Silene kingii (S. Wats.) Bocquet (King's campion)
A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

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COVER PHOTO CREDIT

Silene kingii (King's campion). Photograph by Sherel Goodrich, USDA Forest Service, used with permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *SILENE KINGII*

Status

Silene kingii (King's campion) is a regional endemic restricted to high-subalpine and alpine habitats in northwestern Wyoming, western Colorado, and Utah. The abundance and distribution of the species are poorly understood throughout its range, including in USDA Forest Service (USFS) Region 2. *Silene kingii* has no federal status, and it is not designated a sensitive species by any unit of the USFS or the Bureau of Land Management. The NatureServe global rank for *S. kingii* is vulnerable (G3). In USFS Region 2, the Colorado Natural Heritage Program and the Wyoming Natural Diversity Database ranks it as critically imperiled (S1). It is reported but unranked (SNR) in Utah. These global and subnational ranks have no regulatory status.

Primary Threats

Threats to specific *Silene kingii* occurrences are not documented. The current level of anthropogenic threats to this species appears to be low due to its occurrence in the alpine and high sub-alpine zones. Recreational activities and livestock grazing in *S. kingii* habitat may pose a threat to some occurrences. As the human population grows in areas with easy access to *S. kingii* habitat and as recreational use increases, recreational impacts may become substantially more significant. *Silene kingii* may be vulnerable to competition from aggressive, non-native vascular plant species, but currently, no specific sites are known to be at risk. Global climate change that leads to warmer temperatures is a potential threat to all species currently restricted to sub-alpine and alpine-tundra zones since changing conditions in these zones are likely to lead to less potential habitat for *S. kingii*. A potential risk to this species is that the lack of knowledge about its abundance and distribution obscures its true vulnerability.

Primary Conservation Elements, Management Implications and Considerations

Silene kingii is an herbaceous perennial species that is endemic to mountain ranges in Utah, Wyoming, and Colorado. The majority of the known occurrences in both Wyoming and Utah are on National Forest System land. Eighteen of the 20 known occurrences in Wyoming are on land managed by USFS Region 2. A critical conservation implication of this situation is that a significant loss of occurrences on National Forest System land would likely have a substantial impact of the viability of the species in Wyoming. Within Region 2, emphasis may best be placed on finding new *S. kingii* occurrences and on monitoring known occurrences. The information available suggests that *S. kingii* may be found in more areas in the alpine and sub-alpine zones within its range than are currently known.

Little is known about the life history or reproductive biology of *Silene kingii*. The species may experience periods of prolonged dormancy. The frequency with which natural recruitment occurs is unknown, but the species is believed to be robust in the Uinta Mountains. Pollinators may be required for reproduction. These facets of its life history are important in understanding the best management practices and need further study. There are no management plans directly concerning *S. kingii*. Management practices that increase either the frequency or intensity of natural perturbations, or by themselves apply additional stresses to the plants, may significantly negatively affect population viability.

The taxonomic status of many Silene species, including *S. kingii*, has been the subject of several revisions. The taxon name *S. kingii* is accepted in the most recent edition of the *Flora of North America*. Some taxonomists in Utah treat *S. kingii* as a variety of *Lychnis apetala* (var. *kingii*) while others, including some in Colorado, refer to the taxon as *Gastrolychnis kingii*. *Silene kingii* co-occurs with *S. hitchguirei* (synonyms: *L. apetala* var. *montana*, *S. uralenesis* ssp. *montana*). There has been some confusion in distinguishing between *S. kingii* and *S. hitchguirei* plants, especially when mature flowers, seeds, and/or leaves are missing. This has led to uncertainty with respect to the historical range and abundance of *S. kingii*.

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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). *Silene kingii* (King's campion) is the focus of an assessment because it is a rare taxon in Region 2. A rare species may require special management, so knowledge of its biology and ecology is critical. This assessment addresses the distribution, habitat, ecology, and population biology of *S. kingii* throughout its range but particularly on National Forest System lands in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species 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 scientific knowledge accumulated prior to initiating the assessment. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and an outline 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, this assessment cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

Scope

This assessment examines the biology, ecology, conservation, and management of *Silene kingii* with specific reference to the geographic and ecological characteristics of USFS Region 2. Little information is available on most aspects of the biology and ecology of *S. kingii*. This being the case, I have had to link what is known about *S. kingii* with information derived from studies of other species in the *Lychnis* group. It is important to note that the relevance of the observations and research on other species to *S. kingii* needs to be established by rigorous study. In particular, more research into the distribution, abundance, reproductive biology, demography, community ecology, and potential vulnerability of *S. kingii* is needed to confirm the information presented in this assessment.

Although some of the literature relevant to *Silene kingii* may originate from field investigations outside the region, 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 *S. kingii* 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 the assessment, peer-reviewed (refereed) literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. Not all publications on *Silene kingii* may have been referenced in the assessment, but an effort was made to consider all relevant documents. The assessment emphasized the refereed literature, such as taxonomic treatments, because this is the accepted standard in science. However, there is very little refereed literature pertaining to *S. kingii*'s biology and ecology. Therefore, some non-refereed literature was used in the assessment. Although in some cases non-refereed publications and reports may be regarded with greater skepticism, many reports or non-refereed publications on rare plants are reliable. For example, non-refereed publications on rare plants are often 'works-in-progress' or isolated observations on phenology or reproductive biology. In some cases, insufficient funding or manpower may have prevented work in years subsequent to the initial study. One year of data is generally considered inadequate for publication in a refereed journal but still provides a valuable contribution to the knowledge base of a rare plant species. Unpublished data (e.g., herbarium records) were important in estimating the geographic distribution and abundance of this species. These data required special attention because of the diversity of persons and methods used in collection. Records that were associated with locations at which herbarium specimens had been collected at some point in time were weighted more heavily than observations only.

Occurrence data were compiled from the Wyoming Natural Diversity Database (2004), the Colorado Natural Heritage Program (2004), University of Colorado Herbarium (COLO), Colorado State University Herbarium (CS), Colorado College Herbarium (COCO), New York Botanical Garden

Herbarium (NY), National Herbarium of Canada (CAN), the Rocky Mountain Herbarium at the University of Wyoming (RM), the Intermountain Herbarium of Utah State University (UTC), and from the literature. Details of specimens at the Harvard University Herbaria (Kittredge personal communication 2004) and the Field Museum of Natural History were unavailable (Niezgoda personal communication 2004).

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference, as described by Platt, suggests that experiments will produce clean results (Hillborn and Mangel 1997), which may be observed in certain physical sciences but not necessarily in ecology. The geologist T.C. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data. A variety of scientific tools (i.e., observation, inference, experiments, modeling, logical inference) may be used to sort among alternatives and to guide our understanding of the world (Hillborn and Mangel 1997).

Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for articulate ideas is noted, and alternative explanations are 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.

Uncertainty has persisted with respect to the taxonomic treatment of *Silene kingii*. Welsh et al. (2003) considers *S. kingii* to be a variety of a more widespread taxon, *Lychnis apetala*, whereas other authors recognize it as a full species (Dorn 2001, Weber and Wittmann 2001a, 2001b, Hartman personal communication 2004, Morton personal communication 2004, Morton 2005). In addition, uncertainty has clouded the precise range of *S. kingii*. During the most recent examination of *S. kingii* specimens, it was determined that its range is restricted to Utah and Wyoming (Hartman personal communication 2004). However, at least one specimen was identified from San Juan County, Colorado during the examination of herbarium specimens of *Silene* species for the most recent edition of the Flora of North America (Morton personal communication 2004, Morton 2005). Uncertainties with respect to rarity and range sometimes exist because there is 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 extensive areas remain unsurveyed. To some extent, this is true for all rare taxa, but rarity is also relative and many taxa are regarded as not being rare precisely because casual observation has noted that they occur frequently.

A taxon that is referred to as *Silene kingii* var. *novum* (Markow and Fertig 2000, Welp et al. 2000, Wyoming Natural Diversity Database 2004), is morphologically very similar to *S. kingii* and referred to in Dorn (2001) as an "undescribed taxon." This variety is reportedly distinguishable from *S. kingii* var. *kingii* by having predominantly spreading and gland-tipped hairs on the basal leaves (Markow and Fertig 2000, Dorn 2001, Wyoming Natural Diversity Database 2006). This proposed variety of *S. kingii*, var. *novum* is endemic to the Absaroka and Wind River ranges in Wyoming (Markow and Fertig 2000, Dorn 2001, Wyoming Natural Diversity Database 2006). Both varieties of *S. kingii* co-occur in some areas in the Arrow Mountain region on the Shoshone National Forest (Welp et al. 2000). Because this variety of *S. kingii* has not been formally described, it is not discussed in this assessment. However, the likelihood that different varieties exist in the Absaroka and Wind River ranges adds another layer of complexity in understanding the biology and ecology of the species and contributes to the uncertainty as to how *S. kingii* occurrences may need to be managed to maintain maximum levels of genetic diversity.

Publication of the Assessment on the World Wide Web

To facilitate the use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site (http//:www.fs.fed.us/r2/projects/scp/assessments/index.shtml). 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 were peer reviewed prior to their release on the Web. This assessment was reviewed through a process administered by the Society for Conservation Biology, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

Management Status and Natural History

Management Status

Silene kingii occurs in USFS Region 2 in Colorado and Wyoming and Region 4 in Utah. There are a total of 18 known occurrences on the Shoshone National Forest (Region 2) and 19 on National Forest System lands in Utah (Region 4). At least two occurrences are known from public land managed by the Bureau of Land Management (BLM) in Wyoming (WY5 and WY19 in **Table 1**). Neither the USFS nor the BLM designates *S. kingii* as a sensitive species in the states in which it occurs (Bureau of Land Management 2002, USDA Forest Service 2003, Prendusi personal communication 2004, USDA Forest Service 2005). Sensitive species designation is awarded to a species that is "identified by the Regional Forester 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 or predicted downward trend in habitat capability that would reduce a species' existing distribution" (USDA Forest Service 1994a). Sensitive species designation ensures that the potential impacts to populations on National Forest System lands are evaluated prior to development projects.

NatureServe and state natural heritage programs use a system to rank sensitive taxa at state (S) and global (G) levels on a scale of 1 to 5. A ranking of 1 indicates the most vulnerable and 5 the most secure (see Ranks in the **Definitions** section. These ranks have no regulatory status and only serve to indicate a taxon's conservation status. The global status of *Silene kingii* is vulnerable (G3; NatureServe 2004). The Wyoming Natural Diversity Database (2006) and Colorado Natural Heritage Program (2006) rank *S. kingii* as critically imperiled (S1). Fertig (1998) described *S. kingii* as a "high priority taxon" during a review of the rare plants of the Shoshone National Forest. *Silene kingii* occurs in the state of Utah but is unranked (SNR) by the Utah Heritage Program (NatureServe 2004). NatureServe (2004) reports that "distinctiveness of this entity [*S. kingii*] as a taxon at the current level is questionable; resolution of this uncertainty may result in change from a species to a subspecies or hybrid, or inclusion of this taxon in another taxon, with the resulting taxon having a lower-priority (numerically higher) conservation status rank."

Silene kingii is the accepted name in the most recent edition of the Flora of North America (Morton 2005), in a recently published Wyoming flora (Dorn 2001), and by the Integrated Taxonomic Information System (2006). In the most recent edition of A Utah Flora, Welsh et al. (2003) treated the taxon as a variety of *Lychnis apetala*, *L. apetala* var. *kingii*. In Colorado, *S. kingii* is referred to as *Gastrolychnis kingii* (Weber and Wittmann 2001a, 2001b), after the treatment by Löve and Löve (1976). Many Colorado specimens initially identified as *S. kingii* have since been determined to be *S. hitchguirei* (Hartman personal communication 2004).

Although *Silene kingii* has been reported from Montana and Alberta (NatureServe 2004), it is doubtful that the taxon occurs in either of these areas. The Montana Natural Heritage Program botanist is reviewing the status (SU in NatureServe 2004) of *S. kingii* in Montana to determine if it warrants being added to the Montana Species of Concern List or if the occurrence is actually a false report due to misidentification (Mincemoyer personal communication 2004). In Canada, it is reported but unranked (SNR) for Alberta (NatureServe 2004). The precise source of the original report that it occurs in Alberta is unknown, and its occurrence there is also under review (Rintoul personal communication 2004).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

In Region 2, as well as throughout its range, *Silene kingii* occurs on land managed by the USFS, the BLM, and possibly on private land but enjoys no special protection in any area in which it grows. Of the 20 known occurrences in Wyoming, 18 have been reported from the Shoshone National Forest in Region 2 (**Table 1**). Within the Shoshone National Forest, *S. kingii* has been found in the Popo Agie (one occurrence), Fitzpatrick (three occurrences), and Washakie (nine occurrences) wilderness areas. Congress passed the

Table 1. *Silene kingii* occurrences in Wyoming. The information was obtained from Wyoming Natural Diversity Database (2004), and herbarium voucher labels. There is no information on the abundance of *S. kingii* at any occurrence. Those occurrences with specimen verification are indicated as herbarium specimens in the column marked "sources of information."

Arbitrary number	County	Dates observed	Management	Location	Habitat	Comments	Sources of information[1]
1	Fremont	7 Aug 1965	USDA Forest Service (USFS) Shoshone National Forest, Popo Agie Wilderness	East slope of the Wind River Range at top of Valentine Mountain approximately 6.5 miles west of the Dickinson Park Guard Station	Coarse granite soil in alpine zone	Observed in flower. Identified as the var. *novum*	Wyoming Natural Diversity Database (2004)
2	Fremont	13 Aug 1997	USFS Shoshone National Forest, Fitzpatrick Wilderness	From Echo Lake up drainage to saddle between peaks 11801 and 11594, approximately 17 miles south-southwest of Dubois	Whitebark pine forest to alpine meadows on slopes and drainage	In flower and fruit; identified as the var. *novum*	*D. Rosenthal #3912* RM. Wyoming Natural Diversity Database (2004).
3	Fremont	10 Aug 1985 16 Jul 1996 18 Jul 1996	USFS Shoshone National Forest, Fitzpatrick Wilderness	Arrow Mountain region; in the vicinity of Old Glacier Trail, Circle Benchmark, approximately 1.5 miles south of Circle benchmark, "Peak 11696," and on slopes to the north, south and east of Arrow Mountain	Igneous and metamorphic boulder fields, talus slopes, rocky slopes, and alpine meadows	Occurrence includes at least nine sub-occurrences within eight sections. 10-Aug-1985: Observed in late flower and fruit. "Plants may correspond to "var. *kingii*"." 16/18-Jul-1996: Observed in flower and fruit by R. Hartman. "Plants correspond to var. *novum*, an undescribed taxon."	*R.L. Hartman #55486 with D. Rosenthal*, *R.L. Hartman #55463 with D. Rosenthal*, *R.L. Hartman #55577 with D. Rosenthal*, RM. Wyoming Natural Diversity Database (2004).
4	Fremont	29 Jun 1997 7 Jul 1997	USFS Shoshone National Forest, Fitzpatrick Wilderness	Northeast Wind River Range, north and south slope of Whiskey Mountain; two subpopulations: (1) north side of Whiskey Mountain, approximately 3.5 miles southeast of Dubois"; (2) south slope of Whiskey Mountain at junction of the Whiskey Mountain and Ross Lake trail	Two main habitats: (1) North slope colony: Limestone outcrops in pine/spruce forest several years after burn ; (2) South slope colony: rocky ridges and slopes in alpine meadows; calcareous	29-Jun-1997: north slope colony: observed in flower and fruit. Identified as the var. *novum* 7-Jul-1997: south slope colony: observed in flower	*D. Rosenthal #1664* RM. *D. Rosenthal #1945 with C. Binger* RM. Wyoming Natural Diversity Database 2004.
5	Hot Springs	4 Jul 1984	Bureau of Land Management (BLM)	Southeastern Absarokas; Castle Rocks and vicinity in North Fork Owl Creek drainage, approximately 42 miles west-northwest of Thermopolis	Ridge top meadow	No information	*B.E. Nelson #11189* RM

Table 1 (cont.).

