Lesquerella arenosa (Richards.) Rydb. var. *argillosa* Rollins & Shaw (Great Plains bladderpod): A Technical Conservation Assessment

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COVER PHOTO CREDIT

Lesquerella arenosa var. *argillosa* (Great Plains bladderpod). Photograph by Charmaine Delmatier. Reprinted with permission from: Fertig, W., C. Refsdal, and J. Whipple. 1994. Wyoming Rare Plant Field Guide. Wyoming Rare Plant Technical Committee, Cheyenne, WY.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *LESQUERELLA ARENOSA* VAR. *ARGILLOSA*

Status

Lesquerella arenosa var. *argillosa*, or Great Plains bladderpod, is a regional endemic taxon occurring from 765 to 1540 meters (m) (2510 to 5053 feet [ft]) on exposed substrates in badland and grassland habitats of eastern Wyoming, southwestern South Dakota, northwestern Nebraska, and northern Colorado. Currently, there are approximately 36 known occurrences of this taxon, with at least five occurrences on U.S. Forest Service National Forest System lands. Not enough abundance data or demographic information are available to conclude if populations of *L. arenosa* var. *argillosa* are increasing, decreasing, or remaining stable. In addition, little is known about the reproductive biology or ecological requirements of *L. arenosa* var. *argillosa*. This taxon is not currently on the U.S. Forest Service Rocky Mountain Region sensitive species list (U.S. Forest Service 2002), nor is it currently covered under the U.S. Fish and Wildlife Service's Endangered Species Act of 1973 (16 U.S.C. 1531-1536, 1538-1540). However, it is listed as a sensitive species with the U.S. Bureau of Land Management (BLM), Wyoming State Office (U.S. Bureau of Land Management 2001). Because of its small number of occurrences and regional endemism, the Global Heritage Status Rank for the rangewide status of *L. arenosa* var. *argillosa* is G5T3 (vulnerable) (NatureServe 2003). *Lesquerella arenosa* var. *argillosa* is ranked as S1 (critically imperiled) in Wyoming and Colorado, as S2 (imperiled) in Nebraska, and as S3 (vulnerable) in South Dakota (NatureServe 2003). The species is not known to occur in Kansas.

Primary Threats

Lesquerella arenosa var. *argillosa* is vulnerable because of its restricted geographic range, small number of documented occurrences, and vulnerability to human-related and environmental threats. Human-related threats to *L. arenosa* var. *argillosa* include motorized and non-motorized recreation, road construction and maintenance, mining and quarrying activities, structure construction and development, invasion by non-native plant species, and grazing and trampling by livestock. Possible environmental and biological threats to populations of *L. arenosa* var. *argillosa* include changes to the natural disturbance regime (e.g., succession, fire, erosion), environmental fluctuations (e.g., global climate change, drought), genetic isolation, and inadequate pollination. Populations of *L. arenosa* var. *argillosa* on National Forest System lands may be susceptible to impacts from motorized recreation, invasion of non-native plants, and incidental damage from livestock trampling or recreation.

Primary Conservation Elements, Management Implications and Considerations

The current distribution and abundance of *Lesquerella arenosa* var. *argillosa* are not well known. The microhabitat needs of this taxon and the intensity, frequency, size, and type of natural disturbance optimal for persistence of this taxon are unknown. The lack of information regarding the colonizing ability, adaptability to changing environmental conditions, sexual reproductive potential, or genetic variability of this taxon makes it difficult to predict its vulnerability. Surveying high probability habitat for new populations, protecting existing populations from direct damage, documenting and monitoring the effects of current management and recreation activities, and preventing non-native plant invasions are key conservation elements for this taxon. Priorities of future research studies include revisiting and mapping the extent of existing populations, conducting surveys to locate additional populations within Region 2, assessing imminent threats from exotic weed invasion or current land uses, investigating factors affecting spatial distribution (e.g., microhabitat characteristics), exploring biological and ecological limitations, and producing information related to demography and genetic structure.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), U.S. Forest Service (USFS). *Lesquerella arenosa* var. *argillosa* is the focus of an assessment because it has the potential to be listed as a sensitive species in Region 2 (U.S. Forest Service 1995). Within the National Forest System, a sensitive species is a species whose population viability or habitat capability is identified as a concern by a regional forester because of significant current or predicted downward trends in population numbers or habitat capability that would reduce its distribution (U.S. Forest Service 1995). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Lesquerella arenosa* var. *argillosa* throughout its entire range, all of which is in Region 2. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. Furthermore, completing the assessment promptly requires the establishment of some limits concerning the geographic scope of particular aspects of the assessment. This introduction defines the goal of the assessment, outlines its scope and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on scientific knowledge accumulated prior to initiating the assessment. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussions of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations but provides the ecological background upon which management should be based. However, it does focus on the consequences of changes in the environment that result from management (i.e., management implications).

Scope

The *Lesquerella arenosa* var. *argillosa* species assessment examines the biology, ecology, conservation status, and management of this taxon with specific reference to the geographic and ecological characteristics of USFS Region 2. Although some of the literature on this taxon (or related taxa) originates from field investigations outside the region, this document places that literature in the ecological and social context of the southern Rocky Mountains and northern Great Plains. Similarly, this assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of *L. arenosa* var. *argillosa* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but in a current context.

In producing the assessment, a comprehensive literature search was conducted to obtain all literature focusing on *Lesquerella arenosa* var. *argillosa*, as well as related information on the ecological and geographical context of this taxon. We reviewed refereed literature (e.g., published journal articles), non-refereed publications (e.g., unpublished status reports), dissertations, data accumulated by resources management agencies (e.g., Natural Heritage Program [NHP] element occurrence records), and regulatory guidelines (e.g., USFS Forest Service Manual). We incorporated herbarium specimen label information provided by herbarium staff and available in NHP element occurrence records, but we did not visit every herbarium with specimens of this species. The assessment emphasizes refereed literature because this is the accepted standard in science. However, non-refereed publications and reports were used extensively in this assessment because they provide critical information unavailable elsewhere. These unpublished, non-refereed reports were regarded with greater skepticism, and we presented all information with appropriate uncertainty. In addition, we highlighted areas of current research with this taxon and cited if these studies were in progress, in preparation, or in press.

Treatment of Uncertainty

Science represents a rigorous, synthetic 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. Sorting among alternatives may be accomplished using a variety of scientific tools (e.g., experiments, modeling, logical inference). It is difficult to conduct critical experiments in the ecological sciences

and often observations, inference, good thinking, and models must be relied upon to guide the understanding of ecological relations.

In this assessment, the strength of evidence for particular 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 as sound approaches to understanding features of biology and are used in synthesis for this assessment.

Because of a lack of experimental research efforts concerning *Lesquerella arenosa* var. *argillosa*, this assessment report relies heavily on the personal observations of botanists and land management specialists from throughout the taxon's range. When information presented in this assessment is based on our personal communications with a specialist, we cite those sources as "personal communication" In addition, much of the knowledge about the status and habitat characteristics of *L. arenosa* var. *argillosa* is presented in two unpublished survey reports: one prepared by the Wyoming Natural Diversity Database (WYNDD) (Marriott 1992) and the other by the South Dakota NHP (Ode and Backlund 1999). Unpublished data (e.g., NHP element occurrence records) were also important in estimating the geographic distribution and describing the habitat of this taxon. These data required special attention because of the diversity of persons and methods involved with data collection and the inability to verify historical information.

Because there is a paucity of knowledge specific to this taxon (and taxonomically closely-related species [Rollins and Shaw 1973]), we also incorporated information, where available, about other *Lesquerella* taxa endemic to Region 2 and/or adjacent states. These comparisons are not meant to imply that *L. arenosa* var. *argillosa* is biologically identical to these species, but they represent an effort to present possible biological characteristics of *L. arenosa* var. *argillosa*, important considerations when studying this taxon, and potential threats. For example, unpublished status reports for *L. prostrata*, a species known from shaley slopes and dry soils of Wyoming, Utah, and Idaho (Fertig 2000), and *L. paysonii*, a species known from rocky slopes and gravelly soils of Wyoming, Montana, and Idaho (Moseley 1996), provide helpful insights on important issues to consider when studying the biology and conservation of rare *Lesquerella* species. Published greenhouse and field investigations for the relatively well-studied *L. fendleri*, a short-lived desert annual/perennial widespread from Arizona to Colorado and Oklahoma (Dierig et al. 1996, Mitchell 1997, Roll et al. 1997, Mitchell and Marshall 1998), also elucidate important considerations to apply to studies of *L. arenosa* var. *argillosa*. As a result, biology, ecology, and conservation issues presented for *L. arenosa* var. *argillosa* in Region 2 are based on inference from these published and unpublished sources. We clearly noted when we were making inferences based on the available knowledge to inform our understanding of *L. arenosa* var. *argillosa.*

Publication of Assessment on the World Wide Web

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

Peer Review

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

MANAGEMENT STATUS AND NATURAL HISTORY

Lesquerella arenosa var. *argillosa* is a regional endemic taxon of four states within Region 2 and is known from fewer than 40 occurrences globally (**Figure 1**) (Nebraska Natural Heritage Program 2002, South Dakota Natural Heritage Program 2002a, University of Colorado Herbarium 2002, Wyoming Natural Diversity Database 2003). This section discusses the special management status, existing regulatory mechanisms, and biological characteristics of this taxon. Refer to **Table 1** for a summary of federal and natural heritage program ranks of *L. arenosa* var. *argillosa.*

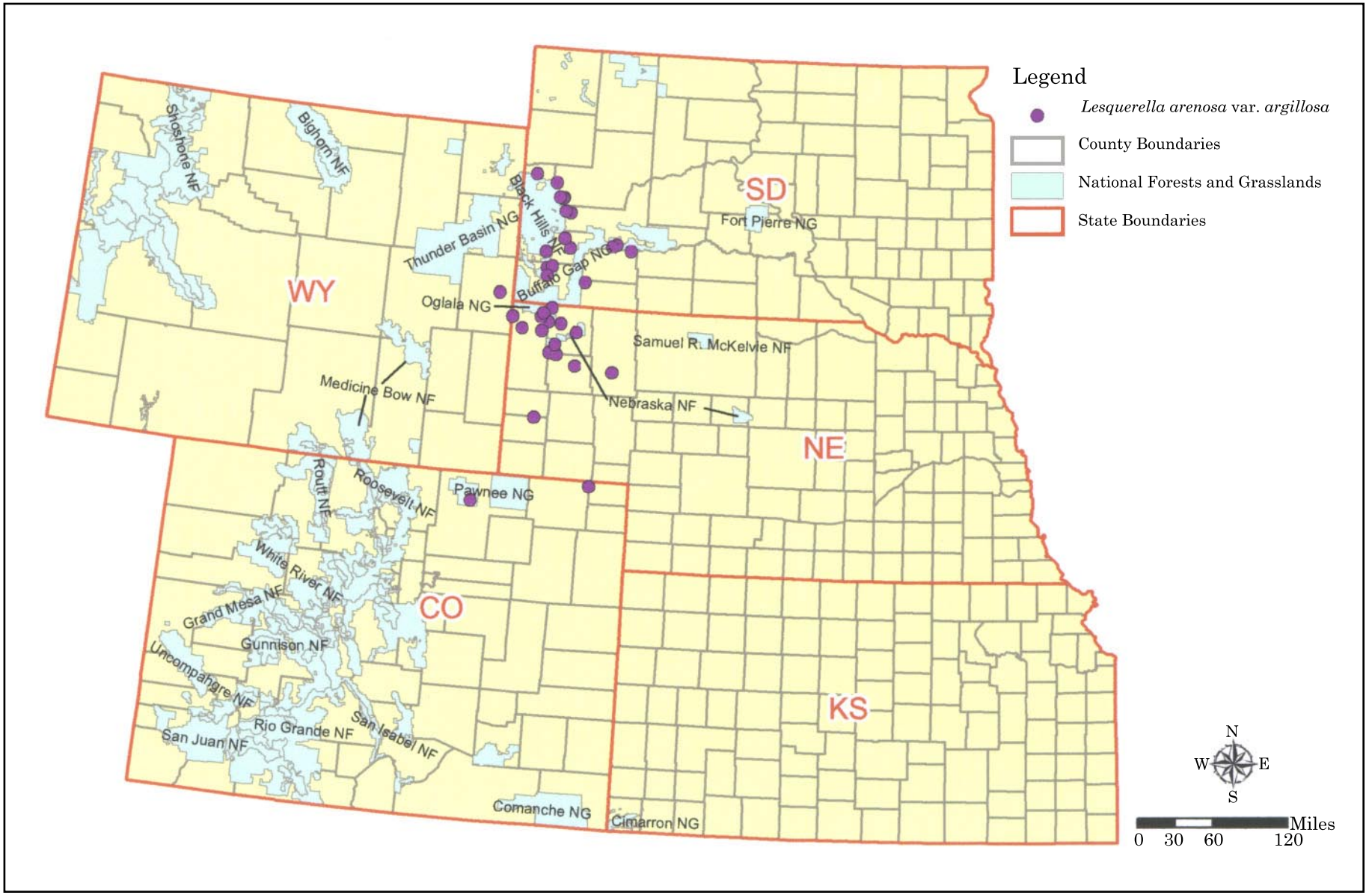

Figure 1. Map of U.S. Forest Service Region 2 illustrating distribution of *Lesquerella arenosa* var. *argillosa* occurrences in Colorado (Logan and Weld counties), Nebraska (Banner, Box Butte, Dawes, Sheridan, and Sioux counties), South Dakota (Custer, Fall River, Lawrence, Meade, Pennington, and Shannon counties), and Wyoming (Converse and Niobrara counties). Each occurrence may include one to several populations. Refer to document for abundance and distribution information. Sources: Nebraska Natural Heritage Program, Lincoln, NE (2002); South Dakota Natural Heritage Program, Pierre, SD (2002); Wyoming Natural Diversity Database, Laramie, WY (2002); University of Colorado Herbarium, Boulder, CO (2002).

Table 1. Conservation and management status of *Lesquerella arenosa* var. *argillosa* as ranked by federal agencies and Natural Heritage Programs in Region 2 states.

Listing	Rank
U.S. Fish and Wildlife Service	Not listed
U.S. Forest Service Region 2	Not listed
Bureau of Land Management - Wyoming	Sensitive
NatureServe Global Ranking	Vulnerable (G5T3)
Colorado Natural Heritage Program	Critically imperiled (S1)
Kansas Natural Heritage Inventory	Not listed; Not known in state
Nebraska Natural Heritage Program	Imperiled (S2)
South Dakota Natural Heritage Program	Vulnerable (S3)
Wyoming Natural Diversity Database	Critically imperiled (S1)

Key to Natural Heritage Program Rankings:

G = Global rank based on rangewide status, T=variety/subspecies rank based on rangewide status

G1, T1	Critically imperiled globally because of extreme rarity (five or fewer occurrences or very few remaining individuals) or because of some factor making it especially vulnerable to extinction.
G2, T2	Imperiled globally because of rarity (six to 20 occurrences) or because of factors demonstrably making a species vulnerable to extinction.
G3, T3	Vulnerable throughout its range or found locally in a restricted range (21 to 100 occurrences) or because of other factors making it vulnerable to extinction.
G4, T4	Apparently secure, though it may be quite rare in parts of its range, especially at the periphery.
G5, T5	Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery.

S= State rank based on status of a species in an individual state

S1	Critically imperiled in the state because of extreme rarity (five or fewer occurrences or very few remaining individuals) or because of some factor making it especially vulnerable to extinction.
S2	Imperiled in the state because of rarity (six to 20 occurrences) or because of factors demonstrably making a species vulnerable to extinction.
S3	Vulnerable throughout its statewide range or found locally in a restricted statewide range (21 to 100 occurrences) or because of other factors making it vulnerable to extinction.
S4	Apparently secure, though it may be quite rare in parts of its statewide range, especially at the periphery.
S5	Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery.

Management and Conservation Status

Federal status

The Endangered Species Act of 1973 (16 U.S.C. 1531-1536, 1538-1540) was passed to legally protect plant and animal species placed on the threatened or endangered list. The listing process is based on population data and is maintained and enforced by the U.S. Fish and Wildlife Service. *Lesquerella arenosa* var. *argillosa* is not listed under the Endangered Species Act (Wyoming Natural Diversity Database 2003).

Lesquerella arenosa var. *argillosa* is not listed as a sensitive species by USFS Region 2 (USFS 2002). This taxon is listed as a sensitive species by Wyoming Bureau of Land Management (Wyoming Bureau of Land Management 2001).

