Chenopodium cycloides A. Nelson (sandhill goosefoot): A Technical Conservation Assessment

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

October 2, 2006

Juanita A. R. Ladyman, Ph.D.
JnJ Associates LLC
6760 S. Kit Carson Cir E.
Centennial, CO 80122

Peer Review Administered by
Center for Plant Conservation

Ladyman, J.A.R. (2006, October 2). *Chenopodium cycloides* A. Nelson (sandhill goosefoot): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/chenopodiumcycloides.pdf [date of access].

ACKNOWLEDGMENTS

The time spent and help given by all the people and institutions mentioned in the Reference section are gratefully acknowledged. I would also like to thank the Colorado Natural Heritage Program, in particular Susan Spackman-Panjabi and David Anderson, and the Colorado Natural Areas Program, in particular Ron West, for their generosity in making their files and records available. I would also like to thank the Kansas Biological Survey, the Oklahoma Biological Survey, the Texas Parks and Wildlife Department, Nebraska Natural Heritage Program, and Natural Heritage New Mexico for providing information. I appreciate access to the files and assistance given to me by Andrew Kratz - Region 2 USDA Forest Service, and Chuck Davis - U.S. Fish and Wildlife Service, both in Denver, Colorado. The information provided by Craig Freeman - the R.L. McGregor Herbarium and Kansas Natural Heritage Inventory, Nancy Brewer - USDA Cimarron National Grassland, and Kelly Allred - New Mexico State University, was very valuable in preparing this assessment. The data provided by George F. Russell - the United States National Herbarium, Michael Powell - Sul Ross State University Herbarium, Carolyn Ferguson and Mark Mayfield - Kansas State University Herbarium, Richard Worthington - Herbarium at the University of Texas-El Paso, Mike Sweeney - New Mexico State University Herbarium, Jane Mygatt of University - New Mexico Herbarium, Amy Buthod - Bebb Herbarium, Caleb Morse - R.L. McGregor Herbarium, and Jackie Poole and Bob Gottfried - Texas Parks and Wildlife Department are also very much appreciated. I would also like to thank Deb Golanty, Helen Fowler Library - Denver Botanic Gardens, especially for her persistence in retrieving some rather obscure articles. Thanks also to David Young with the High Plains Aquifer Information Network for granting me permission to use the map showing the aquifer location. I value the thoughtful reviews of this manuscript by Susan Spackman-Panjabi, Janet Coles, Richard Vacirca, and an unknown reviewer and thank them for their time in considering the assessment.

AUTHOR'S BIOGRAPHY

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

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *CHENOPODIUM CYCLOIDES*

Status

Chenopodium cycloides (sandhill goosefoot) is designated a sensitive species by Region 2 and Region 3 of the USDA Forest Service. It is also designated a sensitive species by the USDI Bureau of Land Management in New Mexico but not in any other state in which it occurs. In Region 2, *C. cycloides* occurs on the Cimarron National Grassland. The species may also occur on the Comanche National Grassland, but no verified reports could be obtained for this assessment. *Chenopodium cycloides* is not known to occur in any areas that are specifically protected from anthropogenic activities. The NatureServe Global rank for *C. cycloides* is vulnerable (G3). *Chenopodium cycloides* is ranked critically imperiled (S1) by the Colorado Natural Heritage Program and the Nebraska Natural Heritage Program, imperiled (S2) by the Kansas Biological Survey and Natural Heritage New Mexico, and vulnerable (S3) by the Texas Parks and Wildlife Department. The taxon is unranked (SU) by the Oklahoma Biological Survey. These ranks indicate conservation status only and have no regulatory function.

Primary Threats

Loss, modification, and fragmentation of habitat for *Chenopodium cycloides* is a significant threat throughout the species' range. Its prairie and shrub habitat has significant economic importance for livestock grazing, oil and natural gas production, mineral extraction, and recreation, all of which contribute to habitat loss, modification, and fragmentation. All known *C. cycloides* occurrences on the Cimarron National Grassland in Region 2 are in areas open to oil and gas development and livestock grazing. Urbanization is also encroaching on *C. cycloides* habitat in all states where it occurs, but at the current time, this is a localized threat. Invasive non-native plant species are likely to contribute to habitat loss and to provide direct competition in some *C. cycloides* occurrences. Environmental, demographic, and genetic stochasticity are potential threats to species viability.

Primary Conservation Elements, Management Implications and Considerations

Chenopodium cycloides is an inconspicuous annual species that has been collected relatively infrequently. Occurrences range in size from fewer than five to several thousand individuals. However, the aboveground abundance of individuals may not reflect the size of the seed bank that is likely to exist at most occurrence sites. Similar to many annual species with temporal variability in abundance, *C. cycloides* occurrences are vulnerable to unintentional extirpation. The absence of aboveground evidence of occupation in some years may lead to the unintentional elimination of the seed bank and extirpation of populations by development projects. Survey protocols to avoid this situation cannot be rigorously defined without additional information regarding the species' normal variation above ground. The patchy and temporally variable distribution of *C. cycloides* plants indicates that monitoring studies over several decades are likely to be needed to understand the species' population dynamics and life history traits. In addition, if certain *C. cycloides* occurrences are determined to need protection, it is important that the area delineated to be under protection is larger than that occupied by *C. cycloides* plants in any given year. Critical stages in the life history of *C. cycloides* are unknown.

Compared to other desert annuals, *Chenopodium cycloides*' fecundity in intermittent favorable years and a persistent and/or large seed bank are likely to be important to occurrence viability. If livestock grazing occurs during seed production in favorable years, it may affect seed bank replenishment. It is not known how quickly disturbed areas are re-colonized or if *C. cycloides* plants are able to persist at frequently disturbed sites. The relative importance of seed rain and the seed bank to (re)colonization has important management implications. Management practices that either increase or decrease the frequency or intensity of natural perturbations or provide additional stresses to the seed bank may negatively affect occurrence viability.

Chenopodium cycloides grows with other vegetation in areas with sandy soil and at the edge of dune blowouts that appear to be transient. However, it may not represent an early successional species in the classical sense but rather one that occupies a specialized ecological niche in communities e.g., *Quercus havardii* (sand shinnery oak) that represents a permanent climax condition maintained by edaphic properties and harsh environmental factors. This view of the successional status of the taxon may influence some human perception of its position within the community. "Early successional" suggests a taxon that is eventually replaced; whereas, one that is "part of a climax community" suggests permanence. There is little information to suggest that *C. cycloides* relies on communities that are maintained by human or livestock disturbance.

There is no information on the minimum size of a viable population for *Chenopodium cycloides*, and therefore it is difficult to predict the consequences of actions that reduce the size of any one population. Patchy distribution and temporal variability in abundance also make understanding the impacts of management decisions particularly challenging. *Chenopodium cycloides* occurrences on National Forest System lands may be particularly important to maintaining species viability because these lands can be managed for conservation of the species. Conservation may not be an option on privately owned lands.

Because *Chenopodium cycloides* lacks attractive flowers and has unremarkable foliage, people unfamiliar with the taxon might dismiss it as a "weed." Thus, it is less likely that the general public will appreciate *C. cycloides* as a taxon worth conserving.

TABLE OF CONTENTS

EDITORS: Janet Coles and Kathy Roche, USDA Forest Service, Rocky Mountain Region

List of Tables and Figures

Tables:

Figures:

Introduction

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Chenopodium cycloides* (sandhill goosefoot) is the focus of an assessment because it is a rare species with a restricted geographic range and specialized edaphic requirements. Region 2 and the Southwest Region (Region 3) have designated *C. cycloides* a sensitive species. Within the National Forest System, a sensitive species is a plant or animal "whose population viability is identified as a concern by a Regional Forester due to significant current or predicted downward trends in abundance or in habitat capability that would reduce a species distribution" (Forest Service Manual 2670.5 (19), USDA Forest Service 1995). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

Goal

Species assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, and conservation status of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, if the information is available, this assessment cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

Scope

This assessment examines the biology, ecology, conservation, and management of *Chenopodium cycloides* with specific reference to the geographic and ecological characteristics of USFS Region 2. Although some of the literature relevant to the species may originate from field investigations of *C. cycloides* and other species of *Chenopodium* outside Region 2, this document places that literature in the ecological and social context of the western Great Plains. Similarly, this assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of *C. cycloides* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting this synthesis, but it is placed in a current context.

In producing this assessment, the peer-reviewed literature, publications that have not been peer-reviewed (non-refereed publications), research reports, and data accumulated by resource management agencies have been reviewed. Where possible, the assessment emphasizes the peer-reviewed literature because this is the accepted standard in science. Since little research has been conducted on *Chenopodium cycloides*, literature that was not peer-reviewed was used in the assessment when the information was otherwise unavailable. In some cases, non-refereed publications and reports may be regarded with greater skepticism. However, many reports or non-refereed publications on rare plants are often 'works-in-progress' or isolated observations on phenology or reproductive biology and are reliable sources of information. For example, demographic data may have been obtained during only one year when monitoring plots were first established. Insufficient funding or manpower may have prevented work in subsequent years. One year of data is generally considered inadequate for publication in a peer-reviewed journal, but it still provides a valuable contribution to the knowledge base of a rare plant species. Unpublished data (e.g., Natural Heritage Program and herbarium records) were important in estimating the geographic distribution and population sizes of *C. cycloides*. These data required special attention because of the diversity of persons and methods used to collect the data. In some instances, records that were associated with locations at which herbarium specimens had been collected at some point in time are considered more reliable than those where only observations were made.

Occurrence data were compiled from the Colorado Natural Heritage Program, the Kansas Biological Survey, the Nebraska Natural Heritage Program, the Texas Parks and Wildlife Department, Natural Heritage New Mexico, the Oklahoma Biological Survey, the University of Colorado Herbarium at Boulder (COLO), the Colorado State University Herbarium (CSU), The New Mexico State University Herbarium (NMC), the University of New Mexico Herbarium (UNM), the Bebb Herbarium (OKL), The University of Kansas Herbarium (KANU), Kansas State University Herbarium (KSC), University of Texas Herbarium (TEX), Lundell Herbarium (LL), the US National Herbarium (US), Missouri Botanical Garden Herbarium (MOBOT), the literature (Freeman 1989, Jennings 1996, Sivinski

1996, Allred 1999) and online databases of the New York Botanical Garden, The Missouri Botanical Garden Herbarium, and the Harvard Herbaria.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference as described by Platt suggests that experiments will produce clean results (Hillborn and Mangel 1997), as may be observed in certain physical sciences. The geologist T.C. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data; sorting among alternatives may be accomplished using a variety of scientific tools (e.g., experiments, modeling, logical inference). Ecological science is similar to geology because of the difficulty in conducting critical experiments and the reliance on observation, inference, good thinking, and models to guide understanding of the world (Hillborn and Mangel 1997).