Arbitrary number	County	Dates observed	Management	Location	Habitat	Comments	Sources of information[1]
6	Park	22 Aug 1983 3 Aug 1986	USFS Shoshone National Forest, Washakie Wilderness	Absaroka Range, "southwest side of Brown Basin" south of Greybull Pass, approximately 5.5 miles south of Francs Peak; approximately 2 miles northwest of Kirwin, headwaters of the Greybull river between Greybull Pass and Yellow Creek	Alpine meadows and rocky slopes; occurs with *Senecio fuscatus* and *Papaver kluanense*	At least two sub-occurrences within two sections. 13-Aug-1986: Observed in flower and fruit. Flowers white. Identified as the var. novum and unspecified variety	*R. L. Hartman #17207a* RM. Wyoming Natural Diversity Database 2004.
7	Fremont	14 Aug 1984	USFS Shoshone National Forest sub-occurrences outside and within Washakie Wilderness	Absaroka Mountains; approximately 32 miles southeast of Meeteetse in the vicinity of Dollar Mountain	Alpine meadows on calcareous substrate	At least two sub-occurrences. No information	*R.S. Kirkpatrick #5524 with R.E.B. Kirkpatrick* RM
8	Park	8 Aug 1966	USFS Shoshone National Forest, Washakie Wilderness	Absaroka Range, "vicinity of Snow Lake, 5 miles north of the confluence of Wiggins Fork and Frontier Creek"	Alpine tundra	Observed in flower; identified as the var. *novum*	Wyoming Natural Diversity Database (2004)
9	Park	19 Aug 1984	USFS Shoshone National Forest, Washakie Wilderness	Absaroka Mountains; on the Shoshone Plateau approximately 24 miles north of Dubois	Dry meadows, alpine	No information	*R.S. Kirkpatrick #5755 with R.E.B. Kirkpatrick* RM
10	Park	14 Aug 1983	USFS Shoshone National Forest	Southeastern Absarokas; ridge just south of Jojo Creek, 1 to 2 miles east-southeast of Jojo Mountain	Rocky alpine ridge with scattered turf communities dominated primarily by *Geum rossii* and *Trifolium nanum*	No information	*R.L. Hartman #16764 with R.S. Kirkpatrick* RM
11	Park	14 Aug 1983	USFS Shoshone National Forest	Southeastern Absarokas; Francs Fork, 4-6 air miles south-southwest of trail head	Alpine meadows	Several sub-occurrences over three sections. No information	*R.L. Hartman #16712* RM
12	Park	22 Aug 1984	USFS Shoshone National Forest (may extend on to private land)	Southeastern Absarokas; Chief Mountain to Galena Ridge, approximately 2.5-3 miles north of Kirwin	Alpine meadows and talus slopes	No information	*R.L. Hartman #19274a* RM
13	Fremont	29 Aug 1984	USFS Shoshone National Forest, Washakie Wilderness	Absaroka Mountains; approximately 28 miles north of Dubois, in the vicinity of Emerald Lake and headwaters of Emerald Creek	Alpine meadows	Two sub-occurrences. No information	*R.S. Kirkpatrick #5755 with R.E.B. Kirkpatrick* RM
14	Park	28 Jul 1984	USFS Shoshone National Forest	Absaroka Mountains; 21 miles west-southwest of Meeteetse, in the vicinity of headwaters of Timber Creek, approximately 3.5 miles southwest of the Timber Creek Ranger Station	Alpine fell fields	Two sub-occurrences. No information	*R.S. Kirkpatrick #5104* RM

Table 1 (concluded).

Arbitrary number	County	Dates observed	Management	Location	Habitat	Comments	Sources of information[1]
15	Park	12 Jul 1983	USFS Shoshone National Forest	Absaroka Mountains; approximately 22 miles west-southwest of Meeteetse and approximately 1 mile northeast of Phelps Mountain	Alpine slopes	No information	*R.S. Kirkpatrick #1082 with R.E.B. Kirkpatrick* RM
16	Park	25 Aug 1984	USFS Shoshone National Forest, Washakie Wilderness	Southeastern Absarokas; Boulder Basin Trail in Castle Creek drainage	Grassy slopes and wooded areas; grassy slopes	At least two sub-occurrences within two sections. No information	*R.L. Hartman #19494* RM
17	Park	25 Aug 1984	USFS Shoshone National Forest, Washakie Wilderness	Southeastern Absarokas; Eleanor Creek north to ridge	Grassy and rocky slopes and ridges	At least two sub-occurrences within two sections. No information	*R.L. Hartman #19351* RM
18	Park	29 Jul 1989	USFS Shoshone National Forest, Washakie Wilderness	Southeastern Absarokas; top of Boulder Ridge - ridge between South Fork Shoshone River and Boulder Creek, approximately 44 miles southwest of Cody	Open, rocky habitats along ridge crest, prominent species include *Haplopappus macronema*, *Erigeron caespitosus*, and *Astragalus aboriginum*	Sub-occurrences in two sections. No information	*E.F. Evert #18037* RM
19	Park	14 Aug 1982 29 July 1984	BLM Carter Mountain Area of Critical Environmental Concern; some sub-occurrences may be on State or private land	Absaroka Range, Carter Mountain, along Carter Mountain Road near the head of Rose Creek, west of Meeteetse. Absaroka Mountains; approximately 21 miles west of Meeteetse, along ridge between the North Fork of Pickett Creek and Little Rose Creek, up to Peak 11448	Alpine meadows	At least five or six sub-occurrences within approximately five sections 14-Aug-1982: Observed in fruit. Identified as var. *kingii*	*R.S. Kirkpatrick #5198* RM. Wyoming Natural Diversity Database (2004).
20	Park	31 Jul 1984	USFS Shoshone National Forest; some sub-occurrences outside and within Washakie Wilderness	North Fork Shoshone River Drainage; Absaroka Mountains; on Sheep Mesa on the divide between Blackwater and West Blackwater creeks	On tundra in fellfield and dry meadow habitats	At least three sub-occurrences within three sections. No information	*E.F. Evert #7284* RM

[1]Herbaria acronyms, RM = Rocky Mountain Herbarium at the University of Wyoming in Laramie, Wyoming, USA, according to Holmgren and Holmgren (1998). Index Herbariorum. 1998 onwards (continuously updated). New York Botanical Garden, Bronx, NY. Available online at: http://sciweb.nybg.org/science2/IndexHerbariorum.asp [Accessed January 2006].

1964 Wilderness Act[1] to protect pristine public lands by designating them as Wilderness Areas (Environmental Media Services 2001). Wilderness is defined in the law as "an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions". In general, the Wilderness Act prohibits commercial activities, motorized access, roads, bicycles, structures, and facilities. However, Congress has granted several exemptions to these guidelines. Individual National Forests can limit the size of groups that visit specific wilderness areas at one time.

On the Shoshone National Forest, at least one *Silene kingii* occurrence is located within the proposed Arrow Mountain Research Natural Area (RNA), which is primarily managed for recreation and bighorn sheep habitat (Houston personal communication 2004). Maintaining bighorn sheep habitat is not necessarily consistent with protecting *S. kingii* habitat. The objectives of the proposed Arrow Mountain RNA are to "1) maintain a reference area for a) monitoring the effects of resource management techniques and practices applied to similar ecosystems, (b) comparing results from manipulative research, and (c) determining the range of natural variability; 2) protect elements of biological diversity; 3) provide a site for non-manipulative scientific research; and 4) provide on-site and extension educational opportunities" (Jones and Fertig 1999). The habitat of *S. kingii* may be protected under objective 2, but specific actions to maintain *S. kingii* populations would not be considered in any management plans because the taxon is not designated a USFS sensitive species. No inventory or monitoring surveys for *S. kingii* have been conducted or are planned on the Shoshone National Forest (Houston personal communication 2004).

At least one *Silene kingii* occurrence (WY-19 in **Table 1**) is within the Carter Mountain Area of Critical Environmental Concern (ACEC) managed by the BLM in Wyoming. An ACEC is an area within public lands where special management attention is required to protect and prevent irreparable damage to important historic, cultural, or scenic values, fish and wildlife resources, or other natural systems or processes, or to protect life and safety from natural hazards (Federal Land Policy and Management Act of 1976, Section 103(a)). Livestock grazing is allowed on the three allotments in this ACEC (Bureau of Land Management 1999). Vehicular use in the ACEC is limited to designated roads and trails (Bureau of Land Management 1999). The ACEC is open to locatable mineral entry. The Carter Mountain ACEC is also open to exploration and development of leasable minerals, subject to application of the standard mitigation guidelines. *Silene kingii* is not explicitly protected, but ACEC status may protect its habitat to some extent because the management objective of the Carter Mountain ACEC is to protect areas of unique alpine tundra and fragile soils (Bureau of Land Management 1999). The Carter Mountain ACEC is an avoidance area for future utility and transportation systems rights-of-way. If rights-of-way through the ACEC cannot reasonably be avoided, then the effects of right-of-way construction on soils, watershed, and alpine tundra will be intensively mitigated (Bureau of Land Management 1999). However, because *S. kingii* is not designated as a BLM sensitive species, there is no certainty that this taxon will be specifically considered in any mitigation plans.

Biology and Ecology

Classification and description

Systematics and synonymy

The Integrated Taxonomic Information System (ITIS) lists *Silene kingii* as the accepted binomial for this taxon (2006). Synonyms of *S. kingii* are listed in **Table 2** and include *Gastrolychnis kingii* in Weber and Wittmann (2001a, 2001b) and *Lychnis apetala* var. *kingii* in Welsh et al. (2003).

Silene is a genus in the Caryophyllaceae, commonly known as the pink or catchfly family. The genus *Silene* is distributed throughout the northern hemisphere, but the greatest diversity of species is in regions of the Middle East and around the Mediterranean Sea. In the United States, the majority of the native, perennial *Silene* species occur west of the Rocky Mountains (Kruckeberg 1961). Supraspecific nomenclature has been a subject for debate over several centuries. The genus *Silene* has been split into several genera, including *Lychnis*, *Cucubalus*, *Agrostemma*, *Coronaria*, and *Melandrium* (Williams 1896, Fernald 1950, Chowdhuri 1955, Oxelman and Lidén 1995).

[1]Wilderness Act of 1964. 16 U.S.C. 1131-1136, 78 Stat. 890 – Public Law 88-577, approved September 3, 1964, United States of America.

Table 2. Synonyms of *Silene kingii* (see Weber and Wittmann 2001a, 2001b, Welsh et al. 2003, Morton 2005).

Synonyms of *Silene kingii*	**Author**
Gastrolychnis kingii	(S. Watson) Weber
Lychnis apetala[1] var. *kingii*	(S. Watson) Welsh
Lychnis kingii	S. Watson
Melandrium kingii	(S. Watson) Tolmatchev
Wahlbergella kingii	(S. Watson) Rydberg
Lychnis ajanensis[2]	S. Watson (see **Figure 1**)

[1]Not related to *S. apetala* Willd., which is an annual species of the Mediterranean and Middle East regions (Williams 1896).

[2]*Lychnis ajanensis* described by Watson in Bot. King's Expl. Exped 5: 37 1871, which is not the same as *L. ajanensis* Regel Bull. Soc. Nat. Mosc. 34:564 1861.

Linnaeus appears to have been the first to differentiate *Lychnis* species from *Silene* species (1753). He based the division on the number of styles, three in *Silene* species and five in *Lychnis* species. However, this character is not consistent between the two genera (Maguire 1950, Chowdhuri 1955). The nature of the capsule valve, which is split in *Silene* but entire in *Lychnis*, was added later as an important diagnostic between the two and has been considered to give a satisfactory segregation of ambiguous species (Chowdhuri 1955). Chowdhuri (1957) included all species of the genus *Viscaria* in the genus *Lychnis* and designated the type species to be *L. flos-cuculi*. The type designated by Britton and Brown (1913) was *L. chaledonica*. The genus *Melandrium* (*Melandryum*) has been applied to segments of both *Silene* and *Lychnis* assemblages (Maguire 1950).

Ruprecht accepted the genus *Gastrolychnis* and described *G. apetala* in 1850. Based on morphological and cytological characteristics, Löve and Löve (1976) proposed that the genus *Gastrolychnis* include all arctic-alpine hermaphroditic taxa that were hitherto included in either *Melandrium* or *Silene* (*Lychnis*). Following this concept, Weber described *G. kingii* in 1985.

Some treatments of *Silene* abandoned the recognition of subgenera but adopted sections in which to classify species. *Silene kingii* is placed in section *Physolychnis* according to Bocquet (1967, 1969) or section *Gastrolychnis* according to Chowdhuri (1957). Greuter (1995) considered that, with the knowledge available at the time, *Silene* and *Lychnis* are generally unnatural assemblages and that however far one may proceed with recognizing segregate genera among the genus *Silene*, "one will inevitably be left with a large, polymorphic and highly paraphyletic residue that cannot be split further." Results from studies that examined nucleotide sequence variation in nuclear ribosomal DNA, chloroplast DNA, and nuclear DNA within the tribe *Silenae* (Oxelman and Lidén 1995, Oxelman et al. 1997, Popp 2004) support this view.

Taxonomic difficulties are reported to be very few amongst North American *Silene* taxa because of sharp morphological discontinuities separating most species (Kruckeberg 1961). Unfortunately, this clarity does not appear to have been entirely true for *S. kingii*. Scott (1995) combined *S. kingii* with *S. hitchguirei* under *Lychnis apetala*, and Welsh et al. (2003) treated *S. kingii* as a variety of *L. apetala*. Welsh et al. (2003) state that, "Pubescence and seed differences appear to be the most useful diagnostic features of this taxon, but pubescence varies considerably and the two phases [var. *kingii* and var. *montana*] not only occur together within populations but are occasionally found mounted on the same herbarium sheet."

J.K. Morton (2005), who wrote the most recent treatment of North American *Silene* species, has not maintained the genus *Lychnis* and has included all North American species in the genus *Silene*. He notes that *S. kingii* is very similar to, and probably a close relative of, *S. uralensis* from which it is distinguished by its non-winged seeds and its elliptic fruiting calyx (Morton personal communication 2004). However, he also notes that some material from the southern Rocky Mountains, growing with *S. uralensis*, is intermediate between the two species, in having narrowly winged seeds (Morton personal communication 2004). More study is needed to resolve the taxonomic issues surrounding *S. kingii* (Weber 2003, Morton 2005). Synonyms for *S. uralensis* are listed in the **Appendix** to this assessment.

It is also worth noting that *Silene hitchguirei* is a synonym for *Lychnis apetala* var. *montana* and *L. montana*, whereas *S. montana* is a completely unrelated taxon found in the Sierra Nevada Mountains of California (Hitchcock and Maguire 1947). Similarly, *L. apetala* is very distinct from *S. apetala*, which is an annual species of the Mediterranean and Middle East regions. This similarity of the names in the literature could lead to confusion for the casual reader.

History of species

Watson (1871) originally described *Lychnis kingii* as *L. ajanensis*, but an Asian species already had priority to the specific epithet. The species was later renamed *L. kingii* in honor of Clarence King who led an expedition into the Uinta Mountains in 1867-1869 (Watson 1877). *Lychnis kingii* was described from a collection from the "Peaks of the Uintas at head of Bear River" (Watson 1877). Watson (1877) and Bocquet (1967) also noted that Parry collected a syntype (*#43* Gray Herbarium) from northwestern Wyoming, with no precise location, in 1873. Maguire (1950) commented that this specimen had naked filaments and a shorter calyx and petals than the one from the Uinta Mountains. Bocquet (1967) revised *Silene*, section *Physolychnis*, and cited the *Watson #153* collection at the Gray Herbarium as the holotype, with isotypes at the New York Botanical Garden Herbarium and U.S. National Herbarium. A digital photograph of the isotype located in the U.S. National Herbarium is shown in **Figure 1** (see **References** section for Internet address). The other original specimens used to describe the species are difficult to locate. The *Parry #43* collection in the Harvard University Herbaria Database, which includes the Gray Herbarium, apparently refers to a collection of *Lupinus kingii*. In addition, the *Watson #153* collection refers to *Dichromena watsonii* at both the New York Botanical Garden Herbarium and the Harvard University Herbaria Databases (see **References** section for Internet addresses).

Since the late 1800s, *Silene kingii* has been collected sporadically in both Wyoming and Utah (Tables 1 and 3). In Wyoming, approximately three occurrences, all on National Forest System land, have been visited in the last decade (WY- 2, 3, and 4 in **Table 1**). In Utah, no collections of *S. kingii* have been reported within the last 10 years. However, USFS personal recorded its presence within vegetation plots on the Wasatch-Cache and Ashley national forests during this period (Goodrich personal communication 2004). In Colorado, *S. kingii* is known from San Juan County (Morton personal communication 2004) and Chaffee County (Kelso personal communication 2004). The date *Silene kingii* was first collected in Colorado is not known. A problem with defining its history in Colorado is that many specimens collected in this state and initially identified as *S. kingii* have since been determined to be other species of *Silene* (Hartman personal communication 2004). No targeted surveys appear to have been made for the taxon in any part of its range.

