Pyrrocoma integrifolia (many-stemmed goldenweed): A Technical Conservation Assessment

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Pyrrocoma integrifolia (many-stemmed goldenweed). ©J.L. Reveal, used with permission of The Academy of Natural Sciences.

Summary of Key Components for Conservation of *Pyrrocoma integrifolia*

Status

Pyrrocoma integrifolia (many-stemmed goldenweed) is a regional endemic restricted to southwestern Montana, east-central Idaho, and northwestern Wyoming. The Rocky Mountain Region of the USDA Forest Service has designated it a sensitive species. The Bureau of Land Management has not listed *P. integrifolia* as a sensitive species in any state in which it occurs. *Pyrrocoma integrifolia* has not been considered for protection under the Endangered Species Act of 1973. The NatureServe Global rank for this taxon is G3? (vulnerable, but with questions about its conservation status). Both the Wyoming Natural Diversity Database and the Idaho Conservation Data Center rank *P. integrifolia* as critically imperiled (S1). The Montana Natural Heritage Program reports that *P. integrifolia* is a "species of potential concern" but is unrankable (SU) due to a lack of information.

Ninety-three *Pyrrocoma integrifolia* occurrences have been reported since 1872. However, only six of these have been observed within the last decade, and they are more likely than the rest to remain extant. Only one *P. integrifolia* occurrence has been reported from National Forest System land in Region 2. This occurrence was observed in 1961 on the Shoshone National Forest. The only occurrence confirmed to be extant in Wyoming is located in Yellowstone National Park. The majority of *P. integrifolia* occurrences are located in Montana, where it has been found on the Gallatin, Beaverhead, Deerlodge, Helena, and possibly Lewis and Clark national forests (Region 1). In Idaho, *P. integrifolia* has been found on the Targhee and Salmon national forests (Region 4).

Primary Threats

Potential threats to *Pyrrocoma integrifolia* viability are associated with habitat degradation, fragmentation, and loss. Much of the habitat for this taxon may already have been altered through historic land use practices. Recreational activities, livestock grazing, resource extraction, and invasive non-native plant species currently contribute to habitat degradation, fragmentation, and loss throughout the range of *P. integrifolia*. These activities may also directly disturb plants and the seed bank of *P. integrifolia*. The one extant occurrence in Region 2 is exposed to recreation and livestock grazing. The likelihood that resource extraction projects will directly affect the Region 2 occurrence appears to be low at the current time. Livestock grazing and browsing by other herbivores such as arthropods and wild mammals (e.g., deer) could also impact *P. integrifolia* occurrences by removing foliage, reducing seed set, and reducing plant vigor. High intensity fires that kill the taproot and the seeds of *P. integrifolia* may be a threat. On the other hand, fire suppression may lead to loss of meadow and shrub-grasslands and contribute to habitat loss. Declines in abundance or changes in assemblage of pollinator species are potential threats if *P. integrifolia* requires cross-pollination for long-term viability.

Elements of demographic stochasticity, genetic stochasticity, environmental stochasticity, and natural catastrophe may be threats to *Pyrrocoma integrifolia*. Vulnerability of *P. integrifolia* to stochasticities may increase if the numbers of individuals and/or occurrences decrease substantially due to habitat loss, direct destruction, or by attrition due to poor reproductive output. The Region 2 occurrence may be particularly vulnerable to stochasticities because it is an isolated occurrence disjunct from the center of abundance. Information on *P. integrifolia* occurrences is incomplete, and there might be threats and potential threats in addition to the ones that are currently identified. Imminent threats to particular occurrences are also difficult to evaluate because of the lack of up-to-date occurrence location information.

Primary Conservation Elements, Management Implications and Considerations

The range of *Pyrrocoma integrifolia* is restricted to southwestern Montana, east-central Idaho, and northwestern Wyoming. In the past, several specimens were misidentified, leading to erroneous reports that the taxon occurred in Colorado and Utah. The current and historic abundance and range of *P. integrifolia* are not well established, as reflected by the uncertain nature of the NatureServe global rank (G3?). The lack of certainty regarding the abundance and range of *P. integrifolia* makes evaluating its vulnerability subject to error. This lack of knowledge may also lead to the unintentional extirpation of occurrences that could be important in maintaining genetic diversity within the taxon.

Pyrrocoma integrifolia grows between 3,800 and 7,500 ft. (1,200 and 2,300 m) elevation in alkaline meadows, forest openings, open slopes, hillsides, and sagebrush grasslands. The soil conditions are frequently moist, but sometimes the soils have been described as dry. There have been no studies on any aspect of the biology or ecology of *P. integrifolia*, except for one limited analysis of its flavone chemistry. Within its range, *P. integrifolia* generally occurs in areas managed for multiple uses on the national forests, where occurrences may be exposed to prescribed burns. To some extent, the taxon may be adapted to fire since it evolved in habitats that are maintained by fire. Alternatively, occurrences found in wet meadows are unlikely to experience frequent or high intensity burns, and the species may not have evolved to tolerate fire directly.

Some observations suggest that *Pyrrocoma integrifolia* intergrades with other *Pyrrocoma* species in the Bighorn Mountains. This situation needs to be confirmed. Hybridization between *P. integrifolia* and related species may have a number of deleterious consequences, including genetic assimilation by a common species, loss of locally adapted populations, and outbreeding depression. The variation in reported *P. integrifolia* habitat conditions suggests that locally adapted ecotypes of the taxon may exist. Interbreeding among ecotypes may lead to loss of locally adapted populations and outbreeding depression. The possibility of hybridization or local adaptation suggests that it may be detrimental to use seed of *P. integrifolia* collected outside the local area or that of any other *Pyrrocoma* species in restoration seed mixes in areas where *P. integrifolia* occurs.

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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 integrifolia* (many-stemmed goldenweed) is the focus of an assessment because it is a rare species of limited distribution within parts of northwestern Wyoming, southwestern Montana, and east-central Idaho and because Region 2 has designated it a sensitive species (USDA Forest Service 2003a). Within the National Forest System, 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. Common names for *P. integrifolia* are numerous and include many-stemmed goldenweed, manysted goldenweed, entire-leaf goldenweed, entire-leaf pyrrocoma, and small dock.

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 integrifolia* assessment examines the biology, ecology, conservation status, and management of this species with specific reference to the geographic and ecological characteristics of Region 2. Because of the limited amount of available information for *P. integrifolia*, relevant studies of other *Pyrrocoma* species were also reviewed. Although some of the literature relevant to the species may originate from field investigations outside of Region 2, this document places that literature in the ecological and social contexts of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *P. integrifolia* 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, 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 information was unavailable elsewhere. In some cases, non-refereed publications and reports may be regarded with greater skepticism. However, many non-refereed reports and 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 the year when monitoring plots were first established, but 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 and herbarium records were particularly important in estimating the geographic distribution and population sizes of *Pyrrocoma integrifolia*. 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 were given greater weight than observations alone. Because *P. integrifolia* can be difficult to identify in the field, specimen collection and deposition at accessible herbaria are especially important.

Occurrence data were compiled from records provided by the Wyoming Natural Diversity Database (WYNDD; 2004), Montana State University Herbarium (MONT), the University of Montana Herbarium (MONTU), Stillinger Herbarium at the University of Idaho (ID), the Idaho State University (IDS), the New York Botanical Garden (NY), the Gray Herbarium

(GH)[1], and from the literature (Greene 1894b, Hall 1928, Mayes 1976). The Montana Natural Heritage Program and Idaho Conservation Data Center had no occurrence records at the time this report was written (Miller personal communication 2004, Cooke personal communication 2005).

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. Because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, 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 (e.g., 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 our 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 in any discussion of *Pyrrocoma integrifolia* is in the identification of specimens. Mistaken identity can lead to over- and underestimates of abundance. Collections made in both Colorado and Utah, initially identified as *P. integrifolia*, have since been determined to be other species.

The range of *Pyrrocoma integrifolia* is restricted to parts of Wyoming, Montana, and Idaho. Reports of hybridization between *Pyrrocoma* species (e.g. Fertig 1999) have added to uncertainty regarding the abundance and range of *P. integrifolia*. Even without hybridization and similarity to other taxa, the rarity of a taxon can be difficult to establish. There is the always the possibility that additional surveys would reveal more occurrences. When most information has been collected relatively casually, a criticism with defining a taxon as rare is that there are extensive areas yet unsurveyed. To some extent, this is true, but rarity is also relative and many taxa are regarded as not being rare precisely because localized casual observation has noted that they occur frequently.

The taxonomic treatment adopted by the identifying botanist can also affect the apparent range and abundance of a taxon. The specimen (*Fisser #638* RM) collected in 1961 on the Shoshone National Forest (WY-7 in **Table 1**) is accepted as *Pyrrocoma integrifolia* by several authorities including Fertig (1998, 1999, 2000a, 2000b), Beauvais et al. (2000), and WYNDD (2004). However, the identity appears to depend upon the taxonomic treatment being followed, and annotations on the herbarium specimen suggest that further examination would be constructive. C.L. Porter identified the specimen as *P. clementis* in 1965, R.A. Mayes annotated it as *P. clementis* var. *villosa* in 1976, and an anonymous annotation on the specimen sheet indicates that the specimen is *Haplopappus integrifolius*. In the Flora of North America, Bogler (2006) accepted *P. integrifolia* and *P. clementis* var. *villosa* as separate species. An alternative taxonomy proposed in the literature regarding *P. integrifolia* suggests that *P. clementis* var. *villosa* be submerged into *P. integrifolia* (Cronquist 1994, Welp et al. 2000). This taxonomic concept may be the basis by which occurrence WY-7 (**Table 1**) was determined to be *P. integrifolia*. Current information indicates that either taxonomy allows this occurrence on the Shoshone National Forest to be treated as a sensitive species because *P. clementis* var. *villosa* is also a regional endemic species with few occurrences known to be extant (Ladyman 2006).

Another element, not of uncertainty but of caution, especially when considering some 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 appropriate to consider when seeking 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,

[1]Member of Harvard Herbaria Databases (2005).

Table 1. Information for occurrences of *Pyrrocoma integrifolia* in Wyoming.

State-number	County	Location	Management	Dates observed	Habitat	Observations	Source of information[1]
WY-1	Park, Teton	Yellowstone National Park	Yellowstone National Park	Jul-1904	No information	Jul-1904: In flower; determined by A. Nelson; annotated by R.A. Mayes in 1976	*O.M. Oleson #115a* RM; Wyoming Natural Diversity Database (2004)
WY-2	Park	Yellowstone Plateau, Mammoth Hot Springs area, east of the "YACC Camp" above Ft. Yellowstone	Yellowstone National Park	3-Aug-1995; Jun-2004	Moist meadow with *Phleum pratense*, *Poa* spp., *Astragalus canadensis*, *A. agrestis*, and *Antennaria* sp, at approximately 6,290 ft.	3-Aug-1995: Specimen collected; 2004: A minimum of 50 plants, likely more, in an area of approximately 30 m by 10 m	*J. Whipple #4541* YELLO; Wyoming Natural Diversity Database (2004)
WY-3	Park	Northern range likely near Crystal bench or Junction Butte; "Camp Roosevelt Cooke City Road west of Lamar Bridge."	Yellowstone National Park	8-Aug-1926	No information	Specimen with two stems in flower and fruit; originally identified as *Pyrrocoma lanceolata* by A. Nelson; annotated *Haplopappus lanceolatus* by D.G. Despain 1973; annotated *H. integrifolius* by Evert July 1993	*H.S. Conrad #1887* YELLO (YELLO Acc. #3007)
WY-4	Unknown	Unknown [Likely from the northern range in Yellowstone National Park in Park County]	Yellowstone National Park	1920s or 1930s (likely)	No information	Possibly a duplicate of YELLO Acc. #3007	YELLO Acc. # 3006; no collection details except general location. It may be duplicate collection at occurrence 4 (Whipple personal communication 2005).
WY-5	Park	Southwest camp near Swan Lake [Original report indicated specimen was from Montana]	Yellowstone National Park	1-Aug-1919	No information	No information	MONT Acc. #36585
WY-6	Washakie (Big Horn)	Bighorn Range, head of Middle Fork of the Powder River [probably near the Hazelton Road]	Bureau of Land Management, Worland Field Office	19-Jul-1901	Mountain sides	Annotated *Haplopappus integrifolius* by C.L. Porter 1951; annotated *Pyrrocoma integrifolia* by Mayes in 1976	*L.N. Goodding #307* RM; Wyoming Natural Diversity Database (2004)
WY-7	Fremont	Southeast Wind River Range, Brown Canyon area, about 10 miles south of Lander	Shoshone National Forest	24-Jul-1961	Three-tip sagebrush grassland on north-facing slope	24-Jul-1961: In flower; annotated as *Pyrrocoma clementis* by Porter in 1965, *P. clementis* var. *villosa* by Mayes in 1976; an anonymous undated annotation was made indicating it to be *Haplopappus integrifolius*	*H.G. Fisser #638* RM; Wyoming Natural Diversity Database (2004)

[1]Herbarium abbreviation:

MONT: Herbarium at Montana State University.

RM: Rocky Mountain Herbarium, University of Wyoming.

YELLO: Herbarium at Yellowstone National Park.

biology, and ecology among these species (Hall 1928, Lane and Hartman 1996, Morgan and Simpson 1992). Therefore, discretion must be used when considering the relevance of observations of *Haplopappus* species to *P. integrifolia*.

Publication of Assessment on the World Wide Web

To facilitate their use, species conservation assessments are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, Web publication will facilitate the 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 at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

Management Status and Natural History

Management Status

Pyrrocoma integrifolia is a regional endemic of northwestern Wyoming, southwestern Montana, and east-central Idaho. Approximately 93 *P. integrifolia* occurrences have been reported throughout its range since 1880. How many of these occurrences are extant is unknown. There are seven reported occurrences of *P. integrifolia* in Wyoming; one of these is on National Forest System land in Region 2 (WY-7 in **Table 1**).

The NatureServe global[2] rank for *Pyrrocoma integrifolia* is G3?, which indicates that the taxon is probably vulnerable (NatureServe 2005). The question mark after the numeric rank indicates that the conservation status is uncertain (Nature Serve 2005) and that more information is needed to establish the species' current range and abundance. The Wyoming Natural Diversity Database (2004) and the Idaho Conservation Data Center both designate *P. integrifolia* critically imperiled (S1) (NatureServe 2005). The taxon is tracked in Wyoming (Wyoming Natural Diversity Database 2004) but not in Idaho (Cooke personal communication 2005). In 2001, the Idaho Native Plant Society (2001) listed the taxon *Haplopappus integrifolius* as "under review." Taxa that are under review by the Idaho Native Plant Society are recognized as being potentially "of conservation concern in Idaho, but lack sufficient data to base a recommendation regarding their appropriate classification" (Idaho Native Plant Society 2001). The Montana Natural Heritage Program reports that *P. integrifolia* is a "species of potential concern" but judges it to be unrankable (Montana Natural Heritage Program 2003, 2005a). Taxa are deemed unrankable either due to a lack of information or substantially conflicting information about status or trends (Montana Natural Heritage Program 2003). NatureServe ranks only serve to indicate conservation status and have no regulatory authority.

Region 2 of the USFS lists *Pyrrocoma integrifolia* as a sensitive species (USDA Forest Service 2003a, 2005a), but neither Region 1 nor Region 4 lists it as sensitive (USDA Forest Service 2001). The Bureau of Land Management (BLM) has not designated *P. integrifolia* as a sensitive species in any state in which it occurs (USDI Bureau of Land Management 2000, 2004, Montana Natural Heritage Program 2005, Idaho Fish and Game Department 2005, USDI Bureau of Land Management Wyoming 2004). *Pyrrocoma integrifolia* is not and has never been a candidate for listing as threatened or endangered under the federal Endangered Species Act.

The U.S. Fish and Wildlife Service has not assigned a wetland indicator status to *Pyrrocoma integrifolia* (USDI Fish and Wildlife Service 1988, USDI Fish and Wildlife Service 1996, USDA Natural Resources Conservation Service undated). The reason it has no status is not documented. Jean and Crispin (2001) reported that *P. integrifolia* is a species of palustrine and/or riparian wetland habitats. However, occurrence information indicates that the taxon is not typically associated with riparian systems, and although many occurrences are associated with wet conditions, *P. integrifolia* plants can grow in a variety of environments (e.g., compare MT-15, MT-18, MT-19, MT-20, MT-22, and MT-49 in **Table 2**). Considering its preferred habitat, *P. integrifolia* could be classed as a facultative wetland (FACW) species, or possibly a facultative (FAC) species. FACW species usually occur in wetlands (estimated probability 67 to 99 percent),

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

Table 2. Information for occurrences of *Pyrrocoma integrifolia* in Montana (MT) and Idaho (ID). The state in which occurrence UK-1 occurs cannot be determined (see text).

State - number	County	Location	Management	Dates observed	Habitat	Observations	Source of information[1]
UK-1	Unknown	"Washington. Snake River" [see text]	Unknown	1872	No details	*Pyrrocoma integrifolia* (A. Gray) Greene (determined by R. A. Mayes, 1976); mounted on the right side of the sheet; another syntype is mounted on the left (Burke #s.n., see record number 8674)	*J.M. Coulter #s.n.* GH (GH Barcode 8675)
MT-1	Unknown	Rocky Mountains [see text]	Unknown	Undated	No details	*Pyrrocoma integrifolia* (A. Gray) Greene (determined by R. A. Mayes, 1976); mounted on the left side of the sheet; another syntype is mounted on the right (Coulter #s.n., see record number 8675)	*J. Burke #s.n.* GH (GH Barcode 8674)
MT-2	Unknown	Southwest Montana	Unknown	21-Jul-1880	No details	*Pyrrocoma integrifolia* (A. Gray) Greene determined by R. A. Mayes, 1976	*S. Watson #183* GH
MT-3	Wheatland or Judith Basin	At Barrow's Ranch near Judith Gap	Unknown	21-Aug-1882	No details	*Pyrrocoma integrifolia* (A. Gray) Greene (determined by R. A. Mayes, 1976); verification D. E. Boufford, 1982	*W. M. Canby #s.n.* GH
MT-4	Unknown	Belt Mountains	Unknown	14-Jul-1886	On open hills	Mixed specimens on the sheet: Type of *Stenotus andersonii* (NY 260041) and *Pyrrocoma integrifolia* (NY 260047)	*F.W. Anderson #3561* NY
MT-5	Lewis and Clark	25-Jul-1887: Helena; 3-Sep-1887: Helena Fairgrounds	Private	25-Jul-1887; Sep-3-1887	No details	No details	25-Jul-1887: MONT Acc. No. 1644. Sept. 3 1887: *F.W. Anderson #509 and #s.n.* MONTU [Apparently duplicate collections in same place]
MT-6	Cascade	Sun River	Unknown	30-Jul-1887	No details	No details	MONT Acc. No. 1645
MT-7	Beaverhead	Along Big Hole River	Private and/or Beaverhead National Forest	Jul-1888	Meadows	No details	MONT Acc. No. 1642
MT-8	Cascade	Smith River Basin	Unknown	15-Aug-1899	No details	RM: Originally identified as *Aplopappus integrifolius*, annotated *Pyrrocoma integrifolia* by R.A. Mayes 1976	*J.W. Blakenship #s.n.* RM, MONTU; MONT Acc. No. 44004

Table 2 (cont.).

State-number	County	Location	Management	Dates observed	Habitat	Observations	Source of information[1]
MT-9	Powell	1901: Deer Lodge; prior 1910: Deer Lodge Valley	Private	15-Jul-1901	No details	No details	1901: MONT Acc. No. 1641; in Jones (1910) as *Hoorebekia integrifolia*
MT-10	Lewis and Clark	Belmont Mt. near Empire	Private and/or Helena National Forest	Sep-1902	Elevation 6,000 ft.	No details	MONT Acc. No. 1643
MT-11	Unknown	Alkali Flats	Unknown	1-Aug-1910	No details	Originally identified as *Aplopappus integrifolius*; annotated *Pyrrocoma integrifolia* by R.A. Mayes 1976	*J.W. Blankinship #s.n.* RM
MT-12	Unknown	Upper Marias Pass	Glacier National Park or Lewis and Clark National Forest	Prior 1910	No details	No details	Jones (1910) as *Hoorebekia integrifolia*
MT-13	Park	Flathead Creek, northwest of Wilsall	Private	11-Aug-1921	No details	No details	*W.N. Suksdorf #753* HSC, ID, MONTU, RM
MT-14	Park	Suksdorf's Gulch, 9 miles northwest of Wilsall	Likely private	20-Sep-1921	No details	No details	*W.N. Suksdorf #1015* HSC, ID
MT-15	Beaverhead	Polaris	Private and/or Beaverhead National Forest	6-Sep-1921	In shallow, coarse gravel soil at elevation 6500 ft. on steep west slope	Common; originally identified as *Aplopappus integrifolius*; later anonymously annotated as *Pyrrocoma integrifolia*	*T.D. Howe #85* RM
MT-16	Unknown	No details	Missoula National Forest	1-Aug-1921	Clayey loam at 6,000 ft.	Originally identified as *Aplopappus integrifolius*; later anonymously annotated as *Pyrrocoma integrifolia*	*H.E. Richards #R-3* RM
MT-17	Gallatin	Gardiner vicinity	Yellowstone National Park	9-Aug-1922	No details	No details	MONT Acc. No. 36584, MONT Acc. No. 36587; duplicates
MT-18	Unknown	Squaw Creek	Beaverhead National Forest	21-Jul-1922	On "S. E. slope" [in context it may indicate steep east slope or southeast slope] at 7,000 feet in gravelly loam soil; associates species: *Koeleria cristata*, wheat grass, lupine, and *Sieversia*	Limited distribution, abundant; believed to be grazed moderately by cattle; "More data needed" on forage value; flowering period July-August; seed dispersal September-October; originally identified as *Aplopappus integrifolius*; later anonymously annotated as *Pyrrocoma integrifolia*	*H.W. Elofson #31* RM

Table 2 (cont.).

State-number	County	Location	Management	Dates observed	Habitat	Observations	Source of information[1]
MT-19	Unknown	No details	Missoula National Forest	2-Jul-1923	Elevation 4,500 ft.; sandy loam soil	Originally identified as *Aplopappus integrifolius*; later anonymously annotated as *Pyrrocoma integrifolia*	*J.H. Clack #C-24* RM
MT-20	Beaverhead	Alaska Basin (also in the vicinity of Henry's Lake, Idaho)	Unknown	27-Jul-1930	Open fields and prairies; elevation: 7,500 ft.	No information	MONT Acc. No. 17646
MT-21	Beaverhead	Jul-1930: Lakeview; 1931: Lake View, Centennial Valley	Bureau of Land Management and/or private	Jul-1930; 6-Aug-1931	1931: elevation: 6,500 ft.	No information	1930: MONT Acc. No. 17648. 1931: MONT Acc. No. 61246 & MONT Acc. No. 63150 – duplicates
MT-22	Gallatin	Meadow Creek	Gallatin National Forest	28-Jul-1932	Level ground in gumbo silt in open mountain meadow with grasses and rabbitbrush; elevation 7,200 ft.	Scarce and scattered; originally identified as *Aplopappus integrifolius*; later anonymously annotated as *Pyrrocoma integrifolia*	*J.C. Whitham #1247* RM
MT-23	Unknown	Missoula to Butte	Unknown	19-Jul-1934	No details	Annotated *Pyrrocoma integrifolia* by R.A. Mayes 1976	*G.E. Osterhout #8064* RM
MT-24	Madison	0.25 miles northwest of Northern Rocky Mountain Vigilante Experiment Station	National Forest	19-Jul-1936	Grass with clay soils on 3 % east slope at 6,080 ft.	Originally identified as *Aplopappus integrifolius*. Confirmed by S.F. Blake	*E. Dobrinz #59* RM
MT-25	Silver Bow	1895: Butte; 1936: Butte	Private	31-Jul-1895; 10-Jul-1936	1936: In dry exposed sandy field at 5,000 ft.	MONTU specimen: plant is "7 inches high with yellow and orange flowers. Land grazed by horses and cattle."	1895: *P.A. Rydberg #2808* NY 2 sheets. 1936: MONT Acc. No. 26735, *K.L. Doyle #397* MONTU
MT-26	Jefferson-Silver Bow	No details	Unknown	Jul-1936	In moist forested area at elevation 6,534 ft. (both specimens); sheltered exposure on grazed land (MONTU specimen)	15 inches tall with yellow flower, and first identified as *Oonopsis foliosa* (MONTU specimen)	MONT Acc. No. 26824, *M. Babich #184* MONTU
MT-27	Gallatin	No details except for county	Unknown	4-Aug-1939	Wet site	Identified as *Aplopappus integrifolius*	*F.H. Rose #961* ID, MONTU
MT-28	Beaverhead	Pioneer Range, Vipont [Vipond] Park, east of Sheep Mt.	Unknown	31-Jul-1945	In rapidly drying meadow	RM: "Pappus sordid, but very abundant, contrary to Hall's key." Annotated *Pyrrocoma integrifolia* by R.A. Mayes 1976	*C.L. Hitchcock and C.V. Muhlick #13020* RM; MONT Acc. No. 29476

Table 2 (cont.).

State-number	County	Location	Management	Dates observed	Habitat	Observations	Source of information[1]
MT-29	Beaverhead	No details except for county	Beaverhead National Forest	20-Jun-1946	Mountain meadow at 6,500 ft.	Originally identified as *Aplopappus integrifolius*; confirmed by S.F. Blake	*O.W. Ayers #A-6* RM
MT-30	Beaverhead	Pioneer Range, 7 miles south of Wise River	Unknown	25-Jul-1946	Meadows	Originally identified as *Haplopappus integrifolius*; annotated *Pyrrocoma integrifolia* by R.A. Mayes 1976	*C.L. Hitchcock and C.V. Muhlick #1470* RM
MT-31	Granite	West side of grade between Philipsburg and 1 mile from Rook Creek	Unknown	19-Jul-1946	No details	Identified as *Haplopappus integrifolius*; annotated *Pyrrocoma integrifolia* by R.A. Mayes 1976	*C.L. Hitchcock and C.V. Muhlick #14733* RM
MT-32	Granite	5 miles north of Phillipsburg	Likely private (near Deerlodge National Forest)	24-Jul-1950	Gentle open slopes	Not very common here; later seen more abundantly in meadows nearby; rays: orange-yellow; identified as *Haplopappus integrifolius* var. *integrifolius*	*A. Cronquist #6756* ID
MT-33	Park	"Yellowstone Winter Game Range." [A comparatively small area in the northern section of Yellowstone Park and the adjoining Absaroka National Forest consisting of the drainages of the Yellowstone and Lamar Rivers is commonly called the Northern Yellowstone Winter Range (Grimm 1939)]	Yellowstone National Park	23-Jun-1952	Wet meadow, associated with *Juncus balticus*	No details	MONT Acc. No. 44308
MT-34	Deerlodge	Modesty Creek	USDA Forest Service Intermountain Forest and Range Experiment. Station	28-Jul-1958	In high parks; in park type vegetation in grass-forb community with *Festuca idahoensis, F. scabrella* and *Erigeron* sp.; deep black gravelly loam soil	Scattered. 12- to 18-inch perennial plant with yellow-orange flowers; identified as *Aplopappus integrifolius*	*J.E. Schmautz #267* RM, *J.E. Schmautz #JES-267* MONTU

Table 2 (cont.).