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

One element of uncertainty in determining the historical abundance and range of *Chenopodium* species is that they are often regarded as "weedy" and therefore have been intentionally omitted from some wildflower guides (e.g., Gates 1934). There is a legal definition[1] of a noxious weed, but "weedy" used in the above context is used to describe plants that do not have desirable or attractive qualities from a human perspective. For example, native species that have important ecological value but do not provide good forage for livestock have been classed as "weeds" (e.g., Whitson et al. 2001). A plant that is puny and unattractive is also often described as weedy.

Another problem in evaluating the abundance and range of *Chenopodium cycloides* is the apparent difficulty that non-specialists have in distinguishing it from other *Chenopodium* species in the field (Brewer personal communication 2004). Observations that lack voucher specimens to support them, particularly those made at the edge of the range, need to be regarded with skepticism. Even recent surveys sometimes combine all *Chenopodium* species under the collective title "*Chenopodium* species," probably because the plants can be difficult to identify.

Some workers suggest that additional surveys may find *Chenopodium cycloides* and that the species is more widespread than currently believed (Sivinski 1995, Jennings 1996). Such comments are speculative, and the rarity of a taxon can be difficult to establish. There is always the possibility that additional surveys will reveal more occurrences. When most information has been collected relatively casually, a criticism with defining a taxon as rare is that there are extensive areas yet unsurveyed. While this is true to some extent, rarity is also relative and many taxa are regarded as not being rare precisely because casual observation has noted that they occur frequently.

Publication of the Assessment on the World Wide Web

To facilitate the use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site (http://www.fs.fed.us/r2/projects/scp). Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More importantly, Web publication will facilitate the revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. This assessment was reviewed through a process administered by the Center for Plant Conservation, employing two recognized experts on

[1]Federal Noxious Weed Act of 1974 7 U.S.C. §§ 2801-2814, January 3, 1975, as amended 1988 and 1994.

this or related taxa. Peer review is designed to improve the quality of communication and to increase the rigor of the assessment. USFS personnel made additional editorial changes prior to publication.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Chenopodium cycloides is an annual plant species endemic to sandy soils of eastern Colorado, western Nebraska, western Kansas, eastern New Mexico, and western Texas (**Figure 1**). The taxon is also reported to occur in Oklahoma, but no specimens or verifiable observations could be located for this report (Butler personal communication 2004). Due to its rarity and limited geographic range, the USDI Fish and Wildlife Service (USFWS) included *C. cycloides* as a Category 2 (C2) candidate for listing in 1993 under the Endangered Species Act (1973). The C2 list included species that might have warranted listing as threatened or endangered, but for which the USFWS lacked sufficient biological data to support a listing proposal. In February 1996, the USFWS revised its candidate policy and eliminated the C2 designation (U.S. Fish and Wildlife Service 1996). Under the revised candidate list, only those species for which there is enough information to support an endangered or threatened listing proposal are included. These were formerly known as "Category 1 Candidate Species." The USFWS no longer categorizes species, such as *C. cycloides*, that are rare but for which there is little information on population trend or vulnerability to extinction. In some states, USFWS classifies species that lack sufficient biological data to support a listing proposal as Species of Concern. The USFWS emphasizes that it draws attention to Species of Concern "for planning purposes only" and that they have no protection by law. Species of Concern are "taxa for which further biological research and field study are needed to resolve their conservation status or are considered sensitive, rare, or declining on lists maintained by Natural Heritage Programs, State wildlife agencies, other Federal agencies, or professional/academic scientific societies" (U.S. Fish and Wildlife Service 2005). The New Mexico Ecological Services Field Office has designated *C. cycloides* a Species of Concern (U.S. Fish and Wildlife Service 2005).

NatureServe and many state natural resource programs use a system to rank sensitive taxa at global (G) and state or subnational (S) levels on a scale of 1 to 5. A ranking of 1 indicates the most vulnerable and of 5, the most secure (see "Ranks" in the **Definitions** section). These ranks carry no regulatory status. The NatureServe (2006) global rank for *Chenopodium cycloides* is between vulnerable and apparently secure (G3G4), and its rounded global status is vulnerable (G3). The Colorado Natural Heritage Program and the Nebraska Natural Heritage Program both rank the species critically imperiled (S1). The Kansas Biological Survey and Natural Heritage New Mexico designate it as imperiled (S2), and the Texas Parks and Wildlife Department ranks it as vulnerable (S3). *Chenopodium cycloides* remains unranked (SU) by the Oklahoma Biological Survey.

Region 2 and Region 3 of the USFS designate *Chenopodium cycloides* as a sensitive species (USDA Forest Service 2005). USDI Bureau of Land Management (BLM) in New Mexico also designates it as a sensitive species (Sidle 1998). *Chenopodium cycloides* is not designated a sensitive species by the BLM in any other states in which it occurs.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Chenopodium cycloides occurs on land managed by the USFS, the BLM, state agencies, the Department of Defense, and on private land (**Table 1**). The species may occur on land managed by the National Park Service in New Mexico (USDI National Park Service 2001, 2002), but no occurrences can be confirmed (Conrod personal communication 2004). The State of Kansas (Kansas Biological Survey 2004) lists *C. cycloides* as a species of concern. No specific management plans have been written for this species in any area where it occurs.

The intention of the USFS designation of *Chenopodium cycloides* as a sensitive species is to prevent a downward trend of the taxon, which would lead to its listing as threatened or endangered by the USFWS (USDA Forest Service 1995). Because it is designated a sensitive species, USFS policy (Forest Service Manual 2670.32) requires that potential effects on *C. cycloides* be reviewed in a biological evaluation before executing projects that may impact known occurrences or habitat and that the impacts of the activities must be avoided or minimized. While projects that affect individual occurrences may be allowed, the permitted activities must not result in a loss of viability or create significant trends towards federal listing of the taxon (USDA Forest Service 1995). The designation of *C. cycloides* as a sensitive species by federal agencies is also valuable because it raises awareness of the species among professional

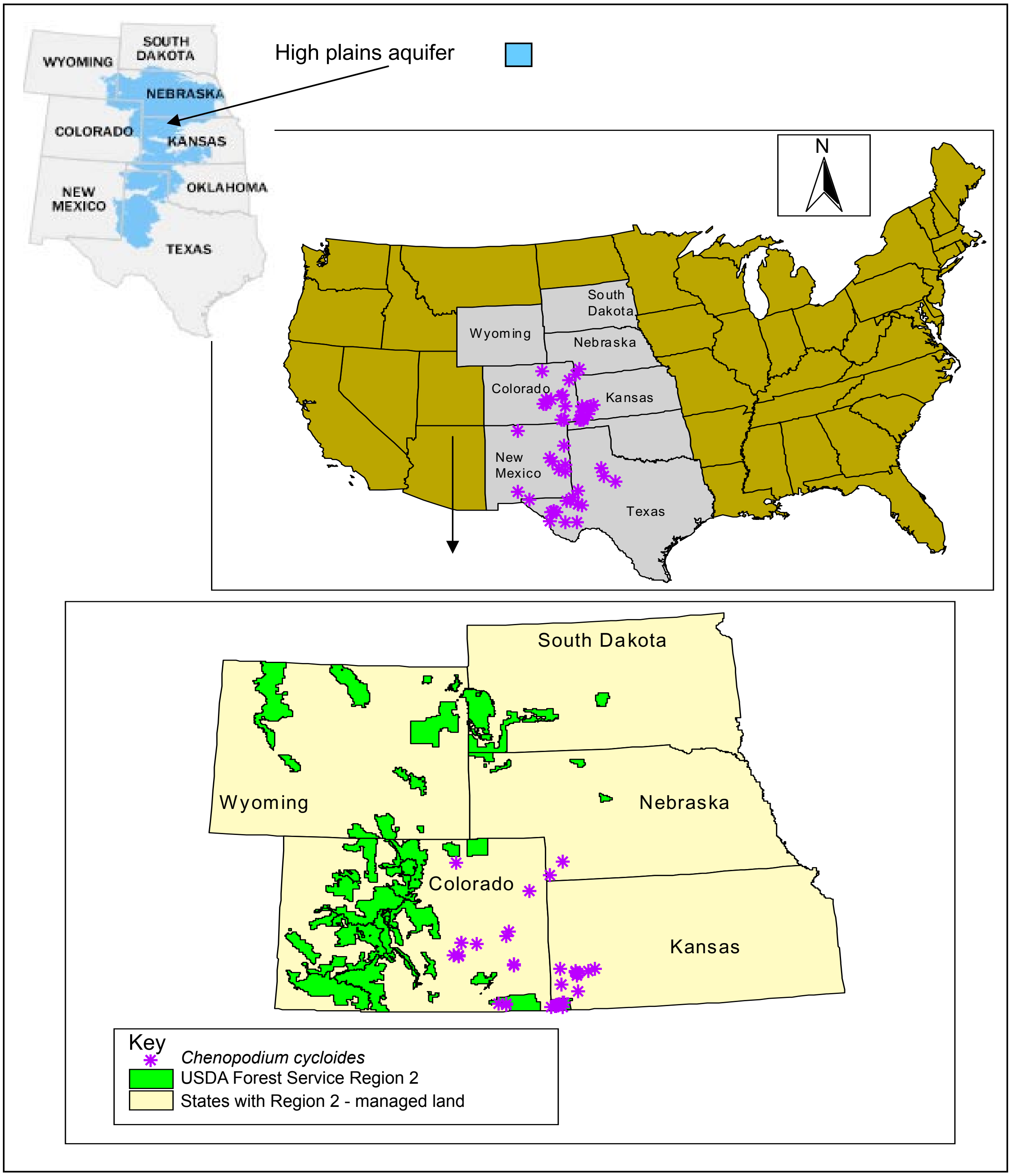

Figure 1. Range of *Chenopodium cycloides*. Each purple star on the map may represent more than one *C. cycloides* occurrence. There are at least nine known *C. cycloides* occurrences on the Cimarron National Grassland in Kansas. Two occurrences are near the Comanche National Grassland boundary in Colorado. The inset map is from the High Plains Aquifer Information Network (URL<http://www.hiplain.org/>), and is used with permission.

Table 1. Occurrences of *Chenopodium cycloides*.