Non-technical description

The following description is derived from Morton (2005), Markow and Fertig (2000), Welsh et al. (1993), Dorn (1992, 2001), and Scott (1995). *Silene kingii* is a low-growing, compact, perennial, herbaceous plant. It has a thick, fleshy taproot and a many-branched caudex. The stems are 5 to 20 cm tall, erect, unbranched below the flowers, and bear two to four pairs of leaves. It is covered throughout with short, spreading and densely glandular hairs. The stalked basal leaves grow in tufts. Each basal leaf has linear to lance-shaped blades that are 1.5 to 10 cm long and 1.5 to 5 mm wide. The hairs on the basal leaves are non-glandular and point downwards. The stem leaves are essentially stalkless, linear or lance-shaped, and 1 to 4, or sometimes up to 6, cm long. The flowers are 10 to 20 mm in diameter and usually only one, but sometimes two or three, at the top of the stem. The flower stalk is usually erect, but sometimes it is somewhat curved or reflexed near the tip. The petals are light pink to purple, with 2-lobed blades that taper to a narrow base and are mostly concealed within a somewhat inflated, urn-shaped, glandular-hairy calyx. The calyx has ten prominent purplish veins. Each flower has five, or sometimes only four, stigmas. Stigmas and stamens equal the corolla. The fruit is a capsule from 1 to 18 mm in length. The capsule dehisces with five curved teeth, which later split into ten, at its mouth. The dark brown seeds are kidney shaped, wingless, 0.75 to 1 mm long, and have small bumps on the seed coat surface. **Figure 2** and **Figure 3** are photographs of *S. kingii*.

In order to make a positive identification of *Silene kingii*, it is essential that mature flowers, seeds, and leaves are available (Welp et al. 2000). *Silene hitchguirei* and *S. uralensis* may be mistaken for *S. kingii*. In addition, Welp et al. (2000) cautions that *S. drummondii* morphologically resembles *S. kingii*. *Silene hitchguirei* has seeds with narrow wings on the margins and a non-inflated calyx (Welp et al. 2000, Morton 2005). *Silene uralensis* has seeds with broad wings on the margins and an inflated calyx. *Silene drummondii* usually has two to several flowers with a non-inflated calyx and stems over 20 cm tall (Dorn 1992, 2001). Descriptions of *S. hitchguirei* and *S. uralensis* are available in several botanical texts, including Welsh et al. (2001), Dorn (1992, 2001), and Morton (2005).

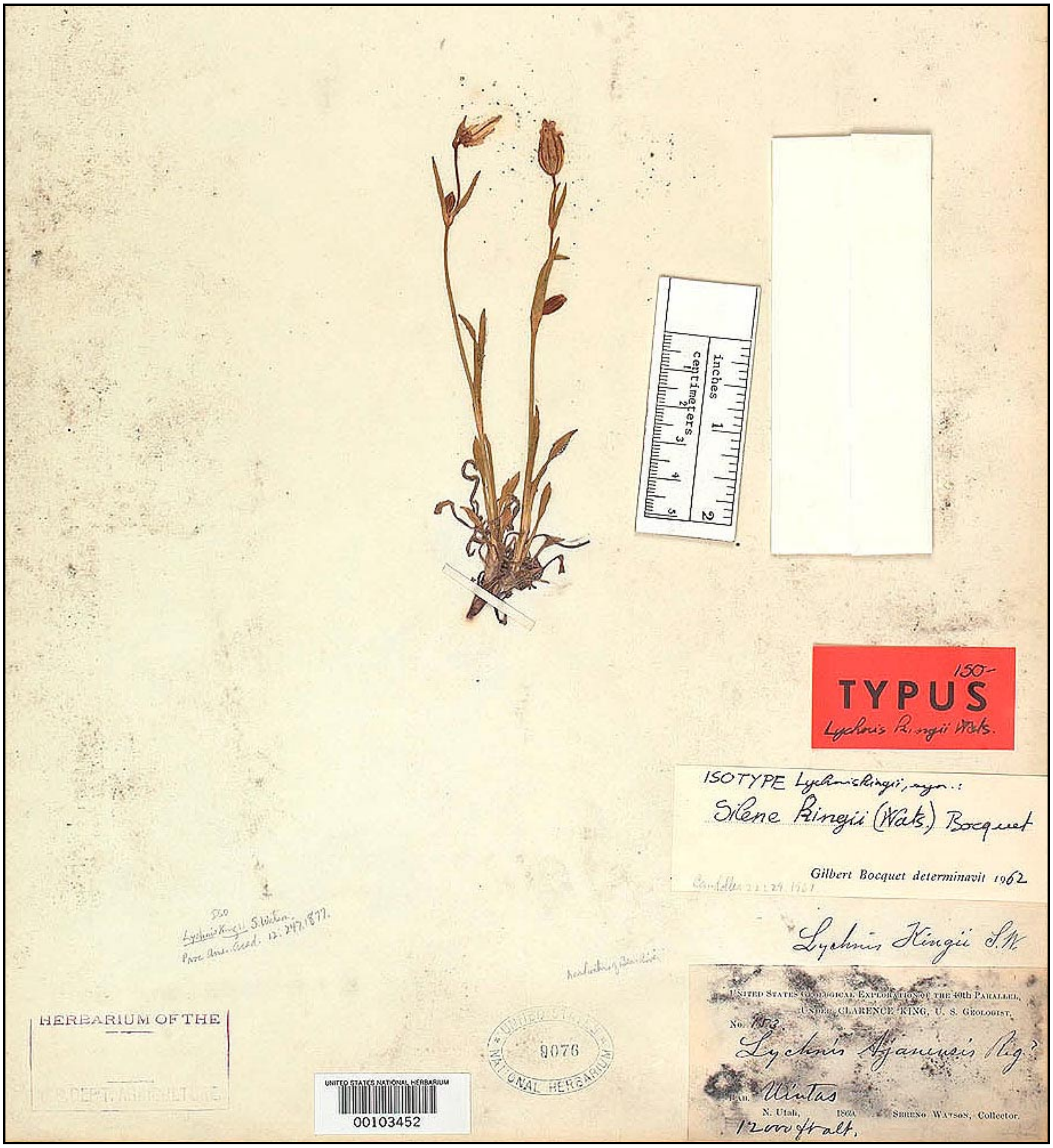

Figure 1. Photograph of the isotype specimen of *Silene kingii* at the U.S. National Herbarium. Image courtesy of the U.S. National Herbarium, Smithsonian Institution, Washington, D.C., used with permission.

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

Technical descriptions of *Silene kingii* appear in Dorn (2001), Maguire (1950), Harrington (1964), and Watson (1877) as *Lychnis kingii*; Welsh et al. (2003) as *L. apetala* var. *kingii*; and Weber and Wittmann (2001a, 2001b) as *Gastrolychnis kingii*. Morton (2005) provides a detailed description of *S. kingii* in the most recent edition of the Flora of North America. A detailed description is also published on the Wyoming Natural Diversity Database website (Markow and Fertig 2000). A photograph of an isotype specimen (**Figure 1**) is available on the U.S. National Herbarium website (see **References** section for Internet address).

Distribution and abundance

Silene kingii is a regional endemic restricted to high-subalpine and alpine habitats in northwestern Wyoming, western Colorado, and Utah. The abundance

Figure 2. *Silene kingii* in the Uinta Mountains. Photograph by Sherel Goodrich, used with permission.

of *S. kingii* in Utah and Wyoming appears to be comparable; it is much less abundant in Colorado.

In Colorado, *Silene kingii* is known from one location in San Juan County, but details of its precise location are not available (Morton personal communication 2004, Morton 2005). One other collection was made from Mt. Belford in the Sawatch Range in Chaffee County (Colorado College Herbarium specimen, Kelso personal communication 2004). The abundance of this species in either county is unknown. Another specimen collected from the Sawatch Range in Colorado was later identified as *S. hitchguirei* (Neely *#2275* and *Carpenter #1984* UTC). Therefore, since the Mt. Belford collection has not been verified since the original identification was made, this occurrence needs to be confirmed. No other details of the abundance or distribution of *S. kingii* in Colorado could be found for this report.

In Wyoming, *Silene kingii* is known from the Absaroka and Wind River ranges in Fremont, Hot Springs, and Park counties (**Table 1**). Eighteen of the 20 known *S. kingii* occurrences in Wyoming are on the Shoshone National Forest in Region 2 (**Table 1**; **Figure 4** and **Figure 5**). Only three of these occurrences (WY-2, 3, and 4 in **Table 1**), all on National Forest System land, have been observed within the last decade. Occurrence

Figure 3. Close-ups of the flower of *Silene kingii*. Photographs by Sherel Goodrich, used with permission.

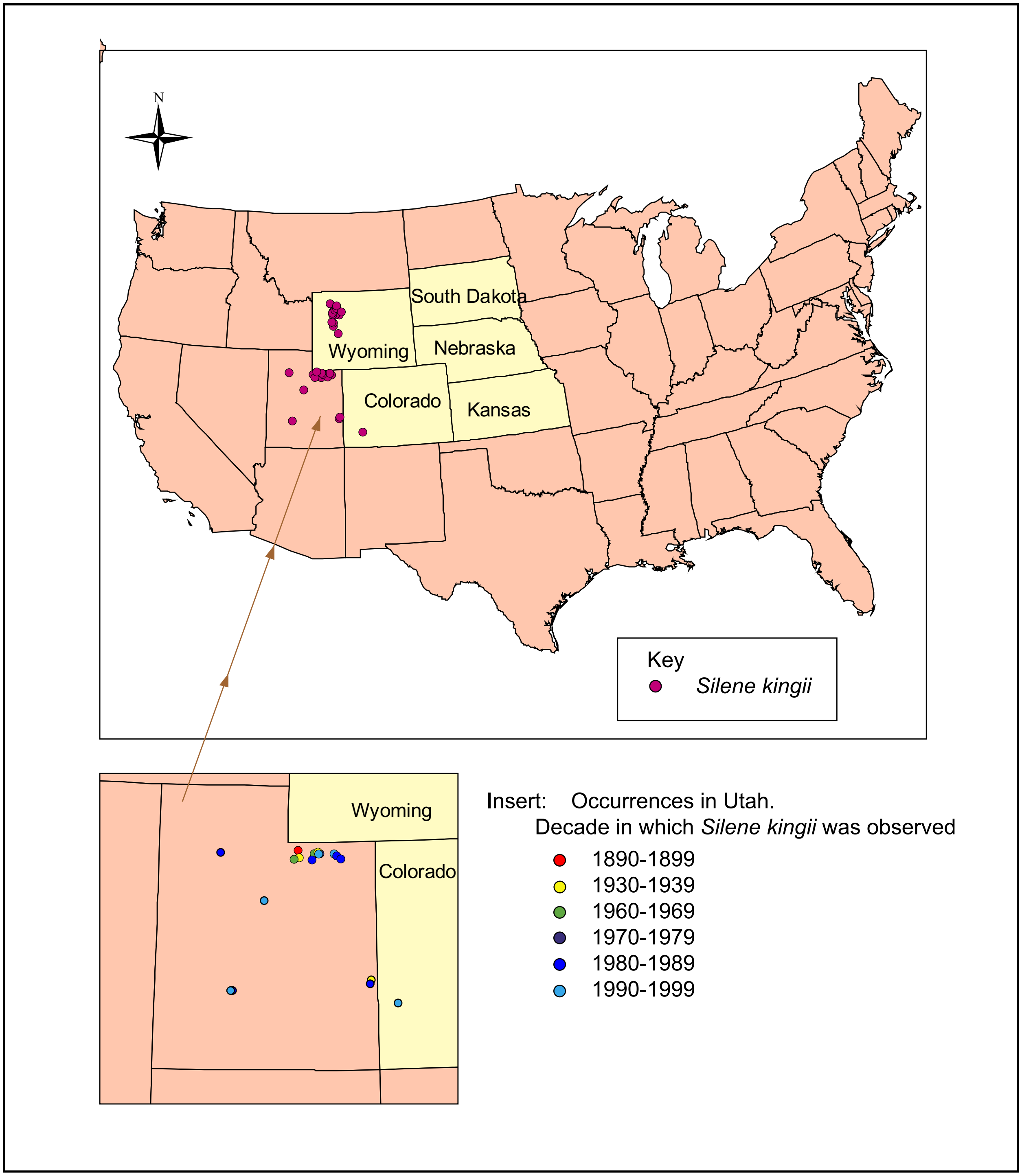

Figure 4. Global range of *Silene kingii*. The inset indicates the decades when the occurrences were last observed in Utah. Positions of the occurrences are approximate and only indicate the species' general distribution. Occurrences in Region 2 are shown in **Figure 5**.

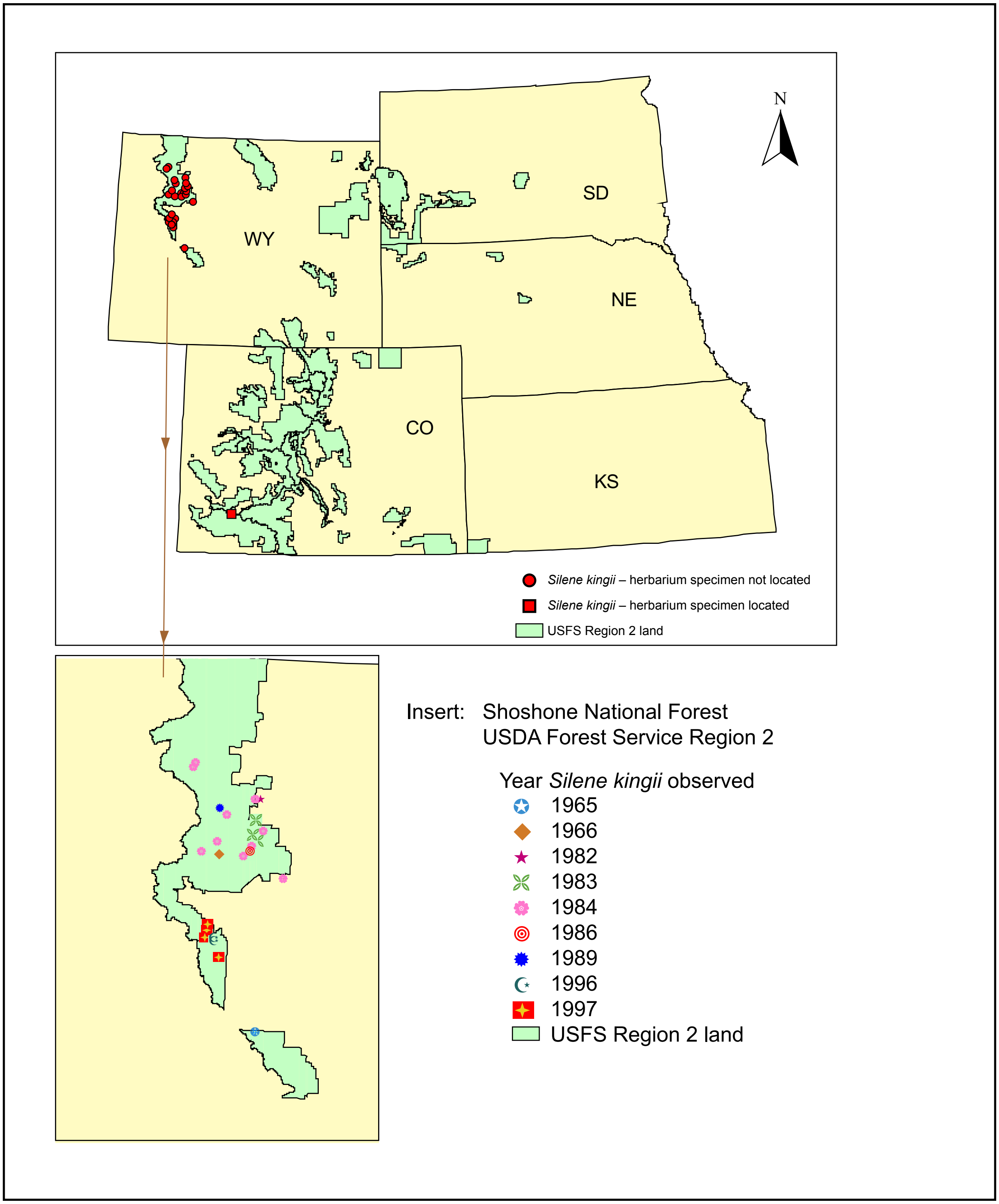

Figure 5. *Silene kingii* occurrences on land managed by USDA Forest Service, Region 2. The inset shows the years when the occurrences were last observed on the Shoshone National Forest. Positions of the occurrences are approximate and are meant to illustrate the species' general distribution.