Heritage program status

The Global Heritage Status Rank for the rangewide status of *Lesquerella arenosa* var. *argillosa* is G5T3 (NatureServe 2003). G (global) ranks are based on the rangewide status of the species as a whole, while T (trinomial) ranks are based on the rangewide status of the subspecies or variety. The global rank indicates that the **species** *L. arenosa* is considered demonstrably widespread, abundant, and secure (G5), but the trinomial rank of the **variety** *L. arenosa* var. *argillosa* is vulnerable (T3) (**Table 1**) (NatureServe 2003).

State NHPs collect information about the biological diversity of their respective states, maintain databases of species of special concern, and assign state heritage ranks based on the imperilment of species within the state. *Lesquerella arenosa* var. *argillosa* has been ranked as critically imperiled (S1) in Wyoming and Colorado (Colorado Natural Heritage Program 2003, Wyoming Natural Diversity Database 2003), as imperiled (S2) in Nebraska (Nebraska Natural Heritage Program 2002), and as vulnerable (S3) in South Dakota (South Dakota Natural Heritage Program 2002a). In Wyoming, plant species of special concern are also prioritized for conservation attention within the state on a three-part scale (low, medium, and high) based on global rankings. *Lesquerella arenosa* var. *argillosa* is ranked as medium priority for conservation attention in the state of Wyoming (Medium priority species are regional endemics ranked G3T3 or of greater concern (e.g. G2T2, G1T1) that receive some protection or have low threats, or disjunct species that are poorly protected) (Fertig and Heidel 2002). This taxon is not known from Kansas, the fifth state comprising Region 2, and thus it is not currently listed or ranked in that state (Kansas Natural Heritage Inventory 2000).

Heritage databases draw attention to species of concern potentially requiring conservation strategies for future success as a result of limited distribution and abundance. However, these lists are not associated with specific legal constraints, such as limiting plant harvesting or restricting damage to critical habitats.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Known populations of *Lesquerella arenosa* var. *argillosa* occur in a variety of land ownership and management contexts; refer to **Figure 1** for a map of occurrences and **Table 2** for a list of management contexts. This taxon occurs in USFS Oglala National Grassland (Nebraska), Fort Robinson State Park (Nebraska), Chadron State Park (Nebraska), BLM Newcastle Field Office (Wyoming), USFS Pawnee National Grassland (Colorado), Badlands National Park (South Dakota), Pine Ridge Indian Reservation (South Dakota), Badlands Bombing Range (South Dakota), private lands, and other (unknown) lands (Nebraska Natural Heritage Program 2002, South Dakota Natural Heritage Program 2002a, University of Colorado Herbarium 2002, Wyoming Natural Diversity Database 2003). Of 36 known occurrences of *L. arenosa* var. *argillosa*, at least five are on USFS National Forest System lands. Several historical occurrences with imprecise location information occur in close proximity to USFS National Forest System lands (e.g. Black Hills National Forest (South Dakota) (D. Ode personal communication 2003). All of the federal lands supporting occurrences are managed for multiple uses (Fertig 1999) with an effort to prevent damage to populations and habitats of species of special concern or sensitive species.

Although *Lesquerella arenosa* var. *argillosa*has been identified as a taxon of special concern and BLM sensitive taxon, there are few specific regulatory mechanisms at the federal or state level to regulate its conservation. This species is not designated as a USFS sensitive species and thus does not receive protection from policies designed specifically for sensitive species. This taxon may obtain protection from various conservation strategies designed to protect plants and animals on federal lands. While managing lands for multiple uses, the USFS is directed to develop and implement management practices to ensure that species do not become threatened or endangered (U.S. Forest Service 1995). The National Environmental Policy Act (U.S. Congress 1982) requires an assessment of impacts of any significant federal project (e.g. USFS, BLM, or National Park Service) to natural environments. For example, the Newcastle BLM office included in the vegetation resources section of its management plan: "Maintain or enhance essential and important habitats for special status plant species on BLM-administered public land surface and prevent the need for any special status plant species being listed as threatened and endangered species." (U.S. Bureau of Land Management 2000). In addition, the National Park Service prohibits the collection of any native plants without permit (U.S. National Park Service 2002). The USFS prohibits the collection of any sensitive plant species except by permit (U.S. Forest Service 1995). Travel management plans in USFS National Forest System lands with occurrences of *L. arenosa* var. *argillosa* generally allow motorized recreation to occur throughout the grasslands, with some exceptions (J. Abegglen personal communication 2002, C. Bradshaw personal communication 2002, M. Marston personal communication 2002, M. Erk personal communication 2003, T. Weisbeck personal communication 2003). Occurrences of this taxon in areas with restricted travel (e.g., Toadstool Park in USFS Oglala National Grassland, USFS Pawnee National Grassland) may benefit from protection from motorized recreation impacts (J. Abegglen personal communication 2002, M. Marston personal communication 2002).

Table 2. *Lesquerella arenosa* var. *argillosa* occurrence information. Includes state, county, date the site was last observed, estimated abundance, and land management context.

State	Number of Occurences	County	Date Last Observed	Estimated Abundance	Elevation (m)	Management Area/Ownership
Colorado (2 sites)	1	Logan	1983	Not Available (NA)	1,200	Not Available (NA)
	1	Weld	1997	"occasional"	1,540	USFS Pawnee National Grassland
Nebraska (16 sites)	1	Banner	1996	500 individuals; "common"	Not Available (NA)	NA
			1988	"fairly abundant"	NA	NA
	3	Box Butte	1968	"few plants"	NA	NA
			1970	NA	NA	NA
			1988	"not very abundant"	NA	NA
			1939	"scattered to common"	NA	Chadron State Park
	5	Dawes	1891	NA	NA	NA
			1995	"common"	NA	USFS Oglala National Grassland
			1996	NA	NA	USFS Oglala National Grassland
	1	Sheridan	1966	NA	NA	NA
			1988	NA	NA	USFS Oglala National Grassland
			1988	"scattered to common"	NA	Fort Robinson State Park
	5	Sioux	1955	NA	NA	NA
			1892	NA	NA	NA
			1996	100-150 individuals; "locally common"	NA	USFS Oglala National Grassland
	1	Unmappable	1889	NA	NA	NA
South Dakota (17 sites)			NA	NA	1,067	NA
	3	Custer	1914	NA	1,524	NA
			1927	NA	1,128	NA
			NA	NA	1,189	NA
	3	Fall River	1967	NA	1,097	NA
			1985	40	1,113	Private
	1	Lawrence	1937	NA	1,219	NA
			NA	NA	1,033	NA
	4	Meade	1895	NA	1,036	NA
			1927	NA	1,067	NA
			1953	NA	1,113	NA
			1927	NA	1,036	NA
	4	Pennington	1947	NA	829	Badlands National Park
			1967	NA	861	Badlands National Park
			1914	NA	1,128	NA
	2	Shannon	1984	1500 individuals; "common"	950	Pine Ridge Indian Reservation
			1999	"several hundred plants"	765 to 777	Badlands Bombing Range, U.S. Department of Defense
Wyoming (1 site)	1	Niobrara	1991	3,500-11,000 individuals	1280 to 1475	BLM Newcastle

Sources: Nebraska Natural Heritage Program, Lincoln, NE (2002); South Dakota Natural Heritage Program, Pierre, SD (2002); Wyoming Natural Diversity Database, Lamarmie, WY (2002); University of Colorado Herbarium, Boulder, CO (2002).

The Newcastle BLM office was the only agency that specifically included mention of *Lesquerella arenosa* var. *argillosa* in its published resource management plan (U.S. Bureau of Land Management 2000). The management actions for *L. arenosa* var. *argillosa* and other special status plant species in that planning area include: general surveys to note locations, specific surveys performed before allowing any surface-disturbing activities, and requirements to avoid, protect, and/or enhance the discovered populations during these activities. In addition, Sandee Dingman, Resource Management Specialist at Badlands National Park described that they are initiating surveys of historical populations of *L. arenosa* var. *argillosa* in the summer of 2002, followed by creation of a potential habitat model in the fall 2002, and additional ground surveys for new populations in 2003 (S. Dingman personal communication 2002). No other land management organizations, including USFS National Grasslands and Forests, with known occurrences of *L. arenosa* var. *argillosa* have management plans that specifically address conservation of this taxon (J. Abegglen personal communication 2002, M. Marston personal communication 2002, M. Moravis personal communication 2002).

Some state Natural Heritage Programs maintain databases with certain species on special watch due to their rarity or potential downward population trend. These lists are developed to draw attention to specific species requiring special management plans and/or conservation strategies for conservation of the species. These lists are not associated with specific legal constraints, such as limits to plant harvesting or damage to habitats supporting these plants. Natural Heritage Programs in four states within Region 2 (Colorado, Nebraska, South Dakota, and Wyoming) consider *Lesquerella arenosa* var. *argillosa* a species of concern (**Table 1**) due to its regional endemic status.

Quantitative population monitoring has not been initiated for any populations of *Lesquerella arenosa* var. *argillosa*. State Natural Heritage Programs keep occurrence records for this species, which often include repeated observations of individual populations but lack detailed demographic or abundance information. For example, a few specific Nebraska populations of *L. arenosa* var. *argillosa* have been observed intermittently since 1889 and most recently in 1988. See *Population Trends* for pertinent information on trends. No monitoring or conservation programs have been established for this species.

Existing regulations do not seem adequate to conserve *Lesquerella arenosa* var. *argillosa* over the long term, considering that the current abundance and distribution of this taxon is not well-known, and specific populations may be threatened by a variety of human-related and ecological threats.

Biology and Ecology

Classification and description

Systematics and synonymy

Lesquerella arenosa (Richardson) Rydberg var. *argillosa* Rollins and Shaw is a member of the Brassicaceae (Cruciferae, mustard) family. The geographical distribution of the genus *Lesquerella* stretches from the Arctic to South America (Payson 1922). Of the 95 species within this genus, 83 are native to North America (Rollins and Shaw 1973). Within North America, the genus is native to the arid parts of the western U.S., probably originating in central Texas and radiating outward from there. Rollins and Shaw (1973) found the greatest diversity of *Lesquerella* species in Mexico, the southwestern U.S., and the Rocky Mountain and intermontane basin region of the western U.S.

Payson (1922) published the original monograph on the genus *Lesquerella*, and analyzed several morphological characteristics to elucidate the taxonomy of this genus. Rollins (1939), Maguire (1942), Maguire and Holmgren (1951), Mulligan (1968), Mulligan and Porsild (1969) have also contributed information to refine the taxonomic understanding of the genus *Lesquerella*. Rollins and Shaw (1973) created a thorough reference for the genus *Lesquerella* in North America by using information from field studies of populations, an extensive review of herbarium materials, experimental work with several species, and a cytological survey of the genus. Reed Rollins (now deceased) is considered the American expert on the mustard family, and he provided an extensive taxonomic treatment of this genus in 1993 (Rollins 1993). Based on recent taxonomic work on the genus *Lesquerella*, researchers have proposed combining the genera *Physaria* and *Lesquerella* (into *Physaria*) and segregating several taxa into a new genus *Paysonia* (O'Kane et al. 1999, O'Kane and Al-Shehbaz 2002, S. O'Kane personal communication 2002). Proposed nomenclatural changes for *L. arenosa* var. *argillosa* based on this work would change the scientific name

to *Physaria arenosa* (Richardson) O'Kane and Al-Shehbaz var. *argillosa* (Rollins and Shaw) O'Kane and Al-Shehbaz. This species assessment uses the name *L. arenosa* var. *argillosa* for this taxon, as treated in the PLANTS and Integrated Taxonomic Information System databases (U.S. Department of Agriculture/ Natural Resources Conservation Service 2001, Integrated Taxonomic Information System 2002).

The species *Lesquerella arenosa* has been divided into two varieties: *L. arenosa* var. *argillosa* and *L. arenosa* var. *arenosa* (U.S. Department of Agriculture/Natural Resources Conservation Service 2001). *Lesquerella arenosa* var. *argillosa* does not have any known synonyms. Common names for this variety include: Secund bladderpod (Colorado Natural Heritage Program 1999, Nebraska Natural Heritage Program 2002, South Dakota Natural Heritage Program 2002b), Great Plains bladderpod (U.S. Department of Agriculture/Natural Resources Conservation Service 2001), and Sidesaddle bladderpod (Fertig and Heidel 2002, Wyoming Natural Diversity Database 2002).

History of taxon

Lesquerella arenosa was first described by John Richardson, who placed it in a different genus. It was placed into *Lesquerella* by Per Axel Rydberg (Payson 1922). The genus name honors a bryologist and paleobotanist, Leo Lesquereux (Payson 1922). The species epithet "arenosa" means "in sand" in botanical Latin and refers to the preferred soil type of this species. The variety *L. arenosa* var. *argillosa* was described by Rollins and Shaw with the type specimen from Fall River County, South Dakota (Rollins and Shaw 1973).

The presence of *Lesquerella arenosa* var. *argillosa* was recorded as early as 1891 in Nebraska. In contrast, the first record of *L. arenosa* var. *argillosa* in Colorado occurred in 1983 by Weber and Wittmann (Weber 1989; University of Colorado Herbarium 2002).

Morphological characteristics

Members of the family Brassicaceae are characterized by bisexual flowers with four sepals and four petals in a cross-like formation, simple or compound racemes, one superior ovary, and the production of fruits called silicles or siliques (Dorn 1992). Identification of species within this family and genus relies extensively on fruit characteristics (Great Plains Flora Association 1986, Marriott 1992).

Members of the *Lesquerella* genus (commonly known as "Bladderpods") can be recognized by a basal cluster of grayish leaves, elongate stems with yellow flowers, and round or oval fruit (Marriott 1992). The characteristic bladderpods (silicles) of *Lesquerella* are spherical (inflated or cup-shaped), lack a distinct midrib, and are seldom more than twice as long as wide (Payson 1922, Rollins and Shaw 1973). In addition, all members of the genus have trichomes (hairs or bristles) on plant tissue surfaces causing the typical silvery-gray color. Rollins and Shaw (1973) suggested that dense, overlapping trichomes (such as on *L. arenosa* var. *argillosa*) may function to prevent water loss by reducing air movement along the plant's surface and reflecting light rays. In addition, *Lesquerella* species tend to have flowers clustered together on many inflorescences, which causes many plants growing together to appear very showy (Rollins and Shaw 1973). Payson (1922) noted that while the basic petal color for all *Lesquerella* species is yellow, the petals of several species, including *L. arenosa*, have red or purple edges, especially as the flowers wither. This characteristic varies in its extent throughout the genus and is also present in the closely-related genus *Physaria* (Payson 1922).

Lesquerella arenosa var. *argillosa* has been described as an annual or short-lived perennial herb (Rollins and Shaw 1973, Great Plains Flora Association 1986, Northern Great Plains Floristic Quality Assessment Panel 2001, U.S. Department of Agriculture/Natural Resources Conservation Service 2001) (**Figure 2**). Several botanists with substantial experience with this taxon in the field have challenged this characterization and suggest that this plant is more of a taprooted perennial than an annual (D. Ode personal communication 2003). It has several semi-prostrate stems that are 10 to 20 cm long and densely pubescent (Fertig 1999). The stem leaves are entire, elliptical, and 1 to 4 mm wide; the basal leaves are oblanceolate, long-petioled, and 2 to 10 mm wide. The flowers are 6 to 8 mm long with yellow petals that may dry to a reddish or lavender color. The fruits (silicles) are pubescent with appressed hairs, and occur on recurved pedicels on one side of the flowering stem.

The following technical description of *Lesquerella arenosa* var. *argillosa* was provided by Great Plains Flora Association (1986):

> Plants annual to short-lived perennials; more or less densely stellate pubescent, trichomes sessile or on a short stalk,

Photograph by Charmaine Delmatier. Reprinted with permission from: Fertig, W., C. Refsdal, and J. Whipple. 1994. Wyoming Rare Plant Field Guide. Wyoming Rare Plant Technical Committee, Cheyenne, WY.