State-number	County	Location	Management	Dates observed	Habitat	Observations	Source of information[1]
MT-35	Powell	Northeast of Deer Lodge, on damp ground along secondary road that parallels highway north of Cottonwood Creek	Likely private (near Deerlodge National Forest)	21-Jul-1963	No details	No details	MONT Acc. No. 59847
MT-36	Deerlodge	Approximately 28 miles east of Wisdom on Hwy 43	Likely private (near Beaverhead National Forest)	17-Jul-1964	In lush river bottom land	No details	*R. Spellenberg and D. Sutherland #709* HSC
MT-37	Beaverhead	Red Rock Lake Refuge	U.S. Fish and Wildlife Service	25-Jul-1968	Grassland with *Galium, Gaillardia,* and *Festuca*, at elevation 6,700 ft.	Sparse	MONT Acc. No. 64689
MT-38	Beaverhead	Red Rock Lake Refuge	U.S. Fish and Wildlife Service	2-Aug-1968	Grassland with *Artemisia, Lupinus*, and *Achillea*, at 6,600 ft.	Rare	MONT Acc. No. 64450
MT-39	Missoula	1971: Clearwater River, 0.3 miles west of Blanchard Lake, 12.1 miles south southwest of Seeley Lake Post office; 1976: On floodplains of the Clearwater River, between the river and Harpers Lake Campground.	Montana Fish, Wildlife and Parks Department and/or Montana State Trust Lands	21-Jul-1971; 2-Jul- 1976	On river terrace in fescue grassland with *Festuca scabrella* and *Potentilla gracilis*; elevation 3,800 ft. on level ground	Frequent; rays: yellow; identified as *Haplopappus integrifolius* by C. Feddema 1972	*P.F. Stickney #2348* RM. MONT Acc. No. 66264 & MONT Acc. No. 66366 – duplicates. *T.J. Watson #1288* 1976 MONTU
MT-40	Granite	1924: Near Phillipsburg, hills southwest, roadside; 1974: Philipsburg; 1975: Philipsburg exit on US Highway 10A, approximately 1 mile west of Philipsburg	Likely private	5-Jul-1924; 1974; 30-Jul-1975	No details	1924: RM; annotated *Pyrrocoma integrifolia* by R.A. Mayes 1976. MONTU; determined by K.H. Lackschewitz III/1983	*J.E. Kirkwood #1791* 1924 RM (possibly duplicate); *J.E. Kirkwood #1791* 1924 MONTU; *Mayes #157* 1974 in Mayes (1976); *T.J. Watson #1201* 1975 MONTU
MT-41	Beaverhead	5 miles west of Jackson on State Route 278	Unknown	28-Jul-1974	No details	No details	*R.A. Mayes #155* RM, Mayes (1976)
MT-42	Beaverhead	20 miles west of Dillon on State Route 278	Private, or possibly Beaverhead National Forest	28-Jul-1974	No details	No details	*R.A. Mayes #154* RM, Mayes (1976)
MT-43	Deerlodge	15 miles north of Wisdom on State Route 43	Unknown	Likely 1974	No details	No details	*Mayes #156* in Mayes (1976)

Table 2 (cont.).

State-number	County	Location	Management	Dates observed	Habitat	Observations	Source of information[1]
MT-44	Deerlodge	5 miles north of Warm Springs Mt. On US Hwy 10	Unknown	Likely 1974	No details	No details	*Mayes #160 in Mayes (1976)*
MT-45	Deerlodge	Along entrance to Georgetown Lake campground from US Hwy 10	Unknown	Likely 1974	No details	No details	*Mayes #161 in Mayes (1976)*
MT-46	Powell	15 miles east of Helniville on State route 272	Unknown	Likely 1976	No details	No details	*Mayes #158 in Mayes (1976)*
MT-47	Powell	2 miles south of Garrison on US Hwy 10	Unknown	Likely 1976	No details	No details	*Mayes #159 in Mayes (1976)*
MT-48	Park	Dailey lake approximately 15 miles north of Gardiner, south shore of lake	Montana Fish, Wildlife and Parks Department	9-Jul-1991	With *Distichlis stricta, Festuca arundinacea, Spartina gracilis*, and *Scirpus nevadensis*; elevation: 5,241 ft.	No details	*E. Evert #21654* RM
MT-49	Beaverhead	East Pioneer Mountains along Quartz Hill Gulch road (USFS Road # 187)	Beaverhead National Forest	4-Jul-1992	Open, dry, rocky grassland with scattered J*uniper scopulorum* and *Artemisia tridentata*; other associated species: *Koeleria cristata* and *Stipa comata*; aspect 10 % east; elevation: 5,800 ft.	Common; flowers: yellow; identified as *Haplopappus integrifolius*	*M. Mantas #584* ID
MT-50	Gallatin	Madison Range: along trail approximately 1 mile southwest of Albino Lake and approximately 12 miles south of Big Sky	Gallatin National Forest; may extend on to private land	17-Jul-1992	Mesic sagebrush-grassland with *Festuca idahoensis, Stipa richardsonii, Pentaphylloides floribunda*, and *Artemisia cana* at 7,200 ft.	No information	*E.F. Evert #23911* RM
MT-51	Beaverhead	Tendoy Mountains. Little Water Canyon, approximately 4 miles west of Dell	Beaverhead National Forest	12-Jul-1994	MONT: elevation approximately 7,100 ft.; moist canyon bottom with *Elymus cinereus* and *Iris missouriensis*	No information	*J. Vanderhorst #5241a* MONTU; MONT Acc. No. 74573

Table 2 (cont.).

State-number	County	Location	Management	Dates observed	Habitat	Observations	Source of information[1]
MT-52	Beaverhead	Pioneer Mountains, along USFS Road 187	Beaverhead National Forest	28-Jul-1996	Elevation: 2,350 m	No information	*C. Morse #1000* MONTU
MT-53	Gallatin	Yellowstone Plateau: in West Yellowstone along the former Union Pacific Railroad right-of-way just south of Yellowstone Avenue; at least two sub-occurrences over two contiguous sections	Gallatin National Forest (may extend to private land)	20-Jul-1997	Disturbed, sandy soil with *Berteroa incana* and *Gayophytum diffusum*; elevation: 6,670 ft.	No information	*E.F. Evert #33803* RM
MT-54	Madison	Madison Valley: South Madison Fishing Access along the east side of the Madison River, approximately 25 miles south of Ennis	Private or Beaverhead National Forest	22-Jul-1997	Wet sedge meadow with *Carex nebrascensis, Deschampsia cespitosa, Iris missouriensis*, and *Triglochin maritimum*; elevation: 5,680 ft.	No information	*E.F. Evert #34000* RM
MT-55	Powell	1993: Ovando Valley, at pond margins 0.25 miles east of Kleinschmidt Lake; 1997: Ovando Valley around ponds north of Kleinschmidt Lake; 2001: Ovando vicinity	Private	1-Jul-1993; 6-Aug-1997; 19-Jul-2001	1993: In moist alkaline meadows around the margins of a pond with *Juncus balticus* and *Antennaria microphylla*; 1997: In moist meadows with *Agropyron smithii* and *Juncus balticus* 2001: Rangeland	1993: Local; 1997: Common; 2001: *Pyrrocoma integrifolia* is an abundant rangeland forb	*P. Lesica #6028* 1993 MONTU; *P. Lesica #7498* 1997 MONTU; 2001: MONT Acc. No. 76773
MT-56	Park	Yellowstone (R.) Valley, no collection date	Likely Yellowstone National Park	Undated	No information	No information	MONT Acc. No. 36586 & MONT Acc. No. 36583 – duplicates
MT-57	Silver Bow	No collection date or locality details except for county	Unknown	Undated	No information	No information	MONT Acc. No. 1640
MT-58	Beaverhead	Along Hwy 43 approximately 1 mile west of Wisdom	Likely private	9-Jul-1983	In gravelly soil with Phleum pratense and Achillea millefolium	Common in gravelly soil	*P. Lesica #2696, #2695, #2699* MONTU

Table 2 (cont.).

State-number	County	Location	Management	Dates observed	Habitat	Observations	Source of information[1]
MT-59	Beaverhead	1983: Along Hwy 43 approximately 2 miles north of Wisdom; 1990: Along Hwy 43 approximately 2 mile north of Wisdom	Likely private	9-Aug-1983; 28-Jul-1990	1983: In moist meadow with *Phleum pratense* and *Hordeum jubatum*; 1990: In wet meadows with *Phleum pratense* and *Poa pratensis*	1983: Common in moist meadow; original identification *Haplopappus lanceolatus* and annotated *H. integrifolius* by P.L. in 1990; 1990: Common in moist meadow	*P. Lesica #2781* 1983 MONTU; *P. Lesica #5196* 1990 MONTU
MT-60	Beaverhead	Big Hole National Battlefield; 9 miles west of Wisdom on State Hwy 43; on bench between visitor center and housing	National Park Service	19-Jul-1980	Growing with *Aster occidentalis* and *Tragopogon dubius* at 6,300 ft.	Scarce; in a large clump; identified as *Haplopappus integrifolius*	*J. Pierce #869* MONTU
MT-61	Beaverhead	At Divide Bridge Campground on the Big Hole River just west of Divide	Beaverhead National Forest	14-Jul-1990	In meadow with *Elymus cinereus* and *Poa pratensis* at 5,400 ft.	Locally common in meadow; identified as *Haplopappus integrifolius*	*P. Lesica #5159* MONTU
MT-62	Beaverhead	Red Rock Lakes Wildlife Refuge on ledge of north slope above main road south of upper Red Rock Lake [distinct from MT-37]	U.S. Fish and Wildlife Service	10-Jul-1986	On dryish ledge with *Hedysarum boreale, Astragalus leptaleus,* and "*Bupleurum*"	No details; identified as *Haplopappus integrifolius*	*K.H. Lackschewitz #11005* MONTU
MT-63	Pondera	Approximately 5 miles south of Heart Butte	Not available	19-Jul-1988	In heavy soil of a moist alkaline meadow around a pond in the grasslands with *Grindelia squarrosa* and *Juncus balticus*	Common in [localized area]; identified as *Haplopappus integrifolius*	*P. Lesica #4656* MONTU
MT-64	Powell	Grant Kohrs Ranch National Historic Site. At least two sub-occurrences. Suboccurrence 1: near bank of Clark Fork River near southern boundary of Ranch; suboccurrence 2: North hayfield near north boundary	National Park Service	22-Jul- 1983	Suboccurrence 1: Sandy soil, alkaline meadows, full sun; suboccurrence 2: Moist soil, alkaline meadows with *Cirsium* and *Muhlenbergia*	Suboccurrence 2: 3 to 5 dm tall; identified as *Haplopappus integrifolius*	*G. Ray #167, #175*

Table 2 (cont.).

State-number	County	Location	Management	Dates observed	Habitat	Observations	Source of information[1]
MT-65	Beaverhead	Mud Creek Road to Trail Creek in the Tendoy Mountains	Bureau of Land Management	18-Jul- 1988	In extensive alkaline meadows with *Glaux maritima* and *Triglochin* sp.	Identified as *Haplopappus integrifolius*	*K. Urbanska, K.H. Lackschewitz, and R. Bayer #11541* MONTU
MT-66	Beaverhead	Along a backwater slough of Beaverhead River 0.5 miles southwest of Dalys	Bureau of Land Management	6-Jul-2003	In moist meadow with *Juncus balticus* and *Poa pratensis* at 5,350 ft.	Common in meadow; identified as *Haplopappus integrifolius*	*P. Lesica #8690* MONTU
MT-67	Granite	Petersons Meadows	Unknown	12-Aug-1993	With *Potentilla fruticosa, Gentiana affinis, Erigeron gracilis*, and *Danthonia parryi* at 7,200 ft.	A large dominant population; identified as *Haplopappus integrifolius*	*K.H. Lackschewitz and M. Cooper #12014* MONTU
MT-68	Beaverhead	0.25 miles northeast of Monida	Bureau of Land Management and/or private	11-Jul-1986	In dryish place with few grasses at 6,700 ft.; with *Astragalus leptaleus, Sphaeralcea* sp. and *Castilleja* sp.	No information; identified as *Haplopappus integrifolius*	*K.H. Lackschewitz #11015* MONTU
MT-69	Beaverhead	Just southeast of Monida [not far from border with Idaho]	Private	27-Jul-1987	In moist meadow with *Juncus balticus* and *Potentilla fruticosa*	Common in meadow; identified as *Haplopappus integrifolius*	*P. Lesica #4433* MONTU
MT-70	Silver Bowa	Highland Mountains. Along Moose Creek in Moosetown area approximately 15 miles south of Butte	Bureau of Land Management and/or private	3-Aug-1997	In meadows with *Potentilla fruticosa* and *Juncus balticus*	Common in meadows; identified as *Haplopappus integrifolius*	*P. Lesica #7497* MONTU
MT-71	Silver Bowa	Just below saddle between two hills north of Moose Creek	Beaverhead National Forest	30-Jun-1990	In moist meadow with *Potentilla fruticosa* and *Carex praegracilis*	Common in meadow; identified as *Haplopappus integrifolius*	*P. Lesica #5749* MONTU
MT-72	Park	22 miles south of Livingstone on US Highway 89	Likely private	7-Jul-1976	No information	No information; identified as *Haplopappus integrifolius*	*T.J. Watson #1313* MONTU
MT-73	Powell	Near Deer Lodge	Private	23-Jun-1970	Meadow low and wet at least in spring; meadow has been mowed in past few years	No information; identified as *Haplopappus integrifolius*	*M. Mooar #12,070* MONTU

Table 2 (cont.).

State-number	County	Location	Management	Dates observed	Habitat	Observations	Source of information[1]
MT-74	Deerlodge	Near Warm Springs	Montana Fish, Wildlife and Parks Dept., and/or private (may be owned by Institution)	23-Jun-1970	Very alkaline fine clay with puddles	No information; identified as *Haplopappus integrifolius*	*M. Mooar #12,089* MONTU
MT-75	Deerlodge	Anaconda-Pintlar Range. Along road east of Pintler Lake	National Forest	8-Jul-1992	Moist place with *Erigeron lonchophyllus, Senecio pseudaureus, Grass species*, and *Carex* spp. at 6,320 ft.	No information; identified as *Haplopappus integrifolius*	*K.H. Lackschewitz #11886* MONTU
MT-76	Madison	Ruby valley. South side of Ruby River just east of Ledford Creek Road	Private	28-Jul-1992	Around margins of calcareous wet meadows with *Tragopogon pratensis* and *Juncus balticus*	Common; identified as *Haplopappus integrifolius*	*P. Lesica #5805* MONTU
MT-77	Granite	Rough Fescue Ridge	Unknown	23-Aug-1977	In prairie vegetation	A few plants at the summit of the ridge; identified as *Haplopappus integrifolius*	*K.H. Lackschewitz #7930* MONTU
ID-1	Fremont	Henry's Lake	Private or Targhee National Forest	1-Sep-1899	On wet bottom lands	Cited by Hall (1928). Annotated *Pyrrocoma integrifolia* by R.A. Mayes 1976	*A. Nelson and E. Nelson #6797* RM
ID-2	Fremont	Near head of Duck Creek	Targhee National Forest	9-Aug-1911	Elevation 6,800 ft. "Black, rather sticky, somewhat gravelly soil," with roll-leaf *festuca*, *Koeleria* spp., and *Potentilla* spp.	Originally identified as *Pyrrocoma integrifolia*, later anonymously identified as *Aplopappus integrifolius* but [later?] anonymously annotated as *P. integrifolia*	*A.E. Aldous #206* RM
ID-3	Fremont	1918: Little Dry Creek; 1934: Little Dry Creek Canyon, Spencer	Private or Targhee National Forest	18-Jul-1918; 14-Jan- [?]1934	1918: Grassy places; 1934: No information	Both specimens annotated *Pyrrocoma integrifolia* by R.A. Mayes 1976; remarks on 1934 specimen label: H.J. Rust 798, July 11 1916	*H.J. Rust #798* 1918 ID; *J.H. Christ #2899* 1934 ID
ID-4	Clark	1.5 miles south of Monida	Private or Targhee National Forest	20-Jul-1946	In meadows on high divide	Annotated *Pyrrocoma integrifolia* by R.A. Mayes 1976; *Haplopappus integrifolius* var. *integrifolius* by KH Lee; originally identified as *H. uniflorus*	*J.H. Christ #15526* ID
ID-5	Lemhi	7 miles east of Leadore on state route 29	Salmon National Forest	Likely 1974	No information	No information	*R.A. Mayes #153* in Mayes (1976)

Table 2 (concluded).

State-number	County	Location	Management	Dates observed	Habitat	Observations	Source of information[1]
ID-6	Fremont	Henrys Lake Mountains: above Raynolds Pass, approximately 3.5 miles northwest of Henrys Lake. Occurrence over 2 sections	Targhee National Forest	7-Jun-1992	Mostly forbs and grasses, a few scattered *Pinus flexilis*; elevation: 7,000 to 7,400 ft.	No information	*S. Markow #7167* RM
ID-7	Clark	Centennial Mountains: East of Beaver Creek along Dairy Creek, north of Dubois. Sub-occurrences over 2 sections	Targhee National Forest	25–Jun-1992	Mostly *Artemisia* with many forbs and grasses; elevation: 6,000 to 6,200 ft.	No information	*S. Markow #8238* RM
ID-8	Clark	Centennial Range; left Fork Creek approximately 100 ft. above confluence with Dairy Creek; approximately 5 miles north of Spencer	Targhee National Forest	19-Jul-1995	Grass/forb community with *Phleum pratense, Castilleja miniata, Geranium viscosissimum*, and *Dactylis glomerata*; elevation approximately 6,000 ft.	No information	*S. Markow #11176* ID, RM

[1]Herbarium abbreviation:

CS: Herbarium, Biology Department at Colorado State University.
GH: Gray Herbarium, Harvard University.
HSC: Vascular Plant Herbarium, Humboldt State University
ID: Stillinger Herbarium, University of Idaho.
MONT: Herbarium, Montana State University.
MONTU: Herbarium, University of Montana.
NY: William and Lynda Steere Herbarium, New York Botanical Garden Herbarium.
RM: Rocky Mountain Herbarium, University of Wyoming.
YELLO: Herbarium, Yellowstone National Park.

but they are occasionally found in non-wetlands. FAC species are equally likely (estimated probability 34 to 66 percent) to occur in wetlands or non-wetlands (USDI Fish and Wildlife Service 1988, USDI Fish and Wildlife Service 1996, USDA Natural Resources Conservation Service undated).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

As a USFS-designated sensitive species in Region 2, *Pyrrocoma integrifolia* 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). The goal of the designation is to avoid the loss of species viability and to prevent the creation of significant trends toward Federal listing as Threatened or Endangered under the Endangered Species Act of 1973 (USDA Forest Service 1995). Designation as a sensitive species requires that a biological evaluation of potential impacts to the species be made prior to any major project on National Forest System land (USDA Forest Service 1995). Currently, there are no plans that specifically address the management of *P. integrifolia*.

Three specific directives are associated with sensitive species designation (USDA Forest Service 1995):

1. develop and implement management practices to ensure that the species does not become threatened or endangered because of Forest Service actions

2. maintain viable populations of…[the]….plant species in habitats distributed throughout their geographic range on National Forest System lands

3. develop and implement management objectives for populations and/or habitat of sensitive species.

In Wyoming, *Pyrrocoma integrifolia* occurrences have been reported on land managed by the Shoshone National Forest (Region 2), the BLM Worland Field Office, and the National Park Service (**Table 1**). The *P. integrifolia* occurrence on the Shoshone National Forest was reported in 1961, and its current status is uncertain. In addition, its taxonomic status is unclear (see Treatment of Uncertainty section). The occurrence on BLM land is from a collection made in 1901, and there is no current information on the status of the taxon in the area. *Pyrrocoma integrifolia* occurs in Yellowstone National Park (**Table 1**; McGougall and Baggley 1936). National parks are managed to preserve their scenic or historic significance. Logging, mining, and other activities allowed in national forests are generally prohibited in national parks (Environmental Media Services 2001). Yellowstone National Park does not currently have an official list of sensitive species, but if it did, *P. integrifolia* would be included (Whipple personal communication 2005). One of the *P. integrifolia* occurrences in Yellowstone National Park (WY-2 in **Table 1**) is checked periodically and, as of June 2004, remains extant and apparently secure (Whipple personal communication 2005).

In Montana and Idaho, *Pyrrocoma integrifolia* occurrences have been reported from National Forest System land managed for multiple uses. *Pyrrocoma integrifolia* occurrences are afforded no special protection on National Forest System land outside of Region 2, as neither Region 1 nor Region 4 consider it a sensitive species. In Montana, three occurrences (MT-36, MT-37, and MT-62 in **Table 2**) have been reported from the Red Rock Lakes National Wildlife Refuge, managed by the U.S. Fish and Wildlife Service. Management of national wildlife refuges principally focuses on wildlife conservation, and any recreational uses are required to be compatible with that mission (Environmental Media Services 2001, USDI Fish and Wildlife Service 2006). The National Park Service has designated Red Rock Lakes National Wildlife Refuge as a National Natural Landmark (USDI Fish and Wildlife Service 2003). Hunting is allowed in some areas within the refuge, but off-road motorized travel is prohibited throughout the area (USDI Fish and Wildlife Service 2003).

Additional occurrences near the Red Rock Refuge region may be protected from development through conservation easements with private lands. Occurrences MT-19, MT-20, and MT-22 (**Table 2**) are located in the Alaska Basin/Centennial Valley region in Montana. The Nature Conservancy has purchased several conservation easements in this region, which will limit urban development and habitat fragmentation (The Nature Conservancy 2005a, 2005b). The Nature Conservancy has also been working with local ranch owners to create a weed-free environment throughout the region (The Nature Conservancy 2005a). These easements were not established specifically for

Pyrrocoma integrifolia, but they may contribute to maintaining its habitat. However, the occurrences in the Alaska Basin, Centennial Valley, and Red Rock Refuge region were all reported 20 or more years ago, and their current status is not known.

No systematic monitoring programs have been developed for this species, and there are no documented attempts of active management practices anywhere within the species' range.

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. The Asteraceae is an exceptionally large and diverse family that has been divided into several sub-families, tribes, and sub-tribes. Bremer (1994) presented a classification that divided the Asteraceae into three subfamilies, 17 tribes, and 82 sub-tribes. *Pyrrocoma* is a member of the tribe *Astereae* and subtribe *Machaerantherinae* (Nesom 2000). Nesom (1994) estimated that at least 189 genera and approximately 3,020 species comprise the Astereae. Fifteen of those genera currently constitute the sub-tribe *Machaerantherinae*: *Benitoa*, *Corethrogyne*, *Grindelia*, *Hazardia*, *Isocoma*, *Lessingia*, *Machaeranthera*, *Olivaea*, *Oonopsis*, *Pyrrocoma*, *Rayjacksonia*, *Stephanodoria*, *Xanthisma*, *Xanthocephalum*, and *Xylorhiza* (Nesom 2000). See **Table 3** for the scientific taxonomic classification of *P. integrifolia*.

The history of the genus *Pyrrocoma* is quite convoluted, and its members have been subjected to various treatments. Because the identities of many specimens of *Pyrrocoma* have been subject to revision, it might appear that the similarity among species detracts from their uniqueness and potential importance to a functioning ecosystem. However, revisions are often a result of more specimens becoming available for examination and the diversity within the genus being better understood, using the most effective classification techniques available.

Cassini (1819) wrote the original description of the genus *Aplopappus*. Less than two decades later, Hooker (1833) described the genus *Pyrrocoma* based on one specimen, initially remarking that the specimen that he examined appeared to be related to *Carthamus* species, tribe *Cardueae*, and *Liatris* species, tribe *Eupatorieae*. Soon thereafter, de Candolle (1836) described the genus *Aplopappus* as being composed of seven sections but retained *Pyrrocoma* as a separate genus with two sections and four species. Gray (1881) treated *Pyrrocoma* as a section in the genus *Aplopappus*.

At the end in the nineteenth century, E.L. Greene (1894a) wrote of the vastly differing opinions of the position of the genera within the *Astereae*. The broadest concept appears to have been taken by Otto Kuntze who published his opinion that even members of the genus *Solidago*, as well as species under *Chrysopsis*, *Aplopappus*, and *Bigelovia*, were all species of the genus *Aster* (Kuntze 1891). In a less expansive but still encompassing concept, many genera,

Table 3. Scientific taxonomic classification of *Pyrrocoma integrifolia*, after Integrated Taxonomic Information System (2005), with sources (not necessarily the original source) of particular portions cited below.

Kingdom	Plantae (Plants)
Subkingdom	Tracheobionta (Vascular plants)
Division	Magnoliophyta (Flowering plants)
Class	Magnoliopsida (Dicotyledons)
Subclass	Asteridae
Order	Asterales
Family	Asteraceae (Sunflower Family)
Tribe	Astereae[1,2]
Subtribe	*Machaerantherinae*[1]
Genus	*Pyrrocoma* (goldenweed)[1,2]
Species	*Pyrrocoma integrifolia* (Porter ex Gray) Greene

[1]Nesom (2000)
[2]Bogler (2006)

including *Pyrrocoma*, *Grindelia*, *Hazardia*, *Isocoma*, *Machaeranthera*, *Oonopsis*, *Rayjacksonia*, *Xanthisma*, *Xanthocephalum*, and *Xylorhiza*, were considered to constitute the "*Haplopappus* group" (Hall 1928, Bremer 1994). Early in the twentieth century, the name *Haplopappus*, rather than *Aplopappus*, was established. In Greek, the prefix *haplo* refers to an element being single or simple, which in this case refers to the one-whorled pappus (Gledhill 1992). Hall (1928) believed that generic segregates of the *Haplopappus* group proposed by previous authors such as Greene (1894a) and Rydberg (1906) were more effectively treated as sections of one inclusive genus, the oldest name of which was *Aplopappus* (Cassini 1819), later called *Haplopappus*. After Hall (1928) wrote his treatment of *Haplopappus*, some authors retained *Pyrrocoma* species in the genus *Haplopappus* (e.g., Cronquist 1994, Welsh et al. 2003), while others recognized a narrower generic segregation (e.g., Hartman 1990, Lane and Hartman 1996, Bogler 2006).

Mayes (1976) undertook a cytotaxonomic and chemosystematic study and revised *Pyrrocoma* in his unpublished dissertation. He did not validate any of the nomenclatural changes he proposed in his dissertation, but many were formalized later, e.g., by Kartesz and Gandhi (1991) and Brown and Keil (1992). There are now between 10 and 14 formally recognized species of *Pyrrocoma*, several with infraspecific varieties, all of them limited to western North America (Bremer 1994, Nesom 2000, Bogler 2006). Among these are several taxa that are rare and endemic to relatively small regions of the western United States (Mancuso and Moseley 1991, Mancuso 1997, Urie and van Zuuk 2000, Kaye 2002, Beatty et al. 2004).

An aspect to consider when discussing species 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 arose from a common ancestor. However, *Machaeranthera* species 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. integrifolia* to future environmental changes (e.g., elevated carbon dioxide levels) even though the species appear to be very different.