WY-6 (**Table 1**) needs to be confirmed since the specimen was described as having white petals; *S. kingii* petal color ranges from light pink to purple, whereas *S. hitchguirei* petal color ranges from white to pale pink (Morton personal communication 2004, Morton 2005). It is possible that the light pink petals looked almost white or perhaps dried white, and the notation was made after collection.

Silene kingii appears to have a wider range in Utah, where it is known from Duchesne, Grand, Piute, Summit, Uinta, and Utah counties (**Figure 4**, **Table 3**). All 19 of the documented *S. kingii* occurrences are on Region 4 National Forest System land. Nine occurrences have been reported from the Wasatch-Cache National Forest, five occurrences on the Ashley National Forest, two occurrences each on the Fishlake and Manti-La Sal national forests, and one occurrence on the Uinta National Forest. Only five of the 19 occurrences have been observed since 1990 (UT-3, 4, 8, 11, and 19 in **Table 3**).

It must be noted that many, particularly older, records do not have precise location information, and this may cause errors in determining the exact number of occurrences. In some cases, a site may have been revisited and designated as a new occurrence, or discrete occurrences in the same general vicinity may have been thought to be the same site. An occurrence in **Table 1** or **Table 3** may be composed of two or more sub-occurrences that have been observed in adjacent sections of a topographic map. Ideally, an occurrence is equated with an interbreeding population, which might be composed of several sub-occurrences that interact either through pollination or seed dispersal. However, it is unknown how sub-occurrences of *Silene kingii* interact; discrete interbreeding populations may occur in close proximity to one another, or the interaction may be such that a population extends over several square miles. Therefore, in some cases, an occurrence in **Table 1** or **Table 3** may be more accurately described as a sub-occurrence, being part of a larger population, or there may be multiple populations within one occurrence. As of this writing, there is insufficient information to make an accurate delineation of what comprises an interbreeding population.

Although *Silene kingii* has been described as locally common (Goodrich personal communication 2004), it never appears to be abundant. For example, in the Uinta Mountains, there are typically only a few individuals in a given area, and it rarely contributes more than 0.1 percent ground cover (Goodrich personal communication 2004). On the other hand, plants can be described as being locally common because individuals tend to be consistently found within certain alpine and sub-alpine habitats (Goodrich personal communication 2004). For example, *S. kingii* is frequently encountered when USFS personnel make ecological surveys using macroplots in the Uinta Mountains (Goodrich personal communication 2004).

Silene kingii has also been reported to occur in Cascade County (Booth 1966) and in Park County within the upper Yellowstone River watershed in Montana (Montana Natural Heritage Program 2001). However, *S. kingii* has had an uncertain status in this state for at least two decades (Lesica et al. 1984), and no specimens or carefully documented observations could be found for this assessment to support its occurrence in Montana (Mincemoyer personal communication 2004, Seibert personal communication 2004). Similarly, although there is a report of it occurring in Alberta, Canada (NatureServe 2004), there is no evidence of its existence there (Fabijan personal communication 2004, Rintoul personal communication 2004). Morphologically similar taxa, such as *S. uralensis* or *S. drummondii*, occur in these regions.

Population trend

Available information indicates that *Silene kingii* is a rare species that tends to occur frequently but not in high abundance in certain locations. Detailed information on the current or historic abundance of *S. kingii* is unavailable. Labels associated with herbarium specimens of *S. kingii* do not include information on abundance. There are no data in the literature or within the NatureServe Network to provide a critical determination of the long-term trends of *S. kingii* over its entire range or within Region 2. Uncertainties associated with the identification of some *Silene* species, especially in Colorado, compound the difficulties in estimating trends. It appears that the known range of *S. kingii* is only slightly larger than when the taxon was first described at the end of the 19th century (Watson 1877).

Habitat

Silene kingii has been collected at elevations between approximately 2,500 and 3,800 m in Wyoming (**Figure 6**) and between 3,200 and 3,800 m in Utah. *Silene kingii* grows on igneous or metamorphic talus slopes and rock outcrops in meadows or on limestone ridges within spruce-fir forests in the upper sub-alpine and alpine zones. Probably because of its frequent occurrence on calcareous substrates, the taxon has

Table 3. Occurrences of *Silene kingii* in Utah. All occurrences are associated with herbarium specimens (see column marked "sources of information"). There is no information on the abundance of *S. kingii* at any occurrence. This list is likely to represent an incomplete number of occurrences in Utah because specimens (number unknown) from several herbaria were on loan and unavailable to the author of this assessment.

Arbitrary number	County	Date observed	Management	Location	Habitat	Comments	Sources of information[1]
1	Duchesne	21-Jul-1983	Ashley National Forest	Uinta Mountains; 14.3 km 20° north of Tabiona, Big Ridge	Alpine tundra; with *Geum rossii* and *Carex rupestris*	Petals light pink 3-4 mm long, quickly withering. Flower and Fruit. Annotation: *S. kingii* J.K. Morton, 1993	*S. Goodrich #19150* NY
2	Duchesne	30-Jul-1980	Ashley National Forest	Uinta Mountains; Garfield Basin, Drift Lake	Engelmann spruce-alpine fir-montane meadow community; sandy, bouldery, quartzite	Flower, Fruit. No other information	*E.J. Neese #9405 with S.L. Welsh* NY
3	Duchesne	7-Aug-1993	Ashley National Forest	Uinta Mountains; 0.25 mile north of Rose Peak, AMF	Rocky wind-swept alpine ridge; alpine/ *Carex* community	Flower. No other information	*A. Huber #280* NY
4	Duchesne	7-Aug-1991	Wasatch National Forest	41 mile at 332 degree of Duchesne, Wasatch National Forest, Uinta Mountains East Fork Duchesne River, 0.3 mi southwest of Rocky Sea Pass	11,000 ft.; alpine community	*Lychnis apetala* var. *kingii*; Annotated for Flora North America: "*Silene kingii* by J.K. Morton 1993. No other information	*S. Goodrich #23450*; Ashley National Forest Herbarium and CAN
5	Grand	18-Jul-1933	Manti-La Sal National Forest and/or La Sal Mountain State Forest	West slope of Mt. Hobbs at 11,800 ft. and west rocky slopes of Mt. Hobbs at 12,000 ft.	200 ft. above timberline	*#17909*: "Blades 6mm., retuse, pink" (Original specimen label). "Seed wingless, leaves pubescent, glandular" (handwritten anonymous comment on sheet). *#17910*: "Petals pink." Annotations: *#17909*: *S. kingii* J.K. Morton 1995. *#17910*: *S. kingii* var. *kingii* R.L. Hartman 1988. *S. kingii* J.K. Morton 1995	*B. Maguire, A.G. Richards, R. Maguire, R. Hammond. #17909 and # 17910*; Flora of the La Sal Mountains, UTC[2]
6	Grand	17- Jul-1984	Manti-La Sal National Forest	South slope of Manns Peak, approximately 18 miles east southeast of Moab at 11,800 ft. elevation; Grand-San Juan county line	Lush turfy alpine community	Annot: *S. kingii* var. *kingii* R.L. Hartman 1988. *S. kingii* J.K. Morton 1995. No other information.	*J.S. Tuhy #1806* Herbarium of Brigham Young University, UTC[2]

Table 3 (cont.).

Arbitrary number	County	Date observed	Management	Location	Habitat	Comments	Sources of information[1]
7	Piute	19-Jul-1984	Fishlake National Forest	Tushar Mountains; Horse Heaven near Mt. Brigham at 10,960 ft.	*Smelowskia-Artemisia frigida-Senecio* alpine tundra community	Annot: *S. kingii* var. *kingii* R.L. Hartman 1988. *S. kingii* J.K. Morton 1995. No other information	*A. Taye #2818*; Herbarium of Brigham Young University, UTC[2]
8	Piute	18-Jul-1991	Fishlake National Forest	Tushar Mountains; Edna Peak, east-facing slope	East-facing slope; in *Potentilla*, *Phlox pulvinata*, and *Polemonium viscosum* community	Bud, Flower. Annot: *S. kingii* J.K. Morton 1993	*A. Taye #5085 with R. Kass* NY
9	Summit-Duchesne	29-Jul-1967	Wasatch-Cache National Forest	On Bald Mountain at about 11,000 ft.	Growing in a tight clump of grass; soil hard and rocky	"Growing near a footpath." Initially identified as *L. apetala* ssp. *montana* (1967). Annot: *S. kingii* var. *kingii* R.L. Hartman 1988. *S. kingii* J.K. Morton 1995	*B. A. Anderson # s.n.* Plants of Utah - UTC[2]
10	Summit-Duchesne	16-Aug-1933	Wasatch-Cache National Forest	Summit Mountain; Agassiz at 12,433 ft. Summit-Duchesne county line	No information	No information. Annot: *S. kingii* var. *kingii* R.L. Hartman 1988. *S. kingii* JK Morton 1995	*B. Maguire, A.G. Richards, R. Maguire, R. Hammond #4102*. Flora of the La Sal Mountains. UTC[2]
11	Summit	8-Aug-1995	Wasatch-Cache National Forest	Uinta Mountains; North slope of the Uinta Mountain; Gunsight Pass approximately 33 miles south of Mountain View, Wyoming	No information	No information	*C.H. Refsdal #6823 with L. Refsdal* RM
12	Summit	10-Aug-1975	Wasatch-Cache National Forest	Uinta Mountains; above Gunsight Pass, at 12,000 ft.; very near the border of Ashley National Forest	In alpine turf associated with *Carex rupestris* and *Geum rossii*	Occasional. Initially (1975) identified as *Lychnis apetala*. Annot: *S. kingii* var. *kingii* R.L. Hartman 1988. *S. kingii* J.K. Morton 1995	*G.M. Briggs #132* UTC[2]
13	Summit	7-Aug-1936	Wasatch-Cache National Forest	0.5 miles north of Henry's Fork Lake at 10,800 ft.	Meadows on rocky ridge	Initially (1936) identified as *Lychnis apetala*. Annotated: *S. kingii* var. *kingii* R.L. Hartman 1988. *S. kingii* J.K. Morton 1995	*B. Maguire, A.G. Richards, R. Maguire, R. Hammond #14535* "Plants of King's Peak-Gilbert Peak Region, Henrys Forks Basin, Uinta Mountains" UTC[2]

Table 3 (concluded).

Arbitrary number	County	Date observed	Management	Location	Habitat	Comments	Sources of information[1]
14	Summit	22-Jul-1962	Wasatch-Cache National Forest	Uinta Mountains; headwaters of the East Fork of Smith Fork, east side of Red Castle Peak at 11,200 ft.	Rocky meadow adjacent to lake	No information. Annotated: *S. kingii* var. *kingii* R.L. Hartman 1988. *S. kingii* J.K. Morton 1995	*N.H. Holmgren #337* NY "Plants of Utah" UTC[2]
15	Summit	18-Aug-1933	Wasatch-Cache National Forest	Stillwater Basin, Head Bear River at elevation 11,000 ft.	No information	The type locality - "Peaks of the Uintas at head of Bear River" Utah, *Parry #43* (GH) in Maquire (1950). Annotated: *S. kingii* var. *kingii* R.L. Hartman 1988	B. Maguire, *A.G. Richards, R. Maguire #4103* Flora of the Uinta Mountains, Utah UTC[2]
16	Not reported	1869	Wasatch-Cache National Forest	Peaks of the Uintas at head of Bear River	12,000 ft. altitude	No information	The Isotype of G. Bocquet (1967). *S. Watson #153 Lychnis ajanensis* Regel? 1869 US. See **Figure 1**
17	Uintah	1-Sep-1983	Ashley National Forest	Uinta Mountains; summit "baldy" of Leidy Peak	In Precambrian quartzite boulders	Flower, fruit	*E.J. Neese #15151* NY
18	Uintah	19-Aug-1982	Ashley National Forest	Uinta Mountains; 23 miles northwest 319° of Vernal, bench southeast of Marsh Peak	Alpine tundra; with *Geum rossii* and *Carex rupestris*	Petals light pink 3-4 mm long, quickly withering. Flower, fruit	*S. Goodrich #17632* NY
19	Utah	15-Sep-1995	Uinta National Forest	Wasatch Mountains; Santaquin Peak, summit and southeast ridge. Birdseye Quad.	No information	No information	*J. Brasher #2677* UTC[2]

[1]Herbaria acronyms according to Holmgren and Holmgren (1998). Index Herbariorum. 1998 onwards (continuously updated). New York Botanical Garden, Bronx, NY. Available online at: http://sciweb.nybg.org/science2/IndexHerbariorum.asp [Accessed January 2006].

CAN National Herbarium of Canada, Canadian Museum of Nature, Ottawa, Ontario, Canada.
NY William and Lynda Steere Herbarium, New York Botanical Garden, Bronx, New York, USA
US United States National Herbarium, Smithsonian Institution, Washington, District of Columbia, USA.
UTC Intermountain Herbarium, Utah State University, Logan, Utah, USA.

[2]Received photocopies of specimen sheets from Rocky Mountain Herbarium, 2004, where they were on loan.

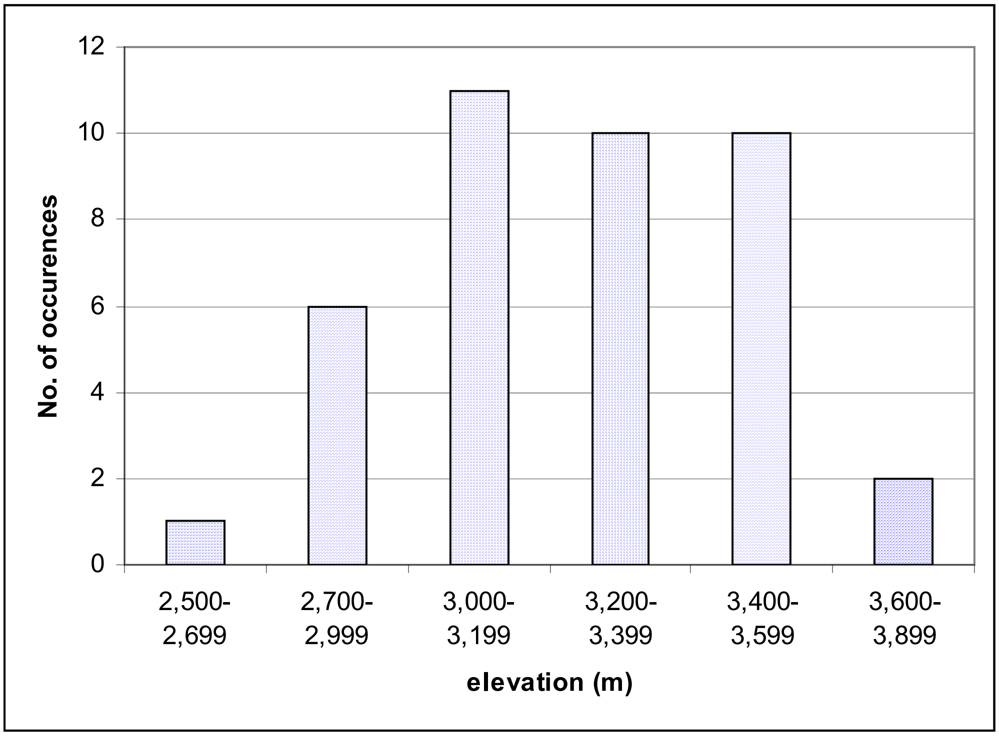

Figure 6. Range of elevations at which *Silene kingii* has been reported in Wyoming.

been described as a calcicole (Slabý 2004). However, it has also been found on quartzite and shales that tend to be acidic (U.S. Geological Survey 2003, Goodrich personal communication 2004).

Silene kingii is a member of alpine and subalpine cushion plant communities. Cushion plants are low-growing species that generally have their perennial parts flat on the soil surface. Reports from both the Shoshone National Forest, Region 2, and in the Uinta Mountains, Region 4, indicate that *S. kingii* is commonly associated with *Kobresia* grasslands or turf communities, which often include *Carex rupestris* (curly sedge) (**Figure 7**, **Table 1**, **Table 3**; Goodrich personal communication 2004). *Geum rossii* (alpine avens) also appears to be a frequent associate (WY-10 in **Table 1** and UT-1, 12, and 18 in **Table 3**). The habitat information that is available for each of the occurrence sites is reported in **Table 1** (Wyoming) and **Table 3** (Utah). *Silene kingii* can occur in *Pinus albicaulis* (whitebark pine) or other high-elevation conifer forest, but it is more often found above tree line. Plant species associated with *S. kingii* are listed in **Table 4**.