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

Figure 2. *Lesquerella arenosa* var. *argillosa* (A) photograph in its natural habitat in Wyoming, and (B) illustration of the vegetative and reproductive structures.

roughly granular, stems (.05) 1-2(3) dm long, several, prostrate and straggling to erect, usually unbranched, often with purplish pigmentation, arising from a several-branched caudex. Basal leaves 1.5-5(7) cm long, 2-10 mm wide, entire to shallowly dentate, oblanceolate and narrowing to a slender petiole, up to 2 X longer than the blade, or the blades obdeltate or narrowly rhombic, subacute to acute and flat; cauline leaves (0.5) 1-2.5(3) cm long; 1-4 mm wide, elliptic to linear, usually entire. Inflorescences dense, buds ovoid to ellipsoid; sepals 4-6(7) mm long, elliptic to oblong, the lateral ones barely saccate, the median thickened at the apex and cucullate; petals 6-8.5(9.5) mm long, 1.5-3(3.5) mm wide, yellow or with varying areas of reddish or lavender pigmentation when dry, spatulate with little distinction between blade and claw or with blades obovate and narrowing gradually to a broad claw; filaments little dilated at the base, paired stamens 4.5-7(8) mm long, single stamens 3.5-6(7) mm long; glandular tissue roughly pentagonal around the single stamens and subtending the paired, absent between the latter. Infructescences elongated, loose and usually secund; pedicels 5-15(20) mm long, stout and usually sharply recurved, but occasionally only divaricately spreading or nearly horizontal. Silicles (3-5) 4-5.5 (6.5) mm long, sessile or nearly so, subglobose, obovoid or broadly ellipsoid, the valve exterior densely pubescent with spreading or closely appressed trichomes, the valve interior glabrous, or rarely very sparsely pubescent; septum entire and smooth or slightly wrinkled longitudinally, the funiculi attached about ½ their lengths; styles 3-5.5(6.5) mm long and slender, the stigmas expanded; seeds 2-2.7 mm long, flattened and suborbicular or slightly wider than long, red-brown, lacking margins or wings. Stellate trichomes on the silicles with the rays closely appressed.

To distinguish between the two varieties of *Lesquerella arenosa* using morphological characteristics, it is necessary to observe the hairs present on the fruits (Marriott 1992). The fruits of *L. arenosa* var. *argillosa* have hairs that lie flattened to the surface (appressed), whereas the fruits of *L. arenosa* var. *arenosa* (and other *Lesquerella* likely present in the area) have spreading hairs (Rollins and Shaw 1973, Great Plains Flora Association 1986, Dorn 1992, Marriott 1992, Fertig 1994). Marriott (1992) noted that the difference between spreading and appressed hairs is a subtle character and suggested that researchers observe sample material from both varieties for more confident identification.

Other *Lesquerella* species have wider basal leaves or S-shaped fruit stalks (Dorn 1992). *Lesquerella ludoviciana* has taller stems, narrower leaves, involute (curled) basal leaves, yellow petals, and non-secund fruit with glabrous interiors (Rollins and Shaw 1973, Fertig 1994). *Lesquerella alpina* is somewhat similar in habit and leaf form to *L. arenosa* var. *argillosa*, but the silicles are not subglobose and do not occur on recurved pedicels (Rollins and Shaw 1973). Rollins and Shaw (1973) suggested several unofficial groups within the genus *Lesquerella* based on general similarities, and *L. arenosa* was placed in the same group as *L. alpina*, *L. arizonica*, *L. calcicola*, *L. cinerea*, *L. globosa*, *L. intermedia*, *L. lata*, *L. ludoviciana*, *L. montana*, *L. rectipes*, and *L. valida*.

Technical descriptions of the family, species, and varieties are presented in Great Plains Flora Association (1986) and Rollins and Shaw (1973). Line drawings and photos are available in Fertig (1994, 1999).

Distribution and abundance

Regional distribution

The species *Lesquerella arenosa* is known from six western U.S. states (Montana, North Dakota, South Dakota, Nebraska, Wyoming, and Colorado) and three Canadian provinces (Alberta, Manitoba, and Saskatchewan) (Great Plains Flora Association 1986, U.S. Department of Agriculture/Natural Resources Conservation Service 2001). *Lesquerella arenosa* var. *argillosa* occupies the southern portion of this range, and *L. arenosa* var. *arenosa* occupies the northern portion. It is likely that there are areas of overlap within South Dakota, Wyoming, and Nebraska, although it is unclear to what extent these varieties are sympatric. Rollins and Shaw (1973) noted that *L. arenosa* var. *argillosa* occurs in the Black Hills of South Dakota and Nebraska, an area with an absence of *L. arenosa* var. *arenosa*. One record from Wyoming documented both varieties of *L. arenosa* at the site (Marriott 1992), but this is the only explicit record of this kind.

Specifically, *Lesquerella arenosa* var. *argillosa* is found in eastern Wyoming, southwestern South

Dakota, northwestern Nebraska, and northern Colorado (**Figure 1**) (Weber 1989, Fertig 1994, U.S. Department of Agriculture/Natural Resources Conservation Service 2001, Nebraska Natural Heritage Program 2002, South Dakota Natural Heritage Program 2002b, University of Colorado Herbarium 2002, Wyoming Natural Diversity Database 2002). The Kansas Natural Heritage Inventory confirmed that this taxon has not been identified in their state (C. Freeman personal communication 2002, Kansas Natural Heritage Inventory 2000). **Figure 1** illustrates the distribution of *L. arenosa* var. *argillosa* based on reviewed literature, state Natural Heritage Program records, and herbarium specimens (Nebraska Natural Heritage Program 2002, South Dakota Natural Heritage Program 2002b, University of Colorado Herbarium 2002, Wyoming Natural Diversity Database 2002). Because of its narrow range, *L. arenosa* var. *argillosa* is considered by the Wyoming Natural Diversity Database to be a "regional endemic", a taxon with a global range restricted to a portion of Wyoming and one to two adjacent states. The entire range of the taxon is less than the total area of the state of Wyoming (Fertig and Heidel 2002).

The estimated distribution of *Lesquerella arenosa* var. *argillosa* on USFS National Forest System lands in Region 2 is presented on **Figure 1** and in **Table 2**. *Lesquerella arenosa* var. *argillosa* occurs in USFS Oglala National Grassland (Pine Ridge Ranger District; 4 occurrences) and USFS Pawnee National Grassland (1 occurrence). The management context and land ownership information is extrapolated from available information provided in element occurrence records by botanists, such as any notes on land management, and coordinate data. There is considerable uncertainty in transferring latitude and longitude data provided by collectors, especially from historical collections, into Geographic Information System (GIS) mapping programs because the data provided by the collectors cannot be verified and is often imprecise. In addition, occurrences often occur at the boundary between two land ownership contexts. Thus, the number of occurrences in each National Grassland or National Forest is estimated, and many occurrences do not have a known land designation (i.e., "NA").

The specific distribution and abundance by states within Region 2 follows and is also summarized in **Table 2**. Abundance information is largely lacking in occurrence records of this taxon.

Colorado distribution and abundance

Weber and Wittmann (2000) documented the addition of *Lesquerella arenosa* var. *argillosa* to the Colorado flora as a result of individuals found in Logan County in 1983. Another population was recorded from USFS Pawnee National Grassland in Weld County in 1997 (University of Colorado Herbarium 2002) (**Figure 1**, **Table 2**). No abundance information for either of these occurrences was presented (**Table 2**). In Hazlett (1998), *L. arenosa* var. *arenosa* is listed as part of the flora of USFS Pawnee National Grassland, although *L. arenosa* var. *argillosa* is not currently listed.

Nebraska distribution and abundance

Lesquerella arenosa var. *argillosa* exists in Banner, Box Butte, Dawes, Sheridan, and Sioux Counties in northwestern Nebraska (Rollins and Shaw 1973, Nebraska Natural Heritage Program 2002) (**Figure 1**, **Table 2**).

Records for *Lesquerella arenosa* var. *argillosa* in Nebraska indicate that this species can be scattered to locally common (Nebraska Natural Heritage Program 2002) (**Table 2**). One population estimate stated that there were 100 to 150 plants in an 800 meter squared area; another estimated about 500 individuals in a 1000 meter squared area (Nebraska Natural Heritage Program 2002). At one site, *L. arenosa* var. *argillosa* was common in 1970 but not very abundant in 1988 (Nebraska Natural Heritage Program 2002). According to G. Steinauer (personal communication 2002), this species may be more common on the Nebraska panhandle than existing records indicate.

South Dakota distribution and abundance

In South Dakota, there are recorded populations of *Lesquerella arenosa* var. *argillosa* in Custer, Fall River, Lawrence, Meade, Pennington, and Shannon Counties (Rollins and Shaw 1973, U.S. Department of Agriculture/Natural Resources Conservation Service 2001, South Dakota Natural Heritage Program 2002b) (**Figure 1**, **Table 2**).

D. Ode (personal communication 2002) suggested that *Lesquerella arenosa* var. *argillosa* is locally abundant within the southwest region of the state. For example, within the Badlands Bombing Range

occurrence (Ellsworth Air Force Base, northeastern Shannon County), Ode and Backlund (1999) recorded at least six populations of several hundred individuals each (**Table 2**). D. Ode (personal communication 2002) also suggested that this plant is commonly found in Badlands National Park. S. Dingman (personal communication 2002) stated that they will be revisiting historical populations of this taxon within Badlands National Park during the summer of 2002. Description of the *L. arenosa* var. *argillosa* occurrence from Pine Ridge Indian Reservation in Shannon County indicated that there was "a viable population in suitable native habitat" (South Dakota Natural Heritage Program 2002b), but the record did not include the size of the population (**Table 2**). Abundance of this taxon in USFS Black Hills National Forest is not known. *Lesquerella arenosa* var. *argillosa* is not documented from USFS Black Hills National Forest, however, several historical records with imprecise locations information occur in close proximity to the forest boundary or on intermingled private land. In contrast, another element occurrence record from Fall River County indicated that there were "few plants found" despite suitable habitat (South Dakota Natural Heritage Program 2002b) (**Table 2**).

Wyoming distribution and abundance

Within Wyoming, *Lesquerella arenosa* var. a*rgillosa* is known from Niobrara County (Wyoming Natural Diversity Database 2002) (**Figure 1**, **Table 2**). Reports of this species from the Black Hills in Crook County (Dorn 1992) have been re-identified as *L. arenosa* var. *arenosa* (Marriott 1992). The online *Atlas of the Vascular Flora of Wyoming* (University of Wyoming 1998) produced by the Rocky Mountain Herbarium also records this species in Natrona and Carbon Counties, but Dr. Ronald Hartman (herbarium curator) and B.E. Nelson (herbarium manager) hypothesized that these occurrences were either misidentifications or erroneous database entries (R. Hartman personal communication 2002, B. Nelson personal communication 2002).

Information from element occurrence records indicates that *Lesquerella arenosa* var. *argillosa* is locally abundant (Wyoming Natural Diversity Database 2002) (**Table 2**). Of three recorded populations comprising the Niobrara County occurrence (east of the Old Woman Creek Hills), one population was estimated at 3,000 to10,000 individuals, the other two were estimated at 500 to 1,000 individuals within the area surveyed, and many more individuals were likely adjacent to the survey area (Marriott 1992).

Population trend

Data on population trends for *Lesquerella arenosa* var. *argillosa* within USFS Region 2 do not exist. Quantitative population or demographic monitoring has not been initiated for any populations of this taxon. Fertig (1999) stated that the Wyoming populations have been observed since 1991 (most recently in 1993) and are most likely stable.

Lesquerella arenosa var. *argillosa* seems to be locally abundant, based on the few observations with abundance information. However, there was one observation where this taxon was "not very abundant in 1988; common in 1970." (Nebraska Natural Heritage Program 2002). It is possible that this taxon is more abundant and occurs more frequently within its range than documented in existing records, but population trends are unknown (Fertig 1999, G. Steinauer personal communication 2002).

Habitat characteristics

General habitat

Rollins and Shaw (1973) found that all members of the genus *Lesquerella* tend to live in open, wind-swept, dry environments, and Payson (1922) noted that most *Lesquerella* species are found on calcareous soils. *Lesquerella arenosa* var. *argillosa* is also found in dry, open settings within grasslands or badlands characterized by barren areas, rocky outcrops, or roadsides of gravel, shale, or limestone (Fertig 1994). These badland formations are derived from soft, sedimentary material and tend to have high erosion and deposition rates and poorly developed soils. Harsh microenvironments prevent the development of substantial or continuous vegetation cover (i.e., limit competition or succession) (S. Dingman personal communication 2002, Marriott and Faber-Langendoen 2000). Thus, these areas are often only sparsely-vegetated with cushion plants, short grasses, bunchgrasses, and low shrubs (Ode and Backlund 1999, Nebraska Natural Heritage Program 2002). *Lesquerella arenosa* var. *argillosa* often occurs at the ecotone between the badland formations and adjacent vegetated grasslands, where the formation walls are less steep yet there is still little competition from other vegetation (S. Dingman personal communication 2002). Reported elevations for *L. arenosa* var. *argillosa* range from 765 to 1540 m (2510 to 5053 ft) (South Dakota Natural Heritage Program 2002b, University of Colorado Herbarium 2002, Wyoming Natural Diversity Database 2002).

Substrate characteristics and microhabitats

Most of the time, *Lesquerella arenosa* var. *argillosa* does not grow in true soil with developed horizons, but on raw parent material. Substrate characteristics and microhabitats of *L. arenosa* var. *argillosa* are discussed by state.

In southwestern South Dakota, *Lesquerella arenosa* var. *argillosa* is known from barren substrates of the White River badlands and other geologic outcrops (Ode and Backlund 1999, S. Dingman personal communication 2002). These exposed outcrops may include claystones, mudstones, siltstones, sandstones, limestones, and shales of the Chadron, Brule, Spearfish, Madison, or other formations exposed in the Black Hills (Marriott et al. 1999). South Dakota NHP records (2002b) include the following descriptions of *L. arenosa* var. *argillosa* substrates and microhabitats: rocky outcrops; redbed foothills; shaley butte; limestone ridge; dry prairie hillside; gravelly hillsides; gully bank in rangeland pasture; barren loose rock outcrops; foot of dry limestone cliff; northerly facing buttes of sandy tableland; broken butte; open, rocky ground; low, white, gumbo clay mounds at foot of butte; mostly barren clay soils.

In Wyoming, *Lesquerella arenosa* var. *argillosa* was reported from areas in Niobrara County with whitish, flaky soils derived from a pale stratum of the Niobrara formation (a yellow or gray chalky limestone) (Marriott 1992, Wyoming Natural Diversity Database 2002). At two of the sites, the presence of *Astragalus bisulcatus*, a selenium-tolerant plant, led the researcher to believe that the soils were seleniferous (Marriott 1992). In addition, this taxon was abundant along an improved gravel road wherever the road shoulder had chipped rock derived from this same pale Niobrara stratum (Marriott 1992). *Lesquerella arenosa* var. *argillosa* was also abundant at the quarry where the material was chipped (Marriott 1992), although the researcher did not indicate if the plants were growing on undisturbed, exposed areas near the quarry or in areas that had been actively disturbed by quarrying

In Nebraska, no detailed descriptions of *Lesquerella arenosa* var. *argillosa* habitat are available, but NHP element occurrence records list several different substrates and microhabitats: badlands area and upper badlands slopes; base of eroded bluffs; open, barren prairie pasture hillside; dry, sandy, chalky, rocky soil; rocky bluffs on side of river; irregular eroding siltstone outcrops; eroding rocky clay slopes. One record from Fort Robinson State Park (Sioux County) listed *L. arenosa* var. *argillosa* in rocky, open, pine-forested hillside (Nebraska Natural Heritage Program 2002).

In Colorado, *Lesquerella arenosa* var. *argillosa* was found on a clay ridge, and in an area with sandy soils (University of Colorado Herbarium 2002). No additional information was available from the Colorado NHP element occurrence records (Colorado Natural Heritage Program 2003).

Vegetation associations and associated plants

The erodible habitats with *Lesquerella arenosa* var. *argillosa* may be considered sparsely vegetated habitats (i.e., "Sparse Vegetation" subclass [Grossman et al. 1998]), rather than representatives of a distinct plant community. Examples of these communities in the Black Hills may include Eroding Great Plains Badlands Sparse Vegetation (CEGL002050) or Redbeds (Siltstone, Sandstone, Gypsum) Sparse Vegetation (CEGL005261) (Grossman et al. 1998). These habitats are characterized by loose, easily eroded substrates and total vegetative cover usually less than 10 percent (Marriott and Faber-Langendoen 2000). Where *L. arenosa* var. *argillosa* is found in vegetated grasslands, it primarily occurs on exposed substrates in bare spaces or breaks in the vegetation (Marriott 1992). Marriott (1992) found that *L. arenosa* var. *argillosa* was common where there were small spaces in the vegetation, while the other variety of *L. arenosa* (var. *arenosa*) was present within the vegetated grassland.