State	No.	Land management	County	Dates observed	Location	Habitat	Abundance	Comments	Information sources[1]
CO	1	Private	Weld	27 Aug 1997, 3 Sep 1997	In vicinity of Wells Cow Camp	Aug 1997: "Slope: 0-3%. Aspect: all. Soil: Derived from eolian deposited sand from the Quaternary. Surrounding sand sage prairie. Associated species include *Andropogon hallii, Calamovilfa longifolia, Bouteloua gracilis, Chenopodium leptophyllum*, and stinkhorn mushrooms. *Artemisia filifolia* present but infrequent" Sep 1997: *Andropogon hallii-Calamovilfa longifolia* grassland on eolian deposited sand; with *Chondrosum gracile* and *Chenopodium leptophyllum*	Aug 1997: four individuals observed Sep 1997: four plants	Aug 1997: Plants are annuals; plants were multi-branched and robust; fruiting and plants were prolific; late summer rains may account for their large size and abundant fruit. Sep 1997: Reproductive status: flower and fruit. Colorado Natural Heritage personnel (1997) commented that, "while only 4 individuals were seen, there is extensive potential habitat surrounding the occurrence. Very little disturbance." Also commented: "Plant is unmistakable with its bright red fruits and fused calyx lobes."	*D. Clark #634* September 1997 COLO; Colorado Natural Heritage Program (2004, 2006)
CO	2	Private	Yuma	28 Aug 1999	Fox Ranch, on bluffs north of Arikaree River	Plants at lower edge of large sand sage prairie on less sandy bluffs rear the floodplain; in loamy sand (soils not extremely sandy) with *Andropogon hallii, Bouteloua gracilis, Bouteloua hirsuta, B. hirsuta, Yucca glauca,* and *Thelesperma megapotamica*. Elevation 3,930 to 3,950 ft.	Approximately 10 plants observed in less than 0.1 acre	Reproductive status: flower and fruit; area not searched extensively	*S. Kettler #s.n.* COLO; Colorado Natural Heritage Program (2006)
CO	3	Private	Cheyenne	30 Jun 2000	Southwest of Wild Horse	Colonizing loose sand of two-track in sandsage prairie with *Paspalum setaceum, Psoralidium lanceolatum,* and *Paspalum setaceum, Psoralidium lanceolatum,*	No information	Reproductive status: flower and fruit	*D. Clark #1235 with C. Crawford* COLO; Colorado Natural Heritage Program (2006)
CO	4	Private	Cheyenne	30 Sep 2000	County Road 2 approximately 9 miles south of Aroya	Loose sand in sand sage prairie with *Ambrosia acanthicarpa* and *Oligosporus filifolius*	No information	Reproductive status: flower and fruit	*D. Clark #146 with C. Crawford* COLO; Colorado Natural Heritage Program (2006)
CO	5	Private	Lincoln	23 Jul 2001	County Road 11	Loose sand in sand sage prairie with *Leiostemon ambiguus* and *Chamaesyce missurica*	No information	Survey in Eastern Plains of Colorado; reproductive status: fruit	*D. Clark #152* COLO; Colorado Natural Heritage Program (2006)

Table 1 (cont.).

State	No.	Land management	County	Dates observed	Location	Habitat	Abundance	Comments	Information sources[1]
CO	6	Colorado State	El Paso	29 Sep 2000	Approximately 2 to 3 miles east of Black Squirrel Creek; occurrence distributed between 2 sections	With *Bouteloua gracilis, Artemisia filifolia,* and *Aristida purpurea* in a swale between dunes in good to fair condition sand sage prairie	2000: At least 30 to 40 plants	2000: An approximate 35 acre development is occurring along a road 2 to 3 miles west of the site; existing gravel pit approximately 2 miles west of site	Colorado Natural Heritage Program (2004, 2006)
CO	7	Colorado State and /or Private	El Paso	24 Aug 1998, 7 Jul 2003	1998: Northern part of Bohart ranch approximately 23 miles east-southeast of Colorado Springs; east of Ellicott Hwy 2003: Chico Basin	1998: Transitional between mixed grass and sand sage prairie; sand blowout with *Palafoxia sphacelata, Cycloloma atriplicifolium, Euploca convolvulacea,* and *Triplasis purpurea* 2003: Associated plant community: mixed annual Chenopodiaceae, Asteraceae; habitat type: dunes; total bare ground: 50%; light exposure: open; topographic position: interdune basin; parent material: sand; elevation: 5,200 ft.	1998: Less than 100 individuals 2003: Estimate 100 to 200 individuals in approximately 50+ acres	1998: Reproductive status: flower and fruit; tend to colonize areas with exposed sand 2003: Reproductive status: Fruit	*D. Clark #819 with N. Lederer, T. Kelso, and G. Maentz* 1998 COLO, KANU; Colorado Natural Heritage Program (2006)
CO	8	Department of Defense	Pueblo	9 Sep 2001	Signal Rock sandhills region	The site consists of a complicated mosaic of vegetation communities including shortgrass prairie dominated by blue grama (*Bouteloua gracilis*), sand sagebrush (*Oligosporus filifolius*) and greasewood-alkali sacaton shrubland (*Sarcobatus vermiculatus/ Sporobolus airoides*); other vegetation includes rabbitbrush (*Chrysothamnus nauseosus*), cholla (*Cylindropuntia imbricata*), Opuntia (*Opuntia* sp.), and numerous other species of grasses and forbs; aspect: flat; slope 1-5%; moisture: hydric; light exposure: full sun; soil: sand; dominant plant community: *Artemisia filifolia/Andropogon hallii*	2001: Number of individuals counted = 136 within 100-meter transect; estimated population size: over 200	2001: 5% with flowers, 95% with fruit; no evidence of disease, predation or injury; the occurrence is located in a sand sage community that is located in a proposed wildlife refuge; there has been no grazing since the 1940's, little anthropogenic disturbance, few weeds. 2001: there are definable threats, but they are not expected to impact the site within the next 5 years; area is a military installation but likely to be decommissioned within the next 15 years 2001: Management may be needed in future to maintain the current good quality habitat (Colorado Natural Heritage Program 2004)	Colorado Natural Heritage Program (2004)

Table 1 (cont.).

State	No.	Land management	County	Dates observed	Location	Habitat	Abundance	Comments	Information sources[1]
CO	9	Private	Pueblo	14 Sep 1935	26 miles south of Fountain	1935: On sandhills	No information	Jennings (1996) commented that if this site was along the main road between Colorado Springs and Pueblo the site is now near the north city limit of Pueblo and may have been lost to urbanization	*J. Christ #1677* 1935 CS; Jennings (1996); Colorado Natural Heritage Program (2004)
CO	10	Colorado Division of Wildlife and the Army Corps of Engineers, Department of Defense	Bent	30 Jul 1998, 31 Jul 1998	South shore of John Martin Reservoir; below the east side of the elevated dam road at John Martin Reservoir; occurrence distributed within three sections	30 Jul: Growing on sand dunes in sand sage prairie; in loose sand with *Cycloloma atriplicifolium* 31 Jul: Sand sage prairie with *Eriogonum annuum, Erigeron bellidiastrum,* and *Oligosporus filifolius*	No information	*Chenopodium cycloides* occurred in concentrated clusters throughout this sand sage prairie; reproductive status: flower and fruit.	*D. Clark #744* 30 July 1998 COLO, KANU; *D. Clark #758* 31 July 1998 COLO; Colorado Natural Heritage Program (2006)
CO	11	Patented land (some minerals owned by the federal government)	Las Animas	14 Sep 1994, 13 Oct.1995	Mesa de Maya Region in southeastern Colorado; on road to ranch	1994: Sandy clearings within grassland; with *D. Clark #744Schizachyrium scoparium, Andropogon gerardii, Lycurus phleoides, Eriogonum annum, Chenopodium leptophyllum,* and *Gutierrezia sarothrae* 1995: Roadside, in sandy soil with *Cycloloma atriplicifolium* and *Schizachyrium scoparium*	1994: Six plants seen	1994: Flora of the Mesa de Maya Region; reproductive status: fruit 1995: reproductive status: fruit	*D. Clark #539* 1994 COLO; *C.L. Crawford #s.n.* 1995 COLO; Colorado Natural Heritage Program (2006)
CO	12	Private Patented land (some minerals owned by the federal government and/or the State of Colorado)	Las Animas	27 Jul 1947	Mesa de Maya Region; 5 miles south of Kim (**No plants were found in this area during surveys in 1994 and 1995** (Jennings 1996))	1947: Sandy area	1947: Frequent	Original identification as *Chenopodium pallescens* Standl.; reproductive status: fruit; annotations: "*C. cycloides* A. Nels. (I am keeping separate)", determined by H.D. Harrington, 1949. *Chenopodium cycloides* A. Nelson, determined by R.L. McGregor 1990	*C.M. Rogers #5039* 1947 COLO; Jennings (1996); Colorado Natural Heritage Program (2006)
CO	13	Colorado State and/or private	El Paso	8 Aug 2001	Bohart Ranch area	In sandsage prairie; soils are not loose sands but more loamy (maybe loamy sands); with *Artemisia filifolia, Stipa comata*, and *Calamovilfa longifolia* at elevation 5,480 to 5,530 ft.	Approximately 200 plants while walking 0.25 to 0.5 miles	Large number of plants most of which flowering and/or fruiting; few or no non-natives in area; area was not thoroughly searched	Colorado Natural Heritage Program (2006)

Table 1 (cont.).

State	No.	Land management	County	Dates observed	Location	Habitat	Abundance	Comments	Information sources[1]
CO	14	Colorado State	El Paso	5 Jul 2001	Crow's Roost	No Information	Approximately 30 to 40 plants	Plants flowering and/or fruiting; homes and paved highway within 0.3 miles to the west; landscape is good towards east; non-natives are present in low abundance and do not appear to impact occurrence	Colorado Natural Heritage Program (2006)
CO	15	Colorado State	El Paso	8 Aug 2001	Bohart Ranch	2001: In sand hill dunes with *Artemisia filifolia, Stipa comata*, and *Calamovilfa longifolia* at elevation 5,820 ft. (1,774 m).	2001: At least 30 to 40 plants in area	2001: Most plants were flowering and/or fruiting; area not thoroughly searched; no non-natives in area	Colorado Natural Heritage Program (2006)
CO	16	Colorado State	El Paso	24 Aug 1998	Bohart Ranch - Chico Basin	Total tree cover 0%. Associated plant community: *Oligosporus filifolius, Dalea cylindriceps, Andropogon hallii, Calamovilfa longifolia, Chenopodium subglabrum, Palafoxia sphacelata*; habitat type: sandsage prairie, sand blowout; light exposure: open; moisture: dry habitat; geomorphic land form: Quaternary Aeolian sand deposits; soil texture: sand; elevation 5,700 ft.	Approximately 50 individuals	Unusual seasonal precipitation of over 14.5 inches from end of June to day of visit	Colorado Natural Heritage Program (2006)
KS	1	Private	Finney	19 Jul 1988, 6 Jul 1990, 30 Jun 1991	1988: US 83, approximately 1 mile south of junction with Business 83, south of Garden City, Southwind Development on east side of the highway June 1991: Southwind Development area	1988: Rolling sandhill prairie south of road into the development; scattered blowouts June 1991: Top and slopes of stabilized sand dunes and around blowouts July 1991: West edge of Southwind Development; area of rolling sand hills; edge of small blowouts	1988: Locally common to abundant, especially around blowouts Jun 1991: Common in the area Jul 1991: Rare and dwarfed this year	1988: Plants to 3 ft. tall 1991: Rare and dwarfed this year	*C.C. Freeman, R.E. Brooks, and C.L. Lauver #2617* 1988 OKL, KANU, MO; *R.L. McGregor #40192* July 1990 KANU; *R.L. McGregor #40438* 1991 KANU; Jennings (1996)

Table 1 (cont.).