It is widely accepted that many taxa within the *Machaerantherinae* pose a taxonomic challenge (Greene 1894a, Morgan and Simpson 1992), and *Pyrrocoma integrifolia* is apparently no exception. Gray (1881) first published the name *Aplopappus integrifolius*. T.C. Porter described this taxon from plant specimens collected by Coulter and Burke from Wyoming but did not publish the name (Gray 1881). Greene (1894b) subsequently described *P. integrifolia*. Rydberg (1900) described a new variety of *P. integrifolia* var. *pumila*, which he placed in synonymy with *P. howellii*. *Pyrrocoma howellii* has since been placed in synonymy with *P. uniflora* var. *uniflora* (Integrated Taxonomic Information System 2005). However, *P. howellii* has been used to describe two different taxa (Rydberg 1900), and the specific specimens (type and isotype) on which Rydberg based his concept of *P. integrifolia* var. *pumila* were annotated as *P. integrifolia* by R.A. Mayes in 1976 (Mayes 1976, New York Botanical Garden 2005). Hall (1928) recognized four subspecies of *Haplopappus integrifolia*: subspecies *typicus*, *insecticruris*, *liatriformis*, and *scaberulus*. Two of these subspecies have since been elevated to specific level: *P. insecticruris* is endemic to southwestern Idaho, and *P. liatriformis* is a regional endemic of Idaho and Washington (USDA Natural Resources Conservation Service 2004.). *Pyrrocoma integrifolia* var. *scaberula* is a synonym of *P. liatriformis* (Integrated Taxonomic Information System 2005). Synonyms of *P. integrifolia* include *Aster canbyi* (Kuntze 1891), *Aplopappus integrifolius* (Gray 1881), *Haplopappus integrifolius* (Hall 1928), and *Hoorebekia integrifolia* (Jones 1910). **Table 4** is an overview of synonyms for *P. integrifolia* and its proposed subspecies and varieties.

The affinities of *Pyrrocoma integrifolia* have been subject to various interpretations. Gray (1881) considered that *Aplopappus integrifolius* had an affinity with "*A. lanceolatus* or *paniculatus* and *A. uniflora*." Discussing all the taxa as within the genus *Haplopappus*, Hall (1928) considered *P. integrifolia*'s essential characters standing between *P. crocea* and *P.*

Table 4. Synonyms of *Pyrrocoma integrifolia* and the taxonomic status of proposed subspecies and varieties according to Integrated Taxonomic Information System (2006). Additional sources of particular names are cited below. See also Bogler (2006).

Accepted name (Integrated Taxonomic Information System 2005)	Synonym
Pyrrocoma integrifolia[1]	*Aster canbyi*[2]
	Aplopappus integrifolius[3]
	Haplopappus integrifolius[4]
	Hoorebekia integrifolia[5]
Pyrrocoma uniflora var. *uniflora*[1]	*Pyrrocoma integrifolia* **var. pumila**[6]
	Pyrrocoma howellii[1]
Pyrrocoma liatriformis[1]	***Haplopappus integrifolia* ssp. *liatriformis***[4]
Pyrrocoma insecticruris	***Haplopappus integrifolia* ssp. *insecticruris***[4]
None (possibly the specimens are only morphological variants)	***Haplopappus integrifolia* ssp. *scaberulus***[4]

[1]Published in Greene (1894b)
[2]Published in Kuntze (1891)
[3]Published in Gray (1881)
[4]Published in Hall (1928)
[5]Published in Jones (1910)
[6]Published in Rydberg (1900)

lanceolatus. Mayes (1976) concurred that the taxon was closely related to *P. crocea*. Another opinion holds that the rare species *P. clementis* var. *villosa* should be submerged into *P. integrifolia* (Cronquist 1994, Welp et al. 2000). Rather than being a variety of *P. clementis*, Cronquist (1994) considered that *P. clementis* var. *villosa* is "better included in *Haplopappus integrifolius*." This may be the basis on which the specimen annotated by Mayes (1976) as *P. clementis* var. *villosa* is now considered to be *P. integrifolia* (see Treatment of Uncertainty section and WY-7 in **Table 1**).

History of species

Hooker (1833) was the first to describe a taxon in the genus *Pyrrocoma* and derived the name from the Greek words *pyrrhos* meaning tawny and *kome* meaning hair [of the head] in reference to the reddish-colored pappus of the seed (Weber and Wittmann 2001). The ancestral *Pyrrocoma* species is believed to have originated in the area presently occupied by the central and southern Rocky Mountains and was likely a member of the Madro-Tertiary geoflora (Chaney 1947, Axelrod 1958, Mayes 1976). The derived taxa were likely to have migrated west and north from this region during the Pliocene and Pleistocene (Mayes 1976). Under pressures of increasing aridity, the derived *Pyrrocoma* taxa are likely to have adapted to xeric conditions (Stebbins 1952). *Pyrrocoma integrifolia* remains near the center of origin and is apparently closely related to the ancestral species, occupying moister habitats than many of its relatives and retaining several of the more ancestral characteristics of *Pyrrocoma* (Hall 1928, Mayes 1976).

John Merle Coulter and J. Burke were apparently among the first to collect *Pyrrocoma integrifolia*. Coulter probably collected *P. integrifolia* during the Hayden expedition of 1872 (Hayden 1873) in either Montana or Idaho near the boundary of what is now Yellowstone National Park (UK-1 in **Table 2**). The collection by J. Burke (GH Barcode 8674 in Harvard Herbaria Database (2005) and MT-1 in **Table 2**) is undated but is mounted on the same sheet as Coulter's collection. Joseph Burke is known to have traveled though the center of *P. integrifolia*'s range in southwestern Montana into Idaho in 1845 specifically to collect plants (Knowles and Knowles 1995). Whether the undated herbarium specimen was from 1845 or from a later time is not clear.

Seven *Pyrrocoma integrifolia* occurrences have been reported in Wyoming since the taxon was first collected in the Bighorn Range in 1901 (WY-6 in **Table 1**). Five of these occurrences were observed prior to 1950. The identity of the specimen on the Shoshone National Forest (WY-7 in **Table 1**) may depend on the taxonomic treatment used. This specimen represents the southern edge of the range of *P. integrifolia* (**Figure 1**). It was collected in 1961 and annotated as *P. clementis* by C.L. Porter in 1965. It was later annotated as *P. clementis* var. *villosa* by R.A. Mayes. An anonymous and undated annotation indicating it to be *Haplopappus integrifolius* also appears on the specimen sheet, which

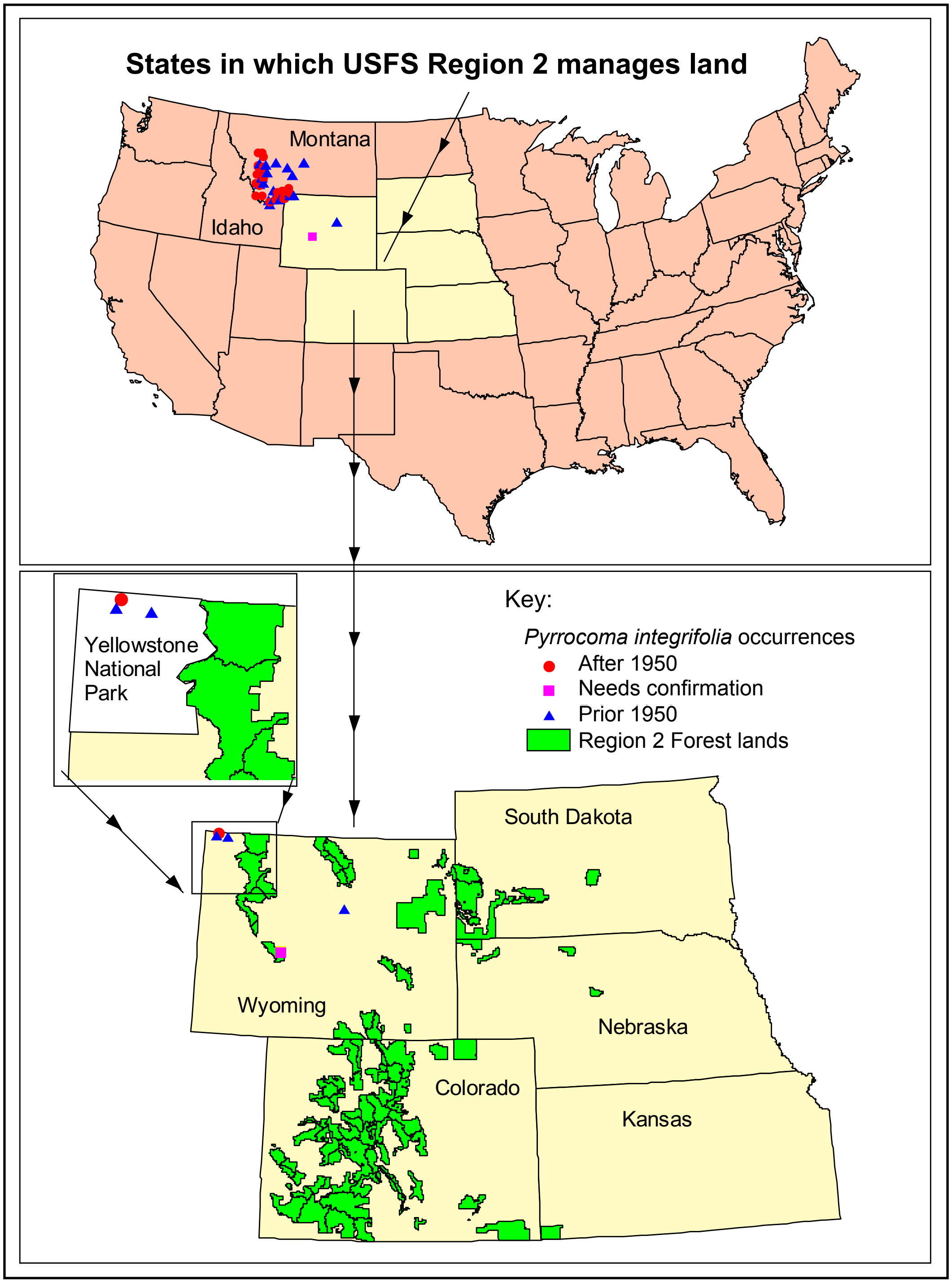


Figure 1. Global range of *Pyrrocoma integrifolia* (above) and distribution within Region 2 (below).

was accepted by Fertig (1999), Beauvais et al. (2000), Fertig (2000a, 2000b), and Wyoming Natural Diversity Database (2004). The occurrence at Yellowstone Park (WY-2 in **Table 1**) was first found in 1995 and was confirmed to be extant in 2004 (Whipple personal communication 2005).

Since *Pyrrocoma integrifolia* was first discovered, it has been collected sporadically in both Montana and Idaho. Approximately 77 occurrences of *P. integrifolia* have been observed in Montana. Of these occurrences, approximately nine were reported prior to 1900, 23 were reported between 1900 and 1949, 27 were observed between 1950 and 1989, and 18 have been observed since 1990 (**Table 2**, **Figure 1**). Eight occurrences have been reported from Idaho, four prior to 1950, one in 1974, and three in the 1990s.

An early *Pyrrocoma integrifolia* collection made in 1872 by Coulter was from the Snake River, purportedly from Washington (MT-1 in **Table 1**; Harvard Herbaria Database 2005). Rather than being in Washington, the actual location is likely to be somewhere near the Yellowstone region of Idaho, Wyoming, or Montana, where Coulter was working as a botanist on the Hayden expedition (Hayden 1873). In addition, despite the labels on the herbarium specimens, Gray (1881) reported that specimens collected by Coulter and Burke were from Wyoming (see occurrences UK-1 and MT-1 in **Table 2**).

Non-technical description

Pyrrocoma integrifolia is a perennial herbaceous plant with a woody taproot. It has two to five ascending stems arising from a thick, branched caudex. The stems are 12.5 to 50.5 cm tall and tinged with a reddish color. The stems are mostly smooth and hairless, sometimes becoming slightly furry-hairy (tomentose) toward the top. The basal leaves are oblanceolate to spatula-shaped, 7 to 21 cm long, and 1.2 to 3.5 cm wide, usually smooth and hairless but sometimes slightly rough. Stem leaves are smaller, only 1.1 to 3 cm long and 0.3 to 0.15 cm wide, few in number, alternate and stalkless with a clasping base. Flower heads are solitary, or they may number up to four per stem. The flower head involucres are 1.1 to 1.7 cm high. The phyllaries have a pale hyaline border and a thick tough whitish base, and they are green (herbaceous) at the tip. The ray flowers are yellow and 10 to 20.5 mm long while the central, disk flowers are 6 to 10.2 mm long. The four-sided fruits are achenes. Each achene is oblong, narrowed at each end, and marked by fine longitudinal lines. The pappus is composed of approximately 35 to 45 rigid, unequal, tawny or brownish bristles that are 6 to 8.5 mm long (Mayes 1976, Dorn 2001, Fertig 2000b). **Figure 2** is an illustration of *P. integrifolia*, and **Figure 3** includes photographs of the flowering plant.

Mature flower heads are required for definitive identification of this species. *Pyrrocoma clementis* var. *clementis*, *P. clementis* var. *villosa*, *P. uniflora*, and *P. lanceolatus* are all morphologically similar to *P. integrifolia*. Therefore, a combination of characters must be used to distinguish among the taxa, because any single characteristic can be shared by two or more taxa (**Table 5**). *Pyrrocoma clementis* var. *clementis* has hairy achenes, and the involucral bracts are obovate in shape with an abruptly acute tip (Dorn 2001). *Pyrrocoma clementis* var. *villosa* has wholly green (herbaceous) phyllaries and smooth (hairless) achenes (Dorn 2001). *Pyrrocoma uniflora* has involucres only 5 to 10 mm long and disk corollas 5 to 7, rarely 7.5, mm long. *Pyrrocoma lanceolatus* has four or more flower heads per stem, and the involucral bracts are 5 to 10 mm long and green only at the tips (Hall 1928, Dorn 2001). Hall (1928) remarked that the bracts of *P. integrifolia* are broader than those of *P. clementis*. However, phyllary width varies within *P. integrifolia*. Among the specimens collected in Yellowstone National Park, the most recent collection (*Whipple #4541*; WY-2 in **Table 1**) has narrower phyllaries than the YELLO Acc. No. 3006 and YELLO Acc. No. 3007 specimens (WY-3 and WY-4 in **Table 1**). The latter specimens look very similar to each other and are likely to be from the same population (Whipple personal communication 2005).

Pyrrocoma species may be mistaken for species in other genera. Species such as *Agoseris* may be mistaken for vegetative *Pyrrocoma* species early in the growing season (Mancuso 1997). Rydberg (1900) described *Stenotus andersonii* from material collected by F.W. Anderson (*#3561*; type specimen) from the Belt Mountains in 1886 A flowering stem of *P. integrifolia* was mounted on the same specimen sheet (specimen sheet at New York Botanical Garden Herbarium (2005) Internet site: http://sciweb.nybg.org/science2/vii2.asp. It is not clear if the two taxa were actually distinguished at the time they were collected.

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

A detailed technical description and a line drawing of *Pyrrocoma integrifolia* (labeled *Haplopappus integrifolius*) are in Hall (1928). Other comprehensive technical descriptions are published in McDougall and Baggley (1936), Mayes (1976), Dorn (1984, as *H. integrifolius*), Dorn (1988), Dorn (2001), Hitchcock and Cronquist (2001), and Bogler (2006). Photographs and collection details of specimens collected in 1886 (MT-4 in **Table 2**) and 1895 (MT-25 in **Table 2**) are on the Internet site of the New York Botanical Garden Herbarium (2005).

Distribution and abundance

The abundance and distribution of *Pyrrocoma integrifolia* are not well defined. Available information indicates that it is a regional endemic in contiguous parts

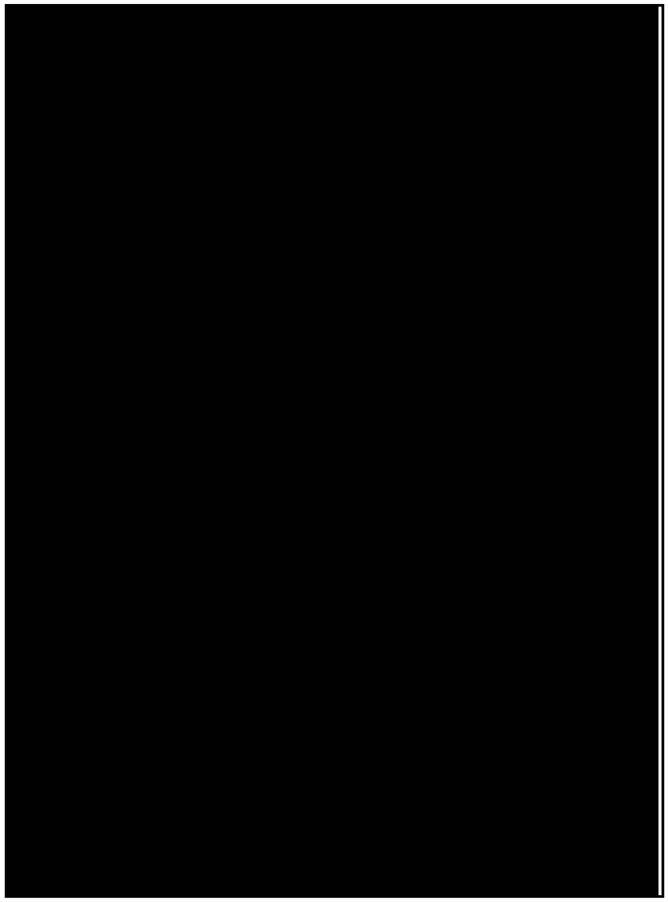


Figure 2. Illustration of *Pyrrocoma integrifolia* from Hall (1928). Used courtesy of the Carnegie Institution of Washington, D.C.

Figure 3. Figure 3. A close-up photograph of the head (left) and whole plants of *Pyrrocoma integrifolia* (right). The photographs are courtesy of James Reveal (©J.L. Reveal, used with permission of The Academy of Natural Sciences).

Table 5. Achene and floral characteristics that distinguish *Pyrrocoma integrifolia* from *P. clementis* var. *villosa*, *P. clementis* var. *clementis*, *P. uniflora*, and *P. lanceolata* (after Bogler 2006). See **Definitions** section for explanation of technical terms.

Species	Achene	Flowers per stem	Involucre	Phyllaries	Floret
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 to 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.
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 to 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 to 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 to 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 to 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.

of Montana, Idaho, and Wyoming (**Figure 1**). There are approximately 380 miles between the most northern and most southern occurrences and approximately 310 miles between the westernmost and easternmost occurrences (**Figure 1**). Approximately half of the occurrences range-wide are from an area of approximately 28,000 square miles (160 x 170 miles) within the Greater Yellowstone region (USDI Geological Survey 2000, Greater Yellowstone Coordinating Committee 2001). The 18 million-acre Greater Yellowstone Ecosystem is one of the largest relatively intact temperate zone ecosystems left on earth (Keiter and Boyce 1991).

Seven occurrences of *Pyrrocoma integrifolia* have been reported over the last century in Wyoming, from Fremont, Park, possibly Teton, and either Washakie or Big Horn counties (**Table 1**). Only one *P. integrifolia* occurrence has been found in Region 2, from the Shoshone National Forest. The status of the *P. integrifolia* occurrence on the Shoshone National Forest not only appears to be taxonomically uncertain (see Treatment of Uncertainty section), but its presence has not been confirmed since the original collection in 1961 (Houston personal communication 2005). One Wyoming occurrence is from the Bighorn Mountains, most likely on BLM land (WY-6 in **Table 1**). Five Wyoming occurrences are from Yellowstone National Park in Park County; only three of these have locations that can be mapped (inset in **Figure 1**). The *P. integrifolia* occurrence at Swan Lake was originally reported to be from Montana, but current state boundaries indicate that the collection was likely made in what is now Yellowstone National Park in Wyoming (WY-5 in **Table 1**). The Shoshone National Forest occurrence and the BLM occurrence are disjunct from the majority of occurrences, which are within, or north, or west, of Yellowstone National Park (**Figure 1**).

Pyrrocoma integrifolia occurs most frequently in Montana, where 77 occurrences have been reported. Of these 77 occurrences, 37 were reported before 1950, and nine of those before 1900 (**Table 2**). Occurrences have been documented from Beaverhead, Cascade, Deerlodge, Gallatin, Granite, Lewis and Clark, Madison, Missoula, Park, Pondera, Powell, Silver Bow, and possibly Jefferson counties in Montana (**Table 2**). *Pyrrocoma integrifolia* has been reported from the Gallatin and Beaverhead-Deerlodge national forests (Region 1). In 1886, a *P. integrifolia* occurrence (MT-4 in **Table 2**) was reported from the Belt Mountains. These may be the Little Belt Mountains, which would be at the eastern edge of the taxon's range, or the Big Belt Mountains, which is more central within its range. If *P. integrifolia* occurs in the Big Belt Mountains, it would likely be on land managed by the Helena National Forest, whereas if the taxon were in the Little Belt Mountains, it would be on the Lewis and Clark National Forest. The Helena and Lewis and Clark national forests are both in Region 1.

Pyrrocoma integrifolia appears to be less common in Idaho, where it has been reported only from Clark, Fremont, and Lemhi counties near the Montana border (**Table 2**, **Figure 1**). *Pyrrocoma integrifolia* occurs on the Salmon and Targhee national forests (Region 4) in Idaho.

The range of *Pyrrocoma integrifolia* has been reported to extend into Utah (Tidestrom 1925, Mayes 1976). However, Welsh et al. (2003) reports that specimens from Utah that were identified as *P. integrifolia* have since been found to more closely match the characteristics of *P. clementis*. *Pyrrocoma integrifolia* has also been ascribed to Colorado, but Hartman and Nelson (2001) stated that the reports were either unsubstantiated or the collections were misidentified. Two specimens of Utah material and three of Colorado material that retain the name *P. integrifolia* in herbarium records (CS, HSC, and RM) were located while collecting occurrence records for this report. They are listed in **Table 6** for reference purposes.

There is very little information on the abundance of *Pyrrocoma integrifolia* within occurrences. The taxon has been described as common (MT-14, MT 48), frequent or abundant (MT-28, MT-54) but of limited distribution (MT-17, MT-33), and scarce, rare, sparse, and scattered (MT-21, MT-33, MT-36, MT-37). Only one occurrence has quantitative data associated with it. As of 2004, there were at least 50 plants in an area of approximately 30 m by 10 m at the extant occurrence in Yellowstone National Park (MT-2 in **Table 2**; Whipple personal communication 2005). These observations suggest that the plants seldom grow in dense colonies, but under some circumstances, they may be quite frequent in localized areas. These data also imply that occurrences tend to be geographically isolated.

Population trend

No trends in *Pyrrocoma integrifolia* population size can be deduced from current information. It is apparently a rare taxon of limited range. Few quantitative data are available describing either its historic or current abundance. In **Figure 1**, the blue symbols represent occurrences reported prior to 1950, and the red symbols indicate those reported after 1950. No collections have been made from areas east of Helena, Montana

Table 6. Specimens mistakenly identified as *Pyrrocoma integrifolia* in Colorado (CO) and Utah (UT) (Hartman and Nelson 2001, Welsh et al. 2003).

State	County	Date Observed	Location	Source of Information[1]	Habitat and Comments
CO	Weld	Not given	Central Plains Experimental Range, Pawnee National Grassland	*W.M. Klein #3261* CS	Edge of disturbance
CO	Archuleta	11-Sep-51	On private ranch near Pagosa Springs	*E Adams #s.n.* CS	In barley field
CO	Archuleta	08-Jun-58	1 miles north of Pagosa Springs	*V. Cornforth #s.n.* CS	Open slope, 2164 ft.
UT	Beaver	25-Jul-64	Big Flat, ~5 miles south of Puffer Lake, Fishlake National Forest	*S.L. Welsh and G. Moore #3321* HSC	Open meadow with species of *Agropyron* and *Poa*. Elevation ~10,000 ft.
UT	Sanpete	28-Aug-25	Cove Paddock No. 3, Manti National Forest, Great Basin Experimental Station	*C.L. Forsling and E.W. Nelson #574* RM	Elevation 10,000 ft.

[1]Herbarium abbreviation:

CS: Herbarium, Biology Department at Colorado State University.

HSC: Vascular Plant Herbarium, Humboldt State University.

RM: Rocky Mountain Herbarium, University of Wyoming.

since 1950 (**Figure 1**). The absence of *P. integrifolia* reports within the last 56 years suggests that its range in Montana may have contracted. However, rates of plant collecting in general have decreased within the last two decades (1980s and 1990s) in the United States (Prather et al. 2004a, 2004b), and it is possible that the absence of recent *P. integrifolia* collections from east of Helena may reflect this general trend. The decline in general collecting activity in the 1980s and 1990s does not, however, explain the complete absence of *P. integrifolia* collections from 1950 through the 1970s. Collecting activity at most herbaria peaked in the 1930s and again in the 1960s (Prather et al. 2004a). In addition, the decline in collections across all herbaria studied was less severe for Rocky Mountain region herbaria (Prather et al. 2004a). More field studies are needed to determine how many *P. integrifolia* occurrences remain extant throughout its historic range.

Habitat

Pyrrocoma integrifolia was originally described as occurring in the "high cold mountain meadows of Wyoming and Montana" (Greene 1894b). The taxon is reported to grow between approximately 3,800 and 7,500 ft. (1,200 and 2,300 m) elevation in alkaline meadows, forest openings, open slopes, hillsides, and sagebrush grasslands (**Table 1**, **Table 2**; Fertig 1999). *Pyrrocoma integrifolia* grows in association with a wide range of vascular plant species (**Table 7**). Most of the species in **Table 7** were obtained from herbarium specimen labels. The exceptions to this are *Sarcobatus vermiculatus*, *Sporobolus airoides*, *Helianthus uniflorus*, *Iva axillaris*, *Agropyron spicatum*, *Pinus contorta*, and *P. ponderosa*, which Mayes (1976) reported to be associates of *Pyrrocoma integrifolia*.

Pyrrocoma integrifolia tends to be found in mesic environments, but it can grow in a variety of soil types, moisture levels, and communities (**Table 1**, **Table 2**, **Figure 4**). The available information does not support the idea that *P. integrifolia* is an obligate wetland species, and its position in riparian communities has not been described. Descriptions of occurrence soils range from dry (e.g., MT-49 in **Table 2**) to moist (e.g., WY-2 in **Table 1**) and have various drainage properties (**Figure 4**). Soils have been described as clay, implying that they have naturally poor drainage characteristics, or gravelly loam, suggesting a naturally very rapidly draining substrate. Water table depth also influences soil moisture, and a shallow water table will maintain moist conditions in a permeable soil (Dwire et al. 2006). Soil and habitat descriptions on specimen labels were used to estimate the wetness of the sites occupied by *P. integrifolia* (**Figure 4**). In some cases, the conditions were clear because the sites had been described as "dry," "moist," or as "a wet sedge meadow," which is obviously moist. In other cases, conditions were more difficult to assess, and the tolerance to dry and well-drained soils implied by the results in **Figure 4** may have been overestimated. For example "well-drained" was the estimated condition of a community described as "Mostly forbs and grasses, a few scattered *Pinus flexilis*." *Pinus flexilis* prefers

Table 7. Vascular plant species occurring with *Pyrrocoma integrifolia*.