The following associated vegetation descriptions are from herbarium and NHP records of *Lesquerella arenosa* var. *argillosa* and are presented by state:

Wyoming: *Stipa comata-Elymus smithii* grassland; sagebrush-grassland; with *Astragalus bisulcatus*, *Cryptantha* sp., *Dalea* sp., *Eriogonum* sp., *Hymenopappus filifolius*, *Mentzelia* sp., *Oenothera cespitosa*, *Oryzopsis hymenoides*, *Penstemon eriantherus*, and *Senecio canus* (Wyoming Natural Diversity Database 2002).

South Dakota: on mounds and outcrops which are mostly barren or have shortgrass (blue grama, buffalograss, short upland sedges)-dominated communities, xerophytic to xero-mesophytic grassland types with bunch grasses predominating; bottomland, xero-mesophytic grass (pioneer); with *Astragalus barrii*, *A. gilviflorus*, *A. missouriensis*, *A. racemosus*, *Eriogonum pauciflorum*, *Gutierrezia* sp., *Hymenoxys* sp., and *Lomatium* sp. (Ode and Backlund 1999, South Dakota Natural Heritage Program 2002b).

Nebraska: rocky mixed-grass prairie; sandhills prairie pasture; rocky open pine forested hillside; With *Astragalus sericoleucus*, *A. spathulatus*, *Cryptantha cana*, and *Townsendia grandiflora* (Nebraska Natural Heritage Program 2002).

Colorado: with *Yucca glauca* (University of Colorado Herbarium 2002).

Reproductive biology and autecology

Details concerning the reproductive system of *Lesquerella arenosa* var. *argillosa* are largely unknown. In this and subsequent sections, we summarize available observations of *L. arenosa* var. *argillosa* as well as present information from other congeners endemic to USFS Region 2 or adjacent states. These comparisons are not meant to imply that *L. arenosa* var. *argillosa* necessarily reproduces in a similar manner to other *Lesquerella* species, but they represent an effort to elucidate potential reproductive mechanisms for this taxon and suggest avenues for future research.

Reproduction

Members of the *Lesquerella* genus produce fruits called silicles (Great Plains Flora Association 1986). When the seeds mature, the silicles dry and dehisce (break and burst open) to disperse the seeds via gravity or wind. Often, in the case of *Lesquerella*, the septum remains on the pedicel after the valves have fallen away, a useful identifying characteristic for Brassicaceae (Great Plains Flora Association 1986). *Lesquerella arenosa* var. *argillosa* flowers from April to June, with fruits present in late May-June. The dried fruits may persist longer (Marriott 1992).

There is no specific information concerning the extent of vegetative reproduction in *Lesquerella arenosa* var. *argillosa*. Moseley (1996) documented that *L. paysonii*, a species known from rocky slopes and gravelly soils of Wyoming, Montana, and Idaho, reproduces only from seed. Observations of this species in the field indicate that *L. arenosa* var. *argillosa* has a taproot (D. Ode personal communication 2003), but evidence of vegetative reproduction was not discussed.

Details concerning life history and strategy, pollination biology, dispersal mechanisms, and seed ecology follow in subsequent sections.

Life history and strategy

There are no studies on the life history, longevity, demographic rates, fecundity, or dispersal of *Lesquerella arenosa* var. *argillosa* currently available. Therefore, we can only hypothesize about the strategies of this taxon. Most members of the *Lesquerella* genus, including *L. arenosa* var. *argillosa*, are annual or perennial herbs living in harsh environments with dry, rocky, and/or eroding soil conditions (Rollins and Shaw 1973). *Lesquerella arenosa* var. *argillosa* has usually been characterized as an annual, biennial, or short-lived perennial (Rollins and Shaw 1973, Great Plains Flora Association 1986, Northern Great Plains Floristic Quality Assessment Panel 2001). However, botanists familiar with this taxon indicate that its habit is that of a taprooted perennial, rather than an annual (D. Ode personal communication 2003). Based on vegetation strategies described by Grime (1979), *L. arenosa* var. *argillosa* could be considered a stress-tolerant (s-selected) species with characteristics on the continuum between r-selected and k-selected strategies. Plants with a perennial life history, ability to withstand harsh and unproductive environments, and capability to access resources with well-developed roots are considered stress-tolerant (Grime 1979, Barbour et al. 1987). The taproot of *L. arenosa* var. *argillosa* presumably aids this plant to access water resources, anchor it in loose soil, store resources, and mediate the effects of disturbance. Tsuyuzaki and Titus (1996) found that species tolerance to erosion on andesitic volcanic material on Mount St. Helens was dependent on well-developed root systems; all of the species flourishing in erosional gullies were well-rooted perennial species. This taxon is probably more of a stress-tolerant ruderal than a stress-tolerant competitor (Grime 1979), because it has capabilities to colonize and tolerate barren, stressful, dynamic environments and seems to be a poor competitor, evidenced by its absence from vegetated grasslands. However, unlike early seral ruderal species, *L. arenosa* var. *argillosa* probably does not rely on disturbances to open up new areas for colonization, as badland habitats tend to be sparsely-vegetated. The ability of *L. arenosa* var. *argillosa* to withstand wind and water erosion and deposition is unknown. The Northern Great Plains Floristic Quality Assessment Panel (2001) assigned a coefficient of conservatism of 8 (out of 10) to *L. arenosa* var. *argillosa*, presumably based on its fidelity to and dependence on pristine, natural badland habitats (compared to the low fidelity of weedy annual forbs exploiting a variety of highly degraded habitats). The hypothesized life cycle of this perennial plant is depicted in **Figure 3**.

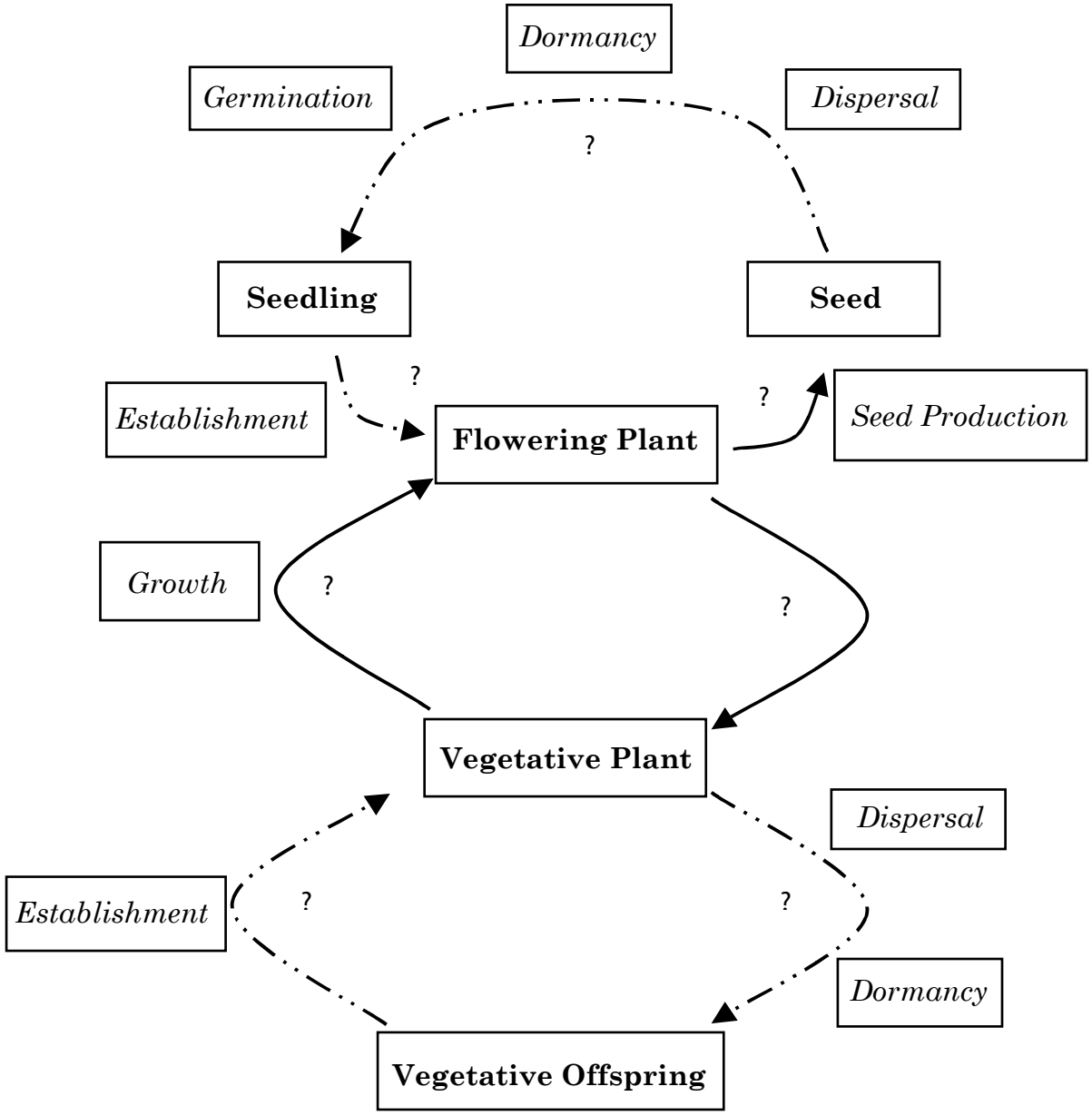

Figure 3. Schematic representation of the hypothesized life cycle of *Lesquerella arenosa* var. *argillosa*. Dotted lines indicate juvenile phases of the life cycle and solid lines indicate mature phases of the life cycle. Extent of sexual and vegetative reproduction is unknown for this species. Rates of growth, dispersal, and seed production are also unknown (indicated by "?"). Figure adapted from Grime (1979).

Pollinators and pollination ecology

Pollination biology and specific pollination mechanisms for *Lesquerella arenosa* var. *argillosa* are not known. Cross-pollination is the norm in *Lesquerella* species, with bees and flies being the most commonly observed pollinators (Rollins and Shaw 1973). However, Rollins and Shaw (1973) also stated that self-compatibility is present in at least some species of this genus. Ode and Backlund (1999) observed bees visiting the flowers of *L. arenosa* var. *argillosa* in South Dakota, but they did not rule out the option that self-fertilization could occur in this species.

Field and greenhouse research on *Lesquerella fendleri*, a short-lived desert annual/perennial known from Arizona to Colorado and Oklahoma, may shed light on aspects of *Lesquerella* pollination biology (Dierig et al. 1996, Mitchell 1997, Roll et al. 1997, Mitchell and Marshall 1998). Dierig et al. (1996) noted that *L. fendleri* is self-incompatible, has outcrossing rates of 86 to 89 percent, and thus does not tend to

produce selfed seed. Small bees, characterized as pollen foragers, were the most abundant visitors to *L. fendleri*, and these insects were frequently visiting flowers in the field (Dierig et al. 1996, Mitchell and Marshall 1998). Mitchell and Marshall (1998) found that *L. fendleri* plants with more pollen tended to be visited more frequently by pollinators, and those plants consequently sired more offspring. In addition, the reproductive success (seeds per fruit, proportion of flowers setting fruit, and total seed production) of individual *L. fendleri* plants was greatest when the density of other *L. fendleri* plants within 1m was high (Roll et al. 1997). This most likely resulted from increased pollinator visitation to those high density areas. Mitchell (1997) discovered in experimental manipulations that seed set per fruit increased with additions of up to 100 pollen grains per fruit, and then additional pollen did not increase the seed production any further.

These studies emphasize the importance of pollinators to the reproductive success of *Lesquerella fendleri* within the *Lesquerella* genus; the role of pollinators for *L. arenosa* var. *argillosa* is not known. Important issues related to the pollination of rare plants that have yet to be researched for *L. arenosa* var. *argillosa* include the extent of self-pollination, identification of effective pollinators, the effect of plant density on pollination, genetic implications of pollination, and the effect of environmental fluctuations on pollination.

Dispersal mechanisms

Details of seed dispersal mechanisms in *Lesquerella arenosa* var. *argillosa* are not well known. The bladder-like fruit pods produced by *Lesquerella* species dry when they ripen, and then dehisce to release seed. Dispersal could presumably occur by gravity, wind, water, or soil/substrate movement (i.e., erosion and deposition). Moseley (1996) suggested that animal transport of *L. paysonii* seeds could be possible, in addition to dispersal by gravity or water.

Moseley (1996) also pointed out that because *Lesquerella paysonii* plants tend to be prostrate and low-growing (similar to *L. arenosa* var. *argillosa*), the seed pods are low to the ground, and the capability for long-distance dispersal may be minimal. Cabin (1996) found that the vast majority of *L. fendleri* seeds remained within 1 m of the parent plant.

Dispersal success of *Lesquerella arenosa* var. *argillosa* likely depends on patterns of precipitation, wind, erosion; animal activities; topographic heterogeneity; and availability of suitable "safe" sites.

Seed viability and germination requirements

No information is available concerning the fertility, seed viability, and germination requirements of *Lesquerella arenosa* var. *argillosa*.

Lesquerella lyrata and *L. lescurii*, annual *Lesquerella* species in the southeastern U.S., both have long-lived seed banks and thus can persist at a site without producing seeds every year (Baskin et al. 1992, Baskin and Baskin 2000). Work with *L. fendleri* indicated that the majority of seeds in the soil can persist for at least three years (Cabin 1996). Field and greenhouse studies of *L. fendleri* in Arizona and New Mexico suggest that the reproductive success of *L. fendleri* can be affected by availability of germination sites, genetic considerations, environmental conditions, and landscape heterogeneity (Cabin 1996). For example, 80 to 90 percent of all soil seeds are in the top 2 cm of soil, and *L. fendleri* seeds are unable to emerge from below 2 cm of soil (Cabin 1996). Bleakly (1999) found that numbers of *L. aurea*, a biennial/perennial from New Mexico, varied greatly from year to year, probably depending on the timing and amount of precipitation. Although the *Lesquerella* species discussed here are annuals and short-lived perennial species, these studies suggest that seed longevity, germination needs, and climatic fluctuations should be studied for *L. arenosa* var. *argillosa*, as they may affect the reproductive success.

Cryptic phases

No information regarding cryptic phases of *Lesquerella arenosa* var. *argillosa* is available. Seed dormancy can be an important adaptation for plant populations to exploit favorable conditions in a harsh environment (Kaye 1997). Evans and Cabin (1995) suggested that seed dormancy is an often-ignored stage in the life history of plants, and seed bank dynamics have important implications for the genetic structure and survival of emerging populations. For example, the seeds of *L. fendleri* have demonstrated significantly different germination times, as a result of different dormancy cycles. These genetically different dormancy characteristics could serve to form genetically-distinct metapopulations, decrease intraspecific competition, and increase fitness in a fluctuating environment (Hyatt and Evans 1998, Hyatt et al. 1999). It is not known whether a persistent seed bank exists or what the extent

of seed dormancy for *L. arenosa* var. *argillosa* is. Details of seed longevity, patterns of seed dormancy, and factors controlling seed germination for *L. arenosa* var. *argillosa* have not been studied.

Phenotypic plasticity

Phenotypic plasticity is demonstrated when members of a species vary in height, leaf size, flowering (or spore-producing) time, or other attributes, with change in light intensity, latitude, elevation, or other site characteristics. The extent of phenotypic plasticity in *Lesquerella arenosa* var. *argillosa* is unknown. Issues of phenotypic anomalies in *L. arenosa* var. *argillosa* and similar species were occasionally found in the available literature; however, phenotypic plasticity was not explicitly discussed. For example, Marriott (1992) recorded that some *L. arenosa* var. *argillosa* plants in disturbed areas (roadside or quarry) commonly presented one to two aberrant (enlarged) flowers per plant, and sometimes had small or aborted fruit, despite being very robust. The possible causes of this variation (e.g., unsuitable environmental conditions or possible lack of outcrossing) were not discussed, and there were no other discussions of phenotypic variation. Fertig (2000) found that some *L. prostrata* plants were smaller and produced fewer fruits, perhaps resulting from early flowering due to moist spring conditions. It is possible that fluctuations in environmental conditions (e.g., water availability) could also cause changes in flowering or growth of *L. arenosa* var. *argillosa* as well.

Mycorrhizal relationships

The existence of mycorrhizal relationships with *Lesquerella arenosa* var. *argillosa* or related taxa was not discussed in the literature.

