bighorn National Forest in 2004 and continued in 2005 and 2006 (Karow personal communication 2005, 2006).

The Biological Evaluation for *Pyrrocoma clementis* var. *villosa* in the Final Environmental Impact Statement of the recently revised Bighorn National Forest Management Plan (USDA Forest Service 2005a, 2005b) stated that: "Grazing allotment management plans can be modified to contain considerations for this species and exclosures constructed, if needed to maintain viable populations; Continuation of an aggressive program to eradicate and manage noxious weeds would serve to protect potential habitat for this species; …There would also need to be protection from any ground disturbing activities or from changes in soil moisture in the area of its existing and potential habitat in the immediate vicinity." This last consideration implies the need to protect the taxon from impacts of motorized vehicles.

Common methods of protecting sensitive areas from anthropogenic threats include erecting fences, establishing barriers to all-terrain vehicle traffic, and/or posting signs indicating that the areas are closed. However, the success of signage and barriers in protecting areas vulnerable to disturbance is variable and depends on the site and the users' compliance. Management practices that have been implemented within the Bighorn National Forest and may be beneficial to *Pyrrocoma clementis* var. *villosa* include restricting recreational vehicle traffic and routing hikers to designated trails (USDA Forest Service 2004a, 2005b). Monitoring occurrences before and after management practices have been implemented would be a way to determine their effects on *P. clementis* var. *villosa*. Monitoring protocols need to be designed so that the variability due to environment conditions can be differentiated from the impacts of management practices on the taxon's status. Motorized vehicle use in some of the areas in which *P. clementis* var. *villosa* is known to occur is currently under review, and a final document and decision in compliance with the National Environmental Policy Act is scheduled for release in November 2006 (USDA Forest Service 2005c, Karow personal communication 2006).

Other common methods of conserving rare taxa include such diverse approaches as seed banking and designating occupied sites as protected areas (e.g., wilderness areas, research natural areas). Seed repositories have been established to save seed in case restoration is needed in the future (Global Crop Diversity Trust 2004, Royal Botanic Gardens, Kew undated, Center for Plant Conservation undated). However, seed banking may have limited value for restoring taxa whose ecology is not understood. If microhabitat requirements are not known, the necessary conditions for maintaining an occurrence may not be met even if germination and seedling establishment can be achieved. Therefore, re-establishing occurrences that have been extirpated may be a very difficult task. The Center for Plant Conservation (CPC) is dedicated to preventing the extinction of native plants in the United States and maintains many taxa as seed, rooted cuttings, or mature plants, depending upon the taxon's requirements. However, *Pyrrocoma clementis* var. *villosa* is not included in the current CPC National Collection (Center for Plant Conservation undated). *Pyrrocoma clementis* var. *villosa* is not known to occur in any of the protected areas currently established on the Bighorn National Forest.

## *Information Needs*

There is little information on the abundance, distribution, and range of *Pyrrocoma clementis* var. *villosa* both on National Forest System land and rangewide. Significant progress in understanding the abundance of *P. clementis* var. *villosa* at the western edge of the Bighorn National Forest has been made within in the last three years, but further inventory is needed to establish where the taxon occurs throughout the national forest. There is no information on the population structure or the persistence of either individuals or occurrences of *P. clementis* var. *villosa*. Periodic monitoring of existing sites would clarify these issues. Monitoring occurrences is essential in order to understand the implications of existing and new management practices. The consequences of a change in management practices can be objectively evaluated when inventories collect baseline data followed by periodic monitoring after the new management is implemented. In these cases, monitoring protocols need to be designed so that the effects of the environment can be differentiated from the effects of management.

The factors that influence colonization and plant establishment, and contribute to different numbers of plants at each *Pyrrocoma clementis* var. *villosa* occurrence are not known. Habitat requirements of *P. clementis* var. *villosa* need to be more rigorously defined in order to assess the potential for an occurrence to maintain or increase in size. More information is needed regarding life history and population dynamics of this species for the same reason. A better understanding of the potential vulnerability of *P. clementis* var. *villosa* occurrences to environmental and genetic stochasticities is needed. Because so little is known about the biology and ecology of *P. clementis* var. *villosa*, additional research needs to be conducted before attempting to establish new populations artificially at the expense of existing occurrences or before including this species in vegetation restoration projects. The potential impact of non-native invasive species is unknown, but they may compete with *P. clementis* var. *villosa* for resources and contribute to loss of habitat (Sheley and Petroff 1999).