State	No.	Land management	County	Dates observed	Location	Habitat	Abundance	Comments	Information sources[1]
KS	2	Private	Finney	3 Jul 1995, 3 Jul 1997	1995: 7.5 miles south and 1.5 miles west of Holcomb 1997: Approximately 7 miles south of the Arkansas River in the Garden City dune belt	1995: Level to gently rolling sandsage prairie in dune tract; dunes well vegetated, few blowouts 1997: Gently rolling sandsage prairie; shallow depression and low ridges; sand exposed and loose in most areas	1995: Rare; approximately 10-15 plants on west facing slope 1997: Estimated 20 plants present in early flowering condition	No comments	*C.C. Freeman and J.A. Freeman #7257* KANU 1995; Kansas Biological Survey (2004)
KS	3	Private	Hamilton	19 Jul 1988	South of the Arkansas River; 1.8 miles south of US 270; roadside and adjacent prairie pasture east of highway	Sandsage prairie and sandy road cut and some widely scattered blowouts with loose sand; plants on rolling to choppy dune in sandsage prairie	Scattered to locally common blowouts with loose, shifting sand; Kansas Biological Survey (2004) note: observed scattered plants; not a large population	Plant to 4 ft. tall; grazed	*C.C. Freeman, R.E. Brooks and C.L. Lauver #2630* KANU; Jennings (1996); Kansas Biological Survey (2004)
KS	4	Unknown	Hamilton	Aug 1985	Only county record available	No information	No information	Originally identified as *Chenopodium leptophyllum*, annotated by H.A. Wahl 1967	*A.S. Hitchcock #s.n.* KSC; Jennings (1996)
KS	5	Private	Kearny	8 Jul 1996	6.4 miles north-northeast of the Grant County line, on KS 25	Area of sand dunes and blowouts southwest of highway and into the sandsage prairie; growing at edges of blowouts and on slopes of sand dunes	Fairly common	Plants to 4 ft. tall	*M. McGlohon #s.n.* KANU
KS	6	Private	Kearny	1 Jul 1991, 12 Jul 1992	KS 25, approximately 4.0 miles north of the Grant-Kearny County line; occurrence distributed within two sections	1991: Sandsage prairie; at edge of small blowout 1992: On east side of road; area of sand dunes; scattered on crests and slopes of dunes	1991: Small local colony	No comments	*R.L. McGregor #40445* 1991 KANU; *R.L. McGregor #40632* 1992 KANU; Jennings (1996)
KS	7	Private	Kearny	19 Jul 1988	7.0 miles northeast of Grant County line	Sandsage prairie in sandhills; scattered blowouts in the area with loose sand	Locally abundant especially east of highway; most abundant on slopes of blowouts	Plants in flower; plants in grazed and ungrazed prairie	*C.C. Freeman, R.E Brooks, and C.L. Lauver #2626* KANU, MO [Duplicates sheets at KANU]; Jennings (1996)

Table 1 (cont.).

State	No.	Land management	County	Dates observed	Location	Habitat	Abundance	Comments	Information sources[1]
KS	8	Private	Kearny	27 Jun 1988	Southeast of Highway KS 25; 4.0 mi north-northeast of Grant County line	Extensive area of sand dunes with well-developed blowouts; sand sage prairie	*Chenopodium cycloides* locally common in the area; mostly at the edge of blowouts	No comments	*C.C. Freeman #2591* KANU [Duplicate sheets at KANU]; Jennings (1996); Kansas Biological Survey (2004)
KS	9	Unknown	Grant	Aug 1895	Sand hills	Sand hills	No information	Type 1902 "This specimen is too immature to show the characters of the species, which is an excellent one," annotation by P. C. S[tandley]. Flower. Verified by A. Tiehm, 1986. Verified: R. L. McGregor. 1989. *Chenopodium cycloides* A. Nelson Determined by: R.L. McGregor (KANU) 1990, Annotated Isotype W. Jennings	*A.S. Hitchcock #435* 9 August 1895 MO [Holotype]; *A.S. Hitchcock #435* 1895 KSC, GH, RM [Isotypes]; *A.S. Hitchcock #43509* (09 likely refers to day in month it was collected) August 1895 NY [Isotype]; *A.S. Hitchcock #640* 9 August 1895 GH (not considered an isotype because it has a different collection number; Jennings 1996); Kansas Biological Survey (2004)
KS	10	Private	Grant	13 Jul 1988	Cimarron River valley	Sparsely vegetated sandy wash; with *Dalea villosa, Erigeron bellidiastrum, Mirabilis glabra, Evolvulus nuttallianus,* and *Chenopodium pratericola*	Scattered	No comments	*R.L. McGregor #39199* KANU (Duplicate specimens), NY, RM (Jennings 1996)

Table 1 (cont.).

State	No.	Land management	County	Dates observed	Location	Habitat	Abundance	Comments	Information sources[1]
KS	11	Cimarron National Grassland, Region 2	Morton	18 Jun 1957	Approximately 5 miles west northwest of Rolla	Sandy soil	Scarce	[In 2004: Active cattle grazing allotment; open to current and future oil/gas exploration.]	*L.C. Hulbert #2851* KSC
KS	12	Cimarron National Grassland, Region 2	Morton	23 Jun 1988	2.5 miles north and 5.5 miles west of Rolla Rolling sandhill prairie at south edge of Cimarron River floodplain	Rolling sandhill prairie at south edge of Cimarron River floodplain; scattered sandy blowouts with loose sand; *Stillingia sylvatica* abundant on slopes, also *Penstemon ambiguus*	*Chenopodium cycloides* rare; Kansas Biological Survey (2004) noted: observed 35 plants in three groups, mostly on W-facing slope and in shady depression below slope	1988: Flowers, most plants with immature fruits [In 2004: Active cattle grazing allotment; open to current and future oil/gas exploration.]	*C.C. Freeman #2549* KANU; Kansas Biological Survey (2004)
KS	13	Cimarron National Grassland, Region 2	Morton	26 Jun 1988, 20 Jul 1988, 8 Jul 1990, 2 Jul 1991	Jun 1988: South of Forest Rd 690, approximately 0.5 miles east of junction with KS 27 and approximately 0.1 mile south of road July 1988: South of Forest Rd 690, approximately 0.5 miles east of junction with KS 27 and approximately 0.2 mile south of road 1991: Area of dunes in sandhills south of the Cimarron River, approximately 0.2 mile south of the road	Jun 1988: Dune complex with stabilized and recent blowouts in sandhill prairie 1990: Sand sage rangeland; edge of blowouts 1991: Sandsage prairie; edge of sand dune blowout; rolling hills w/scattered blowouts	Jul 1988: Locally abundant 1988: Estimate 1,000-2,000 flowering and fruiting plants mostly in southernmost blowouts, especially at north entrance to north-facing blowout (Freeman 1989) 1990: Rare 1991: Local colonies in area	1988: minor grazing disturbance Jun 1988: Locally abundant Jul 1988: Locally abundant 1990: Rare and dwarfed this year 1991: Area with good to excellent grass and forb diversity and minimal grazing disturbance [In 2004: Active cattle grazing allotment; open to current and future oil/gas exploration; recreation] Cottonwood Picnic Area, near site.]	*C.C. Freeman #2581* June 1988 KANU; *C.C. Freeman, R.E. Brooks, and C.L. Lauver #2671* July 1988 KANU; *R.L. McGregor #40194* 1991 KANU; Kansas Biological Survey (2004)

Table 1 (cont.).

State	No.	Land management	County	Dates observed	Location	Habitat	Abundance	Comments	Information sources[1]
KS	14	Cimarron National Grassland, Region 2	Morton	27 Jun 1988	Forest Road 705 in rolling sandhill prairie approximately 1 mile south of Cimarron River	Grazed, rolling sandhill prairie; loose, exposed sand, plants mostly at edge of blowouts	Scattered to locally common; observed 14 plants on rim of large blowout located due north of bend in road (Freeman 1989)	Fair grass and forb diversity; [In 2004: Active cattle grazing allotment; open to current and future oil/gas exploration.]	Freeman (1989); Kansas Biological Survey (2004)
KS	15	Cimarron National Grassland, Region 2	Morton	27 Jun 1988	Approximately 1.5 miles south of Cimarron River and approximately 120 yards due east of junction with Forest Roads 705.C and 708; northwest of Elkhart	Rolling sandhill prairie; scattered to abundant blowouts; loose exposed sand at periphery of blowout	Counted 13 flowering and fruiting plants (Freeman 1989)	Good diversity; ungrazed [In 2004: Active cattle grazing allotment; open to current and future oil/gas exploration.]	Freeman (1989); Kansas Biological Survey (2004)
KS	16	Cimarron National Grassland, Region 2	Morton	27 Jun 1988	Dune area northwest of Happy Ditch at end of Forest Road 695.1A. Northeast of Elkhart	Rolling sandhill prairie; abundant blowouts in area w/loose sand	Freeman (1989): estimated 200 plants on dunes due south of gas well and also in dunes 400 yards west south west and 200 yards north of well	1988: No evidence of recent grazing; good grass and forb diversity [2004: Active cattle grazing allotment; open to current and future oil/gas exploration.]	Freeman (1989); Kansas Biological Survey (2004)
KS	17	Cimarron National Grassland, Region 2	Morton	27 Jun 1988	Forest Road 690, 7.5 miles north and 2 miles east of Elkhart on rolling sandhill prairie south of the Cimarron River	Rolling sandhill prairie south of the Cimarron River; scattered to abundant blowouts; loose sand	Freeman (1989): estimated less than 50 plants seen scattered in three blowouts at the site	[2004: Active cattle grazing allotment; current and future oil/gas exploration.]	Freeman (1989); Kansas Biological Survey

Table 1 (cont.).

State	No.	Land management	County	Dates observed	Location	Habitat	Abundance	Comments	Information sources[1]
KS	18	Cimarron National Grassland, Region 2	Morton	24 Jun 1988, 25 Jun 1988	Approximately 6.5 miles west of Elkhart, and then 4.5 miles north; north bank of river, south and south-southeast of gas well at bend in Forest Rd 775 and at south end of Forest Rd 775	Narrow band of rolling sand dunes on north bank of Cimarron River, loose shifting sand in scattered blowouts and along eroding bank 24 June 1988: Eroding gravelly dune sand over silty, gravelly riverbank; sandsage prairie 25 June 1988: Eroding loose sand of dunes and sandsage prairie	Two groups of plants, small group west northwest of largest dune and large group on southeast side of largest dune where 159 plants counted and estimated 300 plants present (Freeman 1989) Observed over 2 days: 24 Jun 1988: Scarce; 15 plants 25 June 1988: Locally abundant, 159 plants counted and est. 300+ plants present	25 Jun 1988: Flowers, most plants in early fruit; plants to 3 ft. tall. Determined by R.L. McGregor 1990. (KANU), Good-excellent grass and forb diversity [In 2004: Active cattle grazing allotment; open to current and future oil/gas exploration.]	*C.C. Freeman #2557* 24 June 1988 KANU; *C.C. Freeman #2567* 25 June 1988 KANU, MO; Freeman (1989); Kansas Biological Survey
KS	19	Cimarron National Grassland, Region 2	Morton	27 Sep 2003	7 miles north of Elkhart; rolling sandsage prairie east of KS 27 and 0.2 miles south of the Cimarron River	Near river; scattered blowouts with exposed sand	Rare; several plants in blowout	[In 2004: Active cattle grazing allotment; open to current and future oil/gas exploration.]	*C.C. Freeman #20026* KANU
KS	20	Unknown	Morton	Aug 1895	Only county record available	No information	No information	Originally identified as *Chenopodium cycloides* , annotated by H.A. Wahl 1967	*A.S. Hitchcock #s.n.* KSC; Kansas Biological Survey (2004)
KS	21	Unknown	Stanton	Aug 1895	Only county record available	No information	No information	Originally identified as *Chenopodium leptophyllum*, annotated by H.A. Wahl 1967	*A.S. Hitchcock #s.n.* 1895 KSC; Kansas Biological Survey (2004)

Table 1 (cont.).