Hybridization

In general, the genetic status, including issues related to hybridization and polyploidy, is unknown for *Lesquerella arenosa* var. *argillosa*. No reports of hybrid individuals were discussed in observations of *L. arenosa*, and it is not clear to what extent the two varieties may form hybrids. Dr. S. O'Kane, Assistant Professor with the University of Northern Iowa, specializes in taxonomic studies of the genus *Lesquerella* and is planning to address the taxonomic and genetic status of this species in the future (S. O'Kane personal communication 2002).

Rollins and Shaw (1973) reported hybrids between other *Lesquerella* species in the western U.S., but hybrids with *L. arenosa* were not specifically mentioned. Rollins and Shaw (1973) further stated that in areas with high diversity of *Lesquerella*, such as the Rocky Mountain region, they have not observed any clear cases of interspecific hybridization. Hybridization is not common in this genus (S. O'Kane personal communication 2002). Dierig et al. (1996) also found that interspecific hybridization was not common between native populations of *L. fendleri* and other sympatric species.

Demography

Little is currently known about population demographics in *Lesquerella arenosa* var. *argillosa*. However, as discussed previously, research on *L. fendleri* and other *Lesquerella* species may provide insights into some of the ecological, spatial, and genetic considerations for *Lesquerella* demography.

Life history characteristics

There is no information regarding population parameters or demographic features of *Lesquerella arenosa* var. *argillosa*, such as metapopulation dynamics, life span, age at maturity, recruitment, and survival.

Life cycle diagram and demographic matrix. A life cycle diagram is a series of nodes that represent the different life stages connected by various arrows that represent the vital rates (i.e., survival rate, fecundity). Demographic parameters, such as recruitment and survival rates, are not currently available for *Lesquerella arenosa* var. *argillosa*, and so there are no definitive data regarding the vital rates that contribute to species fitness. **Figure 3** depicts the hypothesized life cycle for *L. arenosa* var. *argillosa* with "?" to indicate the lack of information regarding these vital rates.

Although stage-based models based on population matrices and transition probabilities can be used to assess population viability (Caswell 2001), adequate quantitative demographic data are needed for input into the model. Fertig (2000) performed demographic monitoring of *Lesquerella prostrata* (Wyoming) by using belt transects and recording the number of individual plants in four age classes: Seedlings (non-flowering rosettes with two to four leaves), Vegetative

(non-flowering rosettes with five or more basal leaves), Reproductive (flowering or fruiting plants with at least one inflorescence), and Dead (dead plants of any size class). Similarly, the stages that could be incorporated into a demographic matrix for *L. arenosa* var. *argillosa* could include seed, seedling, vegetative individuals, and reproductive adults (**Figure 3**).

Population viability analysis. In order to initiate a population viability analysis for *Lesquerella arenosa* var. *argillosa*, the rates of germination, fecundity, survival, and other important parameters require additional study.

Spatial characteristics

Factors affecting the spatial distribution of *Lesquerella arenosa* var. *argillosa* at both regional and local scales have not been studied.

On a regional scale, *Lesquerella arenosa* var. *argillosa* occurs in disjunct occurrences in four states (**Figure 1**). The details of landscape heterogeneity, metapopulation structure, gene flow between populations, dispersal capabilities of this species, and the full range of habitat characteristics tolerated by this taxon are not known. The amount of suitable habitat, such as exposed suitable substrate types, available for *L. arenosa* var. *argillosa* has not been ascertained. It is possible that undiscovered populations of this taxon exist in areas that have not yet been inventoried. For example, USFS Buffalo Gap National Grassland in South Dakota does not currently have any known populations of *L. arenosa* var. *argillosa*, but the adjacent Badlands National Park, Pine Ridge Indian Reservation, and Badlands Bombing Range all have occurrences of this taxon.

Factors that are thought to influence the spatial distribution of other *Lesquerella* species at a local scale include microhabitat characteristics, suitable germination sites for seeds, natural disturbance patterns, seed dispersal mechanisms, interaction with other vegetation, and topographical heterogeneity (Cabin and Marshall 2000, Cabin et al. 2000, Elberling 2000, Fertig 2000). Marriott (1992) suggested that *L. arenosa* var. *argillosa* may be selenium-tolerant and can exist on seleniferous soils. A greenhouse study performed on *L. fendleri* discovered that this species is capable of taking up selenium (Grieve et al. 2001). The researchers even suggested that *L. fendleri* could serve as a phytoremediator of selenium-contaminated soils due to its accumulating ability. Several researchers emphasized that availability of germination sites were important for *Lesquerella* establishment. For example, Fertig (2000) suggested that the abundance of suitable germination microsites may have been partly responsible for the clustered groups of *L. prostrata* that he saw in Wyoming. Research on *L. arctica* in Canada demonstrated that desiccation cracks in the soil contained more seeds, seedlings, and adult plants than would be expected from a random distribution. In this case, desiccation cracks acted as seed traps and may have collected moisture needed for germination (Elberling 2000). The spatial distribution of *L. arenosa* var. *argillosa* individuals within a population has not been described, but it is possible that similar factors, such as availability of microsites with suitable substrates, adequate moisture, and minimal interspecific competition, are important factors affecting the local distribution of *L. arenosa* var. *argillosa*.

In addition, the type, size, frequency, and intensity of disturbances that define the natural disturbance regime in these habitats are unknown. These types of areas are susceptible to high rates of erosion, especially during precipitation events, and the hydrology patterns and topography are typically dynamic (S. Dingman personal communication 2002). Disturbances such as erosion on steep slopes could directly damage (e.g., bury or uproot) existing populations of *Lesquerella arenosa* var. *argillosa*, or play a role in dispersing seeds, exposing seeds, or creating suitable "safe sites" for seeds.

Genetic characteristics and concerns

No information is available concerning the genetic characteristics of *Lesquerella arenosa* var. *argillosa*.

Polyploidy is not a common phenomenon in Brassicaceae, but both diploid and polyploid populations have been reported for *Lesquerella arenosa* (Rollins and Shaw 1973). Chromosome numbers for *L. arenosa* var. *argillosa* range from 13 to 15n, and chromosome numbers for *L. arenosa* var. *arenosa* (in South Dakota) range from 5 to 9n (Rollins and Shaw 1973). The role of polyploidy in the evolution of *L. arenosa* var. *argillosa* is unknown. Dr. O'Kane is planning to address the taxonomic and genetic status of this species in the future (O'Kane 2002).

It is unknown if *Lesquerella arenosa* var. *argillosa* exhibits self-incompatibility (i.e., obligate outcrosser) or if self-fertilization is possible. In general, members of the Brassicaceae family exhibit a "sporophytic multiple allele incompatibility system" (Rollins and Shaw 1973). Self-incompatible plants are incapable of

producing a fertile zygote through self-fertilization. In the sporophytic multiple allele incompatibility system, the genotype of the pollen (namely, several alleles at the S-loci) has to mismatch the genotype of the ovule parent in order for fertilization to proceed. The details of the breeding system would have implications for understanding the genetic issues of this taxon, such as between- and within-population variability, the role of genetics in adaptation, and minimum viable population size.

Several genetic studies have addressed the relationship between the seed bank and adult plants in *Lesquerella fendleri* (Cabin 1996, Cabin et al. 1997, Mitchell 1997, Mitchell and Marshall 1998). Cabin (1996) discovered that the germination and establishment of *L. fendleri* seeds is influenced by seed genotypes. Thus, the genotypes of seedlings that emerge in one season might differ from the genotypes present in the seed bank, which may accumulate and store seeds over a long period of time. Cabin (1996) concluded that *L. fendleri* seedlings are a non-random subset of the seed bank. Further, Cabin et al. (1997) studied the genetic structure of seeds and found that the timing of germination and soil water availability at the time of germination can consequently affect the genetic structure of emerging populations. The extent of a seed bank for *L. arenosa* var. *argillosa*, and the role of genetics in successful germination of *L. arenosa* var. *argillosa* is unknown.

Other studies have focused on the genetics of seed production in *L. fendleri*. Seed set is probably influenced by genetic variation among plants in fitness, propensity to abort seed, or gender specialization, in addition to environmental conditions (Mitchell 1997). Mitchell and Marshall (1998) found that non-random mating is common; some pollen donors yield more offspring than other donors. They suggested that this might occur as a result of better compatibility between maternal and paternal partners, as well as greater pollen output by some individuals. The factors affecting seed output and viability in *L. arenosa* var. *argillosa* have not been studied. It is possible that genetic status and environmental conditions are important variables to consider in the successful reproduction of this taxon.

Factors limiting survival and reproduction

The factors affecting the survival and successful reproduction of *Lesquerella arenosa* var. *argillosa* have not been studied and are not known. Based on the information about other *Lesquerella* species presented in the preceding sections, the survival, growth, and reproduction of *L. arenosa* var. *argillosa* could depend on a range of biological and ecological influences, climatic fluctuations, microsite conditions (e.g., moisture), availability of suitable germination sites, pollinator activities, natural disturbance patterns (e.g., erosion), interspecific competition, disruptions to the seed bank (e.g., seeds buried too deep, predation), dispersal capabilities, and genetic variability to adjust to a fluctuating environment. The establishment of new populations most likely depends on barriers to dispersal and the availability of suitable germination sites.

Community ecology

Herbivores and relationship to habitat

Some lands with *Lesquerella arenosa* var. *argillosa* habitats are leased for livestock grazing (e.g., cattle, bison), and stands of this taxon could be susceptible to grazing impact (J. Abegglen personal communication 2002, C. Bradshaw personal communication 2002, S. Dingman personal communication 2002, M. Marston personal communication 2002). The effects of grazing on *L. arenosa* var. *argillosa* likely depend on the details of the grazing regime (e.g., type, intensity, timing), the palatability of this plant, and the habitat context. *Lesquerella arenosa* and other *Lesquerella* species tend to be dry, wiry plants, and seem not to be palatable to cattle (Northern Prairie Wildlife Research Center 2002). Fertig (2000) also mentioned that *L. prostrata* is not readily grazed by livestock or native wildlife in Wyoming. Large herbivores are known to graze throughout the range of other *Lesquerella* species with no evidence of negative effects (Moseley 1996). *Lesquerella* species found in areas with sheep grazing may be more susceptible to damage because sheep consume shrubby browse and may eat the whole plant, not just upper leafy portion (Anderson et al. 1997). In addition, the habitats of *L. arenosa* var. *argillosa* can be steep and rocky, with minimal forage and low water availability, and are probably not preferred areas for cattle (Marriott 1992, Fertig 2000). Livestock grazing can have an impact on plant species directly by affecting individuals (e.g., grazing, dispersal, trampling) or indirectly by influencing habitat (e.g., soil compaction, facilitating spread of invasive plants, plant community changes). Even if a plant is not palatable, trampling has the potential to do direct damage to plant populations in accessible areas. The grazing regime on USFS National Grasslands with *L. arenosa* var. *argillosa* populations generally consists of light to moderate grazing (at or below Natural Resources Conservation Service standards) from mid-May to mid-October (J. Abegglen personal communication 2002, C. Bradshaw

personal communication 2002, M. Marston personal communication 2002, M. Erk personal communication 2003, T. Weisbeck personal communication 2003). Ode and Backlund (1999) suggested that current livestock stocking rates on the Badlands Bombing Range in South Dakota are compatible with the continued survival of *L. arenosa* var. *argillosa* in that area. However, the authors did not describe the details of the current grazing regime in that area.

The palatability of *Lesquerella arenosa* var. *argillosa* tissues or fruits to other herbivores (e.g., mule deer, white-tailed deer, pronghorn antelope, prairie dogs, other small mammals, insects) is unknown. Although insects may prey upon fruits and seeds, Fertig (2000) did not observe any evidence of herbivory on *L. prostrata* (Wyoming).

Competitors and relationship to habitat

The interactions of *Lesquerella arenosa* var. *argillosa* within the plant community are not well known. However, as discussed previously, *L. arenosa* var. *argillosa* tends to occur on exposed substrate within grassland habitats and open badland habitats, where competition and succession are generally minimal. In general, the areas inhabited by this taxon probably have slow or no natural succession as a result of harsh soil conditions and rapid erosion (Ode 1988). These habitat characteristics suggest that this taxon is a poor competitor, prefers unvegetated areas, and can tolerate harsh, erodible environments beyond the tolerance of other species. Occupying less crowded areas could yield less competition for needed water and nutrient resources. Moseley (1996) also found that *L. paysonii* appeared to be a poor competitor because it was mostly restricted to open plant communities with a high percentage of bare soil and sparse vegetative cover (Moseley 1996). Moseley (1996) suggested that *L. paysonii* may rely on natural surface disturbances (e.g., wind, water erosion, frost heaving, pocket gopher digging) to reduce competition and maintain open soil. *Lesquerella arenosa* var. *argillosa* similarly occurs in sparsely-vegetated badland habitats or exposed substrates in grasslands. The role of disturbances (e.g., wind and water erosion and deposition) or microhabitat characteristics (e.g., nutrient-poor conditions limiting dense vegetation) in maintaining this open habitat is unknown. In badlands habitats, suitable substrates with sparsely-vegetated microhabitats may be plentiful, and the distribution and abundance of *L. arenosa* var. *argillosa* may not limited by habitat availability. In contrast, *L. arenosa* var. *argillosa* in grassland habitats may be restricted to breaks in the vegetation characterized by minimal competition from other vegetation and exposed substrate. This species seems to use topographical features with exposed substrate, such as knolls, slopes, bluffs, and outcrops, that are generally more sparsely-vegetated than areas with more soil development. It is possible that disturbances, such as wind and water erosion or fire, could play a role in some areas to maintain suitable habitat for *L. arenosa* var. *argillosa*, but these issues have not been studied. Fire does not seem to play a pivotal role in the biology of this species because this plant mostly inhabits areas with steep exposed slopes with low fuel loads. However, natural fire regimes may help create potential "open" habitat within grasslands by reducing litter buildup and ground cover by competing plants.

Exotic species compete with native species for space, nutrients, and water. The introduction of exotic species can be a secondary effect of trail and road construction. In some instances, exotic species can outcompete and/or replace native plants. This draws special concern to regionally endemic *Lesquerella* species. Ode and Backlund (1999) felt that one of the main threats to *L. arenosa* var. *argillosa* could be exotic plant species invasion into its habitat. In South Dakota, Russian thistle (*Salsola kali*), kochia (*Kochia scoparia*), or cheatgrass (*Bromus tectorum*) could potentially invade and negatively impact *L. arenosa* var. *argillosa* (Ode and Backlund 1999). S. Dingman (personal communication 2002) has seen yellow sweet clover (*Melilotus officianalis*) and annual brome grasses in *L. arenosa* var. *argillosa* habitat. Because this taxon inhabits harsh environments, the most detrimental invaders would be annual or disturbance-adapted species that can also tolerate harsh conditions (S. Dingman personal communication 2002).

Parasites and disease

There is no known information concerning the role of parasites or diseases in the life cycle of *Lesquerella arenosa* var. *argillosa* or related taxa.

Symbiotic and mutualistic interactions

Insect pollination of flowering plants is an example of an important symbiotic interaction. Plants lure insects to a pollen or nectar reward and the insects carry pollen to other flowers, thus helping to cross-fertilize. The role of pollinators and pollination ecology of *Lesquerella* species was previously discussed in *Pollinators* and *Pollination Ecology.* There is no other

known information concerning the role of symbiotic or mutualistic interactions in the life cycle of *L. arenosa* var. *argillosa*.

CONSERVATION

Threats

There have been limited studies on threats specific to *Lesquerella arenosa* var. *argillosa*. Thus, the information presented in this section is partly based on reports from other *Lesquerella* species in the western United States (*L. aurea*, *L. paysonnii*, *L. prostrata*) with similar growth habits, morphology, and regional endemism. Although these species are often locally abundant within their limited distributions, long-term persistence of this species can potentially be affected by a variety of natural and anthropogenic influences. Threats of overutilization

General disturbances

Although *Lesquerella arenosa* var. *argillosa* can sometimes occur in rugged, inaccessible habitat, populations of this taxon within USFS Region 2 could potentially be influenced by activities associated with grazing, recreation, mining, natural resource development, and road and structure construction. Because this species is found in grasslands below 1540 m in elevation, it is likely not threatened or affected by activities related to timber harvest, thinning, blowdowns, or forest fires.