State	Life form/Taxon	State	Life form/Taxon
	Tree		Shrub or forb
MT	*Juniperus scopulorum*	MT	*Artemisia* sp.
ID	*Pinus flexilis*		
UR[1]	*Pinus contorta*		Shrub
UR[1]	*Pinus ponderosa*	MT	*Artemisia cana*
		MT	*Artemisia tridentata*
	Forb	WY	*Artemisia tripartita* (reported as three tip sage)
MT	*Achillea* sp.	ID, MT	*Pentaphylloides floribunda*
WY	*Antennaria* sp.	UR[1]	*Iva axillaris*
MT	*Antennaria microphylla*	UR[1]	*Sarcobatus vermiculatus*
MT	*Aster occidentalis*		
WY	*Astragalus agrestis*		Grass
WY	*Astragalus canadensis*	MT	*Agropyron* sp. (reported as wheat grass)
MT	*Astragalus leptaleus*[2]	UR[1]	*Agropyron spicatum*
MT	*Berteroa incana* (alien mustard)	MT	*Danthonia parryi*
MT	*Castilleja* sp.	ID	*Dactylis glomerata*
ID	*Castilleja miniata*	MT	*Deschampsia caespitosa*
MT	*Cirsium* sp.	MT	*Distichlis stricta*
MT	*Erigeron* sp.	MT	*Elymus cinereus*
MT	*Erigeron gracilis*	MT	*Festuca* sp.
MT	*Erigeron lonchophyllus*	MT	*Festuca arundinacea*
UR[1]	*Erigeron peregrinus*	MT	*Festuca idahoensis*
MT	*Gaillardia* sp.	MT	*Festuca scabrella*
MT	*Galium* sp.	ID	*Festuca* sp. (reported as roll-leaf festuca)
MT	*Gayophytum diffusum*	MT	*Hordeum jubatum*
MT	*Gentiana affinis*	ID, MT	*Koeleria* sp.
ID	*Geranium viscosissimum*	MT	*Koeleria cristata*
MT	*Glaux maritima*	MT	*Muhlenbergia* sp.
MT	*Grindelia squarrosa*	ID, WY	*Phleum pratense*
MT	*Hedysarum boreale*	MT	*Poa pratensis*
UR[1]	*Helianthus uniflorus*	WY	*Poa* spp.
MT	*Iris missouriensis*	UR[1]	*Sporobolus airoides*
MT	*Lupinus* sp. (also reported as Lupine)	MT	*Stipa comata*
ID	*Potentilla* sp.	MT	*Stipa richardsonii*
MT	*Potentilla gracilis*		
MT	*Senecio pseudaureus*		Grass-like
MT	*Sieversia* sp.	MT	*Carex* spp.
MT	*Sphaeralcea* sp.	MT	*Carex nebrascensis*
MT	*Tragopogon dubius*	MT	*Carex praegracilis*
MT	*Tragopogon pratensis*	MT	*Juncus balticus*
MT	*Triglochin* sp.	MT	*Scirpus nevadensis*
MT	*Triglochin maritimum*	MT	*Spartina gracilis*

[1]UR State was not reported.

[2]Designated a sensitive species by USDA Forest Service Region 2.

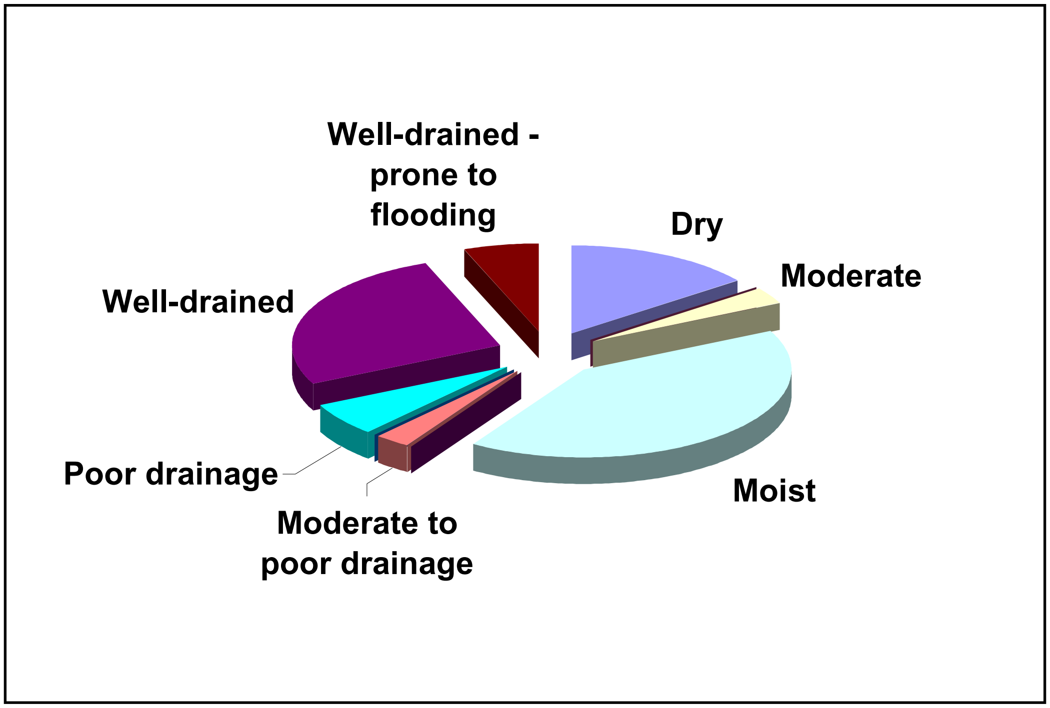


Figure 4. Soil conditions in *Pyrrocoma integrifolia* habitat. The divisions in the pie chart indicate the proportion of the occurrences (40 total) for which a particular type of soil condition was reported.

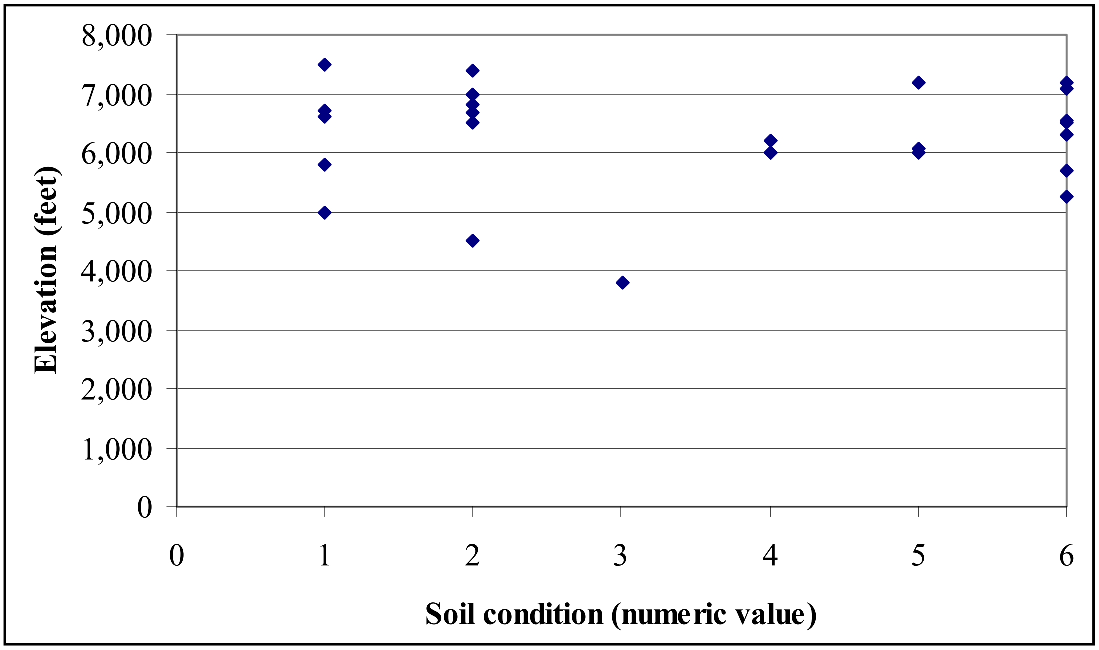
moist, well-drained soil, but it will grow in a wide range of soil types, including very moist conditions (Den Ouden and Boom 1965, Little 1980, Fralish and Franklin 2002). Water table dynamics may be an important aspect of *Pyrrocoma integrifolia* habitat. Water table depth may exhibit seasonal variation, influencing soil moisture accordingly. There is the possibility that *P. integrifolia* requires a habitat that provides wet conditions only during certain stages of its life history or growing season.

The brief habitat descriptions available suggest that *Pyrrocoma integrifolia* may favor fine-textured soils. A common associate, *Artemisia tridentata*, tends to be more common on fine-textured soils; meadow habitat also often develops on fine-textured soils (Knight 1994). Alluvial soils often underlie river terraces where *P. integrifolia* has been found. The degree to which *P. integrifolia* can tolerate saline soils has not been studied. Four species, *Sporobolus airoides*, *Sarcobatus vermiculatus*, *Distichlis stricta*, and *Iva axillaris*, reported to be associates by Mayes (1976), are all species that grow in saline as well as alkaline soil. There is no obvious relationship been the soil conditions and the elevation at which *P. integrifolia* grows (**Figure 5**). One interpretation of the variation in habitat conditions is that distinct ecotypes might occur in different regions.

Reproductive biology and autecology

Pyrrocoma integrifolia is a perennial species with a persistent basal rosette (Nesom 2000). The branching caudex permits restricted lateral spread, but the taxon is unlikely to be able to propagate vegetatively. *Pyrrocoma integrifolia* probably relies on reproduction by seed for long-term persistence. Herbarium specimens indicate that the flowering period is from June into September; seed dispersal is likely to last through October.

Pyrrocoma integrifolia has a chromosome number of n = 6 (Mayes 1976). No specific studies have been made of *P. integrifolia*'s reproductive biology. Flowers of *Pyrrocoma* species are hermaphroditic, having both male and female organs. *Pyrrocoma* species can be self- and cross-pollinated, but maximum levels of seed set in *P. radiata* required cross-pollination (Kaye et al. 1990, Kaye and Meinke 1992, Mancuso and Moseley 1993). A degree of within-flower self-pollination (autogamy) is likely to be advantageous since it can provide reproductive assurance in small, scattered populations (Eckert 2000). On the other hand, self-pollination forced by factors such as a sudden and/or sizeable reduction in population size or by pollinator limitations in a primarily out-breeding species can lead to inbreeding depression, and reproductive assurance would be of only limited use for long-term sustainability (Soulé 1987).



Numeric Value	Soil Condition
1	Dry
2	Well-drained
3	Well-drained - prone to flooding?
4	Moderate
5	Poor-drainage
6	Moist

Figure 5. Graph showing an absence of a relationship between soil moisture conditions and the elevation at which *Pyrrocoma integrifolia* occurs. The fitted line is essentially flat with respect to soil condition (correlation coefficient = -0.0073).

Extensive data have been collected that relate pollinator species to flower shape within the Asteraceae (Leppik 1977). *Pyrrocoma integrifolia* flowers are actinomorphic (radially symmetrical), and are therefore likely to be pollinated by a wide variety of arthropods. These include members of the Hymenoptera (e.g. bumblebees and solitary bees), Diptera, Lepidoptera (specifically butterflies), and to a lesser extent Coleoptera (Leppik 1977). Of these, bees are likely the primary pollinator species (Leppik 1977). The pollen exine of members of the *Haplopappus* group has an elaborate architecture of pyramidal-shaped spines, which facilitate transport on the body of 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 pollen grains 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).

In Wyoming, *Pyrrocoma integrifolia* appears to intergrade with *P. clementis* and *P. uniflora*, producing hybrids that differ primarily in involucre size and color (Fertig 1999). Information on other species within the subtribe *Machaerantherinae* supports the potential for interspecific and intraspecific hybridization (Kuntze 1891, Jackson 1985, Hauber 1986). Hybridization has been critical in the development of many present day taxa, and one can speculate that a certain level of hybridization may be part of normal species development and may be advantageous in a dynamically changing environment (Harlan 1983).

There are no details on the quantity or viability of seed produced by *Pyrrocoma integrifolia*. 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 amount of winter precipitation was positively correlated with the number of seed heads produced (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 as low as 7 °C (44.6 °F; Kaye 2002). If kept moist, some seeds continued to germinate through fall, winter, and spring (Kaye 2002). However, most germination in the field appeared to occur in the spring (Mancuso and Moseley 1993), and the researchers theorized that this was due to dry fall conditions coupled with freezing temperatures. There may be variations between populations of the same *Pyrrocoma* species, depending upon the elevations at which they occur. Within other genera, 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. integrifolia* have not been studied.

Pyrrocoma integrifolia seed dispersal mechanisms are not documented. Water may disperse seeds, especially during periods of intense downpours resulting in surface sheet flow. The bristles at the top of the *P. integrifolia* seed suggest that wind, perhaps in the form of localized dust devils, may also assist in dispersal. Wind-dispersed seeds often move only short distances (Silvertown 1987). A short dispersal range is consistent with the observation that plant occurrences are localized within relatively small areas (see Distribution and abundance section). Seed caching and transport by rodents, ants, and other animals can also contribute to dispersal, but these activities have not been reported for this taxon.

Pyrrocoma integrifolia has a short stature and little lateral spread. The species also does not appear to be highly prolific since it is seldom highly abundant and its occurrences are isolated. Grime et al. (1988) characterized species having a similar life form and regenerative strategy as stress tolerant species. *Pyrrocoma integrifolia* may also be characterized as a K-selected species, defined as those species that have a long life span in relatively stable habitats (MacArthur and Wilson 1967).

Demography

There have been no demographic studies of *Pyrrocoma integrifolia*. Because the species is perennial, plants are expected to be iteroparous, reproducing for a number of years before they die. The longevity of a single individual is unknown.

There is no information on the population structure of *Pyrrocoma integrifolia*. Kaye (2002) analyzed information collected for more than 16,000 *P. radiata* individuals over an 11-year period. The results indicated that mortality was highest for seedlings, followed by juvenile, vegetative, and reproductive plants (Kaye 2002). A plant's chances of survival improved as it increased in size, and perhaps age (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). These results suggested that the survival of adult plants, rather than seedling recruitment, is likely to be a critical stage in the life history of *P. radiata*. 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 effects of livestock grazing (Kaye 2002).

Figure 6 is a simple life cycle diagram for *Pyrrocoma integrifolia*. It is based on Kaye's (2002) demographic studies of *P. radiata* conducted in Idaho and Oregon. *Pyrrocoma integrifolia* shares several attributes with *P. radiata*. They both have a perennial growth habit and do not spread by vegetative reproduction. Both are rare species that occur in rangeland. *Pyrrocoma radiata* is endemic to a region straddling eastern Oregon and western Idaho, whereas *P. integrifolia* is a regional endemic of southwestern Montana and adjacent parts of Idaho and Wyoming. A notable difference is that although both grow in shrub-grassland communities, *P. radiata* grows at lower elevations (650 to 1,500 m [2,100 to 4,900 ft.]) in hotter, drier conditions than *P. integrifolia*. The impact of these differences on the life history is unknown but might be sufficient to invalidate any inferences. On the other hand, in the absence of specific studies of *P. integrifolia*, the conclusions derived from the studies of *P. radiata* are useful to consider, especially in designing future studies for *P. integrifolia*.

Community ecology

There have been no studies of the plant associations containing *Pyrrocoma integrifolia*. *Pyrrocoma integrifolia* can be a member of meadow, grassland, sagebrush-grassland, and openings in forested communities (**Table 1**, **Table 2**). *Festuca idahoensis* and *Poa* species are common in such communities (Knight 1994). There is no information on microbiotic or mycorrhizal associations with *P.*

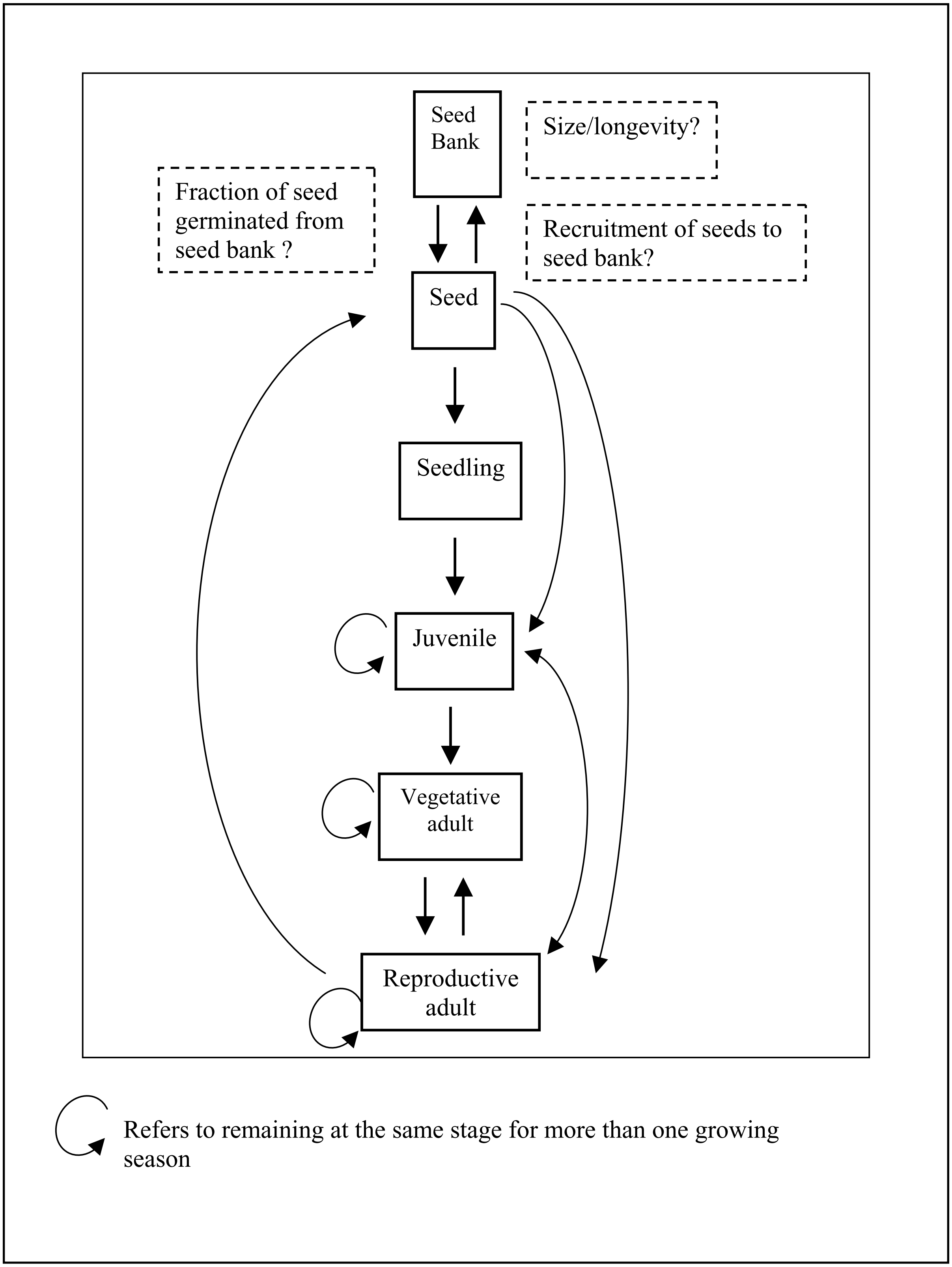


Figure 6. Life cycle diagram for *Pyrrocoma integrifolia* (after Kaye 2002).

integrifolia, and therefore it is unknown if they play a significant role in its ecology. Mycorrhizal associations are important to other members of *P. integrifolia*'s community. Vesicular-arbuscular mycorrhizal (VAM) fungi are commonly associated with members of the Asteraceae and are important to the establishment and maintenance of *Artemisia tridentata* ssp. *wyomingensis* (Bethlenfalvay and Dakessia 1984, Stahl et al. 1998). Mycorrhizal fungi are also well-established symbionts of *F. idahoensis* (Molina et al. 1978, Goodwin 1992). Therefore, *P. integrifolia* will be exposed to mycorrhizal soils and is likely to have an active association with these fungi.

Fire is likely to have had a historic role in maintaining the meadow and sagebrush-grassland habitat of *Pyrrocoma integrifolia* (Arno and Gruell 1983, Knight 1994). It is unknown how *P. integrifolia* responds to fire. 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 recolonization of sites is also not known. The degree to which *P. integrifolia* plants historically experienced fire is not known, but it likely was related to associated vegetation and soil moisture within the occurrence. Moist meadows at higher elevations and riparian zones may have experienced fire infrequently, but occurrences in drier or lower elevation sites are likely to have been exposed to fire more often. Prior to significant European settlement in North America, fire return intervals in alpine meadows were on the order of 300 years, whereas the interval for *Festuca idahoensis/ Danthonia* spp. communities ranged between 15 and 30 years, and for sagebrush steppe between 10 and 40 years (Leenhouts 1998). Prior to 1910, mean fire intervals at *Pseudotsuga* forest-grassland ecotones in high elevation (1,680 to 2,130 m [5,500 to 7,000 ft.]) valleys in southwestern Montana were 35 to 40 years, and they were probably shorter in grasslands (Arno and Gruell 1983).

Asteraceae species that occupy fire-prone communities are often adapted to fire (Martin 1984, Bond and Van Wilgen 1996). However, a taxon's response to fire does not necessarily match what is expected given a certain habitat type. Like *Pyrrocoma integrifolia*, *Hazardia squarrosa* is also in the subtribe *Machaerantherinae* and was once placed in the expansive concept of the genus *Haplopappus* (Nesom 2000). *Hazardia squarrosa* is a shrub of fire-prone habitats in coastal sage scrub, chaparral, and foothill woodland and occurs at relatively low elevations in California. Unlike most matorral plant species, the presence of charred wood or its aqueous extracts actually decreases seed germination of *H. squarrosa* (Baskin and Baskin 2001).

The palatability of *Pyrrocoma integrifolia* to mammalian herbivores has not been specifically documented. 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, Hegnauer 1977, USDA Forest Service 1988a). Based on at least one report (MT-18 in **Table 2**), *P. integrifolia* appears likely to be palatable to livestock. Animals find a plant species palatable through a combination of its morphological, structural, and chemical characteristics (Dayton 1931, Lusk et al. 1961, Hanks et al. 1975, Moghaddam 1977, Nemati 1977, Sheehy and Winward 1981). Some of these characteristics can change during a plant's life cycle; a plant species may be palatable early in the season when the herbage is tender and/or has low concentrations of certain chemicals but become less palatable later in the growing season (Williams and James 1978, Berg et al. 1997). This characteristic would promote some measure of reproductive success by protecting the plants from herbivory during flowering and seed development.

Further research is necessary to determine the effects of mammalian herbivory on *Pyrrocoma integrifolia*. Cattle grazing on *P. radiata* was shown to have a significant negative effect on flower head production (Kaye 2002). If *P. integrifolia* is palatable to livestock, it is unlikely to be toxic to wild animals (e.g., deer and lagomorphs) that may also consume it.

Arthropods also consume *Pyrrocoma* species, and the consequences of their herbivory can result in lower rates of reproduction or damage to vegetative tissue (Mancuso and Moseley 1991, Mancuso 1997, Kaye 2002). Some butterflies (e.g., checkerspots (*Chlosyne* spp.[3]) use members of the Asteraceae as larval host plants (Scott 1997). The pearly or sagebrush checkerspots (subspecies of *Chlosyne gabbii acastus*[4]) may use *P. integrifolia* since they favor a relatively broad range of Asteraceae as host plants, including species of *Haplopappus* and *Machaeranthera* (Scott

[3]Some regard this group as *Chlosyne* while others as *Charidryas* (Scott 1997, Savela 2005, Opler et al. 2006).

[4]There is some disagreement regarding the specific name and grouping: *gabbii acastus* vs. *acastus* vs. *acastus acastus* (Scott 1997, Savela 2005, Opler et al. 2006)

1997). Grasshoppers are also likely to consume *P. integrifolia*. Mean seed production of *P. radiata* was negatively correlated to the intensity of tissue damage by grasshoppers (Kaye 2002). Seed predation by other insects is also likely. Weevils, gelechiid moths, and the larvae of cecidomyiid midges were the primary insects that damaged seeds in the flower heads of *P. radiata* (Kaye 2002). Depending upon the year, insect larvae in *P. radiata* flower heads damaged or consumed a substantial proportion of ovules, and average seed predation varied from a low of 15 percent to a high of 67 percent (Kaye 2002). Environmental factors influenced the degree to which insect larvae impacted *P. radiata* seed. Annual variation in insect predation was correlated with winter precipitation, with more seed damage occurring after dry winters (Kaye 2002). Insects also cause significant damage to developing flowers and seeds of the related species *H. venetus* and *Hazardia squarrosa*, limiting population recruitment in both species (Louda 1982, Louda 1983).

There is a wide range of secondary plant products among members of the Astereae and even within a single genus (Hegnauer 1977). There is only a limited knowledge of the secondary compounds produced by *Pyrrocoma integrifolia* (Mayes 1976). The chemistry of *P. integrifolia* has been studied primarily for taxonomic purposes and not to address palatability (Mayes 1976). Flavones constitute the major flavonoid components in *Pyrrocoma* (Mayes 1976). The flavones that have been extracted from *P. integrifolia* include chrysoeriol 7-O-glycoside, luteolin 7-O-glycoside, chrysoeriol 7-O-diglycoside, apigen 7-O-glycoside, luteolin, and two of an unresolved structure (Mayes 1976). The biological and ecological significance of these compounds to *P. integrifolia* have not been researched. Flavones have been primarily researched for their involvement in defensive responses to microbial infections and in the recognition signals between root microbes and vascular plants (Brignolas et al. 1995, Padmavati and Reddy Arjula 1998, Cowan 1999, Hammerschmidt 1999, Ndakidemi and Dakora 2003).

Pyrrocoma integrifolia flowers may be self- and/or cross-pollinated (see Reproductive biology and autecology section). Flower color, size, shape, and odor influence the types of pollinator species (Bond 1985). *Pyrrocoma integrifolia* is likely to be cross-pollinated by a wide assemblage of arthropods that include bumblebees, solitary bees, flies, and butterflies, as is *P. radiata*, which has a similar flower (Kaye 2002).

An envirogram is a graphic representation of the components that influence the condition of a species and reflects its chance of reproduction and survival. Envirograms have been used to describe the conditions of animals (Andrewartha and Birch 1984) but may also be applied to describe the condition of plant species. Those components that directly affect *Pyrrocoma integrifolia* make up the centrum, and the indirectly acting components comprise the web (**Figure 7**, **Figure 8**). Information to make a comprehensive envirogram for *P. integrifolia* is unavailable. The envirogram in **Figure 7** is constructed to outline some of the resources that are known or are likely to affect the species directly. The dashed-line boxes indicate that the resources are speculative. In summary, resources include soil properties, pollinators, and agents of seed dispersal (i.e., water, rodents, arthropods, wind). Of all the components of climate, precipitation appears most likely to influence the reproductive success of *P. integrifolia*. Precipitation is also likely to influence the abundance of potential pollinators and may affect the intensity of insect predation. Fire has not been included as a resource because although it may be necessary to maintain habitat, its direct effects on *P. integrifolia* are unknown.

Conservation

Threats

Potential threats to *Pyrrocoma integrifolia* viability include habitat degradation, fragmentation, and loss. Human recreational activities, livestock grazing, resource extraction, and invasive non-native plant species contribute to habitat modification (Hendee and Dawson 2001). Activities associated with human recreation, livestock grazing, and resource extraction may also directly disturb plants and the seed bank of *P. integrifolia*. The single occurrence in Region 2 is exposed to human recreation and livestock grazing, but threats from resource extraction appear to be low at the current time. Livestock grazing has the potential to impact *P. integrifolia* occurrences by contributing to herbivore pressure. Other herbivores that are potentially deleterious to *P. integrifolia* occurrences include arthropods and wild mammals (see Community ecology section). Fires hot enough to kill the taproot and the buried seeds of *P. integrifolia* may be a threat. On the other hand, complete fire suppression may lead to a loss of meadow and shrub-grasslands and contribute to habitat loss. Declines in abundance or changes in assemblage of pollinator species are potential threats if *P. integrifolia* requires cross-pollination for the long-term viability of the species.