State	No.	Land management	County	Dates observed	Location	Habitat	Abundance	Comments	Information sources[1]
NE	1	Private	Chase	8 Jul 1999	Approximately 2 miles southwest of Enders	Open places on south-facing dense slope in *Stipa-Carex heliophila* sandsage prairie. *Bouteloua hirsuta - Carex heliophila - Hesperostipa comata* sandsage dune prairie; east of an abandoned road; soil sandy; associated species include *Helianthus petiolaris, Commelina erecta,* and *Ambrosia psilostachya*	Locally common on upper south-facing dune slope; 20 plants scattered	Plants mostly in flower and early fruit	*S.B. Rolfsmeier and N.E. Parker #14788* KANU; Nebraska Natural Heritage Program (2004)
NE	2	Private	Dundy	9 Sep 1996	Approximately 6 miles north and 1 mile east of Haigler	Sandsage prairie; plants mostly found in loose or disturbed soils mainly on the upper slopes or crests of dunes	Population area is 10 acres, 30-50 fruiting plants found scattered through area; locally common on crests and upper slopes of sand sage prairie dunes	1996: Site is grazed, but this does not appear to be a real threat; center pivot development may be a threat	*S.B. Rolfsmeier, G.A. Steinauer, and R. Schneider #12954* KANU; Nebraska Natural Heritage Program (2004)
NM	1	Private	DeBaca	29 Aug 1995	Approximately 2.5 to 3 miles southeast of Fort Sumner, sand dunes west of Bosque Redondo Lake	On deep sandy soils. *Artemisia filifolia, Gaura villosa,* and *Sporobolus giganteus*	Only two plants seen within approximately 1 acre	Pericarp bright red when fresh; [Authors note: several gravel pits in area]	*R. Sivinski #3238* 29 August 1995 UNM
NM	2	Private	DeBaca	31 Aug 1995	Approximately 8 miles south of Fort Sumner on Hwy 20	On deep sandy soils. *Artemisia filifolia, Gaura villosa, Sporobolus flexuosus,* and *Yucca angustissima*	Locally uncommon; a few (3) scattered plants in 100 m	Pericarp bright red when fresh	*R. Sivinski #3248* 31 August 1995 UNM
NM	3	State of New Mexico (may extend onto private land)	DeBaca	27 Aug 1997	1997: 2 miles southwest of Fort Sumner on Hwy. 20	1997: *Artemisia filifolia, Andropogon hallii,* and *Gaura villosa*	No information	1997: Specimen collected. Infrequent on semi stable sand dunes	*R. Sivinski #4076* 1997 UNM
NM	4	Private	DeBaca	20 Aug 1996	5.4 miles north of Sumner Lake turnoff on Hwy 80	*Artemisia filifolia, Sporobolus flexuosus, Setaria macrostachya,* and *Andropogon hallii*	No information	Species collected on localized dunes of quartz sand	*R. Sivinski #3439* 1996 UNM
NM	5	USDA ARS and New Mexico State University	Dona Ana	14 Oct 1913	Jornada Range (likely refers to the Jornada Experimental Range established in 1912)	No information	No information	Mostly inaccessible to public, another specimen collected 10/14 in unknown location in San Andres Mts.	*E.O. Wooton #s.n.* US

Table 1 (cont.).

State	No.	Land management	County	Dates observed	Location	Habitat	Abundance	Comments	Information sources[1]
NM	6	Department of Defense (White Sands Missile Range) and/ or US Fish and Wildlife Wilderness Areas	Dona Ana	14 Oct 1913	San Andreas Mountains	No information	No information	In U.S. herbarium three specimen sheets all marked October 14 1913 from the San Andreas Mountains	*E.O. Wooton #1219* (2 specimens) US
NM	7	State of New Mexico	Quay	28 Aug 1997	Approximately 6 miles northeast of Logan	*Artemisia filifolia* and *Sporobolus cryptandrus*	No information	Specimen collected on sandy berm of ranch road; locally rare	*R. Sivinski #4090* 1997 Acc#93873 UNM
NM	8	Private	Rio Arriba	29 Jul 1979	Approximately 0.5 miles north of Rio Del Osso along highway to Chama, north of Espanola (Appears site is close, within 0.1to 0.2 miles of the Santa Fe National Forest border - Region 3)	Open sandy soils	Scattered individual plants	Originally undetermined and annotated *Chenopodium cycloides* by S. Keller 1991	*D.S. Correll #50897* 1979 NY; Jennings (1996)
NM	9	Likely private	Roosevelt	2 Sep 1987	Along US 70, east of Portales	Mixed forb-grass community	No information	No information	*Higgins #17527* 1987 NY; Jennings (1996)
NM	10	Private	Roosevelt	14 Sep 1954	Along Highway 70, near Kenna	No information	No information	Annotation: (Fruit appears rather large.- Dunn, 1955). Author's note: gravel pit and oil development now near Kenna	*E. Williams #10505* UNM
NM	11	Private (may extend into State of New Mexico)	Roosevelt	17 Aug 1992	Approximately 4.0 miles north of Milnesand	Shinnery sand range; in loose sand at base of small dune stabilized by *Quercus havardii*	Very rare	Authors note: In the Todd Oil Field	*R.L. McGregor #40728* OKL, NMC, KANU
TX	1	Unknown	Andrews	24 Aug 1952	Only county record available	In white sand at 3,400 ft.	Frequent	Annual; annotated by R.M. McGregor, 1990 and B.L. Turner, 2000	*M. McCullough #273* SRSC
TX	2	Likely private	Brewster	21 Aug 1955	Along Scenic Loop at Valentine turn-off	No information	Infrequent	"flowering + fruiting =mid."; determined by B.L. Turner	*B.H. Warnock #13186* LL-TEX

Table 1 (cont.).

State	No.	Land management	County	Dates observed	Location	Habitat	Abundance	Comments	Information sources[1]
TX	3	Likely private	Crane	23 May 1957	3 to 16 miles west of Crane - Monahans Sandhills area	Limestone soil at 2,800 ft.	Frequent	1 to 3 ft. tall, annual, ill-smelling; at early flowering stage	*B.H. Warnock #14660* 1957 LL-TEX, SRSC
TX	4	Likely private	Crane	28 Jun 1957	Approximately 13 miles north of Imperial - Monahans Sandhills area	No information	Abundant locally	Tall annual	*B.H. Warnock #15470* 1957 LL-TEX, SRSC
TX	5	Likely private	Winkler	3 Sep 1960, 26 Jun 1984	1960: 10 miles northeast of Kermit 1984: 16 miles northeast of Kermit, on Kermit Sand Hills, junction of State Hwy 115 and Ranch Road 874 across highway from picnic area	Sandy soil	Frequent annual	UTEP specimen annotated by W. Jennings	*B.H. Warnock #18521* 1960 SRSC; *C.S. Lieb #534* 1984 UTEP
TX	6	Likely private	Winkler	5 Nov 1958	5 miles east of Wink	Sandy soil	Frequent annual, herbaceous	No information	*A.J. Smith #87* SRSC
TX	7	Likely private	Culberson	7 Aug 1949	10 miles west of Kent	Limestone soil	Infrequent annual herb	Annotated by R.M. McGregor, 1990 and B.L. Turner, 2000	*B.H. Warnock #8957 with B.L. Turner* SRSC
TX	8	Likely private	Culberson	4 Jul 1958	Along highway west of Plateau [which is a railroad siding about 18 miles west of Kent (Jennings 1996)]	Deep sand	Frequent erect annual	2 to 4 feet tall; annotated by R.M. McGregor, 1990 and B.L. Turner, 2000	*B.H. Warnock #16606 and M.C. Johnston* SRSC; Jennings (1996)
TX	9	Likely private	Dickens	26 Sep 1935	Only county record available	No information	No information	No information	*H.B. Parks and V.L. Cory #15989* TAES
TX	10	Hueco Tanks State Historic Park	El Paso	11 Sep 1988	Hueco Tanks State Historic Park, east side of East Mountain	In sand	No information	Erect annual; determined by G. Nesom and annotated by W. Jennings	*R.D. Worthington #17393* UTEP, LL-TEX
TX	11	Likely private	Jeff Davis	4 Sep 1925	Only county record available	No information	No information	Originally determined and annotated as *Chenopodium cycloides* by A.H. Wahl 1961, annotated by C.F. Reed 1968, and R.M. McGregor 1990	*B.C. Tharp #3383* TEX, US

Table 1 (cont.).