Some ecologists consider plant-environment relationships to be more important than inter- or intra-species relationships at high elevations (Thilenius and Smith 1985, Körner 2003). Vegetation in the alpine and subalpine zones is patchy over small distances, corresponding to patchiness in microclimates (Billings 1979). What would elsewhere be a trivial microclimatic difference (e.g., different aspects of a small boulder) can create a microsite in the alpine (Johnston et al. 2001). Thus, the position of *Silene kingii* may be more associated with the physical, rather than the biological, features of the site although there is no direct evidence to support this theory.

Reproductive biology and autecology

There have been no systematic studies on the reproductive biology of *Silene kingii*. *Silene kingii* is an herbaceous, perennial plant. Many *Silene* and *Lychnis* species are polycarpic (i.e., fruiting and flowering many times within their lifetimes) (Baskin and Baskin 2001). The flowering and fruiting period of *S. kingii*, as reported from casual observations, extends from June to early September. The basic chromosome number of *Silene* species is n = 12. *Silene kingii* (reported as *L. apetala* var. *kingii*) is diploid, 2n = 24 (Welsh et al. 1993). This number of chromosomes appears to be more typical of Eurasian species than of North American species, which often have 2n = 48 chromosomes (Burleigh and Holtsford 2003).

There is little specific information on the reproductive strategy of *Silene kingii*. Extrapolations may be made from the strategies employed by other

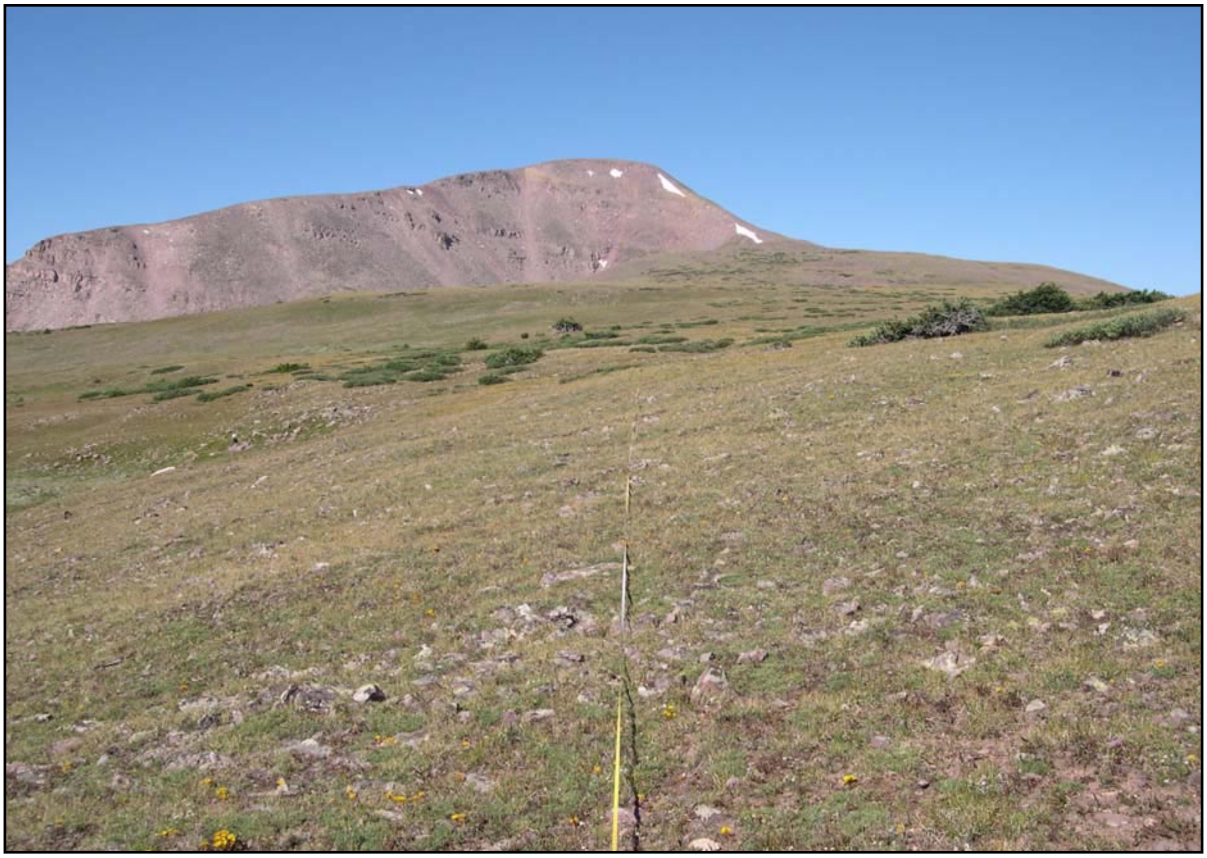

Figure 7. Photograph of *Silene kingii* habitat in the Uinta Mountains, Utah. Photograph by Sherel Goodrich, used with permission.

Table 4. Vascular plant species associated with Silene kingii in Utah and Wyoming. This is not a complete list and represents only those species that have been reported relatively casually in the sources listed in **Table 1** and **Table 3**.

Associated vascular plant species
Abies lasiocarpa (reported as alpine fir)
Artemisia frigida
Astragalus aboriginum
Carex rupestris
Erigeron caespitosus
Geum rossii
Haplopappus macronema
Kobresia sp.
Papaver kluanense
Phlox pulvinata
Picea engelmannii (reported as Engelmann spruce)
Pinus albicaulis (reported as whitebark pine)
Polemonium viscosum
Potentilla sp.
Senecio sp.
Senecio fuscatus
Smelowskia sp.
Trifolium nanum

members of the *Lychnis* group. However, any such speculation must be prefaced with the warning that there is a high degree of variability within *Silene* and that not even all the members of the *Lychnis* assemblage may have similar biology.

Correlations between perennial versus annual life forms have been found within the Caryophyllaceae. Autogamy, or self-pollination, was more common in annual Caryophylloideae than in perennial species, which were mostly cross-pollinated (Jürgens et al. 2002). Correlations between life form and reproductive strategy are also well documented in other vascular plant families (Raven 1979, Plitmann and Levin 1990). *Silene kingii* is a perennial species.

Silene kingii is described as having both stamens and stigmas equaling the corolla. This is consistent with observations that other members of the *Lychnis* group have hermaphroditic flowers (Jürgens et al. 2002). Species in the *Gastrolychnis* genus are, by definition, hermaphroditic (Löve and Löve 1976). However, members of the genus *Lychnis* may be gynodiecious, gynomonoecious, or andromonoecious (Jürgens et al. 2002). It is not clear if a sufficiently large survey has been made to discount the possibility of this type of variation in *S. kingii*. Self-compatibility is typical among species in the Caryophyllaceae, and most *Lychnis* species also have high selfing ability. However, selfing strategies are various and include geitonogamy, as well as autogamy (Jürgens et al. 2002).

Both geitonogamy and out-crossing strategies require pollen vectors. The role of pollinators in maintaining sustainable *Silene kingii* populations is unknown, but their importance within the genus *Silene* has precedence. Pollinators are critical in maintaining fitness in *S. spaldingii* populations (Lesica 1993). Pollinators of *Lychnis* species include members of the Lepidoptera (butterflies, moths, and hawkmoths), Diptera (flies), and Hymenoptera (specifically bees). Within the Lepidoptera, members of the Rhopalocera (butterflies) and Sphingidae (hawkmoths) are reported to be specific pollinators of *Lychnis* species (Jurgens et al. 2002). Pollinators of many *Lychnis* species have diurnal activity (Jurgens et al. 2002), suggesting that pre-dawn to late dusk studies are needed to determine the pollinators of *S. kingii*.

Flower characteristics are important in influencing pollinator assemblage (e.g., butterfly-pollinated flowers are typically brightly colored with little scent) (Faegri and van der Pijl 1979). However, the environment, particularly altitude, also influences pollinator visitors (Hingston and Mcquillan 2000). In alpine environments, flies are especially common and important pollinators (Shaw and Taylor 1986, Kearns and Inouye 1994). Since *Silene kingii* grows at high elevations, flies are likely to be primary pollinators.

Even though *Silene kingii* is perennial, there are several reasons to support speculation that it may be at least partially self-pollinated. This species grows in alpine regions where the length of the growing season is unpredictable but generally short. The climate may also make pollinator activity unreliable. Self-fertilization has been suggested to develop as a by-product of selection for rapid maturation in marginal environments (Arroyo 1973, Guerrant 1989), whereby selection for self-pollination may favor individuals that can complete reproduction early in an unpredictable environment or where pollinators are sometimes scarce (Stebbins 1950, Arroyo 1973, Wyatt 1988, Guerrant 1989, Eckhart et al. 1996). Self-pollinating subspecies also tend to occur in habitats at the geographic or ecological limit of the related outcrosser's range (Stebbins 1950, Vasek 1964, 1968, Solbrig and Rollins, Schoen 1982, Runions and Geber 2000). If *S. kingii* is derived from *S. uralensis* (*L. apetala*), then the species may represent the evolutionary outcome of a species at the edge of its range (see Systematics and synonymy section). Morphologically the *S. kingii* flower appears to be less attractive than that of many other *Silene* taxa. The petals of *S. kingii* are essentially included or only shortly exerted; however, the flower may appear much more attractive to insects. The reproductive organs (i.e., stamens and stigmas) are accessible to casual flower visitors, which may increase the likelihood of cross-pollination. However, the lack of conspicuous floral display, as compared to those of associated species, and the fact that individual plants tend to be widely separated over large areas, suggests that the success for cross-pollination may be relatively low and that *S. kingii* may have evolved to be at least partially self-pollinated.

Kruckeberg (1955, 1961) reported that, although many western *Silene* species could be crossed easily in controlled environments, few combinations produced viable hybrids and most interspecific hybrids were sterile. He observed that a low degree of chromosome pairing and other meiotic aberrations were common in hybrids (Kruckeberg 1955, 1961). However, hybrids have been found in nature. Hybrids between *S. virginica* and *S. caroliniana* have been observed in the southeastern United States (Steyermark 1963, Mitchell and Uttal 1969) and between *Lychnis apetala* and *L. affinis* in the Arctic (Polunin 1959). In addition, hybridization has been critical in the development of many present day taxa. *Silene involucrata* (syn. *L. apetala* var. *involucrata*) originated as an allotetraploid with diploid *S. uralenesis* as the cytoplasmic donor and diploid *S. ajanensis* as the pollen donor (Popp 2004). Similarly, *S. californica* and *S. hookeri* are derived from separate allopolyploidization events between polyploid taxa of different lineages (Popp 2004). Evidence of hybridization between *S. kingii* and sympatric species has been observed. Some material, growing with *S. uralensis*, from the southern Rocky Mountains, is intermediate between the two species in having narrowly winged seeds (Morton personal communication 2004). *Silene kingii* is very similar to, and probably a close relative of, *S. uralensis* (Morton 2005). More research is needed to clarify the significance of these observations and the degree to which hybridization occurs.

There is little specific information on the production or physiological characteristics of *Silene kingii* seed. Seeds of several *Melandrium* and *Silene* species that occur at high elevations and/or in northern Canada have a physiological dormancy period (Baskin and Baskin 2001). *Silene spaldingii* seeds will germinate with as little as a four-week cold treatment (Lesica 1993), but this is less likely for a taxon adapted to a high elevation environment. Evidence suggests that under alpine growing conditions, natural selection may favor seeds with a genetic system for dormancy and delayed germination (Kaye 1997). The frequency with which *S. kingii* seed germinates has not been documented. The importance of the seed bank to population sustainability is also unknown.

Seeds appear most likely to be dispersed relatively locally around parent individuals. Wind, ubiquitous in the alpine tundra, may have a role in dispersing seeds. However, the seeds of *Silene kingii* are wingless and therefore are likely to be less widely dispersed than winged seeds, such as those of *S. uralensis*. *Silene kingii* seeds do not have seed coat modifications that would facilitate incidental dispersal by mammals, but animals, like ants and pikas, that collect and store plant materials may also contribute to seed dispersal.

Demography

Silene kingii is a perennial that reproduces only from seed. A simple life cycle model of the species is diagrammed in **Figure 8**. Solid arrows indicate phases in the life cycle that appear certain, whereas dashed arrows and boxes indicate the phases that are unknown. The steps that particularly need to be clarified are marked by a "?". Transition probabilities between the different stages, from seed production to flowering adult, are unknown. More information is needed to define which of the life history stages has the greatest effect on population growth and survival.

Silene kingii individuals do not grow in dense patches but are relatively sparsely distributed (Goodrich personal communication 2004). The absolute or relative numbers of seedlings, vegetative, and reproductive mature plants within a *S. kingii* population have not been documented. Goodrich (personal communication 2004) believes that *S. kingii* individuals are not long-lived and that recruitment is fairly robust in the Uinta Mountains of Utah.

Current evidence suggests that *Silene kingii*, being short-stemmed, not laterally extensive, and sparsely distributed, is a non-competitive species. It likely relies on sexual reproduction for long-term sustainability. It is also a perennial species that is maintained, at least in the short term, in established populations. These characteristics suggest that it has the profile of a *K*-selected species (MacArthur and Wilson 1967), apparently having a stress-tolerant life strategy (Grime et al. 1988).

Population viability analyses, which typically address environmental stochasticity, demographic stochasticity, genetic stochasticity, and natural catastrophes (Shaffer 1981), have not been undertaken for *Silene kingii*. Environmental stochasticity describes random, unpredictable changes in weather patterns or in biotic members of the community (Frankel et al. 1995). Demographic stochasticity relates to the random variation in survival and fecundity of individuals within a fixed population. Environmental stochasticity and natural catastrophes are typically more important than demographic stochasticity for most population sizes (Shaffer 1987, Menges 1992). Genetic stochasticities are associated with random changes, such as inbreeding and founder effects, in the genetic structure of populations. Although in some cases inbreeding can purge deleterious genes, it more often compromises fitness of many species (Soulé 1980).

Considering the long-term viability of a 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) cited experiments that indicated "the rate of production of quasineutral, potentially adaptive genetic variance in quantitative characters is an order of magnitude smaller

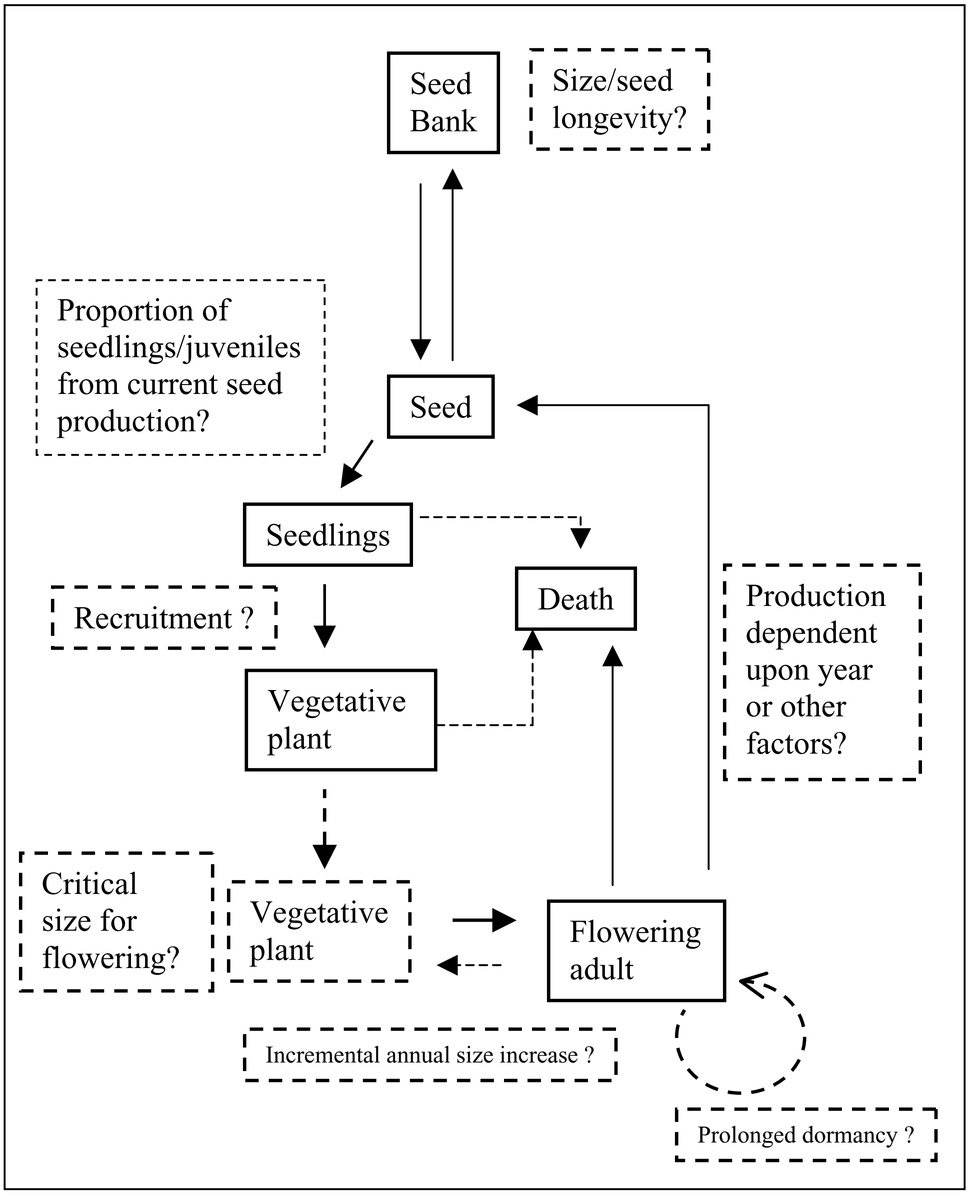

Figure 8. A proposed life cycle diagram for *Silene kingii*. Dashed lines indicate the uncertainties and questions associated with each of the phases.

than the total variance" added through mutation, and suggested that the effective population size should be an order of magnitude higher, approximately 5,000 individuals. Franklin and Franklin (1998) questioned this number on the basis that many estimates of the required mutational variance already partially accounted for deleterious mutations, and heritabilities are often lower than the 50 percent value used by Lande (1995). After taking account of both these points, the effective population size reverted to nearer 500 individuals (Franklin and Franklin 1998). However, it is likely that the minimum viable population size of an organism 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). An additional issue when considering population size in the field is that from a genetic perspective, natural populations often behave as if they were smaller than a direct count of individuals would suggest (Barrett and Kohn 1991).