Livestock grazing (cattle, bison) occurs in regions with *Lesquerella arenosa* var. *argillosa*, but probably poses little direct threat to this taxon. This taxon is typically found in dry, rocky, and sparsely vegetated areas that cattle and other livestock usually avoid due to lack of forage and water (Marriott 1992). Populations of this taxon in less steep, more accessible areas could possibly be impacted by incidental trampling, even if it is not a targeted species. In addition, *L. arenosa* and other *Lesquerella* species tend to be dry, wiry plants, and seem not to be palatable to cattle (Fertig 2000, Northern Prairie Wildlife Research Center 2002). Sheep grazing is not a common land use on USFS National Grasslands with *L. arenosa* var. *argillosa* (J. Abegglen personal communication 2002, C. Bradshaw personal communication 2002, M. Erk personal communication 2003, M. Marston personal communication 2002, T. Weisbeck personal communication 2003).

Lesquerella arenosa var. *argillosa* may be threatened by off-road use by motorized vehicles, foot traffic, or horse travel. While steep slopes with unstable substrates may be unsuitable for structure or road construction, these areas are still susceptible to impacts from off-road vehicle recreation. In USFS Pawnee National Grassland, M. Marston (personal communication 2002) suggested that illegal off-road motorcycle use may be occurring despite restrictions and these activities could negatively affect populations of *L. arenosa* var. *arenosa* by directly damaging existing populations or degrading habitat. Travel management plans for the other USFS National Grasslands with *L. arenosa* var. *arenosa* generally allow unrestricted travel by off-highway vehicles (OHV) (J. Abegglen personal communication 2002, C. Bradshaw personal communication 2002, M. Erk personal communication 2003, T. Weisbeck personal communication 2003), and some popular recreation areas can receive heavy use (M. Erk personal communication 2003). Fertig (2000) also noted that populations of other *Lesquerella*species (e.g., *L. prostrata*, *L. vicina*) could also be threatened by habitat degradation (erosion, soil compaction, trampling) from off-road vehicle recreational activity. In one part of its range (Colorado), *L. vicina* has also been almost destroyed by off-road vehicle activities (Anderson et al. 1997).

Road-building, natural resource developments, and other construction activities could also negatively impact *Lesquerella arenosa* var. *argillosa* in areas where slopes are not as steep and unstable. For example, recent growth of the natural gas industry in southwest Wyoming has caused *L. prostrata* to become susceptible to surface disturbances from road and pipeline construction associated with exploration (Fertig 2000). The extent of these activities within the known range of *L. arenosa* var. *argillosa* is not known. There is currently no natural resource development in USFS National Grasslands with known populations of *L. arenosa* var. *argillosa* (J. Abegglen personal communication 2002, C. Bradshaw personal communication 2002, M. Marston personal communication 2002, M. Erk personal communication 2003, T. Weisbeck personal communication 2003).

On the other hand, road-building and quarry activities could possibly create suitable habitat and facilitate dispersal for *Lesquerella arenosa* var. *argillosa*, as evidenced by existing populations in Wyoming (Marriott 1992, Fertig 1999). *Lesquerella arenosa* var. *argillosa* is currently found in a quarry and along roadsides with chipped rock from that site. Marriott (1992) hypothesized that these quarrying activities would pose a threat only if the operations were expanded significantly.

Although *Lesquerella arenosa* var. *argillosa* may not be significantly threatened by current construction, mining, or road-building activities, Ode and Backlund (1999) recommended that "we should avoid unnecessarily destroying its habitat". They suggested locating construction activities carefully to avoid destruction of potential habitat. Marriott (1992) recommended that no surface-disturbing activities (including herbicide application efforts) should be allowed where *L. arenosa* var. *argillosa* occurs. Surface-disturbing activities, such as natural resource development and structure construction, should avoid known populations and potential habitat, and areas should be surveyed before starting new projects (U.S. Congress 1989, U.S. Bureau of Land Management 2000). While the authors did not provide justification for their statements, they presumably felt that although no active management was necessary for the conservation of this species, efforts should be taken to avoid destroying entire populations.

Environmental threats

Based on information presented in preceding sections of this document, environmental threats to populations of *Lesquerella arenosa* var. *argillosa* could include changes to the natural disturbance regime (e.g., erosion, fire) that would affect competition/succession, exotic species introductions, or global climate changes.

The type, intensity, and frequency of disturbance optimal for the persistence of this taxon have not been studied. Presumably *Lesquerella arenosa* var. *argillosa* benefits from the harsh conditions created by erosion and deposition in badlands habitats to reduce competition from other species, potentially disperse seeds, and possibly create suitable microhabitats (e.g., cracks or gullies) for seed germination. However, these disturbance forces could also uproot or bury existing individuals; the ability of *L. arenosa* var. *argillosa* to tolerate direct impact by erosive forces is not known. Wind and water erosion and potentially fire may play a role in maintaining open habitat in grassland communities (S. Dingman personal communication 2002). Global climate change or other climatic fluctuations could also alter succession or competition dynamics. For example, years with more rain may stimulate grassland growth and could cause encroachments on *L. arenosa* var. *argillosa* habitat. Any anthropogenic structures (e.g., road culverts or road construction) or natural features (e.g., shrubby growth) that increased, decreased, or otherwise interrupted water flow could also potentially cause siltation or gullying and negatively impact existing populations of *L. arenosa* var. *argillosa* (S. Dingman personal communication 2002). S. Dingman (personal communication 2002) found that another rare plant species inhabiting badlands topography in Badlands National Park was negatively affected when shrub growth interrupted overland sheet flow and caused the water to cut currents in the badlands (gullying). Ode and Backlund (1999) and S. Dingman (personal communication 2002) suggested that exotic plant species invasion by annual species that are adapted to dry disturbed habitats (e.g., cheatgrass) could threaten populations of *L. arenosa* var. *argillosa* by outcompeting this taxon for necessary resources.

Threats affecting reproduction

The breeding system of *Lesquerella arenosa* var. *argillosa* has not been studied. If this taxon requires outcrossing and relies on pollination for reproductive success, any declines to pollinator populations could possibly reduce reproductive output. Because this taxon probably has a short-lived perennial life history, successful seed production, dispersal, seed bank, and germination may be important for the persistence of *L. arenosa* var. *argillosa* populations. However, these factors have not been studied for this species. The widespread use of a non-selective pesticide (e.g., grasshopper control using malathion) could possibly threaten this species by reducing pollinators and seed production (Moseley 1996, Ode and Backlund 1999).

While *Lesquerella arenosa* var. *argillosa* seems to thrive in harsh, sparsely-vegetated, erodible habitats, some habitats may not be adequate for sufficient growth and seed set. For example, one observation of a *L. arenosa* var. *argillosa* population in a quarry noted that some plants had dwarf or otherwise aberrant fruit (Wyoming Natural Diversity Database 2002). It is possible that conditions at the site were unsuitable for successful reproduction.

Threats specific to USFS National Forest System lands

The primary threats to *Lesquerella arenosa* var. *argillosa* on USFS Region 2 lands include OHV use, invasion of non-native plant species, and incidental trampling from livestock or recreation activities (e.g., rock collecting, hunting, hiking). USFS Pawnee National Grassland prohibits OHV use, but USFS Oglala National Grassland allows OHV use with some restrictions. For example, OHV use is prohibited in some areas, such as Toadstool Park in USFS Oglala National Grassland, and the occurrence of *L. arenosa* var. *argillosa* in this area may benefit from this protection. As discussed, livestock

grazing occurs on all of the USFS National System lands with occurrences of *L. arenosa* var. *argillosa* (J. Abegglen personal communication 2002, C. Bradshaw personal communication 2002, M. Marston personal communication 2002, M. Erk personal communication 2003, T. Weisbeck personal communication 2003), and it is possible that occurrences of this taxon could be impacted by incidental trampling. Populations of *L. arenosa* var. *argillosa* on USFS National Forest System lands are currently not threatened by disturbances from natural resource development, quarrying, road construction, or pesticide use (J. Abegglen personal communication 2002, C. Bradshaw personal communication 2002, M. Marston personal communication 2002, M. Erk personal communication 2003, T. Weisbeck personal communication 2003).

Conservation Status of the Taxon in USFS Region 2

The Researchers who have observed *Lesquerella arenosa* var. *argillosa* have suggested that threats to this taxon are considered low at present (Marriott 1992, Fertig 1999, Ode and Backlund 1999). Although the number of documented populations throughout the range is low, existing populations seem to be robust. This taxon may not need immediate active management (Ode and Backlund 1999), but much information is needed to further understand its distribution and biology. Much of this taxon's habitat is still intact (Ode and Backlund 1999), and surveys for *L. arenosa* var. *argillosa* may discover new occurrences.

Based on data collected, it would be difficult for one to conclude that the distribution or abundance of *Lesquerella arenosa* var. *argillosa* is declining or expanding throughout its range. Although some populations have been observed several times since their initial identification, the reports do not include detailed habitat, abundance, or demographic information. At best, we can conclude that most of the populations are still in existence and may be locally abundant. In one observation, the researcher noted that the population was "not very abundant in 1988; common in 1970", implying that the population had declined, but they did not hypothesize the causes of decline (Nebraska Natural Heritage Program 2002). In Colorado, 1970 was an above-average precipitation year, and 1988 was a below-average year (Colorado Climate Center 2002). It is possible that fluctuations in population sizes may have been correlated with precipitation fluctuations. Other observers noted that there were probably many more individuals adjacent to the area they surveyed (Wyoming Natural Diversity Database 2002). Although *L. arenosa* var. *argillosa* appears to be abundant, not enough data are available to conclude if populations of this taxon are increasing, decreasing, or remaining stable.

Lesquerella arenosa var. *argillosa* does not seem to be an extreme habitat specialist, restricted to only one specific soil, vegetation, or topographical association throughout its range; but it seems to locally associate with certain exposed soil strata (e.g., local edaphic endemism) and inhabits sparsely-vegetated knolls, bluffs, slopes, and outcrops. This taxon is always found in open areas with exposed substrate, thin soils, and little vegetation coverage. These areas are dynamic environments, susceptible to erosion by wind or water, and other harsh conditions. In Wyoming, *L. arenosa* var. *argillosa* has been consistently associated with a certain stratum of the Niobrara formation (Fertig 1999). In South Dakota, it tends to associate with exposed substrates of the Chadron, Brule, Spearfish, Madison, and other formations (Ode and Backlund 1999, S. Dingman, personal communication 2002). S. Dingman (personal communication 2002) suggested that in Badlands National Park this taxon may be restricted to a narrow ecotone where steep badland walls interface with the edge of the grassland. Thus, *L. arenosa* var. *argillosa* appears to require environments with harsh microhabitats and minimal interspecific competition.

The habitats of *Lesquerella arenosa* var. *argillosa* are not at immediate risk or severely threatened by consequences of land management, but they are generally characterized by high environmental stochasticity. Limiting factors or risks within the habitat could include competition from surrounding vegetation, lack of suitable germination sites, conditions too harsh for adequate growth and development (i.e., siltation or gullying by water), or other fluctuations in natural disturbance processes (e.g., precipitation, wind, fire). Severe surface-disturbing activities, such as mining, construction, or OHV use could endanger specific populations of *L. arenosa* var. *argillosa*. At the time of this assessment, no life history studies have been completed, and the extent of its vulnerability is unknown.

Management of the Taxon in USFS Region 2

Quantitative demographic monitoring and detailed ecological studies of *Lesquerella arenosa* var. *argillosa* have not been completed. Based on the available information pertaining to this taxon and its congeners, we can only hypothesize how changes in the

environment may affect the abundance and distribution of this species.

Management implications

Lesquerella arenosa var. *argillosa* is not at immediate risk as a result of management activities or natural disturbances within its range, but its long-term persistence may rely on adequate management to reduce potential threats. Currently, there are no management actions specifically protecting populations of this species. Because *L. arenosa* var. *argillosa* is a grassland species, it is not threatened or affected by management activities or disturbances typical in forested environments (i.e., timber harvesting, thinning, blowdowns, forest fires). Typical management activities and other human impacts within this taxon's range include livestock grazing, OHV use, non-motorized recreation, quarrying, and introduction of non-native plants. Current livestock grazing practices seem to be compatible with the persistence of *L. arenosa* var. *argillosa*. This taxon is likely not palatable and persists in rocky, steep, dry, barren areas, so it is probably largely ignored by livestock. Extensive off-road/off-trail use by non-motorized and motorized recreation could yield direct damage to existing populations and indirect harm through introduction of weed species and alterations of soil erosion and water flow. Quarrying activities at current levels seem to be providing suitable habitat for *L. arenosa* var. *argillosa*, but the effects of increased quarrying activity are unknown. The invasion of non-native plant species adapted to dry, exposed sites may potentially degrade suitable habitat and outcompete *L. arenosa* var. *argillosa*.

Conservation elements

Lesquerella arenosa var. *argillosa* is a regional endemic with a small number of recorded populations throughout its range in USFS Region 2. The lack of information regarding the colonizing ability, adaptability to changing environmental conditions, reproductive potential, or genetic variability of this taxon makes it difficult to predict its long-term vulnerability. The microhabitat needs of this taxon and intensity, frequency, size, and type of natural disturbance optimal for persistence of this taxon are unknown. The vulnerability of this taxon to human-related activities and environmental changes is not known. We are currently unable to assess the risks for drastic population declines and need for immediate, active management based on the current understanding of this taxon. Surveying high probability habitat for new populations, protecting existing populations from direct damage, documenting and monitoring the effects of current management activities, preventing non-native plant invasions, and studying ecology, biology, and demography of this taxon are key conservation elements.

Tools and practices

There are no existing habitat surveys or population monitoring protocols for *Lesquerella arenosa* var. *argillosa*. Since very little is known about the distribution, biology, and ecology of *L. arenosa* var. *argillosa*, it is difficult to develop a strategic management plan for conservation purposes. However, based on our current understanding of this taxon, we can outline areas where more information will help create baseline data for use in constructing a conservation plan. The following sections identify areas where more information is needed to help understand the taxon, to develop management objectives, and to initiate monitoring and research programs.

Information Needs and Research Priorities

Based on the existing literature, many data gaps in understanding the biology, ecology, and conservation strategies for *Lesquerella arenosa* var. *argillosa* exist. Information needed to address these data gaps can be obtained through surveys and inventories, long-term monitoring plans, and extended research programs. Surveys and inventories are useful in the short-term to locate populations and to determine population sizes and distributions of populations within the region. Populations that are located by surveys or inventories can be immediately protected if threats to the population are imminent, and can subsequently be targeted for long-term research or monitoring programs. Long-term monitoring programs are a useful component of conservation planning, as they answer the question, "What information is needed to preserve species, communities, and ecological systems?" The resulting information can be used to direct management actions and to initiate adaptive management practices as the project proceeds over time. Long-term research studies (e.g., genetic analyses, pollination studies) can supplement the current biological knowledge of the taxon and may be useful in providing feedback for use in long-term monitoring programs.

Species distribution

The actual distribution and abundance of *Lesquerella arenosa* var. *argillosa* are largely undocumented and not understood in sufficient detail

to formulate regional conservation strategies. Extensive inventories are needed to document the actual distribution of this variety and survey potential habitat for additional populations. For example, several element occurrence records for this taxon mentioned that more individuals of *L. arenosa* var. *argillosa* probably existed in adjacent areas, but those areas were not surveyed (Wyoming Natural Diversity Database 2002). The actual distribution of the taxon may be underestimated.

Current reports of taxon distribution provide a useful base of information, but they will not be wholly sufficient in developing a conservation strategy for this taxon in Region 2. Understanding the distribution of *Lesquerella arenosa* var. *argillosa* over its full range is required to develop an effective conservation strategy. Researchers could visit all documented sites, including those surveyed over 100 years ago, to ascertain both current distribution and population status. These sites could be regularly revisited for update reports.

The development of a protocol to survey for new populations within Region 2 would supplement the knowledge regarding current distribution of this taxon. The current distribution map for *Lesquerella arenosa* var. *argillosa* (**Figure 1**) shows that there are "holes" within its range (areas surrounded by or adjacent to areas with the presence of this taxon) that could have undocumented populations. For example, USFS Buffalo Gap National Grassland does not currently have any known populations of *L. arenosa* var. *argillosa*, but the adjacent Badlands National Park, Pine Ridge Indian Reservation, and Badlands Bombing Range all have occurrences of this taxon. Once survey areas have been identified, researchers could further identify areas of potential habitat using topographic maps, geologic maps, land status maps, and aerial or satellite images. For example, *L. arenosa* var. *argillosa* is known from areas with exposed Chadron and Brule Formation substrates in South Dakota. Within areas of suitable parent material, this taxon is known from topographic landforms, such as buttes, ridges, outcrops, and bluffs and seems to prefer sparsely-vegetated areas. In addition, surveys could use existing populations as a starting point because similar habitats may extend along topographic lines or topographical formations. Locations downslope or downwind (e.g., base of a bluff) from existing populations could be surveyed because *L. arenosa* var. *argillosa* seeds are possibly wind, water, and gravity dispersed. S. Dingman (personal communication 2002) has plans to survey for new populations of *L. arenosa* var. *argillosa* at Badlands National Park by using habitat characterizations of existing populations to create a potential habitat model based on geology, topography, plant community composition, and soil type layers within a GIS application.