Prioritizing information needs depends upon management goals and may be influenced by changing circumstances. At the present time, the primary information needs for *Pyrrocoma clementis* var. *villosa* can be summarized as follows:

- ❖ abundance and distribution of the taxon needs to be determined, both on National Forest System land and rangewide

- ❖ natural temporal variability in occurrence size needs to be ascertained

- ❖ reasons for the large increase in abundance of *P. clementis* var. *villosa* individuals between 2004 and 2005 at the Cedar Creek/Hunt Mountain Road (USFS Road 10) occurrence need to be clarified

- ❖ effects of anthropogenic activities on this taxon need to be determined in order to prepare steps towards threat mitigation

- ❖ habitat requirements need to be defined in order to evaluate occurrence sustainability

- ❖ reproductive biology and population dynamics of *P. clementis* var. *villosa* need to be understood in order to assess the potential for pollinator dependency and vulnerability to genetic or demographic stochasticities.

# DEFINITIONS

**Achene –** a small, dry, 1-celled, 1-seeded, indehiscent fruit.

**Acuminate –** tapering to the apex, the sides more or less pinched in before reaching the tip (Harrington and Durrell 1986).

**Allele –** form of a given gene (Allaby 1992).

**Allelopathy –** "The release into the environment by an organism of a chemical substance that acts as a germination or growth inhibitor of another organism" (Allaby 1992).

**Appressed –** lying flat or close against.

**Attenuate –** gradually narrowing toward the tip or base (Harrington and Durrell 1986).

**Autogamous or Autogamy –** self-fertilized, self-fertilization.

**Bulb –** a subterranean leaf-bud with fleshy scales (Harrington and Durrell 1986); a short, modified, underground stem surrounded by usually fleshy modified leaves that contain stored food for the shoot within.

**Campanulate –** bell-shaped rather than cup-shaped with a flaring rim (Harrington and Durrell 1986).

**Caudex –** the perennial region between the base of the stem and the top of the roots that is slowly elongating and commonly branched.

**Chartaceous –** having the texture of still writing paper or parchment (Harrington and Durrell 1986).

**Ciliate –** having a marginal fringe of hairs (cilia) (Harrington and Durrell 1986).

**Corymb –** a flat-topped or convex open inflorescence; corymbiform - having the form of a flat-topped or convex open inflorescence (Harrington and Durrell 1986).

**DNA –** deoxyribonucleic acid (DNA) is a nucleic acid, usually in the form of a double helix.

**Dolomite –** a common rock-forming mineral, CaMg(CO3)2; most often dolomite is associated with limestone (Bates and Jackson 1984).

**Eciliate –** without cilia (hairs).

**Exine –** the outer layer of the wall of a pollen grain, which is highly resistant to strong acids and bases, and is composed primarily of sporopollenin.

**Geophyte –** a land plant that survives an unfavorable period by means of an underground storage organ (Allaby 1992, Raunkiaer 1934).

**Glabrate –** becoming glabrous with age (Harrington and Durrell 1986).

**Glabrous –** "no hairs present at all" or "glabrous" may mean "smooth" (Harrington and Durrell 1986).

**Granite gneiss –** 1) gneiss derived from a sedimentary or igneous rock and having the mineral composition of granite; 2) a metamorphosed granite (Bates and Jackson 1984).

**Heterozygote –** a diploid or polyploid individual that has different alleles at least one locus.

**Holotype –** a single specimen designated or indicated the type specimen by the original author at the time of publication of the original description.

**Homozygote –** an individual having the same alleles at one or more loci.

**Inbreeding depression –** reduction in fitness. Inbreeding depression may be due to deleterious recessive or partially recessive alleles, which are masked at heterozygous loci by dominant alleles, becoming fully expressed in homozygotes or, alternatively, alleles may interact in an overdominant manner, such that the fitness of either type of homozygote is lower than that of heterozygotes (Dudash and Carr 1998).