Community ecology

Silene kingii is a member of well-established plant communities. Succession in alpine areas is slow, especially in cushion plant communities (Johnson 1962, Johnson and Billings 1962, Bamberg and Major 1968).

Because processes at these high elevation regions tend to be outside a strictly linear model of succession, some scientists have suggested that plant succession in the usual sense of the word cannot be applied to many alpine regions (Churchill and Hansen 1958, Billings and Mooney 1959, USDA Forest Service 1999). An additional consideration when determining the successional status of *S. kingii* habitat is that many areas in which it occurs have a history of sheep grazing, which is likely to have influenced the present floristic composition and obscured natural successional relationships (Thilenius and Smith 1985). Microclimate is likely to influence the position of *S. kingii* occurrences (see Habitat section).

Silene kingii grows in the upper subalpine and alpine zones on talus slopes and rock outcrops in meadows or within spruce-fir forests. Analysis of plot data by USFS Region 4 personnel is beginning to indicate that *S. kingii* is widespread in *Carex rupestris* (curly sedge)-cushion plant communities in fellfield settings, whereas it appears to be rare or absent in other alpine communities in the Uinta Mountains, Utah (Goodrich personal communication 2004). *Carex rupestris*-cushion plant communities are less mesic and the soils are coarser and less developed than *Kobresia*-dominated alpine turf (NatureServe 2006). The observation that *S. kingii* is preferentially associated with C. rupestris may not apply to the occurrences in the Absaroka and Wind River ranges in Wyoming, but it is useful to consider while carrying out surveys or developing research plans for *S. kingii*.

Although precise information is lacking, *Silene kingii* appears to be associated with talus and rocky sites that are stabilized by vegetation, and it does not occur on unstable or less vegetated slopes. However, the species must be adapted to a certain amount of natural disturbance, since even at well-vegetated sites, downward soil creep (solifluction) is a continuous process, and freeze-thaw perturbations are common (Thilenius 1975, Davinroy 1993, Johnston et al. 2001).

Competitive ability

The competitive ability of *Silene kingii* is unknown, but its small stature, the absence of rhizomes, and its observed patchy and relatively infrequent distribution within an occurrence suggest that it is not a highly competitive species. The contribution of interspecies competition to the small patch sizes of *S. kingii* is unknown but may be significant. *Silene kingii* plants appear to be most common in areas with low or no tree canopy cover, but its occurrence in *Pinus albicaulis* and pine (*Pinus* spp.) -spruce (*Picea* spp.) forests suggests that it can tolerate some shade.

Fire

The impact or importance of fire on *Silene kingii* is unknown. Fire return intervals may be several centuries in alpine meadows and in some spruce–fir (*Abies* spp.) communities (Leenhouts 1998, Turner et al. 2003). Therefore, *S. kingii* is unlikely to rely on fire to complete any part of its life cycle. Its tolerance to fire is also unknown. Subalpine conifer forests are typically characterized by high-severity fires that kill most of the canopy, either from intense surface fires or from flames spreading through tree crowns (Turner et al. 2003). *Silene kingii* was found on limestone outcrops in burned pine/spruce forest several years after a fire on the Shoshone National Forest (WY-4 in **Table 1**). However, inferences cannot be drawn from this single observation. Limestone outcrops may act as refugia from fire, and therefore *S. kingii* plants may have avoided a direct burn. Alternatively, even if the area was burned, there is no way to know if plants and/or seeds survived the burn or if the site was re-colonized by *S. kingii* via seed rain. *Silene kingii* plants were observed in a nearby area, but there is no way of knowing their relationship to the plants in the burn area.

Interaction with animals

Interactions between *Silene kingii* and the fauna within its community have not been documented. Insects, most probably primarily flies, may be involved in pollination (see Reproductive biology and autecology section). Ants and small mammals may be involved with seed dispersal (see Reproductive biology and autecology section). *Silene kingii* grows in bighorn mountain sheep habitat in both Utah and Wyoming. However, interactions between the two species are unknown. Domestic sheep use *S. kingii*'s habitat, but no observations have been made on the effects of grazing or browsing on the species.

Microbial associations

Members of the Caryophyllaceae typically do not have mycorrhizal associations, but exceptions, or alternative microbial associations, exist (Allen 1991, Brundrett 1991). For example, in Alaska, some *Silene acaulis* plants had vesicles, but no arbuscules (Treu et al. 1995). In addition, the roots of several alpine and arctic *Silene* species experience a variety of intracellular microbial colonizations, which are collectively referred to as dark septate fungi (Bledsoe et al. 1990, Blaschke

1991a, Blaschke 1991b, Treu et al. 1995). Dark septate fungi (DSF) may be involved with nitrogen, carbon, and/or water uptake and management (Mullen et al. 1998, Barrow and Aaltonen 2003). DSF association with *S. kingii* has not been reported. The ecological significance of DSF associations in general needs further research. No symptoms of disease or parasitic associations with *S. kingii* have been reported.

Resources envirogram

An envirogram is a graphic representation of the components that influence the condition of a species and reflects its chance of reproduction and survival. Envirograms have been used especially to describe the conditions of animals (Andrewartha and Birch 1984) but may also be applied to describe the condition of plant species. Those components that directly affect *Silene kingii* make up the centrum, and the indirectly acting components comprise the web. Information to make a comprehensive envirogram for *S. kingii* is unavailable. The envirograms in **Figure 9** and **Figure 10** are intended to outline some of the major components that may affect the species. They are constructed primarily to provide ideas for future field studies. Resources (**Figure 9**) include adequate moisture, suitable soils, and arthropods, such as ants for seed dispersal and flies for pollination. A similar envirogram outlining the malentities and threats to *S. kingii* is discussed in the following Threats section.

CONSERVATION

Threats

Potential threats to *Silene kingii* are derived from recreation activities, livestock grazing, development projects, invasive non-native plant species, and environmental stochasticities that include elements of global climate change. Elements of genetic and demographic stochasticities are also potential threats. There is no information available on the vulnerability of specific occurrences in any part of the species' range, but Markow and Fertig (2000) suggest that threats from anthropogenic activities are probably low given the rugged, high elevation habitat of *S. kingii*. Each potential threat is briefly addressed in the following paragraphs.

The potential impacts on *Silene kingii* from recreation activities need to be studied. Some areas in which *S. kingii* grows in Utah have particularly high numbers of hikers and climbers. The Kings Peak area, for example, apparently is "inundated" with visitors during July and August (Utah Travel Council. 2001-2002). This area includes Henry's Fork and Gunsight Pass (UT-11, 12, 13 in **Table 3**). There is less visitor use on the Shoshone National Forest in Region 2 than in Utah, and at current levels, recreation activities appear unlikely to have the potential to cause more than localized habitat damage in Wyoming. At present, dispersed recreation activities in the Shoshone National Forest include viewing wilderness scenery, auto touring, hiking, horseback riding, fishing, camping, picnicking, small and big game hunting, and gathering of forest products (USDA Forest Service 1986, 2001b). Some use occurs in the area through outfitter and guiding operations. The Washakie Wilderness is a major attraction. In wilderness areas, users travel on horseback or on foot, skis, or snowshoes, and they engage in recreational activities such as backpacking, hiking, fishing, hunting, mountain climbing, photography, nature study, and other activities dependent on the characteristics of the wilderness area. Different types of use tend to be found on the north and south halves of the Shoshone National Forest. The Washakie and North Absaroka wildernesses in the north traditionally experience a large amount of horse and outfitter use while on the Fitzpatrick and Popo Agie wildernesses in the south, use primarily consists of backpacking and hiking (USDA Forest Service 1986, 1994, 1998). All of these types of use have the potential to cause disturbance from trampling.

Impacts from livestock grazing on *Silene kingii* have not been studied. Occurrences WY-14 and WY-19 (**Table 1**) are in active cattle grazing allotments. There is no information on this species' palatability to livestock, but some *Silene* species, such as *S. ovata* (ovate catchfly), are palatable to a variety of animals (Hill 2003). The high-altitude ranges in the Rocky Mountains of Wyoming have experienced periods of intensive sheep grazing since the early 1800s (Johnson 1962, Thilenius 1975, Knight 1994). The effects of historic sheep grazing on the distribution and abundance of *S. kingii* are unknown, but this grazing has caused substantial declines in other palatable plant species (USDA Forest Service 1988). Domestic sheep tend to be selective in their choice of plant species, but predicting the preferred species is difficult (Strasia et al. 1970). This is an important consideration because plant species that sheep select are documented to be more abundant on un-grazed land, indicating that grazing negatively affects abundance (Strasia et al. 1970, Bonham 1972). Sheep grazing use has fluctuated since 1986 on the Shoshone National Forest, but in general, domestic sheep grazing demands have decreased from levels that existed earlier in the twentieth century (USDA Forest Service 1998). Currently, domestic

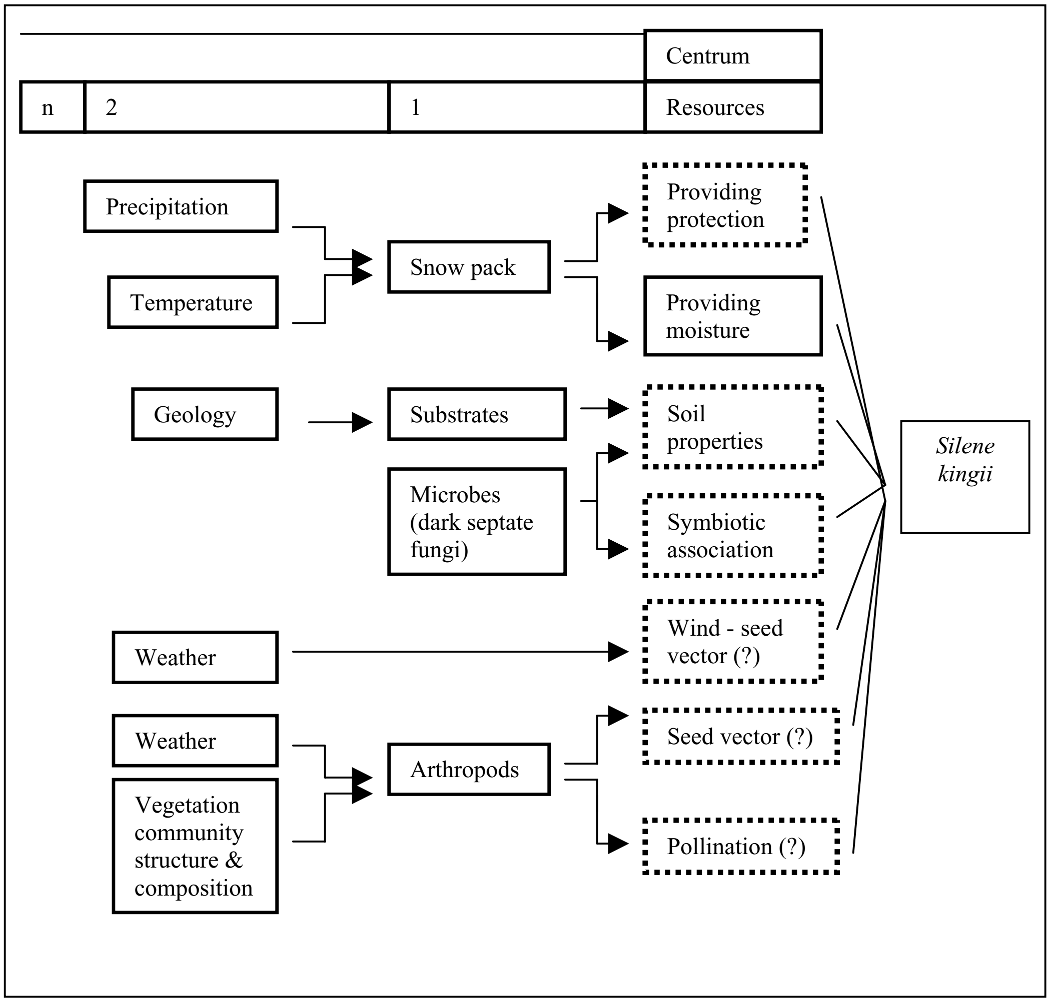

Figure 9. Envirogram outlining the resources of *Silene kingii*. Dotted boxes indicate resources that are either likely but not proven, or of a regional nature.

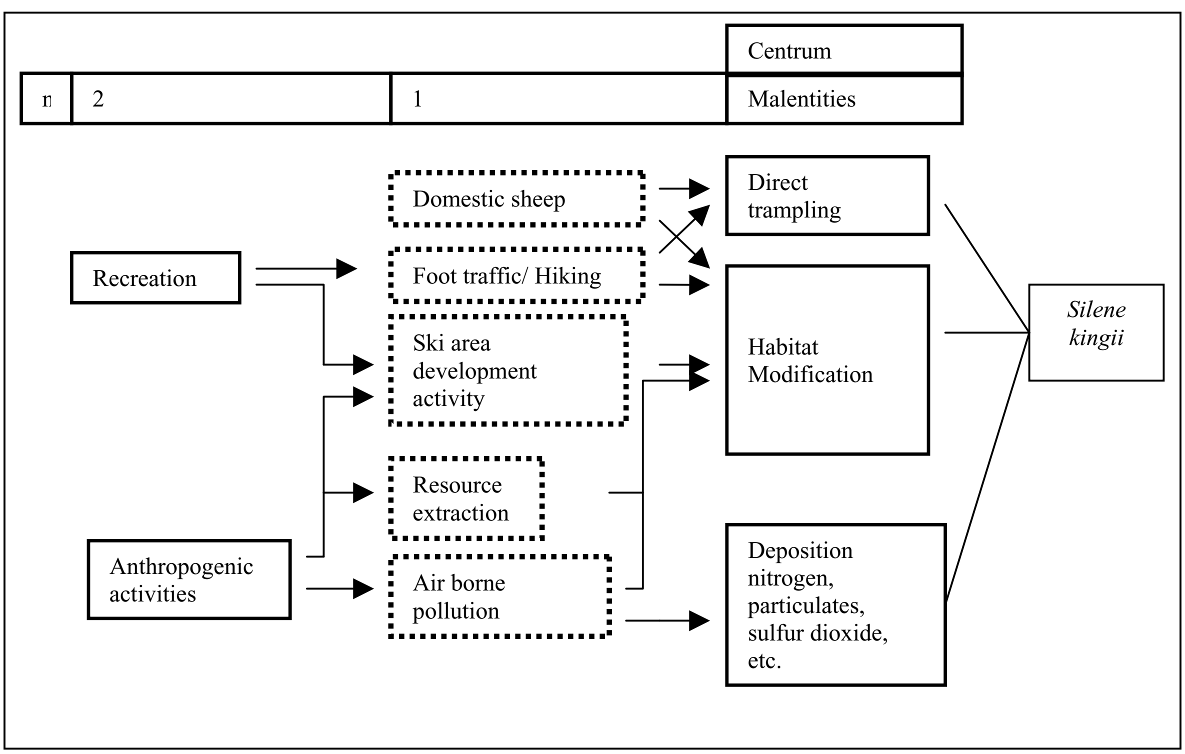

Figure 10. Envirogram outlining the malentities and threats to *Silene kingii*. Dotted boxes indicate factors that are either likely but not proven, or of a regional nature.

sheep are excluded from USFS Region 2 areas with bighorn mountain sheep herds (e.g. WY 4 in **Table 1**), reducing the potential for synergistic or cumulative impacts of multiple species grazing on *S. kingii*. It is not clear if any extant *S. kingii* occurrences on the Shoshone National Forest are in active sheep grazing allotments at the current time (Houston personal communication 2004). In the Wasatch-Cache National Forest in Utah, introduced mountain goats have been cited as a possible threat to rare plants in subalpine and alpine habitats (USDA Forest Service 2001a).