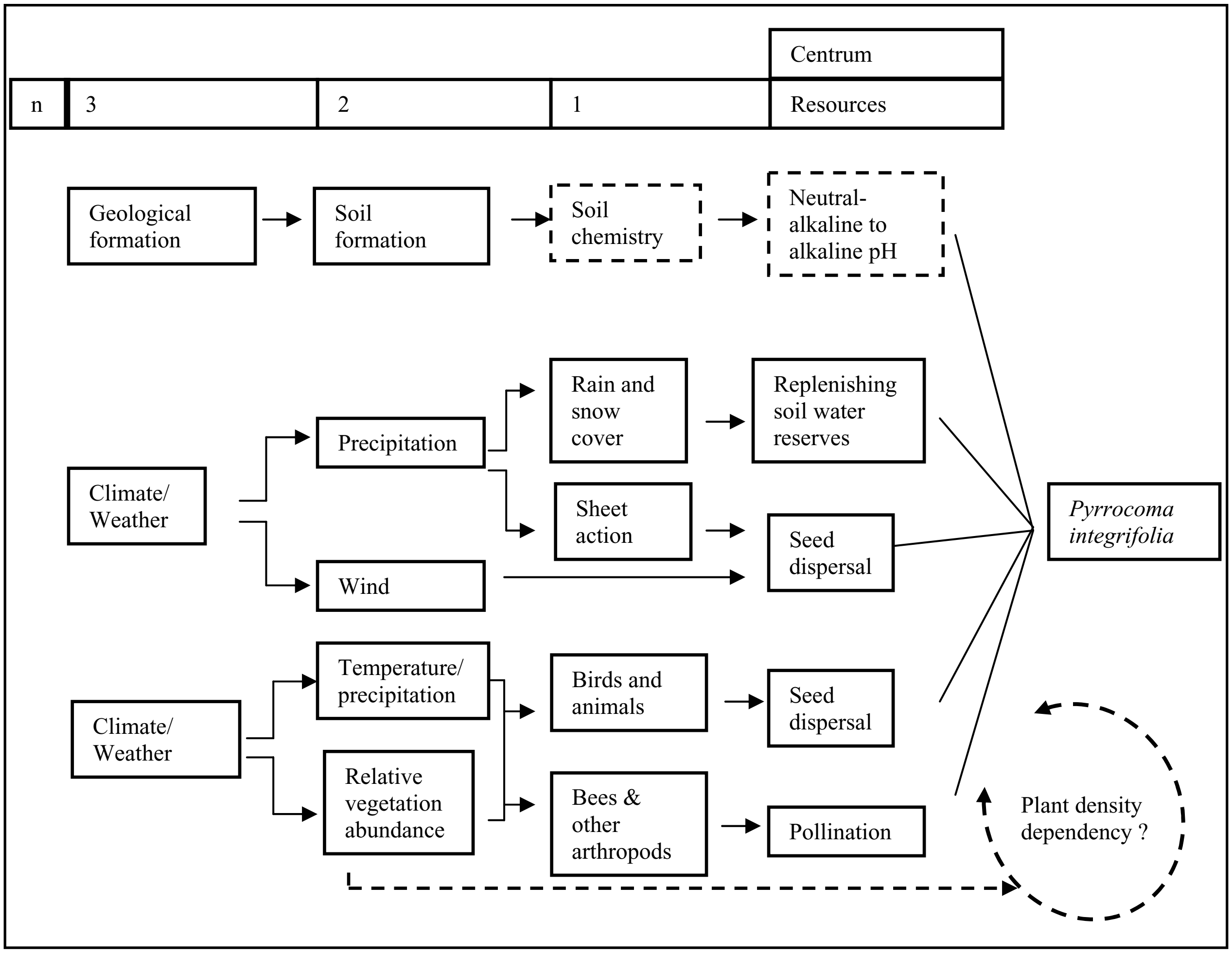


Figure 7. Envirogram outlining the resources of *Pyrrocoma integrifolia*. Factors in dashed boxes need to be confirmed, and dashed lines indicate that the link is speculative.

Demographic, genetic, and environmental stochasticities, along with natural catastrophes, present potential threats to all species with a limited number of occurrences (Shaffer 1981), but the small and disjunct *Pyrrocoma integrifolia* occurrence in Region 2 (WY-7 in **Table 1**) may be particularly vulnerable. The vulnerability to stochasticity is typically assessed in population viability analysis and can be mitigated by maintaining or increasing both the number and size of populations within the taxon's historic range. Information on *P. integrifolia* occurrences is incomplete, and there might be threats in addition to the ones that have been identified. Imminent threats to particular occurrences are also difficult to evaluate because of the lack of precise occurrence location and current occurrence status information.

The Shoshone National Forest Management Plan is in the process of being revised (USDA Forest Service 2005b). Therefore, it is possible that the management of the area in which *Pyrrocoma integrifolia* occurs on the Shoshone National Forest will change in the near future. Changes in management can result in changes to the type or level of threats to *P. integrifolia*.

Recreation

Human recreational activities, including camping, off-road vehicle travel, horseback riding, hiking, river rafting, skiing, and snowmobiling are popular throughout the range of *Pyrrocoma integrifolia*. All of these activities can modify habitat conditions and directly disturb plants. Many recreational activities require roads and trails, if only just to provide the means of getting people to a trailhead. Roads and trails can alter the hydrology of an area by generating overland flow from relatively impermeable running surfaces and cutslopes (Furniss et al. 2000, Board on Environmental Studies and Toxicology 2005). Such hydrologic changes may affect *P. integrifolia* habitat,

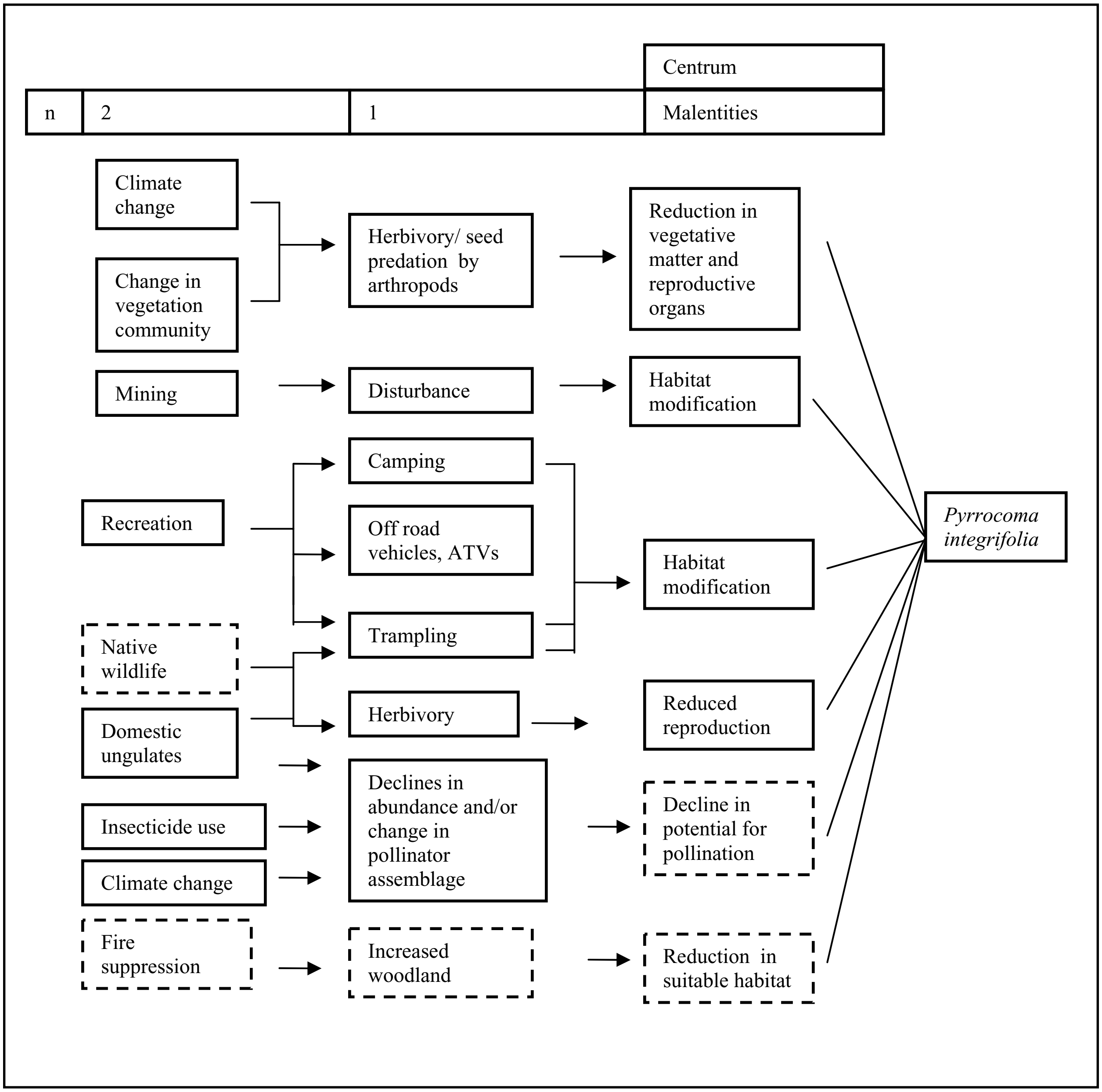


Figure 8. Envirogram outlining the threats and malentities of *Pyrrocoma integrifolia*. Dashed boxes indicate those factors that need to be confirmed.

which is often in mesic meadowland and susceptible to changes in surface and subsurface water flows.

All forms of off-road motorized vehicles (e.g., all-terrain vehicles (ATVs), dirt bikes, off-road vehicles (ORVs), snowmobiles) can severely disturb vegetation, cause accelerated soil erosion, damage the seed bank, 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). In Yellowstone National Park and on the Shoshone National Forest, direct disturbance from ATVs, ORVs, and dirt bikes is likely to result principally from illegal travel away from managed trails. Motorized vehicles are only permitted on mapped trails in the Shoshone National Forest (USDA Forest Service 1988b), and they are restricted in Yellowstone National Park.

The potential for snow compaction due to recreational activities, especially from snowmobiling, is a cause for concern throughout the range of *Pyrrocoma integrifolia*. The area in which *P. integrifolia* occurs on the Shoshone National Forest is open to snowmobiles

(USDA Forest Service 1988b). Snow compaction can cause considerable below-surface vegetation damage (Neumann and Merriam 1972). Substantial reductions in soil temperatures, which retard soil microbial activity and seed germination, may also result from snow compaction (Keddy et al. 1979, Aasheim 1980).

Livestock grazing

Livestock grazing has the potential to alter habitat conditions for *Pyrrocoma integrifolia* and to impact plant reproduction and growth directly through herbivory and trampling. Vascular plant abundance and community composition reflect a complex combination of edaphic conditions, including soil structure, nutrient balance, and microbial community. These conditions change because of livestock trampling and altered levels of nutrient inputs, and they may not be able to revert to the pre-disturbance state (Webb and Stielstra 1979, Webb et al. 1983, Bethlenfalvay and Dakessian 1984). Livestock grazing may also have a detrimental effect on *P. integrifolia* habitat by modifying the hydrological regime (Murray 1997). Trails created by livestock movement patterns can alter surface water flows and change the hydrology of an area (Fredrickson 2004). Inappropriate levels of livestock grazing can lead to soil compaction and changes in vegetation composition and structure that alter hydrological processes and ultimately lead to drier conditions (Rauzi and Hanson 1966, Smeins 1975, Bohn and Buckhouse 1985b, Vallentine 1990, Nicholoff 2003). The effects of hydrological and edaphic changes on the distribution and abundance of *P. integrifolia* have not been studied.

Livestock can change the assemblage of plant species in the community by preferentially consuming some species while avoiding others (Strasia et al. 1970). Some forb species increase at the expense of some grass species due to livestock grazing pressure (USDA Forest Service 1988a). While preferential consumption of some grass species may release competition and encourage proliferation of some forb species, predicting the response of forb species to grazing does not appear to be solely related to their palatability. Even though *Pyrrocoma carthamoides* var. *subsquarrosa* is unpalatable to livestock, impacts from grazing were evident in a study that compared vegetation in grazed and ungrazed plots (Lesica 1995). *Pyrrocoma carthamoides* var. *subsquarrosa* plants were more robust and had more flowering stalks in the ungrazed plots compared to the grazed plots (Lesica 1995). Livestock grazing also influenced the growth and distribution of *P. liatriformis* (Mancuso 1997). The most vigorous populations of *P. liatriformis* occurred within grasslands and grassland-forest transition zone plant communities that are in good condition (Mancuso 1997). The palatability of *P. liatriformis* was not reported. Degradation and loss of high quality habitat due to livestock grazing and other agents of disturbance were recognized as the primary threat to the long-term conservation of *P. liatriformis* throughout its range (Mancuso 1997).

There is no documentation specifically regarding how *Pyrrocoma integrifolia* responds to cattle grazing. Grazing has been shown to affect the reproduction of *P. radiata* (see Community ecology section) and *P. lucida* (Urie and van Zuuk 2000). Kaye (2002) tested for the effects of cattle grazing on *P. radiata* over a ten-year period using three different metrics: plant size over time, population viability, and annual population growth rate. Kaye (2002) employed grazing exclosures to examine these effects. 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 statistically significant after several years of protection (Kaye 2002). After five years of protection, *P. radiata* leaves were significantly longer inside exclosures compared to those outside, and plants within exclosures were taller after seven years (Kaye 2002). Flower head production was also significantly higher inside exclosures than outside after seven years (Kaye 2002). No effects of excluding cattle on population growth rate were detected 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 nine years after fencing. It is not unusual for vegetation to recover very slowly from grazing, 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. 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 might be partially offset in years when there is high fall precipitation (Kaye 2002).

Resource extraction

Mineral extraction does not appear to be an imminent threat to the Region 2 *Pyrrocoma integrifolia* occurrence (WY-7 in **Table 1**). Even so, substantial mineral extraction activities have happened in the past relatively near this occurrence. For example, the Columbia-Geneva Mines strip mine covers approximately 2 square miles approximately 8 miles south of the occurrence. Mining may have contributed to *P. integrifolia* habitat degradation or loss in this area.

Outside of Region 2, many of the *Pyrrocoma integrifolia* occurrences are in a region that is rich in geological resources. Since the mid-1800s, mining for gold, silver, and a variety of other minerals has been a principal source of income for people living within the range of *P. integrifolia*. Several occurrences are located at place names associated with mines (e.g., MT-15, MT-28, MT-49 in **Table 2**). Between 1902 and 1965, 57,261 tons of ore yielding gold, silver, copper, lead, and zinc, were extracted from the Vipond Park-Quartz Hill mining district (Geach 1972). This high productivity suggests that the original vegetation of many areas within the mining district has been substantially impacted and that habitat may have become fragmented.

Threats from resource extraction originate not only from direct disturbance caused by mine installations but also from infrastructure such as roads and power lines. Significant disturbance also arises from informal tracks made from individual vehicle turn-around sites and temporary equipment storage. Water quality in the Greater Yellowstone region has suffered a significant decline due to mining activities (Greater Yellowstone Coordinating Committee 2000). Although mining is still a commercial proposition in the greater Yellowstone region, many mines have now closed (Montana Department of Environmental Quality 2005). Disused mine-installations, mining wastes, and ghost towns remain, but some regions have undergone vegetation restoration (Montana Department of Environmental Quality 2005). Information to assess the current and potential threat of mineral extraction to specific *Pyrrocoma integrifolia* occurrences in these areas is unavailable. Future resource development will depend upon commercial markets.

Invasive plant species

Weeds, defined as non-native plant species, may pose a potential threat to *Pyrrocoma integrifolia* because the taxon does not appear to have the characteristics of a good competitor. That is, *P. integrifolia* is not rhizomatous, does not appear to spread over wide areas, and has a small stature. Some invasive weed species (e.g., *Centaurea* species) secrete allelopathic chemicals into the soil that can contribute to habitat loss (Callaway et al. 1999, Sheley and Petroff 1999, Ridenour and Callaway 2001). Many vectors, including recreationists, motorized off-road vehicles, and livestock, facilitate the spread of weed seeds into the backcountry (Sheley and Petroff 1999). Vulnerability of *P. integrifolia* habitat to invasion by non-native plant species may depend upon the diversity of the plant functional groups present (Pokorny et al. 2005).

Herbicides are generally applied to control the spread of weeds, but most herbicides used to control broadleaf (forb) species can directly affect *Pyrrocoma* species as well as the target plants (Kleijn and Snoeijing 1997, Boutin et al. 2004). Drift from herbicides used in highway right-of-way maintenance may threaten *P. integrifolia* occurrences near highways and roads (e.g., MT-35, MT-36, MT-40 to MT-47, ID-5 in **Table 2**). Biocontrol of non-native plant species may also negatively affect non-target species. Some biological-control herbivores may increase the competitive ability of noxious weeds, and this has the unintended consequence of reducing the relative vigor of non-target species (Callaway et al. 1999).

There is no information about the threat or potential threat from weed invasion to the *Pyrrocoma integrifolia* occurrence in Region 2. Only one *P. integrifolia* occurrence (MT-52 in **Table 2**) has been reported to have a potentially invasive non-native plant species. This is where hoary false madwort (*Berteroa incana*) was reported. Hoary false madwort is not yet listed as a noxious weed in the states of Montana, Wyoming, or Idaho, but it is considered a problem by Stubbendieck et al. (1995) and is listed as noxious in Michigan (Michigan Department of Agriculture 2001-2005). The species of *Cirsium* at MT- 64 (**Table 2**) was not reported. Many *Cirsium* species are native and non-aggressive plants. On the other hand, this report might indicate that there is a potential threat to this occurrence since several non-native *Cirsium* species are particularly invasive and noxious weeds (Sheley and Petroff 1999). Timothy (*Phleum pratense*) and orchardgrass or cocksfoot (*Dactylis glomerata)*, both introduced pasture grasses, were reported at ID-8 (**Table 2** and **Table 5**). The impacts of these species on *P. integrifolia* are not known, but they are good competitors and tend to exclude native vegetation (Esser 1993, Lamb et al. 2006). After one or two decades, orchardgrass is susceptible to eventual replacement by native species (Crane et al. 1983, Leege and Godbolt 1985), but the likelihood that a rare and infrequent species such as *Pyrrocoma integrifolia* can survive that long and become re-established cannot be estimated.

Fire and fire suppression

Prescribed burning may be a useful tool for maintaining suitable habitat for *Pyrrocoma integrifolia*. The direct effects of fire on the taxon are unknown (see Community ecology section). The intensity of the burn may be important to *P. integrifolia* survival and to its ability to re-sprout (Bond and van Wilgen 1996, Whelan 1997). High intensity burns that impact buried seed are particularly likely to be detrimental if seed in the seed bank is essential for recovery of the population after fire. The apparent isolation of known occurrences suggests that re-colonization from seed rain is unlikely. No insight can be gained from the extensive fires that the Yellowstone National Park area experienced in 1988 because the area of the extant Yellowstone *P. integrifolia* occurrence was not burned (Greater Yellowstone Post-Fire Resource Assessment Committee 1988, Whipple personal communication 2005).

The impacts of long-term fire suppression are also difficult to assess. The communities in which *Pyrrocoma integrifolia* grows are to varying extents maintained by periodic burns (Arno and Gruell 1983, Knight 1994, Whelan 1997). Fire suppression has led to a reduction in meadow and grassland area with concomitant increase in forested areas during the last 150 years (Dunwiddie 1977, Arno and Gruell 1983, Knight 1994; see Habitat and Community ecology sections).

Declines in abundance or change in assemblage of pollinator species

Pyrrocoma integrifolia may be vulnerable to declines or changes in species composition of pollinator populations. Pollinators are essential when a certain level of cross-pollination is important for maximum seed set and maintenance of genetic diversity (see Reproductive biology and autecology section). Habitat alteration and fragmentation, and the introduction of non-native plants and animals all contribute to reducing pollinator population sizes as well as causing the extirpation or extinction of individual pollinator species (Bond 1995, Kearns et al. 1998). Some bee taxa nest in abandoned rodent burrows, and grazing by livestock, notably sheep, endangers bee pollinators by destroying potential and existing nest sites and removing food resources (Sugden 1985). Pesticides used to control insect pests related to other management issues can negatively affect the pollinator assemblage and abundance (Kevan 1975, Johansen 1977, Tepedino 1979, Thomson and Plowright 1985). Even if pesticides are not used on National Forest System land, treatments on adjacent land may affect pollinators. Biological control agents are not expected to interfere with populations of non-target arthropods, but they should not be totally discounted as a potential threat to native pollinator species (McEvoy 1996).

Demographic stochasticity and genetic stochasticity

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 greater 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 where occurrences of *Pyrrocoma integrifolia* are small (Pollard 1966, Keiding 1975).

The likelihood that genetic stochasticity is a threat to the viability of *Pyrrocoma integrifolia* occurrences is unknown. Genetic stochasticities are associated with random changes in the genetic structure of populations, such as through inbreeding and founder effects. In some cases, particularly in self-pollinating species, inbreeding can purge deleterious genes (Byers and Waller 1999). 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). On the other hand, the fitness of species that suffer substantial declines in the number or size of populations is more often compromised by inbreeding depression (Soulé 1980). The few, small occurrences suggests that *P. integrifolia* is a naturally rare species that may not be vulnerable to inbreeding depression. The potential for inbreeding depression appears to be most likely if *P. integrifolia* is primarily an outcrossing species and if its occurrences experience (or have experienced) significant long-term declines in size and/or number due to habitat loss, direct destruction, or attrition due to poor reproductive output (Soulé 1987). Poor reproductive output may result from changes in available pollinators if *P. integrifolia* has a similar reproductive system to *P. radiata*, in which maximum reproductive potential requires cross-pollination (Kaye 2002).

Analyses of population viability have not been conducted for *Pyrrocoma integrifolia*, and a minimum viable population size cannot be estimated from available data. From a genetic perspective, natural populations often behave as if they were smaller than a direct count of individuals would suggest, and "effective population size" needs to be distinguished from the physical number of plants within a population (Barrett and Kohn 1991). Considering the long-term viability of a general population, Franklin (1980) and Lande and Barrowclough (1987) concluded that an effective population size of approximately 500 individuals was sufficient to maintain evolutionary potential in quantitative characters under a balance between mutation and random genetic drift. Lande (1995) went on to consider, and cited experiments that suggested, that the effective population size should be an order of magnitude higher, of approximately 5,000 individuals. It is likely that the minimum viable population size will vary significantly from 500 and may approach 5,000 according to the differences in inherent variability among species, demographic constraints, and the evolutionary history of a population's structure (Frankham 1999).

Hybridization between *Pyrrocoma integrifolia* and related species may have a number of deleterious consequences, including the genetic assimilation of a rare taxon by a more common and abundant one, loss of locally adapted populations, and outbreeding depression (Rieseberg 1991). The extent of the potential threat from a loss of genetic integrity by hybridization or introgression cannot be estimated without more information on the frequency of hybridization or on the pollination system of *P. integrifolia* (see Reproductive biology and autecology section). *Pyrrocoma lanceolata* and *P. uniflora* are found within the habitat of *P. integrifolia* at some locations throughout its range (Bogler 2006). In addition to these two taxa, *P. clementis* also grows with *P. integrifolia* in some parts of Region 2 (Fertig 1999, Bogler 2006). Even if in close proximity, hybridization may not occur between related species because several mechanisms exist to keep sympatric taxa genetically isolated from each other and from the resulting hybrids (Grant 1981). These mechanisms include pollinator specificity, differences in pollinator activity, differences in flowering time, and/or dominance of self-pollination (Grant 1981). Hauber (1986) remarked that the observed hybridization and introgression among subspecies of *Haplopappus spinulosus*[5] was mainly caused by man-made disturbances that allowed ecologically and geographically isolated taxa to come into contact. This observation might serve as a caution to using either *P. integrifolia* seed collected outside the local area or any related *Pyrrocoma* species in restoration seed mixes for areas where *P. integrifolia* might occur.

Natural catastrophe and environmental stochasticity

Natural catastrophes include events such as floods and landslides. There is little information on which to base estimates of the potential vulnerability of specific *Pyrrocoma integrifolia* occurrences to catastrophic events. The *P. integrifolia* occurrence in Region 2 does not appear to be located in an area that is susceptible to any particular natural catastrophe, except possibly catastrophic (high intensity) wildfire.

Environmental stochasticity refers to climatic events, such as periods of drought, and biological events, such as arthropod infestations. Global climate change may contribute to threats associated with environmental stochasticity. In the last 100 years, the average temperature in Helena, Montana, has increased 1.3 °F (0.73 °C), and precipitation has decreased by approximately 5 percent in southwestern parts and by approximately 20 percent in central regions of the state (U.S. Environmental Protection Agency 1997). A consequence of the warmer temperatures is evident in Glacier National Park, at the northern edge of *Pyrrocoma integrifolia*'s range. Glacier National Park had an estimated 150 glaciers in 1850 but only approximately 50 glaciers in 1997 (Key et al. 1998). The remaining glaciers are currently in recession, and it is estimated that if current warming trends continue, no glaciers will exist in the park by 2030 (Key et al. 1998).

Some climate change models, such as the United Kingdom Hadley Centre's climate model (HadCM2), have indicated that by 2100, temperatures in Montana could increase by approximately 4 °F (2.2 °C) in spring and summer and by approximately 5 °F (2.8 °C) in fall and winter (U.S. Environmental Protection Agency 1997). In contrast to current trends, the HadCM2 model also predicts that precipitation will actually increase by roughly 10 percent in all seasons except winter, when the range of estimated increase is from 15 to 40 percent (U.S. Environmental Protection Agency 1997). This precipitation is unlikely to be equally distributed through the year; the majority opinion is that weather will become more extreme. This means that the amount of precipitation on extreme wet or snowy days in winter and the frequency of extreme hot days in summer are likely to increase (Pew Center 2005, New Zealand Climate Change Office 2006, U.S. Global Change Research Program 2006). The uneven distribution

[5] Synonym of the current accepted name of *Machaeranthera pinnatifida*.

of precipitation and the higher temperatures that can lead to faster snowmelt suggest that there will be both periods of drought and an increase in the likelihood of flooding events. Other climate models may show different results. Four of the five most widely used General Circulation Models indicate that future climate in western Montana is likely to include higher average temperatures, increasing winter precipitation, declining summer precipitation, a decrease in soil moisture, and an increase in the frequency and severity of droughts (USDI Geological Survey Biological Resources Division 2004).

The potential direct impact of changing weather patterns on *Pyrrocoma integrifolia* is difficult to estimate. Global climate change that is associated with hotter, drier conditions may adversely affect *P. integrifolia*. In particular, warmer temperatures may negatively affect seed production. However, this potential threat may be mitigated, to some extent, by higher precipitation, which might promote flower head production (see Reproductive biology and autecology and Demography sections). Another consideration is that 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 lead to an increase in habitat suitable for *P. integrifolia*. Another aspect of climate change is that milder, wetter winters could increase the frequency of insect outbreaks on both *P. integrifolia* and on forest trees. The number of subsequent wildfires in the dead forest fuel remaining after insect outbreaks might therefore increase. The direct impact of frequent and excessive insect predation and the indirect consequences of an increase in fire frequency might be detrimental to *P. integrifolia* populations (see Community ecology section).