Once located, population sites could be recorded using Global Positioning Systems technology and mapped for future reference. This would assist identification of populations in areas slated for various management, maintenance, or disturbance activities, and it would also allow the selection of populations for future study. Mapping populations of *Lesquerella arenosa* var. *argillosa* would also elucidate the spatial distribution of populations at the regional-level and provide a framework for creating a metapopulation study.

Life cycle, demography, and population trends

Other important issues relate to the taxon's life cycle, demography, and population trends to determine what new information is needed to supplement current understanding.

Lesquerella arenosa var. *argillosa* is thought to be a short-lived perennial forb species, although details about the life cycle have not been studied. Information is lacking on germination requirements, seed survival, extent of asexual reproduction, individual longevity, factors affecting flower development, pollination ecology, and role of the seed bank. This type of species-specific information would be useful in assessing threats to this taxon and developing mitigation and restoration strategies. For example, if a particular species or group of pollinators is predominant, it would be important to determine limiting factors that affect pollinators, which in turn could affect the success of this taxon. Seed bank studies could assess the abundance and spatial distribution of seeds to examine dispersal in this taxon. Studies of germination needs might elucidate potential limiting factors for the establishment of new individuals and populations.

Little data are available on population trends for *Lesquerella arenosa* var. *argillosa*. The existence of several populations has been noted over time, but no long-term demographic monitoring has been initiated. Long-term monitoring studies could yield helpful information, such as temporal patterns of abundance and dormancy, environmental factors that influence abundance (e.g., precipitation fluctuations), whether populations are increasing, decreasing, or remaining stable, and the minimum number of plants necessary to perpetuate the taxon. Certain aspects of demography, as indicated by the first three items below, are a priority in order to provide basic

population information. The remaining items identify information that is also of interest in understanding the taxon, if it can be obtained.

- What are the rates of survival, longevity, and recruitment?
- What are the role, status, and longevity of the seed bank?
- What are the population fluctuations from year to year?
- What is the age at which individuals become reproductive?
- What is the age structure of the population?

The answers to these questions are currently unknown for this taxon. Long-term monitoring programs are required to answer these kinds of questions, and it may take decades for a clear pattern to emerge. Understanding these issues would provide valuable input to the development of conservation plans and adaptive management strategies. Population matrix models that measure individual fitness and population growth provide flexible and powerful metrics for evaluating habitat quality and identifying the most critical feature of the species' life history (Hayward and McDonald 1997). Deterministic demographic models of single populations are the simplest analyses and are used as powerful tools in making decisions for managing threatened and endangered species (Beissinger and Westphal 1998).

Methods for monitoring population trends

Several groups have developed protocols for monitoring population trends of rare plant species. These protocols can be easily accessed and used to develop specific monitoring plans for use in USFS Region 2. For example, Elzinga et al. (1998) is a general reference that provides concrete guidance on designing and implementing quantitative monitoring plans for rare plant species. The monitoring protocols developed by Canada's National Ecological Monitoring and Assessment Network (Roberts-Pichette and Gillespie 1999) aid researchers around the world in establishing effective long-term monitoring protocols.

The distribution of *Lesquerella arenosa* var. *argillosa* should be characterized first in order to design an effective monitoring scheme for this taxon. The monitoring protocol design may need to be revised as understanding of this taxon increases. Studies of other *Lesquerella* species may provide helpful details on how to implement monitoring schemes for *L. arenosa* var. *argillosa*. For *L. prostrata*, Fertig (2000) initiated a demographic study of existing populations that included the use of 30 meter-squared plots along a belt transect to monitor the number of seedlings, pre-reproductive rosettes, flowering adults, and dead individuals. He found that a meter-squared sampling quadrat was a good size to quickly monitor the density of the plant in sparse populations, but this was too large for use in more densely populated colonies. He suggested that plots should be monitored on an annual or biennial basis until a population trend is established and then less frequently after that (Fertig 2000).

Habitat

A variety of different habitats have been described for several populations of *Lesquerella arenosa* var. *argillosa* within Region 2. Observed habitat associations can be a useful starting point for identifying survey areas within Region 2. Not only could surveys be extended from known locations to determine the extent of the existing population, but current knowledge of preferred soils and vegetation types will help conservation biologists to locate any other populations in similar habitats throughout the region. The development of a survey and inventory protocol within Region 2 National Forest System lands would supplement the knowledge regarding habitat associations for this taxon and help to develop land management strategies for conservation of the taxon.

Species' response to habitat changes

The primary question regarding species' response to habitat changes is: "Is the species response to fine- and broad-scale changes in habitat understood in sufficient detail to evaluate effects of management or changes in natural disturbance patterns?" As discussed above, much of the information regarding establishment, reproduction, dispersal, relationship with herbivores, and competition with introduced species has been studied for other species within the genus, but there is little or no species-specific information available. Research studies to evaluate these phenomena would provide valuable input to the development of conservation strategies and management programs.

The types of monitoring studies required to understand how this taxon responds to environmental fluctuations, changes in disturbance regime, or natural succession would be complex and could take decades.

For example, precipitation fluctuations have the potential to affect erosion rates, germination success, pollinator population trends, timing of flowering, and/or growth of surrounding grassland vegetation. Overall, populations of *Lesquerella arenosa* var. *argillosa* tend to be found in highly variable environments, distinguished by harsh soil conditions, rapid erosion rates, and sparse vegetation. Populations have also been found in areas with exposed soil created by quarrying activity. S. Dingman (personal communication 2002) suggested that in such variable environments, it is difficult to understand the dynamics between erosional forces, other vegetation, and growth of *L. arenosa* var. *argillosa*. In some cases, vegetation other than *L. arenosa* var. *argillosa* could provide necessary germination sites by giving protection from erosion. Shrub growth can also assist nearby plants by providing shade, accumulating soil and organic matter, and slowing evaporative water loss from the soil surface. In contrast, other vegetation could also have negative effects by competing with *L. arenosa*, or by altering overland water flow and creating more severely eroding currents (S. Dingman personal communication 2002). In addition, when *L. arenosa* var. *argillosa* individuals are found in a disturbed area, it is impossible to tell if the seeds were already present in the seedbank and responding to appropriate germination conditions, or if the seeds are short-lived and occur only locally, entering and colonizing the site after the disturbance occurred. Studies could be conducted to determine to what extent disturbances are necessary to maintain a population, what disturbance intensity and frequency may be most appropriate, and whether encroaching vegetation would result in local extirpation of a population.

The spatial and temporal dynamics of disturbances and population establishment could also be incorporated into studies of *Lesquerella arenosa* var. *argillosa*. Specifically, landscapes with variable environments are often characterized by a mosaic of suitable establishment sites that could change depending on year or season. Important spatial and temporal factors that would be important to consider include: the availability of suitable habitat throughout the landscape, the distance over which pollen and seeds may be dispersed, the distance and amount of gene flow between different populations, and the topographic location of populations (i.e., top or bottom of slopes, near trails or roads, nearness to grazing rangeland).

Availability of reliable restoration methods

Current information regarding restoration of habitat for this species was not found. There are still too many unknowns regarding habitat preferences and basic population dynamics to know what factors are critical in restoring habitat for this taxon. For example, it is currently not known what types, intensities, or frequencies of disturbance characterize habitats with this taxon. Similarly, if a separate restoration is being implemented (e.g., revegetation project), the revegetation may be successful in itself, but the necessary open habitat of *Lesquerella arenosa* var. *argillosa* may be bypassed. In addition, there has been no research to date involving the harvest, storage, or germination of *L. arenosa* var. *argillosa* seed for use in a restoration project. Beach et al. (2001) performed greenhouse germination experiments of collected seed of *L. ludoviciana* and found that germination was affected by storage, season, and harvest date. In short, information regarding basic biology is needed before restoration methods can be considered.

Identification of research priorities in USFS Region 2

There is so little known about the biology and ecology of this taxon, that there are a large number of research projects that could be implemented. The location of populations and habitat preferences are of primary importance to further the understanding of these species in Region 2. The following types of studies would supplement basic knowledge regarding this taxon:

- Relocation of historical populations and surveys for new populations
- Detailed habitat characterization
- Identification of specific threats to known populations
- Genetic analyses to verify taxonomic status
- Studies related to reproductive biology, including pollinator surveys, germination trials, genetic analyses of disjunct populations, and seedbank analyses
- Evaluation/analysis of the data collected thus far to help develop or modify any future monitoring programs

Other studies, as discussed earlier in this section, would provide valuable information, but have a lower priority in terms of immediate management needs.

Research and data needs that may be useful, but not incorporated into this assessment

One important aspect of long-term monitoring and data gathering is how to manage the data for efficient use. Data acquired during surveys, inventories, monitoring programs, and research projects are most easily accessible if they are entered into an automated relational database. Such a database should be integrated with GIS and allow the following queries and activities:

- Efficient incorporation of data in the field
- Generation of location and habitat maps
- Identification of population locations
- Characterization of associated habitat types
- Identification of population trends over time
- Identification of data gaps that require further information gathering
- Monitoring of success indicators
- Ease of modifying the database as additional information becomes available.

ACRONYMS AND ABBREVIATIONS

BLM	U.S. Bureau of Land Management
GIS	geographic information system
NHP	Natural Heritage Program
OHV	off-highway vehicle
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
WWW	World Wide Web
WYNND	Wyoming Natural Diversity Database

REFERENCES

Abegglen, Jeff. 2002. Wildlife Biologist, Pine Ridge Ranger District, USFS Oglala National Grassland, Chadron, NE. Personal communication.

Anderson, J.L., J.L. Reveal, and R.C. Rollins. 1997. *Lesquerella vicina* (Brassicaceae), a new species from the Uncompahgre River valley in western Colorado. Novon 7: 9-12.

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial Plant Ecology, Second Edition. The Benjamin/Cummings Publishing Company, Inc., Menlo Park, CA.

Baskin, C.C. and J.M. Baskin. 2000. Seed germination ecology of *Lesquerella lyrata* Rollins (Brassicaceae), a federally threatened winter annual. Natural Areas Journal 20(2): 159-165.

Baskin, C.C., J.M. Baskin, and E.W. Chester. 1992. Seed dormancy pattern and seed reserves as adaptations of the endemic winter annual *Lesquerella lescurii* (Brassicaceae) to its floodplain habitat. Natural Areas Journal 12(4): 184-190.

Beach S.E., J.M. Coons, H.R. Owen, B.L. Todd, and M.A.L. Smith. 2001. Germination of *Lesquerella ludoviciana* as affected by seed age. Abstracts for the Proceedings of Environmental Horizons Conference (University of Illinois, Urbana-Champaign), p. 40.

Beissinger, S.R. and M.I. Westphal. 1998. On the use of demographic models of population viability in endangered species management. Journal of Wildlife Management 62(3): 821-841.

Bleakly, D. 1999. New Mexico Rare Plants, *Lesquerella aurea* (Golden Bladderpod) [Online]. New Mexico Rare Plant Technical Council, Albuquerque, NM. Available at http://nmrareplants.unm.edu (Version 15 March 2002).

Bradshaw, Charlie. 2002. Range Conservationist, Douglas Ranger District, USFS Thunder Basin National Grassland, Douglas, WY. Personal communication.

Cabin, R.J. 1996. Genetic comparisons of seed bank and seedling populations of a perennial desert mustard, *Lesquerella fendleri*. Evolution 50(5): 1830-1841.

Cabin, R.J. and Marshall, D.L. 2000. The demographic role of soil seed banks. I. Spatial and temporal comparisons of below-and above-ground populations of the desert mustard *Lesquerella fendleri*. Journal of Ecology 88(2): 283-292.

Cabin, R.J., A.S. Evans, and R.J. Mitchell. 1997. Genetic effects of germination timing and environment: an experimental investigation. Evolution 51(5): 1427-1434.

Cabin, R.J., D.L. Marshall, and R.J. Mitchell. 1998. Do surface plant and soil seed bank populations differ genetically? A multipopulation study of the desert mustard *Lesquerella fendleri* (Brassicaceae). American Journal of Botany 85(8): 1098-1109.

Cabin, R.J., D.L. Marshall, and R.J. Mitchell. 2000. The demographic role of soil seed banks. II. Investigations of the fate of experimental seeds of the desert mustard *Lesquerella fendleri*. Journal of Ecology 88(2): 293-302.

Caswell, H. 2001. Matrix Population Models: Construction, Analysis, and Interpretation. Second Edition. Sinauer Associates, Inc, Sunderland, MA.

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

Colorado Climate Center. 2002. Data Access, Water Year Data [Online]. Colorado Climate Center, Department of Atmospheric Science, Colorado State University, Fort Collins, CO. Available at http://ccc.atmos.colostate.edu/index.shtml (Accessed May 2002).

Colorado Natural Heritage Program. 1999. Conservation Status Handbook: Colorado's Animals, Plants, and Plant Communities of Special Concern, Volume 3, No. 2. Colorado Natural Heritage Program, Fort Collins, CO.

Colorado Natural Heritage Program. 2003. Biological Conservation Database: *Lesquerella arenosa* var. *argillosa*. Colorado Natural Heritage Program, Fort Collins, CO.

Dierig, D.A., T.A. Coffelt, F.S. Nakayama, and A.E. Thompson. 1996. *Lesquerella* and *Vernonia*: oilseeds for arid lands. *In:* J. Janick (ed). Progress in New Crops. ASHS Press, Alexandria, VA, p. 347-354.

Dingman, Sandee. 2002. Resource Management Specialist, Badlands National Park, Interior, SD. Personal communication.

Dorn, R.D. 1992. Vascular Plants of Wyoming, second edition. Mountain West Publishing: Cheyenne, WY.

Elberling, H. 2000. Spatial pattern of *Lesquerella arctica*: Effects of seed bank and desiccation cracks. Ecoscience 7(1): 86-91.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and Monitoring Plant Populations. Technical Reference 1730-1. Bureau of Land Management, Denver, CO.

Erk, Michael. 2003. Rangeland Management Specialist, Fall River Ranger District, USFS Buffalo Gap National Grassland, Hot Springs, SD. Personal communication.

Evans, A.S. and R.J. Cabin. 1995. Can dormancy affect the evolution of post-germination traits - the case of *Lesquerella fendleri*. Ecology 76(2): 344-356.

Fertig, W. 1994. Wyoming Rare Plant Field Guide. Wyoming Rare Plant Technical Committee, USGS Northern Prairie Wildlife Research Center, Jamestown, ND: Available at http://www.npwrc.usgs.gov (Version 16JUL97).

Fertig, W. 1999. State Species Abstract: *Lesquerella arenosa* var. *argillosa*. Wyoming Natural Diversity Database, Laramie WY.

Fertig, W. 2000. Status of Prostrate Bladderpod (*Lesquerella prostrata*) in Southwest Wyoming. [Unpublished report]. Prepared by the Wyoming Natural Diversity Database, Laramie, WY for the Bureau of Land Management, Wyoming State Office, Laramie, WY. Agreement #K910-A4-0011, Task Order #TO-09.

Fertig, W. and G. Beauvais. 1999. Wyoming Plant and Animal Species of Special Concern. [Online] Wyoming Natural Diversity Database, Laramie, Wyoming. Available at http://uwadmnweb.uwyo.edu/wyndd/. Unpublished report.

Fertig, W. and B. Heidel. 2002. Wyoming plant species of special concern [Online]. Unpublished report prepared by the Wyoming Natural Diversity Database, Laramie, Wyoming. Available at http://uwadmnweb.uwyo.edu/wyndd/.

Freeman, Craig. 2002. Associate Scientist, Kansas Natural Heritage Inventory, Lawrence, KS. Personal communication.

Great Plains Flora Association. 1986. Flora of the Great Plains. University Press of Kansas: Lawrence, KN.

Grieve, C.M., J.A. Poss, D.L. Suarez, and D.A. Dierig. 2001. *Lesquerella* growth and selenium uptake affected by saline irrigation water composition. Industrial Crops and Products 13(1): 57-65.

Grime, J.P. 1979. Plant Strategies and Vegetation Processes. John Wiley & Sons, Ltd: Bath, U.K.