Recreation activities and large native and non-native mammals directly affect plants by trampling them. They may also indirectly affect the plants by modifying hydrological properties of the soil and/or causing accelerated soil erosion. A plants' resistance to trampling depends on its stature and erectness and whether it is a graminoid, a forb, or a shrub (Cole 1995). The most resistant plants are low-growing, matted graminoids; the least resistant plants are erect forbs (Cole 1995). Species with their perennating buds located above the ground surface (chamaephytes) are much less resilient than other plants (Cole 1995). Tolerance, defined as the ability of vegetation to withstand a cycle of disturbance and recovery, is correlated more with resilience than resistance (Cole 1995). The least tolerant plants are the chamaephytes, and the most tolerant plants are caespitose, matted and rosette hemicryptophytes, such as *Silene kingii*, where the perennating buds are at or below the ground surface, and geophytes, which possess underground storage organs such as rhizomes or bulbs (Cole 1995). The impact of trampling on *S. kingii* has not been specifically studied. Given the results of Cole (1995), this species is unlikely to be resistant to trampling but may be fairly tolerant of it. Occurrences near established trails (e.g. WY 1 and 3 in **Table 1**) or in active grazing allotments (e.g. WY 14 and 19 in **Table 1**) will be particularly vulnerable to trampling.

Range-wide, development activities such as ski area construction and resource extraction could affect *Silene kingii* habitat. However, no information exists on the vulnerability of specific occurrences, and these potential threats are presented only for consideration. Development projects are unlikely to affect the occurrences in wilderness areas in Region 2 since wilderness areas are maintained to preserve natural resources (USDA Forest Service 1986, 2001b).

As well as threats associated with human activities, there are threats associated with environmental, demographic, and genetic stochasticities (see Demography section). Threats from stochasticities can only be mitigated by maintaining sufficient abundance. The magnitudes of two parameters, number of populations and number of individuals within a population, necessary for long-term sustainability vary among taxa. There is insufficient information on *Silene kingii* available to estimate accurately the numbers or sizes of occurrences that would be necessary to minimize the potential of extinction caused by one or all forms of stochasticity (see Demography section).

Environmental stochasticity includes variation in the physical environment as well as in its biological interactions, such as predators, parasites, disease, and interspecies competition. Impacts of environmental stochasticity on *Silene kingii* may be a particular cause for concern because Goodrich (personal communication 2004) reports that individuals are not long-lived, and the analyses of Menges (1992) and others (e.g., Pimm et al. 1988) showed that short-lived species are particularly vulnerable to environmental stochasticity. Invasion by competitive non-native plant species (weeds) is one element of environmental stochasticity that potentially can be managed at *S. kingii* occurrences. Even though there are no known instances where invasive weeds specifically threaten an occurrence in Region 2, potentially invasive non-native plant species have been observed above the treeline in the Rocky Mountains (Ray 2001). Elimination of invasive species is easiest early in the invasion process (Sheley and Petroff 1999).

Another element of environmental stochasticity for most high-elevation taxa, including *Silene kingii*, is the significant threat of global climate change. Warming could reduce high elevation habitat by causing tree lines to rise by roughly 350 feet (107 m) for every degree Fahrenheit (0.6° centigrade) of warming (U.S. Environmental Protection Agency 1997). Warming temperatures also increase the likelihood that alien aggressive species will invade higher elevations (U.S. Environmental Protection Agency 1997). In the last one hundred years, the average temperature in Logan, Utah, has increased 1.4 °F (0.8 °C), and precipitation has increased by up to 20 percent in many parts of the state (U.S. Environmental Protection Agency 1998a). Based on projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom Hadley Centre's climate model (HadCM2), by 2100 temperatures in Utah could increase by 3 to 4 °F (1.7 to 2.2 °C) in spring and fall, and by 5 to 6 °F (2.8 to 3.4 °C) in winter and summer (U.S. Environmental Protection Agency 1998a). Precipitation is estimated to decrease by approximately 10 percent in summer, to increase by approximately 10 percent in spring, to increase by approximately 30 percent in fall, and to increase by approximately 40 percent in winter (U.S. Environmental Protection Agency 1998a). Based on projections of the same HadCM2 model, temperatures in Wyoming could increase by 4 °F (2.2 °C) in spring and fall, 5 °F (2.8 °C) in summer, and 6 °F (3.4 °C) in winter by 2100 (U.S. Environmental Protection Agency 1997). Similar changes are predicted for Colorado (U.S. Environmental Protection Agency 1997). The majority opinion within the scientific community is that global climate change will cause weather to become extreme (U.S. Global Change Research Program 2006). For example, the amount of precipitation on extreme wet or snowy days is likely to increase while the frequency of extreme hot days in summer may also increase because of the general warming trend.

The potential consequences of these changes in the global climate are very complex (Shaver et al. 2000, Waser et al. 2001). One hypothesis is that a primary effect of warming on plants will occur via changes in soil resource availability (de Valpine and Harte 2001). This hypothesis was supported by studies in a subalpine meadow ecosystem in Colorado, where experimentally induced warming over a six-year period induced a shift from forbs to shrubs (Harte and Shaw 1995, Shaver et al. 2000, deValpine and Harte 2001). A consequence of this change in life-form composition was that both the quality and quantity of soil organic matter changed, which in turn affected carbon-cycling processes (Harte and Shaw 1995, Shaver et al. 2000, deValpine and Harte 2001). However, the studies also indicated that more complicated factors, including the effects of changes in competitive relationships among species, are likely to influence the impacts from warming (de Valpine and Harte 2001). Both a shift from forbs to shrubs and a change in competitive pressures are likely to be detrimental to *Silene kingii*. Results from other studies in the same area of Colorado indicated that warmer temperatures might cause immediate phenological shifts in plant communities at high elevations (Price and Waser 1998). These shifts are likely mediated through changes in environmental cues, such as the timing of snowmelt (Price and Waser 1998). Shifts on longer time scales are also likely as plant fitness, population dynamics, and the community structure of animal mutualists (e.g., pollinators) and predators change (Price and Waser 1998). Asynchrony between appropriate pollinator activity and flower receptivity may be one negative consequence of a change in the flowering time of *S. kingii*. Much more information is needed before any accurate predictions can be made as to the specific responses of *S. kingii* to potential environmental changes. However, current evidence suggests that the impacts are likely to be substantial.

Atmospheric deposition of nitrogen oxides, ammonium, and other acid precursors might be a concern on some parts of the Shoshone National Forest, such as in the Fitzpatrick and Popo Agie wildernesses (USDA Forest Service 1986). Existing sources of this pollution are located off the forest, upwind to the west and south of the wilderness areas (USDA Forest Service 1986). Air pollution is often a subtle environmental perturbation, and its effects are difficult to quantify. The extent to which air pollution is a threat to alpine community structure, and *Silene kingii* in particular, on the Shoshone National Forest is not known with certainty. However, results from experiments have indicated that nitrogen additions in alpine tundra can influence the species composition of the community and are cause for concern (Bowman et al. 1993, Theodose and Bowman 1997). Added nitrogen caused grasses in particular to increase in abundance at the expense of other species in a dry alpine meadow (Theodose and Bowman 1997). An increase in grass is likely to be detrimental to *S. kingii*, especially if it is truly an uncompetitive species.

Demographic stochasticity refers to chance events independent of the environment that may affect the reproductive success and survival of individuals. In very small populations, the loss of even a few plants can have an important influence on the survival of the whole population. For example, seeds may be aborted by a certain percentage of plants, the percentage becoming bigger and perhaps reaching 100 percent as the population shrinks. Demographic uncertainties are likely to be significant where populations have only a few plants (Pollard 1966, Keiding 1975). The potential influence of demographic stochasticity on the viability of individual occurrences of *Silene kingii* is unknown, but it is likely to be lower than that of either environmental or genetic stochasticity.

Genetic stochasticity is associated with changes in the genetic structure of populations. Gene frequencies in a population may change due to founder effects, bottlenecks, inbreeding, or genetic drift (Menges 1991). No studies have been made to determine the genetic structure of any population of *Silene kingii*. An advantage associated with heterozygosity has been observed in most natural populations of a wide range of species (Soulé 1980). Locally endemic species that exhibit reduced levels of polymorphism may suffer from reduced robustness against environmental uncertainty (Karron 1991, Gitzendanner and Soltis 2000). However, while some rare species have less genetic variation than their widespread congeners, there is a broad range of values, and some rare species exhibit levels of diversity equal to or exceeding those of widespread congeners (Gitzendanner and Soltis 2000). Nevertheless, even if the species is highly polymorphic across its range, genetic stochasticity is of particular concern in small populations (Menges 1991). Even among primarily out-crossing species, small population size can lead to a dearth of pollinators and increased selfing (Rathcke and Jules 1993). A study of the perennial, out-crossing *Lychnis viscaria* (syn: *S. viscaria*) found that there was less genetic diversity in small peripheral populations as compared to large populations (Lammi et al. 1999). However, the degree of genetic diversity was not associated with components of fitness such as germination, seedling mass, or seed yield (Lammi et al. 1999). This is in contrast to results of a study on *S. regia*, where there was a positive correlation between population size and seed yield (Menges 1991). These differing results suggest that studies must be made on *S. kingii* directly and that inferences cannot be made from studies of other species.

Malentities envirogram

With the exception of global climate change, malentities or threats at the current time appear to be local. Potential malentities include sources of disturbance (e.g., hikers, campers, and large ungulates) and invasive plant species that will directly compete for resources such as water, nutrients, and light (**Figure 10**). Trampling may be directly deleterious, but this disturbance also has indirect impacts such as soil erosion and modifying hydrological regimes. These impacts need to be assessed on a case-by-case basis (Murray 1997). Recreational activities, livestock grazing, and wildlife browsing are all potential threats but do not appear to be of critical concern at current levels in Region 2. However, the emphasis is on current levels. Even if the intensity of a threat remains the same, an increase in its area of impact will eventually have negative consequences on the species. In addition, it is important to remember that alpine habitats are slow to recover from disturbance (Willard 1979). Therefore, disturbances tend to have cumulative effects, and their impacts should be viewed in total rather than in the context of isolated events.

Conservation Status of Silene kingii in Region 2

Silene kingii is a regional endemic that appears to be restricted to relatively small areas within its total range. Eighteen of the 20 known occurrences in Region 2 have been found on National Forest System land in Wyoming, but only three of these have been observed within the last 10 years. Little or no information on the abundance of the *S. kingii* plants was provided for any of the occurrences. Therefore, there is no evidence on which to evaluate how the distribution or abundance of this species has changed within the last century. In three cases (WY-3, 6, and 19 in **Table 1**), the same general area was visited twice at intervals of 11, three, and two years, respectively, and plants were found each time. This indicates that plants can persist in the same area for at least 11 years. However, specific occurrence sites were not revisited, and no observations were made to indicate whether *S. kingii* plant numbers have changed or the locations of sub-occurrences have shifted within the occurrence area.

Management plans have not specifically addressed *Silene kingii*, and since it is not designated a sensitive species by USFS, plans are unlikely to do so in the future. The impacts of recreational activities on *S. kingii* occurrences are not clear and need further study. Thirteen of the 20 *S. kingii* occurrences in Wyoming are in wilderness areas, which are considered to have high conservation status. However, unless visitor use is restricted, wilderness areas and the *S. kingii* occurrences therein can experience relatively higher recreational use than other parts of the forest.

Management of Silene kingii in Region 2

Implications and Potential Conservation Elements

There is no doubt that *Silene kingii* represents a unique species, but there have been difficulties in distinguishing it from *S. uralensis* and *S. hitchguirei* within its range (Goodrich personal communication 2004, Hartman personal communication 2004, Morton personal communication 2004). Misidentification can cause problems with defining a species' range and abundance, and it ultimately may obscure the true vulnerability of *S. kingii*.

All of the 20 known occurrences of this species in Wyoming have been confirmed to be *Silene kingii*, and currently, the majority (18 of 20) of these occurrences is on Region 2 National Forest System land. The conservation implication of this situation is that a significant loss of occurrences on National Forest System land would likely have a substantial impact on the viability of the species in Wyoming.

A consideration in managing *Silene kingii* is that it occupies microsites in a landscape consisting of a mosaic of habitat patches that change over distances of a few meters. These patches potentially have very different management needs and responses (Johnston et al. 2001). In addition, the potential interactions among these patches are not understood.

There is no quantitative information upon which to predict the influences of the different types of stochasticity on *Silene kingii*. Short-term analyses of population viability that emphasize demography rather than genetics may be particularly useful because studying the genetics of one or just a few populations may not represent the species in total and may lead to misconceptions (Lande 1988, Menges 1991). Metapopulation analyses based on the proportion of occupied suitable microsites may be an effective alternative method of understanding population viability of this species at the management level (Menges 1991). However, before undertaking such a task, it is very important to understand the precise habitat and microhabitat requirements of *S. kingii*.

The small and scattered nature of the *Silene kingii* occurrences can make it difficult to determine which occurrences may need to be protected. The amount of genetic variation within and among *S. kingii* occurrences is unknown, and there are no estimates of the species' genetic vulnerability. It is likely that the most geographically separated populations will have a significant amount of genetic divergence. Significant loss of genetic diversity may result if populations at the edge of the range are lost. The USFS can take these issues into account when considering which occurrences warrant protection since nearly all known *S. kingii* occurrences are on National Forest System lands. When considering which populations to protect, it is also important to remember that small, peripheral populations may have a high conservation value and can be just as viable as large populations (Lammi et al. 1999). Alleles that were absent in larger populations have been found in small populations (Karron et al. 1988). Habitat type is likely to be important among the occurrence selection criteria. Different habitats may impose different selection pressures and unique genotypes may have formed, or will form in the future (Lammi et al. 1999). Theoretically, traits can evolve in as few as a dozen generations (Garcia-Ramos and Kirkpatrick 1997, Lammi et al. 1999). Such factors might have contributed to the derivation of the two varieties of *S. kingii* in the Absaroka and Wind River ranges in Wyoming.

No information specific to *Silene kingii* has been systematically gathered, and little is available upon which to base predictions regarding the species' response to specific disturbance types or levels. Because *S. kingii*'s cushion plant growth form is likely to be tolerant of some degree of trampling, current levels of domestic livestock grazing and occasional foot traffic are unlikely to be of concern. In contrast, intense or recurring trampling is likely to be deleterious because the species evolved in an environment with low levels of disturbance. Johnston et al. (2001) suggested that alpine areas should be managed to create no new disturbances. This recommendation would clearly benefit *S. kingii*.

The role of pollinators in the reproduction of *Silene kingii* is not known. If certain pollinators are critical for reproduction, and thus long-term population sustainability, there are associated conservation implications. Management practices, such as routine pesticide applications to control forest pests or livestock grazing prescriptions, may need to be re-evaluated. The impacts of sheep grazing on pollinator assemblage and abundance may need to be considered.

Tools and practices

Species inventory

Documented inventory and monitoring activities are important for understanding the status of any taxon. Inventory is particularly necessary for *Silene kingii* because most of the available information about the species is derived from herbarium specimens or from relatively casual observations that do not provide quantitative information on the abundance or the range of the taxon.

The data forms used by the NatureServe Network all request information that is appropriate for inventory purposes (also see Colorado Natural Heritage Program and Wyoming Natural Diversity Database Internet sites in **References** section for examples of data forms). The number of *Silene kingii* plants, the area they actually occupy, and the apparent extent of suitable habitat are important data for occurrence comparison. However, it is important to note that any estimate of suitable habitat without prior critical habitat modeling is subjective and may not be an accurate measure of the area that the taxon can colonize. A sketch of the site indicating the plants' location is helpful for future reference. Collecting quantitative information on whether the plants are flowering or fruiting is also valuable in assessing the vigor and reproductive potential of a population. Details of habitat conditions, such as associated species, canopy cover, soil type, ground cover, aspect, slope, and sources of soil moisture, also contribute to a better understanding of the requirements of this species. Elzinga et al. (2001) describe inventory protocols in further.