Malentities envirogram

In summary, malentities and threats to *Pyrrocoma integrifolia* tend to be interrelated, and their impacts are difficult to predict. One may exacerbate another, and their effects may be multiplicative rather than additive. The malentities and threats identified are outlined in the envirogram in **Figure 8**. Habitat modification and loss appear to be, and probably have been, the greatest threats. Livestock and motorized vehicles can also cause direct disturbance and contribute to the spread of aggressive weeds that flourish in disturbed soils. Some environmental conditions, especially a drought lasting through multiple years, appear to be potentially detrimental (see also Demography section). Although there is little on a local level that can be done to avoid the consequences of global climate change, control of additional pressures, such as preventing accelerated soil erosion or loss of reproductive organs from livestock herbivory, may mitigate the effects of climate change to some extent.

Conservation Status of Pyrrocoma integrifolia in Region 2

Pyrrocoma integrifolia is known to occur in only one area in Region 2, on the Shoshone National Forest (see Distribution and abundance section). This occurrence was observed in 1961, and there are no occurrences on the Shoshone National Forest confirmed to be extant (Houston personal communication 2005, 2006). In a collaborative project between the Shoshone National Forest and the Rocky Mountain Herbarium (University of Wyoming, Laramie, Wyoming), a graduate student initiated a floristic survey of the Wind River Range in 2005 (Houston personal communication 2005). This survey may increase the knowledge of the range and abundance of *P. integrifolia* within the Shoshone National Forest (Houston personal communication 2005). Completion of this survey project is expected at the end of 2006, and no preliminary information on *P. integrifolia* is available at the time of this writing (Houston personal communication 2006).

Management of Pyrrocoma integrifolia in Region 2

Either cattle or sheep have grazed the area in which *Pyrrocoma integrifolia* occurs on the Shoshone National Forest annually since before the turn of the twentieth century (Hicks personal communication 2006). The imprecise location information associated with the 1961 *P. integrifolia* observation (WY-7 in **Table 1**) indicates that the occurrence is most likely in what is now Management Unit 6B and that it might extend into Management Unit 7E (USDA National Forest 1994). Management Unit 7E is managed to provide “wood-fiber production and utilization of large roundwood of a size and quality suitable for sawtimber” (USDA National Forest 1994). This description suggests that there is a well-established tree canopy in Management Unit 7E, which would be unlikely to provide suitable habitat for *P. integrifolia*. Grassland and meadow habitat for *P. integrifolia* appears more likely to be maintained in Management Unit 6B, which is managed for livestock grazing (USDA National Forest 1994). The range condition in Management Unit 6B “is maintained through use of forage management practices, livestock management and regulation of other resource activities…and investment in structural and nonstructural range improvements to increase forage utilization is moderate to high" (USDA Forest Service 1994).

Currently, the Shoshone National Forest occurrence (WY-7 in **Table 1**) is located in the Sawmill Park cattle and horse allotment. For the past five years, the allotment has been grazed as a part of an intensively managed multi-pasture rotation system that includes USFS, state, BLM, and private lands (Hicks personal communication 2006). Intensive grazing management systems have been favored over extensive systems in Management Unit 6B for more than a decade (USDA National Forest 1994). Intensive grazing management is described as "grazing management that attempts to increase production or utilization per unit area or production per animal through a relative increase in stocking rates, forage utilization, labor, resources, or capital" (Forage and Grazing Terminology Committee 1991). Furthermore, "Intensive grazing management is not synonymous with rotational grazing. Grazing management can be intensified by substituting any one of a number of grazing methods that utilize a relatively greater amount of labor or capital resources" (Forage and Grazing Terminology Committee 1991). Intensive grazing management is in contrast to extensive grazing management, which is defined as "Grazing management that utilizes relatively large land areas per animal and a relatively low level of labor, resources, or capital" (Forage and Grazing Terminology Committee 1991). There have been no studies to determine how any *Pyrrocoma* species responds to either management system. There is the possibility that the management of the *P. integrifolia* occurrence might change after revision of the Shoshone National Forest Management Plan is completed (USDA Forest Service 2005b).

Implications and potential conservation elements

Only one occurrence of *Pyrrocoma integrifolia* is known to be extant in Wyoming, (WY-2 in **Table 1**), and there have been relatively few occurrences reported within the last two decades (see Distribution and abundance section). Both occurrences outside of Yellowstone National Park are disjunct from the center of abundance that is within the Greater Yellowstone region (see Distribution and abundance section). The 1961 occurrence in the Shoshone National Forest (WY-7 in **Table 1**) is the southernmost occurrence of *P. integrifolia* and is disjunct by approximately 190 miles. The most eastern *P. integrifolia* occurrence is known from the Bighorn Mountains (WY-6 in **Table 1**), approximately 219 miles southeast of the Yellowstone National Park occurrences (WY-1 to WY-5 in **Table 1**). Neither of these occurrences can be assumed extant. The lack of information on the abundance and distribution of *P. integrifolia* increases its vulnerability to unintentional extirpation.

A key conservation element for this species is in utilizing a consistent taxonomic treatment of *Pyrrocoma* species in the Wind River and Bighorn mountains (Fertig 1999, Beauvais et al. 2000). If *P. clementis* var. *villosa* is merged into *P. integrifolia* as suggested by Cronquist (1994), several extant occurrences of *P. integrifolia* will be located in the Bighorn National Forest in Region 2 (Ladyman 2006). At the present time, the only extant occurrences of *P. clementis* var. *villosa* known to exist are located on the Bighorn National Forest. A management strategy is being refined for rare species on the Bighorn National Forest, and *P. clementis* var. *villosa* occurrences are currently being monitored (USDA Forest Service 2004, Karow personal communication 2005, USDA Forest Service 2005b). In the most recent edition of the Flora of North America, Bogler (2006) has accepted *P. integrifolia* and *P. clementis* var. *villosa* as separate taxa.

Pyrrocoma integrifolia may intergrade with other *Pyrrocoma* species in the Bighorn Mountains (Fertig 1999). The existence of hybrids between *Pyrrocoma* species needs to be critically examined and documented. Variability within a taxon can be generated by environmental conditions and be a consequence of differential gene expression due to "temporary" conditions, such as low light or severe grazing pressure. Variability may also result from the development of local ecotypes. Such variability can sometimes be mistaken for interspecific hybridization; therefore, careful studies are needed to differentiate among the three situations.

Variations in *Pyrrocoma integrifolia* habitat conditions suggest that distinct ecotypes of the taxon might occur in different regions. This potential for local adaptation and the possibility of hybridization between *P. integrifolia* and other *Pyrrocoma* species indicate that seed from one occurrence may not be suitable for use in restoration programs in other regions. Some issues associated with using non-local seed for restoration, including the potential for outbreeding depression, have been discussed by Lesica and Allendorf (1999) and Hufford and Mazer (2003). Outbreeding depression can result when local adaptations are disrupted after non-local genotypes are introduced (Waser and Price 1989, Lesica and Allendorf 1999, Hufford and Mazer 2003).

Prescribed burning is potentially a useful tool for maintaining suitable habitat for *Pyrrocoma integrifolia*. However, the direct effects of fire on the taxon are unknown (see Community ecology section). The intensity of the burn may be important to *P. integrifolia* survival. Fire intensity may affect its ability to re-sprout. High intensity burns that kill *P. integrifolia* seed in the seed bank may be particularly detrimental to recovery after fire in Region 2 because it appears that the Region 2 occurrence is isolated from other occurrences that could provide a natural source of seed.

Tools and practices

Documented inventory and monitoring activities are needed to clarify the status and vulnerability of *Pyrrocoma integrifolia* on National Forest System land. Most of the occurrence information for *P. integrifolia* is derived from herbarium specimens or from relatively casual observations by botanists and does not provide quantitative information on the abundance or spatial extent of the occurrences.

Species inventory

Field survey forms for endangered, threatened, or sensitive plant species are available from the Wyoming Natural Diversity Database (2005), the Montana Natural Heritage Program (2005b) and the Idaho Conservation Data Center (2005). The numbers of *Pyrrocoma integrifolia* individuals, the area they occupy, and the area of apparently suitable but unoccupied habitat are important data to record during inventory. The easiest way to describe occurrences over a large area may be to count patches, make note of their extent, and estimate or count the numbers of individuals within patches. If specific counts cannot be made, a numerical estimate such as "fewer than 10 individuals" or "between 20 to 30 individuals" within a certain area is more useful in estimating abundance trends than are subjective evaluations such as "sparse" or "frequent." Collecting information on individual plant size and reproductive stages (flowering plants versus vegetative rosettes versus seedlings) is also valuable in assessing the vigor and potential persistence of an occurrence. Observations of habitat are also valuable additions to the inventory record. A sketch of the plants' distribution within a site is helpful for future reference. Recording precise geographic information on where plants occur provides the means for relocating occurrences. With the advent of low cost global positioning systems (GPS), such information is relatively easy to collect.

The potential for misidentification needs to be considered during field studies. *Pyrrocoma integrifolia* can be mistaken in the field for other *Pyrrocoma* species. Early in the season, the basal leaves of other Asteraceae genera such as *Agoseris* or *Stenotus* may also be mistaken for vegetative *Pyrrocoma* species (Mancuso 1997). Surveying for *P. integrifolia* during flowering and fruiting is required for definitive identification. Specimen collection and deposition in a public herbarium are advisable unless the size of the occurrence is such that its future would be compromised by the loss of one individual. The minimum size for a viable *P. integrifolia* occurrence has not been researched. A general guideline is a maximum of one collection for every 20 to 50 plants (Colorado Native Plant Society 2001). In the case of *P. integrifolia*, this guideline should be extended to specify that the plants be in flower so that there is no possibility of overestimating its abundance. The *P. integrifolia* specimen collected needs to have flowers and well-developed achenes.

Habitat inventory

Efficient habitat inventory depends upon knowing which habitat parameters most accurately predict an occurrence of *Pyrrocoma integrifolia*. This knowledge will also allow estimates of the likelihood that the species will occur given specific site conditions (Simberloff 1988, Brussard 1991, Falk and Olwell 1992, Wiser et al. 1998, Wu and Smeins 2000). For many rare plant species, predictive habitat models have been developed to predict a species' presence, absence, or abundance (Imm et al. 2001, Fertig and Thurston 2003, Dingman 2005). Managers can use these models to focus field inventory efforts, assess potential development impacts, and evaluate potential restoration or reintroduction sites (Wiser et al. 1998, Boetsch et al. 2003). The development of predictive habitat models has progressed rapidly as statistical techniques have become easier to perform using readily available computational tools (e.g., geographic information systems (GIS) and statistical analysis software) (Guisan and Zimmerman 2000, Store and Jokimaki 2003). However, a caveat to their use is that the models need to be assessed at a scale that is relevant to the required application and should be validated using independent data (Elith and Burgman 2002). It is essential that the models be tested by rigorous ground truthing before they are applied in practice (Imm et al. 2001, Elith and Burgman 2002, Dingman 2005).

No habitat models have been developed for *Pyrrocoma integrifolia*. At the present time, potential habitat for *P. integrifolia* can best be described as any meadow and shrub-grassland habitat that from casual observation appears suitable for the species, but that is not occupied by it. The information currently available for *P. integrifolia* habitat is derived from relatively casual occurrence descriptions and is in insufficient detail to make accurate estimates of which areas will be occupied. The available habitat descriptions suggest that, within the restrictions of the eco-climate zones in which it exists, this species can grow in a variety of meadow and shrub-grassland habitats (see Habitat section). As a general rule, studies that relate the abundance and fecundity of populations to habitat conditions need to be conducted before trying to determine the quality of the unoccupied habitat available for the taxon of interest.

Population monitoring

Monitoring data may be collected at several levels of detail. A simple census of individuals over time can provide an estimate of population stability. If information on the number of reproductive individuals is included, potential trends in population stability may be estimated. Full demographic monitoring of 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). No census surveys or demographic studies of *Pyrrocoma integrifolia* have been reported.

It is very important to define the goals of any monitoring plan and to identify the methods of data analyses before beginning the project. The time commitment per year will depend on the protocols adopted, the skill of the surveyor, and the distance between monitoring plots. A monitoring scheme ought to be robust over years and take into account the variations in surveyor expertise. Monitoring protocols need to include specific observations of habitat characteristics, including a measure or quantitative estimate of the non-native species present, so that changes in abundance or status of the target species can be evaluated in the context of its environment. Annual monitoring is very useful if population size and/or vigor exhibit a high degree of year-to-year variation. This is particularly the case for many annual species or herbaceous perennial species that possess underground organs that undergo prolonged dormancy. For species that exhibit more stable aboveground populations, monitoring may occur at longer intervals. The appropriate interval will be most successfully determined after a period of annual monitoring. A re-sampling schedule of every 5 years after monitoring plots were established was recommended for *Pyrrocoma liatrifomis* (Mancuso 1997) and 3 to 5 years for *P. radiata* (Kaye 2002).

Permanent transects or permanent plots can be used for monitoring occurrences. Lesica (1987) discussed a technique for monitoring non-rhizomatous, perennial plant species using permanent belt transects. Elzinga et al. (1998, 2001) and Goldsmith (1991) discussed in detail the use of rectangular quadrant frames along transect lines to monitor plant populations. Permanent plots are used for demographic monitoring studies, but to assess long-term trends in abundance, their use might lead to certain problems associated with spatial auto-correlation (Goldsmith 1991). If the plot is too small and the establishment of new plots is not part of the original scheme, when plants die and no replacement occurs within the plot, it is impossible to know the significance of the change without studying a very large number of similar plots. Patches of *Pyrrocoma* plants are likely to be persistent, given that seed is likely to be dispersed only short distances and that adult plants are probably long-lived. However, this has not been confirmed. Natural population dynamics may include a series of colonizations and local extirpations of patches. It is important to monitor the areas between patches since the population dynamics of *P. integrifolia* are not known and the potential for patches shifting within a population needs to be recognized.

Permanently marked monitoring plots were used by Mancuso (1997) to monitor *Pyrrocoma liatriformis* in Idaho. The primary objective of this monitoring plan was to obtain a measure of reproductive potential, herbivory, and insect seed predation damage of *P. liatriformis* plants and to assess vegetation trends at each of three sites. The condition and numbers of *P. liatriformis* individuals in each macroplot were recorded (Mancuso 1997). Nested quadrat frequency methods were employed to record the density and cover of other plant species found within the macroplots (Mancuso 1997).

Permanently marked monitoring plots were also used by Kaye (2002) to monitor *Pyrrocoma radiata* in Oregon. This monitoring study was designed to determine long-term population trends and to identify factors that influence and control population growth (Kaye and Meinke 1992). In this case, each plot was composed of five 1-m wide belt transects alternating with 1-m wide walkways. Each transect was broken into ten contiguous 1 x 1 m subplots, for a total of 50 subplots per plot (Kaye 2002). In each plot, the plants were mapped and measured for detailed demographic study (Kaye 2002). The duration of the *P. radiata* study was 11 years (Kaye 2002). Similar studies of the demographics and populations dynamics of *P. integrifolia* will also take many years, and the time commitment each year will be substantial. If such a study is considered for *P. integrifolia*, developing a stage projection model for the taxon after the method of Lefkovitch (1965) may be useful for estimating transition probabilities between the different stages in its life history and for calculating an equilibrium growth rate. A combination of age and size classes and life-history stages was used in developing a matrix model of *P. radiata* population dynamics (Greenlee and Kaye 1997, Kaye 2002). The life-history stages used in this study were seedling, juvenile (= three leaves), vegetative (= four leaves and not reproductive), and reproductive (Greenlee and Kaye 1997, Kaye 2002).

Matrix projection models are useful tools for predicting changes in population growth rate, but care needs to be taken in their interpretation (Bierzychudek 1999, Mills et al. 1999, de Kroon et al. 2000, Erhlén et al. 2001, Doak et al. 2005). A model's usefulness and accuracy may be limited if the study was too short to capture the complete range of year-to-year biological and environmental variability. For example, if germination and recruitment is episodic, a study of even several years duration might not include recruitment events (Bierzychudek 1999, Coles 2003, Doak et al. 2005). Other limitations may include too few individuals to provide accurate transition probabilities and the failure to account for density-dependent vital rates (Bierzychudek 1999, Doak et al. 2005).

Habitat monitoring

Weed management programs that survey for non-native plant species can be part of a general habitat monitoring plan. Since mesic conditions appear to contribute to *Pyrrocoma integrifolia* habitat, monitoring changes in available water may indicate whether habitat modification is likely. For example, monitoring groundwater depth, local snow pack, and local stream flows over several years may indicate if an area is becoming drier and less likely to support *P. integrifolia*. The lack of information on the specific habitat requirements of *P. integrifolia* makes it unlikely that solely monitoring unoccupied habitat would be an effective conservation approach.

Habitat monitoring within occurrences of rare plant species can be associated with population trend monitoring protocols. Important observations to record include the associated species (both flora and fauna), the micro-environment (moist or xeric, shaded or sunny, aspect, slope), and substrate conditions (moist or xeric, sand or clay). Land use and its intensity are important facts to include with the monitoring data. Descriptions of habitat made during population monitoring may clarify how environmental conditions influence a target species' abundance and condition over the long term.

Photographs are useful for augmenting, but not replacing, the quantitative monitoring data gathered for rare plants. Photopoints and photoplots are helpful in visualizing changes over time (Hall 2001). Comparing photographs taken over time facilitates detection of changes in environmental parameters, such as shrub and grass cover, healing of disturbed soil, or evidence of animal presence and utilization of herbage (Hall 2001). Even though digital images are convenient and easy to store, many museums and researchers suggest storing additional slides or even prints, because in 50 years the technology to read current digital media may no longer be available.

Population or habitat management approaches

There have been no systematic monitoring programs and no documented attempts to manage specifically for *Pyrrocoma integrifolia* in Region 2 (see Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies section). Invasive weed control is potentially an important beneficial management practice that is currently being pursued by the Shoshone National Forest (Harper-Lore 2003b). Management practices that have been implemented in Region 2 and that may benefit *P. integrifolia* include restricting recreational vehicle traffic and routing hikers to designated trails (USDA Forest Service 2004, USDA Forest Service 2005b). Methods to conserve rare taxa include such diverse approaches as seed banking and designating occupied sites as special management areas (e.g., special interest areas or research natural areas).

Seed repositories have been established to save seed from commercially, ecologically, and/or socially important plant species in case restoration efforts are needed in the future (e.g., Royal Botanic Gardens at Kew undated, Global Crop Diversity Trust 2004, Center for Plant Conservation undated). However, seed banking may have limited value for restoring taxa whose ecology is not well understood. If microhabitat requirements are not known, the conditions to maintain an occurrence may not be met even if germination and seedling establishment can be achieved. Re-establishing occurrences of poorly understood species may be a very difficult task.

The Center for Plant Conservation 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. It does not appear that *Pyrrocoma integrifolia* seed or other plant parts have been preserved at any repository. *Pyrrocoma integrifolia* is not included in the current Center for Plant Conservation National Collection (Center for Plant Conservation undated).

Pyrrocoma integrifolia occurrences have not been found in protected areas currently established on National Forest System land in Region 2. Assigning wilderness or special management area status is a multifaceted procedure that takes several years (Forest Service Manual[6]). Less formal ways of protecting rare plants can also be utilized. Common methods of protecting sensitive areas from anthropogenic threats include erecting fences, establishing barriers to ATV traffic, and/or posting signs indicating closed areas. However, the success of signage and barriers is variable and depends upon the site and the users' compliance. Monitoring occurrences before and after management practices have been implemented would be a way to determine the effectiveness of the management. Monitoring protocols need to be designed so that the variability due to intrinsic population fluctuations and due to environmental conditions can be differentiated from the effects of management practices. Federal acquisition and protection of private land that contains populations of the taxon of interest is a way to provide public oversight of known occurrences. At the present time, this latter approach does not appear to be an option for *P. integrifolia* conservation in Region 2.

Information Needs

Targeted surveys are needed to clarify the current abundance, distribution, and range of *Pyrrocoma integrifolia*. Historic occurrences need to be relocated. The taxonomic status of the *P. integrifolia* occurrence in the Shoshone National Forest needs to be determined. Periodic monitoring of extant *P. integrifolia* occurrences is required to ascertain the length of time individuals and occurrences persist. The factors that limit occurrence size and abundance of *P. integrifolia* are not known and need to be understood. The taxon's habitat requirements need to be rigorously defined in order to assess the potential for an occurrence to maintain or increase its size and to estimate its tolerance of management practices. More information is needed on the life history and population dynamics of *P. integrifolia* for the same reasons. Colonization rates and availability of appropriate habitat influence how populations recover after significant disturbance. The potential impact of non-native invasive species is also unknown. More information on how *P. integrifolia* responds to increased competition from non-native species is important because invasive species are a substantial problem in many regions of Wyoming, Montana, and Idaho (Markin 1995).

A better understanding of the potential vulnerability of *Pyrrocoma integrifolia* to genetic stochasticity and to disruption of pollinator communities is needed. Because so little is known about the biology and ecology of *P. integrifolia*, research would have to be conducted before including this species in vegetation restoration efforts or before attempting to establish new populations artificially. In the absence of good data, these efforts could put existing occurrences at risk.

The most pressing information needs for *Pyrrocoma integrifolia* can be summarized in approximately the following order:

- ❖ conduct systematic inventories to clarify the species' abundance, frequency of occurrence, and range
- ❖ resolve the taxonomic status of the *Pyrrocoma* species in the Shoshone National Forest
- ❖ ascertain the stability of *P. integrifolia* occurrences through long-term monitoring programs
- ❖ determine the impact of human activities on populations of *P. integrifolia* in order to promote steps towards threat mitigation
- ❖ define the habitat requirements of the species to assess the potential of population viability or recovery from disturbance
- ❖ understand the reproductive biology and population dynamics of *P. integrifolia* to assess the potential for pollinator dependency and vulnerability to stochasticity.

[6] Forest Service Manual: Title 4000 Research, Section 4063 - Research Natural Areas.
Forest Service Manual: Title 2300 - Recreation, Wilderness, and Related resource management. Sections 2320.1 - 2320.6 - Wilderness Management and 2321 - Establishment and Modification of Wilderness Areas.

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).

Affinity – likeness based on relationship or causal connection; may be used to connote a relationship or resemblance in structure between species that suggests a common origin.

Allele – any of two or more alternative forms of a gene that occupy the same position on a specific chromosome.

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 a 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 writing paper or parchment (Harrington and Durrell 1986).

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

Coleoptera – an order in the Class Insecta; members of Coleoptera are commonly called beetles.

Colpi (singular: colpus) – elongated apertures with a length/breadth ratio greater than 2 (Punt et al. 1994).

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.

Diptera – an order in the Class Insecta; members of Diptera are commonly called true flies.

Dolomite – a common rock-forming mineral, $CaMg(CO_3)_2$; most often dolomite is associated with limestone (Bates and Jackson 1984).

Eciliate – without cilia (hairs).

Ecotype – group of plants within a species adapted genetically to a particular habitat but able to cross freely with other ecotypes of the same species (Abercrombie et al. 1973).

Effective population size – the size of an ideal population whose genetic composition is influenced by random processes in the same way as the real population (Wright 1931); the size of an ideal random mating population (with no selection, mutation, or migration) that would lose genetic variation at the same rate as is observed in an actual population; also the size of an ideal population in which all members have equal reproductive expectations.

Equilibrium growth rate (λ) – integrates the effects of survival, growth, and fecundity of the different life history stages into a single parameter (Caswell 1989, Silvertown et al. 1993, Caswell 2001; when λ equals one, the population is stable, when it is <1 the population is in decline, and when it is >1 the population is growing (Mills et al. 1999); ruderal species tend to have high λ values (e.g., for *Dipsacus* species, λ = 2.32) (Caswell 1989); herbaceous perennials tend to have λ of 1 or greater (e.g., for *Senecio integrifolius*, a rare perennial not unlike *Pyrrocoma integrifolia* in both growth habitat and morphology, λ = 1.46) (Widén 1987, Silvertown et al. 1993); Kaye (2002) compared four populations of *P. radiata* over a period of 11 years, and the average λ value was 0.97.

Exine – the outer layer of the wall of a pollen grain, highly resistant to strong acids and bases, and composed primarily of sporopollenin (Punt et al. 1994).

Flavone – a compound, $C_{15}H_{10}O_2$, and the parent substance of a number of important yellow pigments, occurring in leaves, stems and seed capsules (after The American Heritage® Dictionary of the English Language. 2000. Fourth Edition. Published by the Houghton Mifflin Company).

Geitonogamy – fertilization of flowers by pollen from other flowers on the same plant.

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

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

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

Habitat degradation – when the habitat is so diminished in quality that species are no longer able to persist.

Habitat fragmentation – when habitats are separated into small, isolated fragments and even when the total acreage of habitat appears to be sufficient, its fragmented nature prevents a species from surviving.

Habitat loss – when habitat is converted to other uses (e.g., when a road is constructed or water is diverted and a meadow dries out); some people may classify this example as a form of severe habitat degradation.

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

Holocene – an epoch of the Quaternary period, from the end of the Pleistocene approximately 10,000 years ago to the present time (Bates and Jackson 1976).

Holotype – a single specimen designated as 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.

Hyaline – thin, dry, and translucent or transparent (Harrington and Durrell 1986).

Inbreeding depression – reduction in fitness; 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.

Lepidoptera – an order in the Class Insecta; members of Lepidoptera include butterflies and moths.

Limestone – a sedimentary rock consisting chiefly of the mineral calcite (C_aCO_3) with or without magnesium carbonate; common impurities include chert and clay (Bates and Jackson 1984).

Locus (plural loci) – a specific place on a chromosome where a gene is located (Allaby 1992).

Matorral – vegetation of dry land.

Mesic – of, characterized by, or adapted to, a moderately moist habitat.

Metapopulation – is a composite population (i.e., 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.

Noxious weed – a weed arbitrarily defined by law as being especially undesirable, troublesome, and difficult to control (Arizona Bureau of Land Management 2001); the legal definition from the 1974 Federal Noxious Weed Act: Noxious weed means any living stage, such as seeds and reproductive parts, of any parasitic or other plant of a kind, which is of foreign origin, is new to or not widely prevalent in the United States, and can directly or indirectly injure crops, other useful plants, livestock, or poultry or other interests of agriculture, including irrigation, or navigation, or the fish or wildlife resources of the United States or the public health.

Oblanceolate – inversely lanceolate, attached at the tapered end (Harrington and Durrell 1986).

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

Palustrine – "all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and all such tidal wetlands where ocean-derived salinities are below .5 ppt; this category also includes wetlands lacking such vegetation but with all of the following characteristics: (1) area less than 8 ha; (2) lacking an active wave-formed or bedrock boundary; (3) water depth in the deepest part of the basin less than 2 m (6.6 ft.) at low water; and (4) ocean-derived salinities less than 0.5 ppt" (Cowardin et al. 1979); palustrine wetlands may be isolated or may connect wet areas.

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

Paniculiform – borne in a panicle (see above).

Pappus – the modified calyx limb in Asteraceae, forming a crown at the summit of the achene (Harrington and Durrell 1986).

Pedicel – the stalk of a single flower in an inflorescence (Harrington and Durrell 1986).

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

Pleistocene – also referred to as the Ice Age; an epoch of the Quaternary period, beginning two to three million years ago and lasting until the beginning of the Holocene 8,000 years ago (Bates and Jackson 1976).