Grossman D.H., D. Faber-Langendoen, A.S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K.D. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. International classification of ecological communities: terrestrial vegetation of the United States. Volume I, The National Vegetation Classification System: development, status, and applications. The Nature Conservancy: Arlington, VA.

Hartman, Ronald L. 2002. Curator, Rocky Mountain Herbarium, University of Wyoming, Laramie, WY. Personal communication.

Hayward, G.D. and D.B. McDonald. 1997. Matrix population models as a tool in development of habitat models. *In:* J.R. Duncan, D.H. Johnson, and T.H. Nicholls (eds.) Biology and Conservation of Owls in the Northern Hemisphere, 2nd International Symposium, February 5 to 9, Winnipeg, MB. General Technical Report NC-190, U.S. Department of Agriculture, USFS.

Hazlett, D.L. 1998. Vascular plant species of the Pawnee National Grassland. Gen. Tech. Rep. RMRS-GTR-17. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 26 p. [29136].

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

Hyatt, L.A. and A.S. Evans. 1998. Is decreased germination fraction associated with risk of sibling competition? Oikos 83(1):29-35.

Hyatt, L.A., A.S. Evans, and C.C. Baskin. 1999. Annual dormancy cycles in *Lesquerella fendleri* (Brassicacae) seeds stored under both field and laboratory conditions. Canadian Journal of Botany 77(11): 1648-1654.

Integrated Taxonomic Information System. 2002. Integrated Taxonomic Information System Database [Online]. Available at http://www.itis.usda.gov.

Kansas Natural Heritage Inventory. 2000. Rare Plants of Kansas. Kansas Natural Heritage Inventory, Kansas Biological Survey, Lawrence, KS. Available at http://www.kbs.ukans.edu/.

Kaye, T.N. 1997. Seed dormancy in high elevation plants: Implications for ecology and restoration. *In:* T.N. Kaye, A. Liston, R.M. Love, D.L. Luoma, R.J. Meinke, and M.V. Wilson, Eds. Conservation and Management of Native Plants and Fungi. Native Plant Society of Oregon, Corvallis, OR.

Maguire, B. 1942. Great Basin Plants - VII. Cruciferae. American Midland Naturalist. 27:463-471.

Maguire, B. and A.H. Holmgren. 1951. Botany of the intermountain region - II. *Lesquerella*. Madroño. 11:172-184.

Marriott, H. 1992. Field Survey for *Aster mollis*, *Astragalus barrii*, and *Lesquerella arenosa* var. *argillosa* in northeast and central Wyoming. Unpublished report prepared for the Bureau of Land Management, Casper District by Wyoming Natural Diversity Database, The Nature Conservancy, Laramie, WY.

Marriott, H. and D. Faber-Langendoen. 2000. The Black Hills Community Inventory, Volume 2: Plant Community Descriptions. Prepared by The Nature Conservancy and Association for Biodiversity Information, Minneapolis, MN.

Marriott, H., D. Faber-Langendoen, A. McAdams, D. Stutzman, and B. Burkhart. 2000. The Black Hills Community Inventory: Final Report. Prepared by The Nature Conservancy, Minneapolis, MN.

Marston, Maggie. 2002. Resource specialist, Greeley Ranger District, USFS Pawnee National Grassland, Greeley, CO. Personal communication.

Mitchell, R.J. 1997. Effects of pollination intensity on *Lesquerella fendleri* seed set: Variation among plants. Oecologia 109(3): 382-388.

Mitchell, R.J. and D.L. Marshall. 1998. Nonrandom mating and sexual selection in a desert mustard: an experimental approach. American Journal of Botany 85(1): 48-55.

Moravis, Michael. 2002. Superintendent, Fort Robinson State Park, Crawford, NE. Personal communication.

Moseley, R.K. 1996. Report on the Conservation Status of *Lesquerella paysonii* in Idaho. Status Survey Report prepared by Idaho Conservation Data Center, Idaho Department of Fish and Game, Boise, ID for the Idaho Department of Parks and Recreation.

Mulligan, G.A. 1968. Transfers from *Physaria* to *Lesquerella* (Cruciferae). Canadian Journal of Botany 46: 527-530.

Mulligan, G.A. and A.E. Porsild. 1969. A new species of *Lesquerella* (Cruciferae) in northwestern Canada. Canadian Journal of Botany 47: 215-217.

NatureServe. 2003. NatureServe Explorer: An online encyclopedia of life, Version 1.7 [Online]. NatureServe, Arlington, VA. Available at http://www.natureserve.org/explorer.

Nebraska Natural Heritage Program. 2001. Nebraska Plants of Special Concern. Nebraska Natural Heritage Program, Lincoln, NE.

Nebraska Natural Heritage Program. 2002. Element Occurrence Records for *Lesquerella arenosa* var. *argillosa*. Accessed May 2002.

Nelson, B. Ernie. 2002. Manager, Rocky Mountain Herbarium, University of Wyoming, Laramie, WY. Personal communication.

Northern Great Plains Floristic Quality Assessment Panel. 2001. Floristic quality assessment for plant communities of North Dakota, South Dakota (excluding the Black Hills), and adjacent grasslands. Northern Prairie Wildlife Research Center, Jamestown, North Dakota. Available at http://www.npwrc.usgs.gov/resource/2001/fqa/fqa.htm.

Northern Prairie Wildlife Research Center. 2002. Native wildflowers of the North Dakota Grasslands [Online]. US Department of the Interior, US Geological Survey, Biological Resources Division, Northern Prairie Wildlife Research Center, Jamestown, North Dakota. Available at http://www.npwrc.usgs.gov.

Ode, David. 2003. Botanist/Ecologist, South Dakota Wildlife Diversity Program and Natural Heritage Program, Pierre, SD. Personal communication.

Ode, David. 2002. Botanist/Ecologist, South Dakota Wildlife Diversity Program and Natural Heritage Program, Pierre, SD. Personal communication.

Ode, D.J. 1988. Four endemic plants of the northern Great Plains. Proceedings of the North Dakota Academy of Science 42: 7. University of North Dakota Press: Grand Forks, ND.

Ode, D.J., and D. Backlund. 1999. Biological survey of the Badlands Bombing Range, Shannon County, South Dakota. Unpublished report prepared for the Ellsworth Air Force Base by the South Dakota Natural Heritage Program, South Dakota Department of Fish, Game, and Parks, Pierre, SD.

O'Kane, Steve L., Jr. 2002. Assistant Professor, Department of Biology, University of Northern Iowa, Cedar Falls, IA. Personal communication.

O'Kane, S.L., Jr. and I.A. Al-Shehbaz. 2002. *Paysonia*, a new genus segregated from *Lesquerella* (Brassicaceae). Novon: A Journal for Botanical Nomenclature 12(3): 379-381.

O'Kane, S.L., Jr., I.A. Al-Shehbaz, N.J. Turland, and R.C. Rollins. 1999. Proposal to conserve the generic name *Lesquerella* against *Physaria* (Cruciferae). Taxon 48: 163-164.

Payson, E.B. 1922. Monograph of the genus *Lesquerella*. Annals of the Missouri Botanical Garden 8:103-236.

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

Roberts-Pichette, P. and L. Gillespie. 1999. Terrestrial Vegetation Biodiversity Monitoring Protocols. Prepared on behalf of the Vegetation Monitoring Protocols Working Group of the Biodiversity Science Board of Canada for the Ecological Monitoring and Assessment Network. EMAN Occasional Paper Series, Report No. 9, EMAN Coordinating Office, Burlington, Ontario, Canada.

Roll, J., R.J. Mitchell, R.J. Cabin, and D.L. Marshall. 1997. Reproductive success increases with local density of conspecifics in a desert mustard (*Lesquerella fendleri*). Conservation Biology 11(3): 738-746.

Rollins, R.C. 1939. Studies in the genus *Lesquerella*. American Journal of Botany 26: 419-421.

Rollins, R.C. 1993. The Cruciferae of continental North America, Systematics of the Mustard Family from the Arctic to Panama. Stanford University Press, Stanford, California.

Rollins, R.C. and E. A. Shaw. 1973. The genus *Lesquerella* (Cruciferae) in North America. Harvard University Press, Cambridge, Massachusetts.

Rollins, R.C. and O. T. Solbrig. 1973. Interspecific hybridization in *Lesquerella*. Contr. Gray Herb. 203: 3-48.

South Dakota Natural Heritage Program. 2002a. Rare, Threatened, and Endangered Plant Species Tracked by the South Dakota Natural Heritage Program. South Dakota Department of Fish, Game, and Parks, Pierre, SD.

South Dakota Natural Heritage Program. 2002b. Element Occurrence Records for *Lesquerella arenosa* var. *argillosa*. South Dakota Department of Fish, Game, and Parks, Pierre, SD.

Steinauer, Gerry. 2002. Botanist, Nebraska Natural Heritage Program. Personal communication.

Tsuyuzaki, S. and J.H. Titus. 1996. Vegetation development patterns in erosive areas on the Pumice Plains of Mount St Helens. American Midland Naturalist 135(1): 172-177.

University of Colorado Herbarium. 2002. Colorado Vascular Plant Specimen Database. University of Colorado, Boulder, CO.

University of Wyoming - Rocky Mountain Herbarium 1998. Atlas of the Flora of Wyoming. [http://www.esb.utexas.edu/tchumley/wyomap/list.htm]

U.S. Bureau of Land Management. 2000. Record of Decision and Approved Resource Management Plan for Public Lands Administered by the Newcastle Field Office. Newcastle Field Office, Wyoming State Office, Bureau of Land Management, US Department of the Interior.

U.S. Bureau of Land Management. 2001. BLM Wyoming Sensitive Species Policy and List, Instruction Memorandum No. WY-2001-040 [Online]. BLM Wyoming, Wyoming State Office, Cheyenne, WY. Available at http://www.wy.blm.gov/newsreleases/2001/apr/senspecIMlist.pdf.

U.S. Congress. 1982. The National Environmental Policy Act of 1969, as amended 1982 [Online]. US Congress, Washington, D.C. Available at http://ceq.eh.doe.gov/nepa/regs/nepa/nepaeqia.htm.

U.S. Department of Agriculture/Natural Resources Conservation Service. 2001. The PLANTS Database, Version 3.1 [Online] National Plant Data Center, Baton Rouge, LA. Available at http://plants.usda.gov.

U.S. Forest Service. 1995. Title 2600 - Wildlife, Fish, and Sensitive Plant Habitat Management [Online]. USFS Forest Service Manual, Service-Wide Issuances, U.S. Department of Agriculture, Washington, D.C. Available at http://www.fs.fed.us/im/directives/.

U.S. Forest Service. 2002. Regional Forester's Sensitive Species List, USDA Forest Service, Rocky Mountain Region [Online]. Available at http://roadless.fs.fed.us/documents/feis/data/sheets/summspd/tes_supp/r2_ssspecies.pdf.

U.S. National Park Service. 2002. U.S. National Park Service Research Permit and Reporting System [Online]. U.S. Department of the Interior, National Park Service, Washington, D.C. Available at https://science1.nature.nps.gov/permits/servlet/ResearchIndex.

Weber, W.A. 1989. Additions to the Flora of Colorado - XII. Phytologia 67(6):429-437.

Weber, W.A. and R.L. Wittmann. 2000. Catalog of the Colorado Flora: A Biodiversity Baseline [Online]. University of Colorado, Boulder, CO. Available at http://cumuseum.colorado.edu/Research/Botany/Databases/catalog.html.

Weisbeck, Tonya. 2003. Wildlife Biologist/Rangeland Management Specialist, Wall Ranger District, Buffalo Gap National Grassland, Wall, SD. Personal communication.

Wyoming Natural Diversity Database. 2003. Element Occurrence Records for *Lesquerella arenosa* var. *argillosa*. Wyoming Natural Diversity Database, Laramie, WY.

DEFINITIONS

Aberrant — Deviating from expected or normal.

Allele — One of a pair of genes at the identical location (locus) on a pair of homologous chromosomes.

Annual — A plant that completes its entire life cycle (germinates, flowers, and sets seed) in a single growing season.

Appressed — Lying close to (pressed against) an organ, as hairs appressed to a leaf.

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

Bisexual — Containing both male and female reproductive organs in a single flower.

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

Carpel — The plant organ that bears the ovules.

Cross-breeding — A breeding system in which sexual reproduction involves the mating and union of gametes of different individuals.

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

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

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

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

Endangered — Defined in the Endangered Species Act as any species which is in danger of extinction throughout all or a significant portion of its range.

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

Entire — Having a margin that lacks any toothing or division, as the leaves of some plants.

Fertility — Reproductive capacity of an organism.

Fitness — Success in producing viable and fertile offspring.

Fruit — A mature ovary, contains seeds.

Genotype — Genetic constitution of an organism.

Glabrous — Smooth, without hairs, trichomes, or glands.

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

Habitat fragmentation — The break-up of a continuous landscape containing large patches into smaller, usually more numerous, and less connected patches; can result in genetic isolation.

Herbaceous — An annual or perennial plant which dies back to the ground at the end of the growing season because it lacks the firmness resulting from secondary growth.

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

Inflorescence — A group of flowers attached to a common axis in a specific arrangement.

Involute — Rolled inward; so that the lower side is exposed and upper is concealed.

Locus — (in genetics) Position of a gene (alleles) on a chromosome or within a DNA molecule.

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

Oblanceolate — Lance-shaped, but broadest above the middle and tapering to the base.

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

Ovule — (in plants) Part of female reproductive system that becomes a seed after fertilization.

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

Petiole — Leaf stalk.

Phenotype — The external visible appearance of an organism.

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

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

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

Prostrate — Flat on the ground.

Pubescent — Bearing hairs of any sort.

Raceme — An elongate inflorescence with pedicellate flowers arising from a central, unbranched axis.

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

Recurved — Curved backward.

Rosette — A cluster of leaves arranged in a circle, often in a basal position.

Ruderal — Temporary, often disturbed, habitats.

Secund — With the flowers or branches all on one side of the axis (often bt twisting of the pedicels).

Seleniferous — Containing selenium.

Self-incompatible — Plants incapable of producing a fertile zygote through self-fertilization; can involve morphological structures or genetic mechanisms.

Septum — A partition in an ovary formed by wall between adjacent carpels.

Sexual reproduction — Reproduction involving the union of gametes.

Silicle — A fruit like a silique, only it is more round and not much longer than wide

Silique — An elongate fruit usually containing two valves separated by a membranous partition to which the seeds are attached. Siliques and silicles are characteristic fruits of the Brassicaceae.

Sporophyte — The diploid, spore-producing phase of the life cycle of an organism .exhibiting Alternation of Generations

Subglobose — Not quite spherical.

Superior ovary — An ovary that is attached to the receptacle above the level of attachment of the other flower parts.

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

Sympatric — Occupying the same geographic region.

Threatened — Defined in the Endangered Species Act as any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Trichome — Any hair-like outgrowth from the epidermis.

Viability — The capability for living or continuing to develop.

Zygote — Cell formed from the union of two gametes.

References Used in Compiling Definitions of Terms

Gifford, E.M. and A.S. Foster. 1989. Morphology and evolution of vascular plants, third edition. W. H. Freeman and Co.: New York, NY.

Gleason, H.A. and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. New York Botanical Garden: New York, NY.

Harrington, H.D. 1977. How to Identify Grasses and Grasslike Plants. Swallow Press, Ohio University Press: Athens, OH.

Radford, A.E., W.C. Dickison, J.R. Massey, and C. R. Bell. 1974. Vascular Plant Systematics. Harper & Row: New York, NY.

Smith, J.P. 1977. Vascular Plant Families. Mad River Press: Eureka, CA.

Spackman, S., B. Jennings, J. Coles, C. Dawson, M. Minton, A. Kratz, and C. Spurrier. 1997. Colorado Rare Plant Field Guide. Prepared for the Bureau of Land Management, U.S. Forest Service, and U.S. Fish and Wildlife Service by the Colorado Natural Heritage Program, Fort Collins, CO.

Stearn, K.R. 1991. Introductory Plant Biology, fifth edition. Wm. C. Brown Publishers: Dubuque, IA.

Theobald, D.M. 1998. Tools Available for Measuring Habitat Fragmentation. Presented at the Colorado Chapter of The Wildlife Society Annual Meeting, Grand Junction, Colorado. January 22, 1998.

Weier, T.E., C.R. Stocking, and M.G. Barbour. 1970. Botany, An Introduction to Plant Biology. John Wiley & Sons: New York, NY.

Zomlefer, W. 1994. Guide to Flowering Plant Families. University of North Carolina Press: Chapel Hill, NC.