Habitat inventory

Habitat inventory and mapping permit the evaluation of the potential amount of area available for a species and assist in determining habitat protection priorities, which can be directly incorporated into land-use planning processes. Geographic Information Systems (GIS) are often a primary means of displaying the results of habitat inventories.

Available habitat descriptions suggest that, within the restrictions of the eco-climate zones in which it exists, *Silene kingii* grows in a variety of open to partially shaded habitats. It would be prudent to consider any cushion plant community in alpine tundra and sub-alpine regions above 2,500 m as "potential habitat". However, the available habitat information supplied with occurrence descriptions is too general to make accurate analyses of the habitat requirements of *S. kingii*. This means that at the current time it is not possible to make a rigorous inventory of areas that might actually be occupied by *S. kingii* (see Habitat section). Until the species' requirements for establishment and survival are understood, estimates of the amount of potential habitat are subject to large errors. General considerations as to habitat suitability include the presence/absence of non-native plant species and the level of disturbance. High levels of both factors are likely to indicate degraded habitat conditions for *S. kingii*. The vegetation macro-plot studies ongoing in the Ashley and Wasatch-Cache national forests of Region 4 in the Uinta Mountains (Goodrich personal communication 2004) will be useful in clarifying habitat requirements. However, before using those results to predict habitat availability in Wyoming and Colorado, their direct applicability to the occurrences in those states needs to be confirmed.

Population monitoring

Monitoring studies of *Silene kingii* have not been undertaken in any part of its range. Long-term monitoring of known populations of plant species is very useful for tracking their status with respect to current management and protection activities. Counts of numbers of individuals present, the determination of the amount of annual flowering and seed production, and an assessment of recruitment rates, are needed in order to determine population dynamics and to assess the viability of individual populations. It is very important to set the objectives of the monitoring plan prior to the project's initiation. Poor design can lead to inconclusive results (Elzinga et al. 2001). Consultation with a statistician before data are collected may be well worthwhile.

Elzinga et al. (1998), Goldsmith (1991), and Lesica (1987) have discussed the use of rectangular or square quadrant frames along transect lines to monitor plant populations effectively. Alternatively, macroplots may be used to make demographic studies while monitoring a specific population. Regardless of the methods finally decided upon, all long-term monitoring schemes need to address the patchy and possibly dynamic nature of *Silene kingii* occurrences. Problems associated with spatial auto-correlation can occur when using permanent plots to monitor a dynamic population (Goldsmith 1991). If the size of the plot is too small or if the establishment of new plots is not part of the original scheme, when plants die within the plot and no replacement occurs, it is impossible to know the significance of the change without studying a very large number of similar plots.

An additional or alternate cause for an apparent "dynamic" population is that the plants may undergo periods of prolonged dormancy. *Silene spaldingii*, another rare perennial, tap-rooted species that grows in Montana at lower elevations than *S. kingii*, exhibited prolonged dormancy (Lesica and Steele 1994, Lesica 1999). In each of the six years of the study, a substantial portion of the plants exhibited dormancy, and some plants remained dormant for more than one year (Lesica 1997, 1999). Prolonged dormancy can be inferred by following the fate of marked or mapped individuals for successive years (Lesica 1999). Lesica and Steele (1994) estimated that "when dealing with plants that have prolonged dormancy, it will be necessary to conduct a study for seven years to obtain five years of accurate data."

The use of photopoints and photoplots is recommended to supplement but not replace traditional monitoring protocols. Photographic documentation is very useful in visualizing vegetation changes over time and is increasingly used in monitoring plans. Photopoints are collections of photographs with the same field of view that have been retaken from the same position over a period of time. Photoplots are usually relatively close-up photographs showing a birds-eye-view of the monitoring plot. In both cases, a rebar or some other permanent marker should be placed to mark the location where the photographer stands, and compass directions and field-of-view details must be recorded to make sure the photograph can be accurately re-taken. Even though digital copies are convenient and easy to store, many museums and researchers suggest storing slides or even prints since the technology to read current forms of digital media may not be available in future years.

Specific monitoring plots with photo-points are very useful not only in areas with recreational or resource extraction activities but also in more pristine areas where the consequences of disturbances such as erosion, landslides, and local soil movement can be evaluated. The appropriate frequency for monitoring should be evaluated after sites are visited annually for several years. If relatively little change has occurred over the initial monitoring period, a monitoring schedule with longer intervals between visits may be the most time and cost effective. It needs to be recognized, however, that such a strategy will incur a considerable loss of detail in the data.

Habitat monitoring

The presence of invasive non-native plant species and evidence of anthropogenic disturbance are likely to indicate degraded habitat conditions for *Silene kingii*. However, the lack of information on the habitat requirements of *S. kingii* makes it premature to consider that habitat monitoring in the absence of *S. kingii* plants can be truly effective. Habitat monitoring in known occurrences needs to be associated with population monitoring protocols. Descriptions of habitat are customarily recorded during population monitoring activities in order to link environmental conditions with abundance over the long-term. Parameters that need to be recorded include aspect, slope, and vegetative cover, including lichen and moss, litter, exposed soil, and rock. The extent of canopy cover (shade) experienced by *S. kingii* is also a useful parameter to record and can be measured using a spherical densiometer. Two types of spherical densiometers are available: convex and concave. Measurements need to be made consistently with one or the other type because slightly different results can occur between the two instruments, especially if there are different operators.

Conditions several years prior to the onset of a decrease or increase in population size may be more important than conditions existing during the year the change is observed. Current land use designation and evidence of land use activities are important to include with monitoring data. For example, where possible, it needs to be noted if populations are on an active grazing allotment even though no use by livestock is observed or in a camping area even without the presence of campers. Of course, any signs of local grazing or other herbivory, for example by insects, are important observations to note. Land use details, such as whether the area is popular for hiking or if the occurrence is adjacent to an official or unofficial trail, also need to be recorded. These types of observations may be useful in the future to explain any changes that are observed.

Population or habitat management approaches

Common methods to conserve rare taxa include such diverse approaches as seed banking and designating occurrences as protected areas. Seed banks have been established to save seed in case restoration efforts are need in the future (Royal Botanic Gardens, 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 understood. If microhabitat requirements are not known, the conditions necessary to maintain an occurrence may not be met even if germination and seedling establishment is achieved. Therefore, re-establishing occurrences that have been extirpated may be a very difficult task. The Center for Plant Conservation (CPC) is dedicated to preventing the extinction of native plants in the United States and maintains many taxa as seeds, rooted cuttings, or mature plants, depending upon the taxon's requirements. *Silene kingii* is not included in the current CPC National Collection (Center for Plant Conservation undated).

No population or habitat management actions have been proposed specifically for *Silene kingii*. Beneficial management practices that have been generally implemented within national forests include restricting recreational vehicle traffic and routing hikers to designated trails. In many cases, these policies have been initiated relatively recently, and their effects have not been documented. Because *S. kingii* is not designated a sensitive species, comments on its status would likely be incidental to descriptions of other vegetation types or communities. It is very valuable to monitor the vegetation, specifying all species and their abundance, at sites both before and after management practices change (e.g., before establishing or closing a trail). Such data would be helpful in determining the responses of *S. kingii* to different management regimes.

Information Needs

The most pressing need is to obtain accurate information on the numbers and distribution of *Silene kingii*. Surveys on the San Juan National Forest might be valuable in clarifying the range and abundance of the species in Colorado. It is essential that populations of *S. kingii* be clearly distinguished from those of *S. uralensis* and *S. hitchguirei* and that the relative abundance of these species clarified. The occurrence of two varieties of *S. kingii* in the Absaroka and Wind River ranges (Welp et al. 2000, Dorn 2001, Wyoming Natural Diversity Database 2006) needs to be peer-reviewed and published in the scientific literature. A generally accepted recognition of the two varieties is required in order to determine whether steps need to be taken to ensure that the full extent of the genetic diversity within *S. kingii* is maintained.

Monitoring known *Silene kingii* occurrences is essential in order to understand the implications of existing and new management practices. Where management practices are likely to change, inventory needs to be taken to establish baseline data, and periodic monitoring needs to be conducted after the new policy is initiated. The demographics (e.g., number of seedlings, number of reproductive plants) of each *S. kingii* occurrence are not known. The relative importance of different stages of its life cycle needs to be clarified in order to estimate when it is most vulnerable to disturbance or competition. Further information on the habitat requirements of *S. kingii* would allow more precise management and protection. Factors, both biological and/or ecological, that limit occurrence size and contribute to its patchy spatial distribution are not known and need to be determined.

The reproductive system of *Silene kingii* needs further study. The identity and importance of pollinators need to be determined. If pollinators are critical, management practices, such as routine pesticide applications or livestock grazing, may need to be modified to ensure successful cross-pollination and long-term population sustainability.

The prioritization of information needs depends upon management goals and may be influenced by changing circumstances. Currently, the primary information needs for *Silene kingii* include:

- determine its distribution and abundance
- resolve its taxonomic status
- determine the abundance and distribution of the two varieties of *S. kingii* in Wyoming
- monitor known occurrences at appropriate intervals to determine long-term trends
- determine the elements of suitable (potential) habitat and the tolerance of *S. kingii* to different types of disturbance
- clarify the effects of anthropogenic activities on *S. kingii*
- obtain census information for each occurrence on the Shoshone National Forest
- explore the possibility that there are differences in the microhabitats colonized by *S. hitchguirei*, *S. uralensis*, and each of the varieties of *S. kingii*
- define which of *S. kingii*'s life history stages have the greatest effect on population growth and survival
- clarify the species' reproductive strategy
- identify pollinator species and their role in maintaining populations over the long-term.

Definitions

Agamospermy – when a diploid embryo sac (sporophyte) develops by somatic division of a nucellus or integument cell; no meiosis takes place, so the diploid sporophyte gives rise directly to a diploid gametophyte (Allaby 1992).

Allele – an alternative form of the same gene at a particular location on a chromosome. (Hard et al. 1992).

Allopolyploid – "a polyploid formed from the union of genetically distinct chromosome sets, usually from different species" (Allaby 1992).

Alpine zone – a region occurring above the tree line and below the snow line (Allaby 1992).

Andromonoecious – situations where male and hermaphodite flowers occur on the same plant.

Apomixis – a type of asexual reproduction in plants (i.e., reproduction without fertilization or meiosis) (Allaby 1992).

Arbuscules – a tuft of branching fungal hyphae in certain types of mycorrhiza (Allaby 1992).

Autogamy – in plants, autogamy refers to self-fertilization.

Binomial – derived from the binary nomenclature system in which the name of a species consists of a generic name (genus) and a specific epithet (species)

Caespitose – growing in tufts (Harrington and Durrell 1957).

Calcicole – plants that grow best in calcareous soils.

Calyx – a collective term for all the outer leaf-like structures (sepals) of a flower.

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

Conservation rank – NatureServe and the Heritage Programs Ranking system (Internet site: http://www.natureserve.org/explorer/granks.htm). G3 indicates *Silene kingii* is "vulnerable globally either because it is 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". "S1" designation indicates that the species is "critically imperiled because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the subnation [state]". For an S1 designation there are typically 5 or fewer extant occurrences or less than 1,000 remaining individuals. "S2" designation indicates it is "imperiled in the subnation [state] because of rarity or because of some factor(s) making it very vulnerable to extirpation from the subnation".

Diptera – order of insects that includes flies.

DNA – Deoxyribonucleic acid, usually in the form of a double helix; represents the genetic instructions for each cell in an organism; located in the cell nucleus, in chloroplasts, and in mitochondria.

Fitness – an individual's contribution, relative to other individuals, to the breeding population in the next generation; measures of an individual's reproductive success such as its survival, fertility, and age at reproduction, are typically used as indicators of fitness; the fitness of a group of individuals (e.g., a population) may be defined as the group's ability to maintain itself in its environment; it is therefore a composite measure of individual reproductive success (Hard et al. 1992).

Geitonogamy – where pollen is transferred between flowers on the same plant.

Glabrate – becoming glabrous with age.

Glabrous – hairless, smooth.

Gynodiecious – the condition where female and hermaphodite flowers are on separate plants.

Gynomonoecious – the condition where female and hermaphodite flowers on the same plant.

Hymenoptera – order of arthropods including wasps, ants, bees, and sawflies.

***K*-selected –** species that employ a logistic strategy, are long-lived, and produce only a few progeny.

Lanceolate – lance-shaped; several times longer than wide (Harrington and Durrell 1957).

Lepidoptera – order of arthropods including butterflies and moths.

Malentity – something that is capable of having an adverse effect on the subject organism with no adverse consequence to itself; it can thus adversely influence the subject organism accidentally or intentionally.

Polycarpic – plants that have repeated periods of reproduction (synonym: iteroparous).

Polymorphic – occurring in several different forms.

Quartzite – (1) a metamorphic rock consisting of mainly quartz, formed by recrystallization of sandstone by regional or thermal metamorphism; (2) sandstone consisting of quartz grains cemented by secondary silica (Bates and Jackson 1984).

Retuse – a rounded apex with a shallow notch (Harrington and Durrell 1986).

Rhopalocera – a division of Lepidoptera including all the butterflies; they differ from other Lepidoptera in having club-shaped antennae.

r-selected – species that employ a Malthusian strategy and characteristically have a short life span, early reproduction, low biomass, and the potential to produce large numbers offspring in a short period of time.

Sphingidae – family within the order Lepidoptera that includes hawkmoths.

Stipules – an appendage at the base of the petiole or leaf at each side of its insertion (Harrington and Durrell 1986)

Stochasicity – uncertainty (Frankel et al. 1995).

Trichomes – hair-like outgrowth from the epidermis (Harrington and Durrell 1957).

Trinomial – derived from the Linnaean nomenclature system in which the name of a species consists of a generic name (genus) and a specific epithet (species) and a third name denoting varieties or subspecies.

Vesicles – a small bladder-like structure containing a fluid (Allaby 1992).

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Appendix

Synonyms of Two Taxa That Morphologically Resemble Silene kingii

Table A1. Synonyms of *Silene hitchguirei*, which co-occurs with *S. kingii* in Region 2. This taxon may be mistaken for *S. kingii*, especially in the field by surveyors unfamiliar with the genus.

Synonyms and authors (from Morton 2005)
Silene uralensis (Rupr.) Bocquet ssp. *montana* (S. Wats.) McNeill
Lychnis apetala ssp. *montana* (S. Wats.) Maguire
Lychnis apetala var. *montana* (S. Wats.) C. L. Hitchc.
Lychnis montana S. Watson[1].
Silene wahlbergella Chowdhuri ssp. *montana* (S. Wats.) Hultén
Wahlbergella montana (S. Wats.) Rydb.

Table A2. Synonyms of *Silene uralensis* subsp. *uralensis*, which co-occurs with *S. kingii* in Region 2. This taxon may be mistaken for *S. kingii*, especially in the field by surveyors unfamiliar with the genus.

Synonyms and authors (from Morton 2005)
Silene uralensis subsp. *uralensis* (Rupr.) Bocquet
Gastrolychnis uralensis Rupr.
Wahlbergella apetala (L.) Fr. var. (beta) *arctica* Th. Fr.
Silene uralensis (Rupr.) Bocquet subsp. *arctica* (Th. Fr.) Bocquet
Silene wahlbergella Chowdhuri subsp. *arctica* (Th. Fr.) Hultén
Melandrium apetalum (L.) Fenzl subsp. *arcticum* (Th. Fr.) Hultén
Gastrolychnis apetala (L.) Tolm.& Kozh. subsp. *arctica* (Th. Fr.) Á. & D. Löve
Silene attenuata (Farr) Bocquet
Silene uralensis (Rupr.) Bocquet subsp. *attenuata* (Farr) McNeill
Melandrium apetala (L.) Fenzl subsp. *attenuatum* (Farr) Hara
Wahlbergella attenuata (Farr) Rydb.
Gastrolychnis apetala (L.) Tolm. and Kozh.
Gastrolychnis apetala subsp. *arctica* (Fries) Á. and D. Löve
Gastrolychnis apetala subsp. *uralensis* (Rupr.) Löve
Lychnis apetala L., non *Silene apetala* Willd.
Lychnis apetala var. *glabra* Regel
Melandrium apetalum (L.) Fenzl
Melandrium apetalum subsp. *arcticum* (Fries) Hultén
Silene wahlenbergella Chowdhuri