Pliocene – the epoch extending between 5.4 and 2.4 million years ago; this is the uppermost subdivision of the Tertiary period which began 64 million years ago; it represents the final stages of a global cooling trend that led up to the Quaternary ice ages (see Pleistocene).

Polymorphic (polymorphism) – Having several different forms.

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).

Protandrous – the anthers (male organs) mature before the carpels (female organs).

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 and Heritage Programs Ranking system, NatureServe, Arlington, VA. Available online at: Internet site: http://www.natureserve.org/explorer/granks.htm.

> **G3** indicates that *Pyrrocoma integrifolia* is "**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."
>
> **?** Whenever possible, the most likely rank is assigned and the question mark qualifier is added (e.g., G3?) to express uncertainty in conservation status.
>
> **S1** indicates that *Pyrrocoma integrifolia* is "**Critically Imperiled** - Critically imperiled in the nation or subnation [state] because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the subnation. Typically 5 or fewer occurrences or very few remaining individuals (<1,000)."

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 – 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.

Trinucleate – having three nuclei.

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

References

Aasheim, R. 1980. Snowmobile impacts on the natural environment. *In*: R. Andrews and P. Nowak, editors. Off-road vehicle use: A management challenge. U.S. Department of Agriculture, Office of Environmental Quality, Washington, D.C.

Adler, L.S., R. Karban, and S.Y. Strauss. 2001. Direct and indirect effects of alkaloids on plant fitness via herbivory and pollination. Ecology 82(7):2032–2044.

Allaby, M. 1992. The concise Oxford dictionary of Botany. Oxford University Press, New York, NY.

Allen, P.S. and S.E. Meyer. 2002. Ecology and ecological genetics of seed dormancy in downy brome. Weed Science 50(2):241-247.

Andrewartha, H.G. and L.C. Birch. 1984. The ecological web: more on the distribution and abundance of animals. University of Chicago Press, Chicago, IL.

Arizona Bureau of Land Management. 2001. Arizona Standards for Rangeland Health and Guidelines for Grazing Administration. Arizona Bureau of Land Management's response to the U.S. Department of the Interior's final rule for Grazing Administration issued on February 22, 1995. State guidelines for the administration of grazing in the state of Arizona. Converted to web pages by the Arizona Rangelands project and revised 5 November 2001. Available online at: http://rangelandswest.org/policy/azstandardscontents.html. Glossary available online at: http://www.fs.fed.us/r2/psicc/publications/environmental_impact_statements/eis_uspwp/Glossary.htm.

Arno, S.F. and G.E. Gruell. 1983. Fire history at the forest-grassland ecotone in southwestern Montana. Journal of Range Management 36(3):332-336.

Axelrod, D.L. 1958. Evolution of the Madro-Tertiary geoflora. Botanical Reviews (Lancaster) 24:443-509.

Barrett, C.H. and J.R. Kohn. 1991. Genetic and evolutionary consequences of small population size in plants: Implications for conservation, 3. *In*: D.A. Falk and K.E. Hosinger, editors. Genetics and conservation of rare plants. Oxford University Press, New York, NY.

Baskin, C.C. and J.M. Baskin. 2001. Seeds. Ecology, biogeography, and evolution of dormancy and germination. Academic Press, New York, NY.

Bates, R.L. and J.A. Jackson. 1984. Dictionary of geological terms. Third Edition. Doubleday, New York, NY.

Beatty, B.L., W.F. Jennings, and R.C. Rawlinson. 2004. *Pyrrocoma carthamoides* var. *subsquarrosa*: A technical conservation assessment. October 21. Available in PDF at Internet site: http://www.fs.fed.us/r2/projects/scp/assessments/pyrrocomacarthamoidesvarsubsquarrosa.pdf [Accessed January 2005].

Beauvais, G.P., W. Fertig, and G.P. Jones. 2000. Rare species and the vegetation of Washakie County, Wyoming. Report prepared for the Washakie County planner by the Wyoming Natural Diversity Database, Laramie, WY.

Belnap, J. 2002. Impacts of off-road vehicles on nitrogen cycles in biological soil crusts: resistance in different U.S. deserts. Journal of Arid Environments 52(2):155-165.

Berg, G., P. Esselink, M. Groeneweg, and K. Kiehl. 1997. Micropatterns in *Festuca rubra*-dominated salt-marsh vegetation induced by sheep grazing. Plant Ecology 132:1-14.

Bethlenfalvay, G.J. and S. Dakessian. 1984. Grazing effects on mycorrhizal colonization and floristic composition of the vegetation on a semiarid range in northern Nevada. Journal of Range Management 37(4):312-316.

Bierzychudek, P. 1999. Looking backwards: assessing the projections of a transition matrix model. Ecological Applications 9(4):1278-1287.

Board on Environmental Studies and Toxicology. 2005. Assessing and managing the ecological impacts of paved roads. The National Academies Press, Washington, D.C.

Boetsch, J.R., F.K. Van Manen, and J.D. Clark. 2003. Predicting rare plant occurrence in Great Smoky Mountains National Park. Natural Areas Journal 23(3):229-237.

Bogler, D.J. 2006. *Pyrrocoma* (Asteraceae). Pages 413-424 *in* Flora North America, Vol. 20. Oxford University Press, New York, NY.

Bohn, C.C. and J.C. Buckhouse. 1985. Some responses of riparian soils to grazing management in northeast Oregon. Journal of Range Management 38:378-382.

Bond, W.J. 1995. Assessing the risk of plant extinction due to pollinator and disperser failure. *In*: J.H. Lawton and R.M. May, editors. Extinction rates. Oxford University Press, New York, NY.

Bond, W.J. and B.W. van Wilgen. 1996. Fire and Plants. (Volume 14 in the Population and Community Biology series) Chapman and Hall, London, UK.

Bonham, C.D., S.G. Bousquin, and D Tazik. 2001. Protocol for inventory and monitoring of threatened and endangered plant species. Colorado State University Department of Rangeland Ecosystem Science, Fort Collins, CO and US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. Available online at: http://www.warnercnr.colostate.edu/frws/research/rc/tes1.htm.

Boutin, C. and C.A. Rogers. 2000. Pattern of sensitivity of plant species to various herbicides-an analysis with two databases. Ecotoxicology 9(4):255-272.

Bremer, K. 1994. Asteraceae: Cladistics and classification. Timber Press, Portland, OR.

Brignolas, F., B. Lacroix, F. Lieutier, D. Sauvard, A. Drouet, A.C. Claudot, A. Yart, A.A. Berryman, and E. Christiansen. 1995. Induced responses in phenolic metabolism in two Norway Spruce clones after wounding and inoculations with *Ophiostoma polonicum*, a bark beetle-associated fungus. Plant Physiology 109(3):821-827.

Brown, G.K and D.J. Keil. 1992. New combinations in *Pyrrocoma* (Asteraceae: Astereae) Phytologia 73(1):57-58.

Brussard, P.F. 1991. The role of ecology in biological conservation. Ecological Applications 1:6-12.

Byers, D. and D.M. Waller. 1999. Do plant populations purge their genetic load? Effects of population size and mating history on inbreeding depression. Annual Review of Ecology and Systematics 30:479-513.

Callaway, R.M., T.H. DeLuca, and W.M. Belliveau. 1999. Biological-control herbivores may increase the competitive ability of the noxious weed *Centaurea maculosa*. Ecology 80(4):1196–1201.

Cassini, H. 1819. Sur la famille des Synanthérées, contenant les caractères des tribus. Journal de Physique, de Chimie, d'Histoire Naturelle et des Arts 88: 189–204 [In: Roberts, R.P. 2002. Phylogeny of *Ericameria*, *Chrysothamnus* and related genera (Asteraceae: Astereae) based on nuclear ribosomal DNA sequence data. Ph.D. Dissertation. Louisiana State University. Electronic thesis and dissertation collection. Available in PDF at Internet site: http://etd02.lnx390.lsu.edu/docs/available/etd-1107102-200952/].

Caswell, H. 1989. Matrix population methods. Sinauer Associates, Inc., Sunderland, MA.

Caswell, H. 2001. Matrix population models. Second edition. Sinauer Associates, Inc., Sunderland, MA.

Center for Plant Conservation. Undated. Center for Plant Conservation, St. Louis, MO. Available online at: http://www.centerforplantconservation.org/ASP/CPC_NCList_Find.asp.

Chamberlain, T.C. 1897. The method of multiple working hypotheses. Journal of Geology 5:837-848 (reprinted in Science 148:754-759).

Chaney, R.W. 1947. Tertiary centers and migration routes. Ecological Monographs 17:139-148.

Clark, W.D. G.K. Brown, and R.A. Mayes. 1980. Pollen morphology of *Haplopappus* and related genera (Compositae-Astereae). American Journal of Botany 67(9):1391-1393.

Coles, J.J. 2003. Population biology of *Sclerocactus mesae-verdae* (Boiss. et Davidson) Benson: 2003 Performance Report. Project no.: E-9-R-20. Unpublished report. Colorado Natural Areas Program - Plant Conservation Program, Denver, CO.

Colorado Native Plant Society. 2001. Guidelines for collection of native plants for use in restoration, horticulture, medicinal preparations and scientific research. 16 May 1992 and Updated April 2001. Available online at: http://www.conps.org/pdf/guidelinesforcollection.PDF.

Cooke, S. 2005. Data Coordinator, Idaho Conservation Data Center, Idaho Department of Fish and Game, Boise, ID. Personal communication.

Cowan, M.M. 1999. Plant products as antimicrobial agents. Clinical Microbiology Reviews 12(4):564-582.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31. December 1979. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Also made available online by the Northern Prairie Wildlife Research Center, Jamestown, ND at: http://www.npwrc.usgs.gov/resource/1998/classwet/classwet.htm (Version 04DEC98).

Crane, M.F., J.R. Habeck, and W.C. Fischer. 1983. Early postfire revegetation in a western Montana Douglas-fir forest. Research paper INT-319. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Cronquist, A. 1994. Intermountain Flora, Volume 5: Asterales. New York Botanical Garden, Bronx, NY.

Dayton, W.A. 1931. Important western browse plants. Miscellaneous Publication 101. US Department of Agriculture, Washington, D.C.

de Candolle, A.P. 1836. Prodromus systematis naturalis regni vegetabilis 5:345–351. Treuttel et Würtz, Parisiis (Reprinted in 1966 by J. Cramer, Lehre, Germany).

de Kroon, H., J. van Groenendael, and J. Ehrlén. 2000. Elasticities: a review of methods and model limitations. Ecology 81:607–618.

Den Ouden, P. and B.K. Boom.1965. Manual of cultivated conifers. Martnus Nijhoff, The Hague, Netherlands.

Dingman, S. 2005. Habitat and life history characteristics of *Astragalus barrii* (Fabaceae) in the South Dakota badlands. Master of Science thesis. University of South Dakota, Vermillion, SD. Available online at: http://www.nature.nps.gov/im/units/ngpn/Pages/Inventory/Documents/Final%20Dingman%20Thesis.pdf [Accessed November 2005].

Doak, D.F., K. Gross, and W.F. Morris. 2005. Understanding and predicting the effects of sparse data on demographic analyses. Ecology 86(5):1154–1163.

Dorn, R.D. 1984. Vascular plants of Montana. Mountain West Publishing. Cheyenne, WY.

Dorn, R.D. 1988. Vascular plants of Wyoming. Second edition. Mountain West Publishing. Cheyenne, WY.

Dorn, R.D. 2001. Vascular plants of Wyoming. Third edition. Mountain West Publishing. Cheyenne, WY.

Dudash, M.R. and D.E. Carr. 1998. Genetics underlying inbreeding depression in *Mimulus* with contrasting mating systems. Nature 393:682-684.

Dunwiddie, P.W. 1977. Recent tree invasion of subalpine meadows in the Wind River Mountains, Wyoming. Arctic and Alpine Research 9:393-399.

Durbin, T.D., M.R. Smith, R.D. Wilson, and S.H. Rhee. 2004. In-use activity measurements for off-road motorcycles and all-terrain vehicles. Transportation Research Part D - Transport and Environment 9(3):209-219.

Dwire, K.A., J.B. Kauffman, and J.E. Baham. 2006. Plant species distribution in relation to water-table depth and soil redox potential in montane riparian meadows. Wetlands 26(1):131-146.

Eckert, C.G. 2000. Contributions of autogamy and geitonogamy to self-fertilization in a mass-flowering, clonal plant. Ecology 81(2):532–542.

Ehrlén, J., J. van Groenendael, and H. de Kroon. 2001. How reliable is elasticity analysis? - A comment on Mills et al. Conservation Biology 15:278-280.

Elith, J. and M.A. Burgman. 2002. Predictions and their validation: rare plants in the Central Highlands, Victoria, Australia. Pages 303-314 *in* J.M. Scott, Heglund P.J., Morrison M.L., Raphael M.G., Wall W.A., and Samson F.B, editors. Predicting species occurrences: issues of accuracy and scale. Island Press, Covelo, CA.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and monitoring plant populations. Bureau of Land Management Technical Reference 1730-1. U.S. Department of Interior, Bureau of Land Management, Denver, CO.

Elzinga, C.L., D.W. Salzer, J.W. Willoughby, and J. Gibbs. 2001. Monitoring plant and animal populations. Blackwell Scientific Publishing, Boston, MA.

Environmental Media Services. 2001. Definitions for public land designations, Last update: April 27, 2001. Available online at: www.ems.org [Accessed December 2003].

Esser, L.L. 1993. *Phleum pratense*. *In*: Fire Effects Information System, [Online]. USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available online at: http://www.fs.fed.us/database/feis/ [Accessed August 2006].

Fahey, B. and K. Wardle 1998. Likely impacts of snow grooming and related activities in the West Otago ski fields. Science for Conservation 85. Published by Department of Conservation, Wellington, New Zealand. Document in PDF available at: http://www.doc.govt.nz/Publications/004~Science-and-Research/Science-for-Conservation/PDF/sfc085.pdf.

Falk, D.A. and P. Olwell. 1992. Scientific and policy considerations in restoration and reintroduction of endangered species. Rhodora 94:287-315.

Fertig, W. 1998. The status of rare plants on Shoshone National Forest: 1995-97 Survey results. Unpublished report. Shoshone National Forest, WY.

Fertig, W. 1999. The Status of Rare Plants in the Bighorn Landscape. Unpublished document prepared for The Nature Conservancy by the Wyoming Natural Diversity Database, University of Wyoming, Laramie, WY.

Fertig, W. 2000a. Rare Vascular Plant Species in the Wyoming Portion of the Utah-Wyoming Rocky Mountains Ecoregion. Unpublished document prepared for The Wyoming Nature Conservancy by the Wyoming Natural Diversity Database, University of Wyoming, Laramie, WY.

Fertig, W. 2000b. State Species Abstract - *Pyrrocoma integrifolia*. Wyoming Natural Diversity Database website. Available online at: http://uwadmnweb.uwyo.edu/wyndd/ [Accessed January 2005].

Fertig, W. and R. Thurston. 2003. Modeling the Potential Distribution of BLM Sensitive and USFWS Threatened and Endangered Plant Species in Wyoming. Unpublished document. Bureau of Land Management Wyoming State Office, Cheyenne, WY.

Forage and Grazing Terminology Committee. 1991. Terminology for grazing lands and grazing animals. Originally published in 1991 by Pocahontas Press, Post Office Drawer F, Blacksburg, VA. It was also published in 1992 in the Journal of Production Agriculture 5:191-201. The terminology has been more recently endorsed in a Resolution passed at the XVII International Grassland Congress, Rockhampton, Australia, February 21, 1993.

Fralish, J.S. and S.B. Franklin. 2002. Taxonomy and ecology of woody plants in North American forests. John Wiley and Sons, New York, NY.

Frankel, O.H., A.H.D. Brown, and J.J. Burdon. 1995. The conservation of plant biodiversity. Cambridge University Press, New York, NY. Page 127.

Frankham, R. 1999. Quantitative genetics in conservation biology. Genetic Research, Cambridge 74:237-244.

Franklin, I.R. 1980. Evolutionary change in small populations. Pages 135-150 *in* M.E. Soule and B.A. Wilcox, editors. Conservation biology: an evolutionary-ecological perspective. Sinauer, Sunderland, MA.

Fredrickson, E. 2004. Livestock foraging ecology. Page last modified: 12 Aug 2004. USDA Agricultural Research Service, Washington, D.C. Available online at: http://www.ars.usda.gov/Main/docs.htm?docid=5565 [Accessed December 2005].

Fuhlendorf, S.D., H. Zhang, T.R. Tunnell, D.M. Engle, and A.F. Cross. 2002. Effects of grazing on restoration of southern mixed prairie soils. Restoration Ecology 10(2):401-407.

Furniss, M.J., S.A. Flanagan, and B. A. McFadin. 2000. Hydrologically-connected roads: An indicator of the influence of roads on chronic sedimentation, surface water hydrology, and exposure to toxic chemicals. Stream Notes, pp. 1-2. USDA Forest Service Rocky Mountain Research Station, Fort Collins, CO.

Geach, R.D. 1972. Mines and Mineral Deposits (Except Fuels) Beaverhead County, Montana. Montana Bureau of Mines and Geology Bulletin 85. Montana College of Mineral Science and Technology, Butte, MT.

Gegick, P. and J.A.R. Ladyman. 1999. Characterization of pollen from plants in the Alkali Lakes area of New Mexico. New Mexico Native Plant Society Annual Meeting, Albuquerque, NM.

Gelbard, J.L. and S. Harrison. 2003. Roadless habitats as refuges for native grasslands: interactions with soil, aspect, and grazing. Ecological Applications 13(2):404-415.

Gledhill, D. 1992. The names of plants. Second edition. Cambridge University Press, New York, NY.

Goldsmith, F.B. 1991. Monitoring for conservation and ecology. Chapman and Hall, New York, NY.

Goodwin, J. 1992. The role of mycorrhizal fungi in competitive interactions among native bunchgrasses and alien weeds: a review and synthesis. Northwest Science 66(4):251-260.

Grant, V. 1981. Plant speciation. Second edition. Columbia University Press, New York, NY.

Gray, A. 1881. Contributions to North American botany. I. Notes on some Compositae. Proceedings of the American Academy of Arts and Sciences, Boston, MA XVI (new series vol. VIII): 78-108.

Gray, A. 1884. *Haplopappus*. Synoptical Flora of North America, New York. 1(2):128.

Greater Yellowstone Coordinating Committee. 2000. Greater Yellowstone Area: Water Quality Integrity. Available online at: http://www.nps.gov/yell/gycc/maps/iwwiqualint.htm.

Greater Yellowstone Coordinating Committee. 2001. Greater Yellowstone Coordinating Committee Briefing Guide - Maps. Available online at: http://www.nps.gov/yell/gycc/briefingguide/ [Accessed may 2005].

Greater Yellowstone Post-Fire Resource Assessment Committee. 1988. Preliminary burned area survey of Yellowstone National Park and adjoining national forests: project summary and tabular areas. Document includes pull out map. Publication of cooperating agencies and institutions; National Park Service, USDA Forest Service, National Aeronautics and Space Administration, and Montana State University.

Greene, E.L. 1894a. Observations on the Compositae – IV. Tribe III: *Astereae*. Erythea 2(4):53-60.

Greene, E.L. 1894b. Observations on the Compositae – V. Erythea 2(5): 69-76.

Greenlee, J. and T.N. Kaye. 1997. Stochastic matrix projections: a comparison of the effect of element and matrix selection methods on quasi-extinction risk for *Haplopappus radiatus* (Asteraceae). Pages 66-71 *in* T.N. Kaye, A. Liston, R.M. Love, D. Luoma, R.J. Meinke, and M.V. Wilson, editors. Conservation and management of native plants and fungi. Native Plant Society of Oregon, Corvallis, OR.

Grime, J.P., J.G. Hodgson, and R. Hunt. 1988. Comparative plant ecology – a functional approach to common British species. Allen and Unwin, Inc., Winchester, MA.

Grimm, R. 1939. Winter range in Yellowstone National Park. Yellowstone Nature Notes. Vol. XVI, March-April, Nos. 3-4.

Guisan, A. and N.E. Zimmermann. 2000. Predictive habitat distribution models in ecology. Ecological Modelling 135: 147-186.

Guo, Q. 2004. Slow recovery in desert perennial vegetation following prolonged human disturbance. Journal of Vegetation Science 15:757-762.

Hall, F.C. 2001. Ground-based photographic monitoring. General Technical Report PNW-GTR-503. USDA Forest Service, Pacific Northwest Research Station Portland, OR.

Hall, H.M. 1928. The Genus *Haplopappus*, a phylogenetic study in the Compositae. Carnegie Institute of Washington, Washington, D.C.

Hammerschmidt, R. 1999. Phytoalexins: What have we learned after 60 years? Annual Reviews of Phytopathology 37:285-306.

Hanks, D.L., E.D. McArthur, A.P. Plummer, B.C. Giunta, and A.C. Blauer. 1975. Chromatographic recognition of some palatable and unpalatable subspecies of rubber rabbitbrush in and around Utah. Journal of Range Management 28:144-148.

Harlan, J.R. 1983. Some merging plant populations. Pages 267-276 *in* C.M. Schonewald-Cox, S.M. Chambers, B. MacBryde and W.L. Thomas, editors. Genetics and conservation – a reference for managing wild animal and plant populations. The Benjamin/Cummings Publishing Co., Menlo Park, CA.

Harper-Lore, B., editor. 2003a. The Greater Yellowstone Area: A great cross-boundary management example. Greener Roadsides 12(10):1-7.

Harper-Lore, B., editor. 2003b. The Greater Coordinating Committee Weed Group. Greener Roadsides 12(10):12.

Harrington, H.D. and L.W. Durrell. 1986. How to identify plants. Swallow Press, Athens, OH.

Hartman, R.L. 1990. A conspectus of *Machaeranthera* (Asteraceae: Astereae). Phytologia 68:439-465.

Hartman, R.L. and B.E. Nelson. 2001. A checklist of the vascular plants of Colorado. Rocky Mountain Herbarium, University of Wyoming, Laramie, WY.

Harvard Herbaria Database. 2005. Harvard University Herbaria. Specimen database. Available online at: http://brimsa.huh.harvard.edu/cms-wb/specimens.jsp [Accessed December 2005].

Hauber, D.P. 1986 Autotetraploidy in *Haplopappus spinulosus* hybrids: Evidence from natural and synthetic tetraploids. American Journal of Botany 73(11):1595-1606.

Hayden, F.V. 1873. Sixth Annual Report of the United States Geological Survey of the Territories, Embracing Portions of Montana, Idaho, Wyoming, and Utah. Government Printing Office, Washington, D.C.

Hegnauer, R. 1977. The chemistry of the Compositae. *In*: V.H. Heywood, J.B. Harbourne and B.L. Turner, editors. The biology and chemistry of the Compositae Vol. 1. Academic Press, New York, NY.

Hendee, J.C. and C.P. Dawson. 2001. Stewardship to address the threats to wilderness resources and values. International Journal of Wilderness 7(3):4-9.

Hicks, J. 2006. Rangeland Management Specialist. Shoshone National Forest, USDA Forest Service Region 2, Cody, WY. Personal communication.

Hillborn, R. and M. Mangel. 1997. The ecological detective: confronting models with data. Princeton University Press, Princeton, NJ.

Hitchcock, C.L. and A. Cronquist. 2001. Flora of the Pacific Northwest. Twelfth printing. University of Washington Press, Seattle, WA.

Holsinger, K.E. and L.D. Gottlieb.1991. Conservation of rare and endangered plants: principles and prospects. Pages 195-208 *in* D.A. Falk and K.E. Holsinger, editors. Genetics and conservation of rare plants. Oxford University Press, New York, NY.

Hooker, W.J. 1831. *Pyrrocoma*. Flora Boreali-Americana. Vol. II. Reprinted in 1960, H.R. Engelmann (J. Cramer) and Wheldon & Wesley, Ltd, Codicote, Hertsfordshire, UK.

Houston, K.E. 2005. Soils Scientist - Soils/Botany/Ecology/Invasive Plants/Research Natural Areas, Shoshone National Forest, Wind River Ranger District, Dubois, WY. Personal communication.

Houston, K.E. 2006. Soils Scientist - Soils/Botany/Ecology/Invasive Plants/Research Natural Areas, Shoshone National Forest, Wind River Ranger District, Dubois, WY. Personal communication.

Hufford, K.M. and S.J. Mazer. 2003. Plant ecotypes: genetic differentiation in the age of ecological restoration. Trends in Ecology and Evolution 18:147-155.

Idaho Conservation Data Center. 2005. Rare Plant Report Form and Rare Plant Monitoring Form. Available online at: http://fishandgame.idaho.gov/tech/CDC/report.cfm [Accessed May 2005].

Idaho Fish and Game Department. 2005. Idaho Conservation Data Center. Information updated 12 January 2005. Available online at: http://fishandgame.idaho.gov/tech/CDC/ [Accessed May 2005].

Idaho Native Plant Society 2001. Results of the seventeenth annual Idaho rare plant conference. Available online at: www.idahonativeplants.org/rpc/2001RAREPLANTLIST.DOC.

Imm, D.W., H.E. Shealy, Jr., K.W. McLeod, and B. Collins. 2001. Rare plants of southeastern hardwood forests and the role of predictive modeling. Natural Areas Journal 21:36-49.

Integrated Taxonomic Information System. 2005. ITIS, the Integrated Taxonomic Information System – an authoritative taxonomic information on plants, animals, fungi, and microbes of North America and the world. ITIS is also a partner of Species 2000 and the Global Biodiversity Information Facility (GBIF). Last Updated 23 November 2004. Interactive database available online at: http://www.itis.usda.gov.

Jackson, R.C. 1985. Mitotic instability in *Haplopappus*: structural and genic causes. American Journal of Botany 72(9):1452-1457.

Jean, C. and S. Crispin. 2001. Inventory of Important Biological Resources in the Upper Yellowstone River Watershed. Report to the Environmental Protection Agency. Montana Natural Heritage Program, Helena, MT.

Johansen, C.A. 1977. Pesticides and pollinators. Annual Review of Entomology 22:177–192.

Jones, M.E. 1910. *Hoorebekia*, Asteraceae. Biological Series of the Bulletin of the State University of Montana, Missoula, Montana. Ser. 15:47-51.

Karow, G. 2005. Forester, Timber Shared Services, USDA Forest Service, Bighorn National Forest, Sheridan, WY. Personal communication.

Kartesz, J.T. and K.N. Gandhi. 1991. Nomenclatural notes for the North American Flora VI. Phytologia 71(1):58-65

Kaye, T.N. 1997. Seed dormancy in high elevation plants: implications for ecology and restoration. *In*: T.N. Kaye, A. Liston, R.M. Love, D. Luoma, R.J. Meinke, and M.V. Wilson, editors. Conservation and management of native plants and fungi. Native Plant Society of Oregon, Corvallis, OR.

Kaye, T.N. 2002. Effects of cattle grazing, insect interactions and population ecology of Snake River goldenweed (*Haplopappus radiatus*). Final Report. Unpublished report of the Bureau of Land Management Vale District, Oregon and the Institute for Applied Ecology, Corvallis, OR. Available in PDF online at: http://www.appliedeco.org/reports.html [Accessed January 2005].

Kaye, T.N. and R. Meinke. 1992. Population monitoring and pollination biology of Snake River Goldenweed, *Haplopappus radiatus*. Unpublished report. Oregon Department of Agriculture Conservation Biology Program to the Vale District, Bureau of Land Management, OR.