State	No.	Land management	County	Dates observed	Location	Habitat	Abundance	Comments	Information sources[1]
TX	12	Likely private	Jones	1 Oct 1964	Approximately 4 miles north of Hawley	Sandy roadside	No information	No information	*Mahler #3952* SMU, now BRIT in Jennings (1996)
TX	13	Private	Kent	24 Jun 1944	Approximately 1.5 miles southwest of Jayton	In sandy oak shinnery, on dunes	No information	Annual, flowers; originally identified as *Chenopodium leptophyllum* (Moq.) Nutt. ex S. Watson determined by: C.F. Reed, 1968. Changed to *C. cycloides* (MO) - 22 Jan 1996	*C.L. Lundell #13057* MO, LL-TEX, SRSC
TX	14	Likely private	Loving	3 Jun 1949	Approximately 10 miles east of Mentone	In red sandy soil	Frequent annual	Annotated by Ronald M. McGregor, 1990 and B.L. Turner, 2000	*B.L. Turner #983* SRSC
TX	15	Likely private	Presideo	16 Jul 1941	Vieja Pass, Tierra Vieja Mountains	No information	No information	No information	*L.C. Hinckley #1975* TEX
TX	16	Monahans Sandhills State Park and Private	Ward	6 Jul 1950, 1995	1950: Along Highway 18, approximately 3 miles northwest of Monahans 1995: Monahans Sandhills State Park	1950: Deep sand 1995: In deep, excessively drained, noncalcareous, neutral fine sand. Typic Torripsamments (Kermit Series) free of salts or alkali in open mesquite-Havard oak woodland on cover sands	1950: Frequent 1995: Occasional	1950: annual	*B.H. Warnock and J.O. Parks #8807* 1950 LL-TEX, SRSC; *W.R. Car with J. Poole #14883* 1995 TEX
TX	17	Likely private	Ward	22 Sep 1949	Monahans	In sand	Frequent	Nessmith specimen annotated by Ronald M. McGregor, 1990 and B.L. Turner, 2000	*H. Nessmith #66* SRSC

[1]Herbaria abbreviations:

- COLO: University of Colorado, Boulder, Colorado
- CS: Colorado State University, Fort Collins, Colorado
- GH: Herbaria, Harvard University, Cambridge, Massachusetts
- KSC: Kansas State University, Manhattan, Kansas
- KANU: R.L. McGregor Herbarium, University of Kansas, Lawrence, Kansas
- LL-TEX: Lundell herbarium (LL) integrated at TEX. Specimens from Lundell herbaria (LL and UTD) are cited as LL-TEX
- MO: Missouri Botanical Garden Herbarium, Saint Louis, Missouri
- NMC: Herbarium, New Mexico State University, Las Cruces, New Mexico
- NY: William and Lynda Steere Herbarium, New York Botanical GardenBronx, New York
- OKL: R. Bebb Herbarium, University of Oklahoma, Norman, Oklahoma
- RM: Rocky Mountain Herbarium, University of Wyoming, Laramie, Wyoming
- SMU: Southern Methodist University Herbarium, Dallas, Texas. SMU specimens transferred on permanent loan to Botanical Research Institute of Texas Herbarium, Fort Worth, Texas (BRIT) in 1987
- SRSC: Sul Ross State University Herbarium, Alpine, Texas
- TAES: S. M. Tracy Herbarium, Texas A&M University, College Station, Texas

Table 1 (concluded).

TEX:	Herbarium, University of Texas at Austin, Texas.
UNM:	University of New Mexico, Albuquerque, New Mexico
US:	United States National Herbarium, Smithsonian Institution, Washington, DC
UTEP:	University of Texas Herbarium, Centennial Museum, El Paso, Texas

botanists and other researchers and encourages them to report their observations and collections.

In Region 2, *Chenopodium cycloides* is found on National Forest System lands of the Cimarron National Grassland and possibly on the Comanche National Grassland (Kettler et al. 1993, Hazlett 2004). *Chenopodium cycloides* is included in a document outlining general management strategies for selected sensitive plant species published by Region 2 for the Grand Mesa, Uncompahgre, Gunnison, San Juan, Rio Grande, Pike and San Isabel national forests and the Comanche and Cimarron national grasslands (USDA Forest Service 1999). Field guides that include *C. cycloides* have been compiled for the Pike and San Isabel national forests and the Comanche and Cimarron national grasslands to assist field staff in identifying rare and sensitive species (Kettler et al. 1993, Ryke et al.1993). A management plan specific to *C. cycloides* conservation has not yet been written, and targeted surveys outside of areas in which the species is known to occur on the Cimarron National Grassland are not being conducted (Brewer personal communication 2004).

Species designated as sensitive by the BLM are included in their Special Status Species policy (USDI Bureau of Land Management 2001). The goal of this policy is to ensure that sensitive species are considered in land management decisions through a process of review and evaluation (USDI Bureau of Land Management 2001). *Chenopodium cycloides* is not designated a sensitive species by the BLM in any state except New Mexico, and therefore it receives no protection on BLM managed land outside of that state.

Biology and Ecology

Classification and description

Systematics and synonymy

The genus *Chenopodium* belongs to the Chenopodiaceae, commonly known as the goosefoot family. The word *Chenopodium* is derived from the Greek words "chen" meaning "goose," and "podus" meaning "footed." This descriptive name refers to the shape of the leaves of many *Chenopodium* species, such as *C. album* (lamb's quarters), *C. berlandieri* (pitseed goosefoot), and *C. fremontii* (Fremont's goosefoot) (Crawford 1975). *Chenopodium cycloides* is referred to as a narrow-leaved chenopod, which is an arbitrary designation and includes all species with leaves that are linear to ovate. There are more than one hundred species of *Chenopodium* worldwide. Members of the genus *Chenopodium* are well represented and widespread throughout western North America (Clemants and Mosyakin 2003).

Early taxonomic treatments for *Chenopodium cycloides* appear in Standley (1916), Aellen and Just (1943), and Wahl (1952-1953). In the most recent revision of the Chenopodiaceae, the genus *Chenopodium* is divided into three natural subgenera: subgenus *Ambrosia*, subgenus *Blitum*, and subgenus *Chenopodium* (Mosyakin and Clemants 1996). Within the subgenus *Chenopodium*, there are two sections, section *Grossefoveata* that includes only two species, and section *Chenopodium* (Clemants and Mosyakin 2003). Species within the section *Chenopodium* are arranged in eight subsections (Clemants and Mosyakin 2003), which overlap in their relatedness. *Chenopodium cycloides* is placed in the subgenus *Chenopodium*, section *Chenopodium*, and subsection *Leptophylla* (**Figure 2**; Mosyakin and Clemants 1996). The subsection *Leptophylla* brings together all the narrow-leaved *Chenopodium* species native to the western United States and Canada and includes nine species: *C. cycloides*, *C. leptophyllum*, *C. praetericola*, *C. dessicatum*, *C. foggii*, *C. hians*, *C. subglabrum*, *C. pallescens*, and possibly *C. albescens* (Clemants and Mosyakin 2003).

There are no synonyms for *Chenopodium cycloides*. Tidestrom and Kittel (1941) questioned whether *C. cycloides* might be the same taxon as *C. pallescens*. This question was likely due to an inadequate number of available specimens because there is otherwise a consensus that *C. cycloides* is a distinctive and undeniably unique species (Nelson 1902, Wahl 1952-1953, Crawford 1975, Great Plains Flora Association 1986, Mosyakin and Clemants 1996).

History of species

Albert S. Hitchcock was apparently the first person to collect *Chenopodium cycloides* (collection #435). He made a collection of several individuals in the sand hills of Grant County, Kansas in August 1895. These specimens were initially identified as *C. leptophyllum*, to which *C. cycloides* is closely related, despite looking fairly different (Nelson 1902). Aven Nelson described the taxon *C. cycloides* in 1902. The holotype (*A.S. Hitchcock* #435) is deposited at the Missouri Botanical Garden (MO). Isotypes are deposited at the New York Botanical Garden Herbarium (NY) and Kansas State University Herbarium (KSC). An additional specimen with the same collection number was deposited at the

Kingdom[1]:	Plantae (plants)
Subkingdom[1]:	Tracheobionta (vascular plants)
Division[1]:	Magnoliophyta (angiosperms, flowering plants, phanerogams)
Class[1]:	Magnoliopsida (dicots, dicotyledons)
Subclass[1]:	Caryophyllidae
Order[1]:	Caryophyllales
Family[1, 2]:	Chenopodiaceae (goosefoot)
Genus[1, 2]:	*Chenopodium*
Subgenus[2]:	*Chenopodium*
Section[2]:	*Chenopodium*
Subsection[2]:	*Leptophylla*
Species[1, 2]:	*Chenopodium cycloides* (sandhill goosefoot)

[1]Classification according to Integrated Taxonomic Information System (2006)
[2]Classification according to Clemants and Mosyakin (2003)

Figure 2. Taxonomic classification of *Chenopodium cycloides*.

Rocky Mountain Herbarium (Nelson 1902). Details of the specimens at the Missouri Botanical Garden Herbarium (URL: http://www.mobot.org/MOBOT/Research/herbarium.shtml) and New York Botanical Garden Herbarium (URL: http://sciweb.nybg.org/Science2/VirtualHerbarium.asp) can be viewed on the internet. *Chenopodium cycloides* was apparently first collected in New Mexico in 1913, in Texas in 1925, in Colorado in 1935, and in Nebraska in 1997 (**Table 1**, **Table 2**).

Non-technical description

Chenopodium cycloides is an herbaceous annual. The slender, erect, much-branched stems are 30 to 80 cm tall and green, or blue green, with reddish stripes. They can be smooth and almost glossy or sometimes sparsely covered by a whitish mealy substance. The linear leaf blades are one-veined and somewhat fleshy with entire margins. The undersides are smooth, but the upper surfaces may also be slightly mealy. The small green flowers are in densely crowded clusters arranged in spirals near the ends of the branches (Freeman 1989). Each flower has five stamens and two stigmas. The fruits are reddish brown, oval achenes. The seeds are disc-shaped, 1.3 to 1.5 mm in diameter, with acute margins and a black, wrinkled, slightly bumpy to nearly smooth seed coat (Clemants and Mosyakin 2003). The leaves are non-aromatic (Clemants and Mosyakin 2003); however, Warnock remarked that a specimen (#14660) that he collected in May 1957 from Crane County, Texas was "ill-smelling" (TX-3 in **Table 1**). **Figure 3** is an illustration of *C. cycloides*, and **Figure 4** shows a photograph of the species.

Chenopodium cycloides is somewhat unremarkable as a vegetative plant and has been confused with its relative *C. leptophyllum*, as well as with other linear-leaved *Chenopodium* species. Nelson (1902) remarked that its growth habit and its apparently "winged" fruits might at first glance suggest the genus *Cycloloma*, rather than *Chenopodium*. However, *C. cycloides* is easily distinguished from other *Chenopodium* and *Cycloloma* species when in fruit. In *C. cycloides*, the sepals expand to form a distinctive collar that remains attached to the fruit (Freeman 1989, Spackman et al. 1997, Clemants and Mosyakin 2003). The reddish color of the pericarp is another characteristic that has been commented upon as being diagnostic (e.g., Standley 1916, Sivinski and Lightfoot 1995). However, this is not an invariable feature, and the pericarp may also be brownish or nearly black (Crawford 1975).

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

A technical description, a line drawing, and a color photograph of *Chenopodium cycloides* appear in Spackman et al. (1997), and Mosyakin and Clemants

Table 2. The number of occurrences of *Chenopodium cycloides* by state and the dates they were observed. The dates in bold were the first observation made in each state.