**Inflorescence –** the flowering part of a plant, almost always used for a flower cluster (Harrington and Durrell 1986).

**Involucre –** a whorl of distinct or united leaves or bracts subtending a flower or inflorescence (Harrington and Durrell 1986).

**Iteroparous –** experiencing several reproductive periods, usually one each year for a number of years, before dying.

**Lanceolate –** lancelike; approximately four times as long as wide, broadest in the lower half and tapering toward the tip.

**Limestone –** a sedimentary rock consisting chiefly of the mineral calcite (CaCO3) with or without magnesium carbonate; common impurities include chert and clay (Bates and Jackson 1984).

**Loci –** plural of locus. A specific place on a chromosome where a gene is located (Allaby 1992).

**Matorral –** a vegetation community including drought-resistant shrubs and stunted trees that is shaped by mild, relatively wet winters, hot dry summers, and wildfire.

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

**Metric –** a calculated term or enumeration representing some aspect of biological assemblage, function, or other measurable aspect and is a characteristic of the biota that changes in some predictable way with increased human influence.

**Obovate –** inversely ovate, attached at the narrow end (Harrington and Durrell 1986).

**Panicle –** a compound inflorescence with the younger flowers at the apex or center (Harrington and Durrell 1986).

**Paniculiform –** borne in a panicle (see above).

**Phyllary (phyllaries plural) –** a name used for an involucral bract on the head of a species in the family Asteraceae.

**Polyploidization –** an increase in the number of complete sets of chromosomes; the process of whole genome duplication.

**Polyploidy –** the condition in which an individual possesses one or more sets of homologous chromosomes in excess of the normal two sets found in a diploid organism (Allaby 1992).

**Pubescent –** covered with short soft hairs.

**Raceme –** an inflorescence with pedicelled [stalked] flowers borne along a more or less elongated axis with the youngest flowers nearest the apex (Harrington and Durrell 1986).

**Racemiform –** in the form of a raceme (see above).

**Ranks –** NatureServe conservation ranking system (NatureServe 2006). T indicates the rank of the infraspecific taxon (trinomial). Thee status of infraspecific taxa (subspecies or varieties) are indicated by a "T-rank" following the species' global rank. Rules for assigning T-ranks follow the same principles outlined above. For example, the global rank of a critically imperiled subspecies of an otherwise widespread and common species would be G5T1. **G3G4** indicates that *Pyrrocoma clementis* is between: "**G3: Vulnerable**—Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals" and "**G4: Apparently Secure**—Uncommon but not rare (although it may be rare in parts of its range, particularly on the periphery), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern. Typically more than 100 occurrences and more than 10,000 individuals." **T1** indicates that the variety *villosa* is – "**Critically Imperiled**—Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000) or acres (<2,000) or linear miles (<10)." Internet site: http://www.natureserve.org/explorer/granks.htm.

**Rhizome –** any prostrate elongated stem growing partly or completely beneath the surface of the ground; usually rooting at the nodes and becoming upturned at the apex (Harrington and Durrell 1986).

**Semelparous –** (semelparity) reproducing once and then dying.

**Sessile –** without a stalk of any kind (Harrington and Durrell 1986).

**Speciation –** the development of new species.

**Stipitate glandular –** describes a glandular hair structure that has an enlargement at the apex so it looks like a pin, having a thin stalk and bulbous apex on which surface a sticky-looking substance is secreted.

**Stochasticity –** “randomness” arising from chance. Frankel et al. (1995) replaced the word “stochasticity” by “uncertainty” to describe random variation in different elements of population viability.

**Taproot –** the primary root continuing the axis of the plant downward; such roots may be thick or thin (Harrington and Durrell 1986).

**Tomentulose –** sparingly covered with matted, inter-tangled hairs of medium length.

**Tuber –** a thickened, short usually subterranean stem having numerous buds (Harrington and Durrell 1986).

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