Kaye, T.N., S. Massey, W. Messinger, R. Meinke, and T. Magee. 1990. *Haplopappus radiatus* inventory and cytogeographic survey. Unpublished report. Oregon Department of Agriculture Conservation Biology Program to the Vale District, Bureau of Land Management, OR.

Kearns, C.A., D.W. Inouye, and N.M. Waser. 1998. Endangered mutualisms: the conservation of plant-pollinator interactions. Annual Review of Ecology and Systematics 29:83-112.

Keddy, P.A., A.J. Spavold, and C.J. Keddy. 1979. Snowmobile impact on old field and marsh vegetation in Nova Scotia, Canada: An experimental study. Environmental Management 88(10):409-415.

Keiding, N. 1975. Extinction and exponential growth in random environments. Theoretical Population Biology 8: 49-63.

Keiter, R.B. and M.S. Boyce. 1991. The Greater Yellowstone Ecosystem, redefining America's wilderness heritage. Yale University Press, New Haven, CT.

Kevan, P.G. 1975. Forest application of the insecticide fenitrothion and its effect on wild bee pollinators (Hymenoptera: Apiodea) of lowbush blueberries (*Vaccinium* spp.) in southern New Brunswick, Canada. Biological Conservation 7:301-309.

Key, C.H., D.B. Fagre, and R.K. Menicke. 1998. Glacier retreat in Glacier National Park, Montana. *In*: R.S. Williams and J.G. Ferrigno, editors. Satellite image atlas of glaciers of the world - Chapter J, Glaciers of North America. U.S. Geological Survey Professional Paper 13686-J. Excerpts available at USGS Internet sites: http://pubs.usgs.gov/fs/fs130-02/fs130-02.html and http://www.nrmsc.usgs.gov/research/glacier_retreat.htm.

Kleijn, G. and I.J. Snoeijing. 1997. Field boundary vegetation and the effects of agrochemical drift: botanical change caused by low levels of herbicide and fertilizer. Journal of Applied Ecology 34(6):1413-1425.

Knight, D. 1994. Mountains and plains: the ecology of Wyoming landscapes. Yale University Press, New Haven, CT.

Knowles, C.J. and P.R. Knowles. 1995. Presettlement wildlife and habitat of Montana: An overview. Northern Prairie Wildlife Research Center, Jamestown, ND. Available online at: http://www.npwrc.usgs.gov/resource/habitat/presettl/presettl.htm (Version 16JUL97) [Accessed April 2005].

Kuntze, C.E.O. 1891. Aster. Revisio Generum Plantarum. 1:308-318 (*Aster canbyi* specifically on p. 315).

Ladyman, J.A.R. 2006. *Pyrrocoma clementis* var. *villosa*: A technical conservation assessment. Submitted for publication to USDA Forest Service, Region 2, Denver, CO.

Lamb, E.G., J.F. Cahill, and M.R.T. Dale. 2006. A nonlinear regression approach to test for size-dependence of competitive ability. Ecology 87(6):1452–1457.

Lande, R. 1995. Mutation and conservation. Conservation Biology 9:782-791.

Lande, R. and G.F. Barrowclough. 1987. Effective population size, genetic variation, and their use in population management. Pages 87-123 *in* M.E. Soulé, editor. Viable populations for conservation. Cambridge University Press, Cambridge, UK.

Lane, M.A. and R.L. Hartman. 1996. Reclassification of North American *Haplopappus* (Compositae: *Astereae*) completed: *Rayjacksonia gen. nov*. American Journal of Botany 83:356–370.

Leege, T.A. and G. Godbolt. 1985. Herbaceous response following prescribed burning and seeding of elk range in Idaho. Northwest Science 59(2):134-143.

Leenhouts, B. 1998. Assessment of biomass burning in the conterminous United States. Conservation Ecology [online] 2(1): 1. Available online at: http://www.consecol.org/vol2/iss1/art1/ [Accessed January 2005].

Leftovitch, L.P. 1965. The study of population growth in organisms grouped by stages. Biometrics 21:1-18.

Leppik, E.E. 1977. The evolution of capitulum types of the Compositae in the light of insect-flower interaction. Pages 61-89 *in* V.H. Heywood, J.B. Harborne, B.L. Turner, editors. The biology and chemistry of the Compositae. Academic Press, London, UK.

Lesica, P. 1987. A technique for monitoring non-rhizomatous, perennial plant species in permanent belt transects. Natural Areas Journal 7(2):65-68.

Lesica, P. 1995. Conservation status of *Haplopappus carthamoides* var. *subsquarrosus* in Montana. Unpublished report prepared for the USDA Forest Service and Bureau of Land Management by the Montana Natural Heritage Program, Helena, MT.

Lesica, P. and F.W. Allendorf. 1995. When are peripheral populations valuable for conservation? Conservation Biology 9(4):753-760.

Lesica, P. and J.S. Shelly. 1995. Effects of reproductive mode on demography and life history in *Arabis fecunda* (Brassicaceae). American Journal of Botany 82(6):752-762.

Little, E.L. 1990. The Audubon Society Field Guide to North American Trees – western region. Alfred A. Knopf, New York, NY.

Louda, S.M. 1982. Distribution ecology: variation in plant recruitment over a gradient in relation to insect seed predation. Ecological Monographs 52:25–41.

Louda, S.M. 1983. Seed predation and seedling mortality in the recruitment of a shrub, *Haplopappus venetus* (Asteraceae), along a climatic gradient. Ecology 64:511–521.

Lusk, W.C., M.B. Jones, D.T. Torell, and C.M. McKell. 1961. Medusahead palatability. Journal Range Management 14:248-251.

MacArthur, R.H. and E.D. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, NJ.

Mancuso, M. 1997. Palouse goldenweed (*Haplopappus liatriformis*) monitoring at Craig Mountain—1996 results. Unpublished report prepared by the Idaho Department of Fish and Game, Boise, ID.

Mancuso, M. and R.K. Moseley. 1991. Field investigation of *Haplopappus radiatus*, Region 4 sensitive species on the Payette National Forest. Unpublished report prepared by the Natural Heritage Section, Nongame/Endangered Wildlife Program, Bureau of Wildlife, Idaho Department of Fish and Game, Boise, ID.

Mancuso, M. and R.K. Moseley. 1993. Report on the conservation status of *Haplopappus radiatus* in Idaho. Idaho Conservation Data Center, Idaho Department of Fish and Game, status survey report prepared for Idaho Department of Parks and Recreation, Boise, ID.

Markin, G.P. 1995. Weeds of National Forest Lands of the Northern Rockies. *In*: Biological Control, Ecology and Management of Northern Rocky Mountain Forests. USDA Forest Service, Rocky Mountain Research Work Unit 4151. Available in PDF online at: www.fs.fed.us/rm/ecology/studies/biocontrol/weeds_NFL_report.pdf.

Martin, B.D. 1984. Influence of slope aspect on postfire reproduction of *Encelia farinosa* (Asteraceae). Madroño 31: 187-189.

Mayes, R.A. 1976. A cytotaxonomic and chemosystematic study of the genus *Pyrrocoma* (Asteraceae: Astereae). Unpublished PhD dissertation, University of Texas, Austin, TX.

McDougall, W.B. and H.A. Baggley. 1936. Plants of Yellowstone National Park. United States Government Printing Office, Washington, D.C.

McEvoy, P.B. 1996. Host specificity and biological pest control: how well is research on host specificity addressing the potential risks of biological control? BioScience 46(6):401-406.

Meyer, S.E., D. McArthur, and G.L. Jorgensen. 1989. Variation in germination response to temperature in rubber rabbitbrush (*Chrysothamnus nauseosus*: Asteraceae) and its ecological implications. American Journal of Botany 76(7):981-991.

Michigan Department of Agriculture. 2001-2005. Pesticide and Plant Pest Management Division. Noxious and Restricted Weeds and Prohibited Plants - Michigan. Available online at: http://www.michigan.gov/mda/0,1607,7-125-1569_16993-11250--,00.html [Accessed April 2005].

Miller, M. 2004. Data Assistant, Montana Natural Heritage Program, Helena, MT. Personal communication.

Mills, L.S., D.F. Doak, and M.J. Wisdom. 1999. Reliability of conservation actions based on elasticity analysis of matrix models. Conservation Biology 13(4):815-829.

Misak, R.F., J.M. Al Awadhi, S.A. Omar, and S.A. Shahid. 2002. Soil degradation in Kabd area, southwestern Kuwait city. Land Degradation & Development. 13(5):403-415.

Moghaddam, M.R. 1977. *Reseda lutea*: a multipurpose plant for arid and semiarid lands. Journal of Range Management 30:71-72.

Molina, R.J., J.M. Trappe, and G.S. Strickler. 1978. Mycorrhizal fungi associated with *Festuca* in the western United States and Canada. Canadian Journal of Botany 56:1691-1695.

Montana Department of Environmental Quality. 2005. Historic context – [Mining]. Available at Available online at: http://www.deq.state.mt.us/AbandonedMines/linkdocs/techdocs/27tech.asp [Accessed April 2005].

Montana Natural Heritage Program. 2003. Plants species of concern, April 2003. Montana Natural Heritage Program, Natural Resource Information System, Montana State Library, Helena, MT.

Montana Natural Heritage Program. 2005a. Rare plant field guide. Montana Natural Heritage Program, Helena, MT. Available online at: http://mtnhp.org/plants/index.html?guidebook.asp [Accessed May 2005].

Montana Natural Heritage Program. 2005b. Field observation forms for Species of Concern. Montana Natural Heritage Program, Helena, MT. Available online at: http://mtnhp.org/plants/index.html?guidebook.asp [Accessed May 2005].

Morgan, D.R. 1997. Recticulate evolution in *Machaeranthera* (Asteraceae). Systematic Botany 22:599-615.

Morgan, D.R. and B.B. Simpson. 1992. A systematic study of *Machaeranthera* (Asteraceae) and related groups using restriction site analysis of chloroplast DNA. Systematic Botany 17:511-531.

Moseley, R.K. and M. Mancuso. 1994. Monitoring plan for Snake River goldenweed (*Haplopappus radiatus*) on the Payette National Forest. Unpublished report prepared for Payette National Forest, ID.

Murray, M.P. 1997. High elevation meadows and grazing: common past effects and future improvements. International Journal of Wilderness 3(4):24-27.

NatureServe. 2005. NatureServe Explorer: An online encyclopedia of life [web application]. Version 4.4. NatureServe, Arlington, VA. Available online at: http://www.natureserve.org/explorer [Accessed: March 2005].

Ndakidemi, P.A. and F.D. Dakora. 2003. Legume seed flavonoids and nitrogenous metabolites as signals and protectants in early seedling development. Functional Plant Biology 30(7):729–745.

Nemati, N. 1977. Comparative palatability of *Atriplex canescens*. Journal of Range Management 30:368-369.

Nesom, G. 1994. Subtribal classification of *Astereae* (Asteraceae). Phytologia 76:193-274.

Nesom, G.L. 2000. Generic conspectus of the tribe *Astereae* (Asteraceae) in North America, Central America, the Antilles, and Hawaii. Sida, Botanical Miscellany 20: i-viii, 1-100.

Neumann, P.W. and H.G. Merriam. 1972. Ecological effects of snowmobiles. Canadian Field Naturalist 86(3):207-212.

New York Botanical Garden Herbarium. 2005. Vascular plant database. Available online at: http://sciweb.nybg.org/science2/vii2.asp. Specifically *Pyrrocoma integrifolia* on page: http://207.156.243.8/emu/vh/specimen.php?irn=185416 [Accessed February 2005].

New Zealand Climate Change Office. 2006. Global climate change. New Zealand Ministry for the Environment. Available online at: http://www.climatechange.govt.nz [Accessed January 2006].

Nicholoff, S.H., compiler. 2003. Wyoming Bird Conservation Plan, Version 2.0. Wyoming Partners In Flight. Wyoming Game and Fish Department, Lander, WY. Available online at: http://www.blm.gov/wildlife/plan/WY/Wyoming%20Bird%20Conservation%20Plan.htm Specifically Meadow section at: http://www.blm.gov/wildlife/plan/WY/Meadows.pdf [Accessed December 2005].

Opler, P.A., H. Pavulaan, R.E. Stanford, and M. Pogue, coordinators. 2006. Butterflies and moths of North America. Big Sky Institute at Montana State University and the NBII Mountain Prairie Information Node, Bozeman, MT. Butterflies and Moths of North America Database access available online at: http://www.butterfliesandmoths.org/ [Accessed July 2006].

Padmavati, M. and R. Reddy Arjula. 1998. Enhanced accumulation of flavonoids around the blast (*Pyricularia oryzae*) lesion site in rice (*Oryza sativa* L.). Second International Electronic Conference on Synthetic Organic Chemistry (ECSOC-2). September 1-30, 1998. Available online at: http://www.mdpi.org/ecsoc/.

Pew Center. 2005. Global Climate Change, Pew Center, Arlington, VA. Available online at: http://www.pewclimate.org [Accessed January 2005].

Platt, J.R. 1964. Strong inference. Science 146:347-353.

Pokorny, M.L., R.L. Sheley, C.A. Zabinski, R.E. Engel, A.J. Svejcar, and J.J. Borkowski. 2005. Plant functional group diversity as a mechanism for invasion resistance. Restoration Ecology 13(3):1-12.

Pollard, J.H. 1966. On the use of the direct matrix product in analyzing certain stochastic population models. Biometrika 53:397-415.

Prather, L.A., O. Alvarez-Fuentes, M.H. Mayfield, and C.J. Ferguson. 2004a. The decline of plant collecting in the United States: a threat to the infrastructure of biodiversity studies. Systematic Botany 29:15-28.

Prather, L.A., O. Alvarez-Fuentes, M.H. Mayfield, and C.J. Ferguson. 2004b. Commentary: implications of the decline in plant collecting for systematic and floristic research. Systematic Botany 29:216-220.

Punt, W., S. Blackmore, S. Nilsson, and A. Le Thomas. 1994. Glossary of pollen and spore terminology. LPP Contributions Series, 1. LPP Foundation, Utrecht, The Netherlands.

Raunkiaer, C. 1934. The life forms of plants and statistical plant geography. Clarendon Press, Oxford, UK.

Rauzi, F. and C.L. Hanson. 1966. Water intake and runoff as affected by intensity and grazing. Journal of Range Management 19:351-356.

Ridenour, W.M. and R.M. Callaway. 2001. The relative importance of allelopathy in interference: the effects of an invasive weed on a native bunchgrass. Oecologia 126(3):444-450.

Rieseberg, L.H. 1991. Hybridization in rare plants: Insights from case studies in *Helianthus* and *Cercocarpus*. Pages 171-181 *in* D.A. Falk and K.E. Holsinger, editors. Conservation of Rare Plants: Biology and Genetics. Oxford University Press, Inc, Oxford, UK.

Royal Botanic Gardens, Kew. Undated. The Millennium Seed Bank Project, Wellcome Trust Millennium Building, Wakehurst Place, West Sussex, UK. Available online at: http://www.kew.org/msbp/.

Rydberg, P.A. 1900. Studies on the Rocky Mountain Flora III – some smaller genera of Composites. Bulletin Torrey Botanical Club 27:614-636.

Rydberg, P.A. 1906. Flora of Colorado. Colorado Agriculture Experimental Station Bulletin 100. Experiment Station, Fort Colins, CO.

Ryerson, D.K., D.A. Schlough, C.L. Foreman, G.H. Tenpas, and J.W. Pendleton. 1977. Effects of snowmobile traffic on several forage species and winter wheat. Agronomy Journal 69(5):769-772.

Savela, M. 2005. Researcher, Ecology of Lepidoptera database on the Finnish University and Research Network (FUNET) maintained by Markku Savela. Personal communication. Database available online at: http://www.funet.fi/pub/sci/bio/life/intro.html also http://www.funet.fi/pub/sci/bio/life/insecta/lepidoptera/ [Accessed January 2005].

Scott, J.A. 1997. The butterflies of North America: a natural history and field guide. Stanford University Press, Stanford, CA.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. Bioscience 31:131-134.

Sheehy, D.P. and A.H. Winward. 1981. Relative palatability of seven Artemisia taxa to muledeer and sheep. Journal of Range Management 34:397-399.

Sheley, R.L. and J.K. Petroff. 1999. Biology and management of noxious rangeland weeds. Oregon State University Press, Corvallis, OR.

Silvertown, J., M. Franco, I. Piasanty, and A. Mendoza. 1993. Comparative plant demography – relative importance of life cycle components to the finite rate of increase in woody and herbaceous perennials. Journal of Ecology 81:465-476.

Silvertown, J.W. 1987. Introduction to plant population ecology. Second edition. Longman Scientific and Technical, Harlow, UK.

Simberloff, D. 1988. The contribution of population and community biology to conservation science. Annual Review of Ecology and Systematics 19:473-511.

Smeins, F.E. 1975. Effects of livestock grazing on runoff and erosion. Pages 267-274 *in* Proceedings of American Society of Civil Engineering, Watershed Management Symposium, Utah State University, Logan, UT.

Soulé, M.E. 1987. Viable populations for conservation. Cambridge University Press, Cambridge, UK.

Stahl, P.D., G.E. Schuman, S.M. Frost, and S.E. Williams. 1998. Arbuscular mycorrhizae and water stress tolerance of Wyoming big sagebrush seedlings. Soil Science Society of America Journal 62:1309-1313.

Stebbins, G.L., Jr. 1952. Aridity as a stimulus to plant evolution. The American Naturalist 86:33-44.

Steinback, K.E., L. McIntosh, L. Bogorad, and C.J. Arntzen. 1981. Identification of the triazine receptor protein as a chloroplast gene product. Proceedings National Academy Science USA 78 (12):7463–7467.

Store, R. and J. Jokimaki. 2003. A GIS-based multi-scale approach to habitat suitability modeling. Ecological Modeling 169:1-15.

Strasia, C.A., M. Thorn, R.W. Rice, and D.R. Smith. 1970. Grazing habits, diet, and performance of sheep on alpine ranges. Journal Range Management 23:201-208.

Stubbendieck, J., G.Y. Friisoe, and M.R. Bolick. 1995. Weeds of Nebraska and the Great Plains. Nebraska Department of Agriculture, Lincoln, NE.

Sugden, E.A. 1985. Pollinators of *Astragalus monoensis* Barneby (Fabaceae): new host records; potential impact of sheep grazing. Great Basin Naturalist 45(2):299-312.

Tepedino, V.J. 1979. The importance of bees and other insect pollinators in maintaining floral species composition. Great Basin Naturalist Memoirs 3:139-150.

The Nature Conservancy. 2005a. Long-time ranch family works with The Nature Conservancy to conserve the Centennial Valley. Available online at: http://www.nature.org/wherewework/northamerica/states/montana/news/news1341.html [Accessed April 2005].

The Nature Conservancy. 2005b. The Centennial. Available online at: http://www.nature.org/wherewework/northamerica/states/montana/preserves/art7259.html [Accessed April 2005].

Thomson, J.D., R.C. Plowright, and G.R. Thaler, 1985 Matacil insecticide spraying, pollinator mortality, and plant fecundity in New Brunswick forests. Canadian Journal of Botany 63 (11):2056-2056.

Tidestrom, I. 1925. Flora of Utah and Nevada. Washington Government Printing Office, Washington, D.C.

Urie, S. and K. van Zuuk. 2000. Biological evaluation for sensitive plants, The Carman Watershed restoration and Beckwourth Range allotment project. July 6, 2000. Unpublished document. Sierraville Ranger District, Tahoe National Forest, CA.

U.S. Environmental Protection Agency. 1997. Climate Change and Montana. EPA 230-F-97-008z. Office of Policy, Planning and Evaluation, Climate and Policy Assessment Division, Washington, D.C.

U.S. Global Change Research Program. 2006. US Climate Change Science Program/US Global Change Research Program, Washington, DC. Available online at: www.usgcrp.gov. [Accessed January 2006].

USDA Forest Service. 1988a. Range Plant Handbook Dover Reprint. Dover Publications, Inc., New York, NY.

USDA Forest Service. 1988b. Shoshone National Forest, south half. Forest Service map and interpretative guide. Reviewed in 1989 Rocky Mountain, Region, Denver, CO.

USDA Forest Service. 1995. Forest Service Manual, Title 2600-Wildlife, Fish and Sensitive Plant Habitat Management; USDA Forest Service, Washington, D.C. Available online at: http://www.fs.fed.us/im/directives/fsm/2600/2670-2671.txt.

USDA Forest Service. 2001. Regional Forester Sensitive Species Lists Region 1 (Montana - March 1999; Idaho - March 1999) and Region 4 (April 29, 1994). Available online at: http://roadless.fs.fed.us/documents/feis/data/sheets/summspd/tes_supp/tes_supp.shtml.

USDA Forest Service. 2002. Forest Plan Amendment for Travel Management of the Road and Trail System on the Gallatin National Forest, Montana; Gallatin National Forest; Sweet Grass, Park, Carbon, Gallatin, Madison, and Meagher Counties, Montana. Federal Register 67(240): 76713-76714. Available online at: wais.access.gpo.gov.

USDA Forest Service. 2003a. Region 2. Threatened, endangered and sensitive plants and animals. Supplement No.: 2600-2003-1. Unpublished document. USDA Forest Service, Denver, CO.

USDA Forest Service. 2003b. Vegetation coverages provided by USDA Forest Service Region 2, Lakewood, CO. Unpublished Spatial data.

USDA Forest Service. 2004. Bighorn National Forest – rare plant management strategy. 5 year Action Plan FY 2004-2008. *In*: Draft Environmental Impact Statement and Revised Forest Management Plan. USDA Forest Service, Bighorn National Forest, WY.

USDA Forest Service. 2005a. Threatened, Endangered and Sensitive Species - TES. Forest Service designated Sensitive Species on the National Forests and Grasslands, and related summary information. Forest Service Sensitive Species that are not listed or proposed species under the ESA, 31 October 2005. Available online at: http://www.fs.fed.us/biology/tes/ [Accessed November 2005].

USDA Forest Service. 2005b. Shoshone National Forest—Draft Forest Plan Comprehensive Evaluation Report version 1.1, September 15, 2005.

USDA National Forest. 1994. Final Environmental Impact Statement for the Shoshone National Forest. Land and Resource Management Plan. Park, Fremont, Sublette, Teton and Hot Springs Counties, Wyoming. USDA Forest Service, Cody, WY.

USDA Natural Resources Conservation Service. 2004. The PLANTS Database, Version 3.5. National Plant Data Center, Baton Rouge, LA 70874-4490 USA. Available online at: http://plants.usda.gov.

USDA Natural Resources Conservation Service. Undated. U.S. Fish and Wildlife Wetland Indicator Status searchable database. Available online at: http://plants.usda.gov/wetland.html.

USDI Bureau of Land Management. 2000. Review of Draft BLM (Wyoming) Sensitive Species List DD 11/24/00. Information Bulletin No. WY-2001-004. Available online at : http://www.blm.gov/nhp/efoia/wy/2001ib/WY2001004.html [Accessed May, 2002].

USDI Bureau of Land Management. 2004. Sensitive Species by Field Office - BLM Worland Field Office; BLM Lander Field Office. Updated September 14, 2004. Available online at: http://www.wy.blm.gov/botany/offices.htm.

USDI Bureau of Land Management Wyoming. 2004. Botany - Endemic Plants of Wyoming, Updated September 14, 2004. Available online at: http://www.wy.blm.gov/botany/endemics.htm [Accessed March 2005].

USDI Fish and Wildlife Service. 1988. National list of vascular plant species that occur in wetlands. U.S. Fish and Wildlife Service Biological Report 88 (24).

USDI Fish and Wildlife Service. 1996. National list of vascular plant species that occur in wetlands. Available online at: http://www.fws.gov/nwi/bha/list96.html.

USDI Fish and Wildlife Service. 2003. Red Rock Lakes National Wildlife Refuge. Information last updated August 2003. Available online at: http://redrocks.fws.gov/index.html.

USDI Fish and Wildlife Service. 2006. America's National Wildlife Refuge System. Last updated 23 Aug 2006. Available online at: http://www.fws.gov/Refuges/.

USDI Geological Survey. 2000. Map of the Greater Yellowstone Study Area. Rocky Mountain Mapping Center. Available online at: http://rockyweb.cr.usgs.gov/html/gye/area.html [Accessed March 2005].

USDI Geological Survey Biological Resources Division. 2004. Global Climate Change and Range Shifts of Prairie Nesting Birds: Will the Habitat Be There? USGS Global Change Research in Biology; August 1999 - September 2003. Primary Contact: Douglas H. Johnson, USGS Northern Prairie Wildlife Research Center. Available online at: http://www.nrel.colostate.edu/projects/brd_global_change/proj_55_prairie_birds.html [Accessed June 2004].

Vallentine, J.F. 1990. Grazing management. Academic Press, San Diego, CA.

Waser, N.M. and M.V. Price. 1989. Optimal outcrossing in *Ipomopsis aggregata*: seed set and offspring fitness. Evolution 43(5):1097-1109.

Webb, R.H. and S.S. Stielstra. 1979. Sheep grazing effects on Mojave Desert vegetation and soils. Environmental Management 3:517529.

Webb, R.H., H.G. Wilshire, and M.A. Henry. 1983. Natural recovery of soils and vegetation following human disturbance. Pages 279302 *in* R.H. Webb and H.G. Wilshire, editors. Environmental effects of off-road vehicles: impacts and management in arid regions. Springer-Verlag, NY.

Weber, W.A. and R.C. Wittmann. 2001. Colorado Flora – western slope. Third edition. University Press of Colorado, Boulder, CO.

Welp, L., W. Fertig, G. Jones, G.P. Beauvais, and S.M. Ogle. 2000. Fine Filter analysis of the Bighorn, Medicine Bow, and Shoshone national forests in Wyoming. Unpublished document prepared by the Wyoming Natural Diversity Database, Laramie, WY.

Welsh, S.L., N.D. Atwood, S. Goodrich, and L.C. Higgins. 2003. A Utah flora. Third edition, revised. Brigham Young University, Provo, UT.

Whelan, R.J. 1997. The Ecology of Fire. Cambridge University Press, New York, NY.

Whipple, J. 2005. Botanist. Fort Yellowstone, Yellowstone National Park, WY. Personal communication.

Widén, B. 1987. Population biology of *Senecio integrifolius* (Compositae), a rare plant in Sweden. Nordic Journal of Botany 7:687-704.

Williams, M.C. and L.F. James. 1978. Livestock poisoning from nitro-bearing *Astragalus*. *In*: R.F. Keeler, K.R. Van Kampen, and L.F. James, editors. Effects of poisonous plants on livestock. Academic Press, New York, NY.

Wiser, S.K., R.K. Peet, and P.S. White. 1998. Prediction of rare-plant occurrence: A southern Appalachian example. Ecological Applications 8(4):909-920.

Woodward, L. 1985. Poisonous plants, a colored field guide. Hippocrene Books Inc, New York, NY.

Wright, S. 1931 Evolution in Mendelian populations. Genetics 16:97-159

Wu, B. and F. Smeins. 2000. Multiple-scale habitat suitability modeling approach to rare plant conservation. Landscape and Urban Planning 51:11-28.

Wyoming Natural Diversity Database. 2004. Data compilation for *JnJ Associates* LLC, completed 2004. Unpublished report. Wyoming Natural Diversity Database, University of Wyoming, Laramie, WY.

Wyoming Natural Diversity Database. 2005. Plant Survey Form. Wyoming Natural Diversity Database, Laramie, WY. Available online at: http://uwadmnweb.uwyo.edu/wyndd/ [Accessed May 2005].