State	Number of occurrences	Date observed	State	Number of occurrences	Date observed
Colorado	**1**	**1935**	**New Mexico**	**1**	**1913**
Colorado	1	1947	New Mexico	1	1913
Colorado	1	1995	New Mexico	1	1954
Colorado	1	1997	New Mexico	1	1979
Colorado	2	1998	New Mexico	1	1987
Colorado	1	1999	New Mexico	1	1992
Colorado	3	2000	New Mexico	2	1995
Colorado	2	2001	New Mexico	1	1996
			New Mexico	2	1997
Kansas	**3**	**1895**			
Kansas	2	1957	**Texas**	**1**	**1925**
Kansas	2	1985	Texas	1	1935
Kansas	11	1988	Texas	1	1941
Kansas	2	1990	Texas	1	1944
Kansas	3	1991	Texas	3	1949
Kansas	1	1992	Texas	1	1950
Kansas	1	1995	Texas	1	1952
Kansas	1	1996	Texas	1	1955
Kansas	1	1997	Texas	2	1957
Kansas	1	2003	Texas	2	1958
			Texas	1	1960
Nebraska	**1**	**1996**	Texas	1	1964
Nebraska	1	1999	Texas	1	1984
			Texas	1	1988
			Texas	1	1995

(2003) provide a detailed technical description and a line drawing of the fruit. Other technical descriptions are published in Nelson (1902), Rydberg (1932), Harrington (1964), Correll and Johnston (1970), Crawford (1975), Martin and Hutchins (1981), Great Plains Flora Association (1986), Mosyakin and Clemants (1996), and Weber and Wittmann (2001). A description and color photograph are in Colorado Native Plant Society (1997). A description and a line drawing also appear in the USFS publications by Kettler et al. (1993) and Ryke et al. (1993).

A photograph of the holotype (*A.S. Hitchcock* #435) specimen collected from sand hills in Kansas in 1895 is on the United States National Herbarium web page (URL: <http://www.nmnh.si.edu/botany/index.html?collections>). An isotype herbarium specimen is on the New York Botanical Garden Herbarium web page (URL: <http://sciweb.nybg.org/Science2/VirtualHerbarium.asp>).

Distribution and abundance

Chenopodium cycloides grows in open sandy regions of eastern Colorado, eastern New Mexico, southwestern Kansas, southwestern Nebraska, and western Texas (**Figure 1**). Although it has been reported from Oklahoma, its status there remains uncertain (Biota of North America Program 1998, NatureServe 2006); no well-documented records or specimens of *C. cycloides* from Oklahoma could be located for this report. Jennings (1996) speculated that *C. cycloides* occurs in sand dunes in northeastern Mexico, but there have been no observations to confirm this. The distribution of *C. cycloides* extends south from Nebraska, approximately within the boundary of the High Plains aquifer (inset in **Figure 1**).

Within the states in which Region 2 manages land, *Chenopodium cycloides* is known from Bent, Cheyenne, El Paso, Las Animas, Lincoln, Pueblo,

Figure 3. Illustration of *Chenopodium cycloides* from Spackman et al. (1997). Drawing by Janet Wingate, used with permission.

Figure 4. Close-up photograph of *Chenopodium cycloides* from Spackman et al. (1997). Photographer Craig C. Freeman, used with permission.

Weld, and Yuma counties in Colorado, from Finney, Grant, Hamilton, Kearny, Stanton, and Morton counties in Kansas, and from Chase and Dundy counties in Nebraska (**Table 1**). Until relatively recently, it was believed that the occurrences in Kansas represented the northeastern edge of the species' range (Freeman 1989), but two occurrences in Nebraska (Rolfsmeier et al. 1999) extended its range slightly further north. *Chenopodium cycloides* is known from approximately 16 occurrences in Colorado and approximately 21 occurrences in Kansas (**Table 1**). Thirteen of the occurrences in Colorado and four of the occurrences in Kansas have been found only within the last decade. On National Forest System land in Region 2, *C. cycloides* has been reported to occur infrequently on the Cimarron National Grassland (**Table 1**) and the Comanche National Grassland (Hazlett 1997). However, no specimens or observations with details of site locations on the Comanche National Grassland could be verified for this report. Two occurrences (CO-11, 12 in **Table 1**) are near the boundary of the Comanche National Grassland. Nine of the 17 Kansas occurrences reported in the last 20 years are from the Cimarron National Grassland (**Table 1**).

Since 1913, 11 *Chenopodium cycloides* occurrences have been documented in New Mexico and 17 in Texas. Collections have been made from DeBaca, Dona Ana, Quay, Rio Arriba and Roosevelt counties in New Mexico and Andrews, Brewster, Crane, Culberson, Dickens, El Paso, Jeff Davis, Kent, Loving, Presideo, Ward, and Winkler counties in Texas (**Table 1**). Four of the occurrences from New Mexico and one from Texas have been reported within the last decade (**Table 2**).

A population can be defined as "a group of individuals of the same species living in the same area at the same time and sharing a common gene pool or a group of potentially interbreeding organisms in a geographic area" (National Oceanic and Atmospheric Administration 2004). Without knowing the seed dispersal range and specifics of the pollination biology of *Chenopodium cycloides*, it is not possible to delineate what comprises a single interbreeding group of plants. A less restrictive definition of population, and the one that is used in this report since the species' genetics is unknown, is that it is "a group of individuals of the same species that occurs in a given area" (Guralnik 1982). In this report, the term occurrence and or population can be used interchangeably and includes plants 3 km or less apart in areas of land where there are contiguous stretches of apparently suitable, or potential, habitat. This is consistent with the NatureServe Habitat-based Plant Element Occurrence Delimitation Guidance system (NatureServe 2004). One occurrence of *C. cycloides* often consists of several sub-occurrences (sub-populations). For example, two observations were defined as sub-occurrences and were associated in Kansas (KS-13 in **Table 1**) and New Mexico (NM-1 in **Table 1**). However, it needs to be recognized that patches within any given occurrence may be genetically isolated from each other if pollination or seed dispersal does not occur among them.

Reported *Chenopodium cycloides* occurrence size varies considerably, from fewer than ten individuals (e.g., CO-1 in **Table 1**) to an estimate of more than 1,000 individuals (e.g., KS-13 in **Table 1**). "Sparse," "frequent," and "abundant" have been used to describe the density and abundance of individuals within a population. These terms are relative, and to some extent, knowledge of typical occurrence size is needed to appreciate what is meant. In interpreting such relative terms, it may be useful to consider an example of a record of the same occurrence in the same year that was obtained from two sources (NE-1 in **Table 1**). In one record of this occurrence (*S.B Rolfsmeier and N.E Parker* #14788 KANU), plants were described as "locally common" whereas the other record (Nebraska Natural Heritage Program 2004) indicated that there were "20 plants scattered."

The information provided by state natural resource programs was used as a base in determining the abundance of *Chenopodium cycloides*. Additional information from herbarium specimens and the literature increased the total number of occurrences or was combined with an existing occurrence. Generally, when occurrences were combined, the area of the occurrence increased. Many records, particularly older ones, did not have precise location information. In some cases, a site may have been revisited but was designated a new occurrence, or discrete occurrences in the same general vicinity may have been thought to be the same occurrence. Where the location information was limited to county (e.g., KS-4, 9, 20, 21 and TX-11 in **Table 1**), no guess was made as to the likely collection site. The assessment of the exact number of known occurrences may change when more information about the biology and ecology of *C. cycloides* is available.

Population trend

There is insufficient available information to determine the population trend for *Chenopodium cycloides*. The species appears to have been infrequently encountered by botanists since its first collection (**Table 1**). It is an annual species, and like most annuals, the populations exhibit variable sizes from year to year. For example, Freeman noted that individuals in an occurrence in Kansas (KS-1 in **Table 1**) were sparse and dwarfed in 1990 where they had been relatively frequent and robust in 1988. This variability in both number of individuals and growth habit is likely due to environmental conditions (especially precipitation) affecting seed germination, seedling establishment, and growth (Freeman 1989, Jennings 1996). The role of land use, which may also contribute to variable population size, has not been studied.

The years in which *Chenopodium cycloides* was collected are widely separated, and collection activity appears to be concentrated within certain decades (**Table 2**). It is difficult to say whether this is a reflection of the interest shown by particular botanists or a reflection of variations in the species' abundance. *Chenopodium cycloides* has been found in association with other linear-leaved *Chenopodium* species, and in some cases, it may have been overlooked. A definitive way to test this hypothesis is to resurvey sites where the species was not found. Because *C. cycloides* is an annual, both the initial survey and the resurvey need to be conducted in the same year. Freeman (1989) suggested that a few *C. cycloides* individuals might have been overlooked in large occurrences of other linear leaved species such as *C. pratericola*. However, the discoveries of large *C. cycloides* occurrences in the late 1980s in heavily botanized areas suggested that it was unlikely that the species had gone unnoticed at those sites. Freeman (1989) also suggested that careful observations should be conducted to determine whether the species is subject to extreme variations in population size from year to year.

A significant problem with estimating *Chenopodium cycloides* population trends is that few sites have been visited more than once. Where areas have been revisited, occurrence boundaries were not clearly defined during the first visit, and plants are only known to persist in, or to be absent from, the same general areas. It is also unknown whether reports of sub-occurrences within a known occurrence area indicate an increase in the abundance of the species or whether local extirpations and colonizations have resulted in no net gain or even a decline in abundance.

In 1997, the range of *Chenopodium cycloides* was found to extend north into Nebraska (Rolfsmeier et al. 1999). Additional occurrences were found in New Mexico and Colorado in the late 1990s. However, the available information suggests that the taxon is no more common, at least in some parts of its range, than in the past, and some local extirpations may have occurred. One 1947 occurrence (CO-12 in **Table 1**) found south of Kim, Las Animas County, Colorado, near the boundary of the Comanche National Grassland, was not relocated in surveys of the area made in both 1995 and 1996. In addition, occurrence CO-9 in **Table 1**, located 26 miles south of Fountain, may have been lost to urbanization (Jennings 1996). Few *C. cycloides* collections have been made in Texas since the 1950s. It is surprising that Warnock's field guides for the sand dune country and the Marathon Basin of Texas published in the 1970s (Warnock 1974, Warnock 1977) did not report any specimens of *C. cycloides*, despite his finding specimens in those areas in the 1940s and 1950s (**Table 1**).

Habitat

Chenopodium cycloides occurs in the Southwest Plateau and Plains Dry Steppe and Shrub Province (315) and the Great Plains-Dry Steppe Province (331) as described by Bailey (1995). While both the Southwest Plateau and Plains Dry Steppe and Shrub Province have a semiarid climate, the precise conditions, such as annual high and low temperatures, vary considerably from the north to south within *C. cycloides*' range (Sidle 1998). *Chenopodium cycloides* has been observed at elevations between 1,172 and 1,737 m (3,845 and 5,699 ft.) in Colorado, between 317 and 1,064 m (1,040 and 3,491 ft.) in Kansas, and between 777 and 1,494 m (2,549 and 4,902 ft.) in Texas. These elevations were only those casually noted during collections, and no systematic study has been made to determine the range of elevation at which *C. cycloides* grows. No particular aspect characterizes its habitat, probably because it generally grows on gentle slopes, ranging from 0 to approximately 5 percent inclination. *Chenopodium cycloides* may grow on steeper slopes in dune environments, but no details of the steepest incline that it can colonize are available.

Chenopodium cycloides occurs in sandy soils, frequently but not exclusively around the vegetated edges of blowouts on sand dunes (Freeman 1989, Clemants and Mosyakin 2003). Loose sand per se does not appear to present suitable habitat, and *C. cycloides* plants are not found within the blowouts. Habitat conditions are generally described as "semi-stable" or "stabilized dunes." Vegetation plays a major role in stabilizing the surface of dune sand. Plant root systems stabilize the substrate, and early successional species in this habitat type are often rhizomatous. Plants also create a layer of calm air immediately above their surface thereby reducing the potential for wind erosion. Additionally, dead plants add organic matter to the sand, which helps to hold the soil together. "Blowout" is a general term for unvegetated saucer- or trough-shaped hollows formed by wind erosion on a sand deposit (Bates and Jackson 1984). The formation of blowouts is a natural process in dune environments. The size and depth of blowouts depend on several factors, including the type of soil, the extent to which the area has been grazed, and the existing vegetation. An example of how a blowout can form is when a rabbit digs a burrow and removes the vegetation. Wind then picks up the exposed sandy soil and moves it elsewhere, often depositing it on the lee side of the blowout where it may cover existing vegetation. Livestock grazing can accelerate or enhance blowout initiation. Overgrazing can lead to extensive blowouts, which may take decades to become stabilized by natural revegetation processes (Krickbaum 2006).

Chenopodium cycloides is typically found in open sites along with perennial plant species and has been reported in various vegetation types. The species is most often reported in *Artemisia filifolia* (sand sage) and, less commonly, in short-grass prairie communities in Kansas, Colorado, and New Mexico (**Table 1**). *Chenopodium cycloides* is reported in *Quercus havardii* communities in New Mexico and Texas (**Table 1**). Monahan's Sand Dunes in Texas (TX-16 in **Table 1**) support a coppice shrub community dominated by *Prosopis* species (mesquite), but occurrence records indicate that *Q. havardii* was co-dominant at sites where *C. cycloides* was found (**Table 1**). The coppice shrub community in Monahan's Sand Dunes is unique and known only in Texas. These dunes are likely of more recent origin than the deep sands dominated by *A. filifolia* (Dick-Peddie 1993). The habitat conditions reported at each occurrence site are listed in **Table 1**. **Figure 5** is a photograph of its habitat in Kansas.

In Colorado, *Chenopodium cycloides* occurrences have been found on eolian deposits, which include dune sand and silt, and Peoria loess (Tweto 1979). In addition, at least one occurrence (CO-11 in **Table 1**) has been found on soils derived from Dakota Sandstone and Purgatoire (sandstone and shale) Formation (Tweto 1979). On the Cimarron National Grassland in Kansas, all occurrences are apparently on soils derived from the Vona-Tivoli soil association (Freeman 1989). These soils are composed of loamy, fine sand (McMahon et al. 2002). *Chenopodium cycloides* occurrences on the Cimarron National Grassland occupy the edges of dunes where vegetation is reasonably well established, rather than the central loose-sand blowout areas (Freeman 1989, Freeman personal communication 2004). Two Texas records (TX-3 and 7 in **Table 1**) indicate *C. cycloides* is associated with limestone. These observations should be confirmed because they occur in the Monahans Sandhill area, which are noted to be rich in gypsum (Rosiere undated), and gypsum can be mistaken for limestone by casual observers.

Figure 5. Photograph of *Chenopodium cycloides*' habitat in Kansas, from Spackman et al. (1997). Photographer Craig C. Freeman, used with permission.

Table 3 is a list of the species associated with *Chenopodium cycloides*. This is not an exhaustive list and represents only the observations that were noted on herbarium sheets, in the data provided by state natural resource programs, and in the literature (e.g., Freeman 1989, Jennings 1996). *Chenopodium cycloides* is reported to be invariably associated with *C. pratericola* on the Cimarron National Grassland (Freeman 1989).

Chenopodium cycloides plants do not occur in all areas that to casual observation appear suitable. At the current level of understanding of this species, potential habitat for *C. cycloides* can only be loosely defined as habitat that from casual observation appears suitable for the species, but which is not occupied by it.

Table 3. Species associated with *Chenopodium cycloides*. This is not an exhaustive list and represents only data derived from herbarium sheets, data provided by natural heritage and state natural resource programs, and the literature (see Table 1, text, and Jennings 1996).

State[1]	Associated species	State[1]	Associated species
CO	*Ambrosia acanthicarpa*	NM	*Gaura villosa*
NE	*Ambrosia psilostachya*	CO	*Gutierrezia sarothrae*
CO	*Andropogon gerardii*	NE	*Helianthus petiolaris*
CO, NM	*Andropogon hallii*	NE	*Hesperostipa comata*
CO	*Aristida purpurea*	CO	*Leiostemon ambiguus*
CO, KS, NM	*Artemisia filifolia*[2]	CO	*Lycurus phleoides*
CO	*Bouteloua curtipendula*	TX	*Prosopis glandulosa* (reported as mesquite)
CO	*Bouteloua gracilis*	KS	*Mirabilis glabra*
NE	*Bouteloua hirsuta*	CO	*Opuntia* sp.
CO	*Calamovilfa longifolia*	CO	*Palafoxia sphacelata*
CO	*Calamovilfa gigantea*	CO	*Paspalum setaceum*
NE	*Carex heliophila*	CO	*Psoralidium lanceolatum*
CO	*Chamaesyce missurica*	NM, TX	*Quercus havardii*
KS	*Chenopodium berlandieri*	CO	*Redfieldia flexuosa*
KS	*Chenopodium incanum*	CO	*Sarcobatus vermiculatus*
CO	*Chenopodium leptophyllum*	CO	*Schizachyrium scoparium*
KS	*Chenopodium pratericola*	NM	*Setaria macrostachya*
CO	*Chenopodium subglabrum*	CO	*Sporobolus airoides*
CO	*Chondrosum gracile*	NM	*Sporobolus cryptandrus*
CO	*Chrysothamnus nauseosus*	NM	*Sporobolus flexuosus*
NE	*Commelina erecta*	NM	*Sporobolus giganteus*
CO	*Cycloloma atriplicifolium*	CO	*Sporobolus texanus*
CO	*Cylindropuntia imbricata*	KS	*Stillingia sylvatica*
CO	*Dalea cylindriceps*	CO	*Thelesperma megapotamica*
CO	*Dalea lanata*	CO	*Triplasis purpurea*
KS	*Dalea villosa*	NM	*Yucca angustissima*
CO, KS	*Erigeron bellidiastrum*	CO	*Yucca glauca*
CO	*Eriogonum annum*		
CO	*Euploca convolvulacea*	Fungus:	
KS	*Evolvulus nuttallianus*	CO	*Phallus* sp. (reported as stinkhorn mushrooms)

[1]CO = Colorado, KS = Kansas, NE = Nebraska, TX= Texas

[2]Also reported using synonym *Oligosporus filifolius* (Weber and Wittmann 2001)

Reproductive biology and autecology

Chenopodium cycloides flowers in late June through August and produces fruit in summer through fall (Jennings 1996, Clemants and Mosyakin 2003). Little information is available concerning its reproduction or autecology. Within the genus, most research has been conducted on *C. album* (lamb's quarters), and *C. quinoa* (quinoa). *Chenopodium album* is a focus for study because it is a significant non-native noxious weed in agricultural systems (Cousens and Mortimer 1995) while *C. quinoa* has been studied because it is a grain crop (cultivated for its seed), particularly in Central and South America (Martin et al. 1976). In both cases, differences in growth and morphological characteristics among the three species make direct comparisons to *C. cycloides* unreliable.

Chenopod pollen is dispersed by wind. It is smooth, dry and without the exine architecture that is typical of insect-pollinated species. Pollen from *Chenopodium* species is almost impossible to differentiate from *Amaranthus* pollen, and a combination of pollen from both genera is often referred to as *Chenopodium*-type pollen. *Chenopodium*-type pollen is frequently found at high levels in wind-blown samples and has long been blamed for the allergic reactions that some humans have to pollen in the environment (Wodehouse 1945, Samter and Durham 1955, Rubin and Weiss 1974). Although chenopod pollen is recognized to cause allergic reactions, the allergens that cause pollinosis are not yet well described (Barderas et al. 2002, 2004).

Chenopodium cycloides might be self- or cross- pollinated. Since *C. cycloides* frequently grows among other *Chenopodium* species and there is no evidence that hybrids involving *C. cycloides* exist, it appears likely that *C. cycloides* is predominantly self-pollinated. Hybridization among other *Chenopodium* species, particularly those involving *C. album*, is well documented (Clemants and Mosyakin 2003). The frequency with which hybridization occurs among species of subsection *Leptophylla*, to which *C. cycloides* belongs, has not been studied. No chromosomal data are available for *C. cycloides*, but related taxa (i.e., *C. pratericola*, *C. pallescens*, *C. leptophyllum*, *C. subglabrum*, *C. hians*, *C. foggii*), are all diploid, 2n = 18 (Bassett and Crompton 1971, Crawford 1975, Clemants and Mosyakin 2003).

The quantity of seed produced by a *Chenopodium cycloides* individual each year is likely to vary substantially. Although temperature and precipitation patterns are likely to be critical to seed production, there are many other limiting factors. Such factors include disease (Morrall and Howard 1974), herbivory of flowers and developing seed (Hermann-Parker 1976, Carter et al. 1988), herbivory of vegetative structures (Hendrix 1988, Wisdom et al. 1989, Willms 1991), and genetic disposition (McGinnies et al. 1988).

Nothing is known about the seed biology of *Chenopodium cycloides*. Since this species grows in semi-desert environments prone to long droughts, it is likely to have a persistent seed bank and seeds that exhibit some form of dormancy in order for populations to survive periods with adverse conditions (Venable and Lawlor 1980, Freas and Kemp 1983, Silvertown 1987). Some species of desert annuals have a type of innate dormancy where a fraction of the seeds remain dormant in any one season even if growing conditions are optimal (Brown and Venable 1986, Meyer et al. 1995, Meyer et al. 1998, Garvin and Meyer 2003). This mechanism provides protection against depletion of the seed bank in the event that successful reproduction could not be accomplished in any given year (Freas and Kemp 1983, Silvertown 1987, Moseley 1989). A persistent seed bank is a requirement for continued survival in the ruderal and competitive-ruderal species models of Grime et al. (1988). If a persistent seed bank is important in its life cycle, *C. cycloides* will be vulnerable to disruption of natural seed bank depletion - replacement cycles. The relationship between seed bank size and annual fecundity is unknown. That is, it is not clear how seed production one year influences population size in other years.

The dispersal pattern of *Chenopodium cycloides* seed has not been studied, but the clumped distribution of plants suggests that many seeds may land within a short distance from the parent plant(s). Seed dispersal mechanisms are not documented. *Chenopodium cycloides* seeds appear to lack specialized dispersal mechanisms, such as obvious wings that would facilitate dispersal by wind or hooks that would facilitate dispersal on animal fur. The ecological significance of the adherent, enlarged pericarp on the achene, which is disc-shaped and may be moderately aerodynamic, has not been determined. Seeds are retained on the dried stems of other members of the Chenopodiaceae, such as *Kochia scoparia* (Mexican fireweed) and *Salsola tragus* (tumbleweed), and the wind-blown detached stems contribute to the dissemination of seeds. Given the windy environment in which *C. cycloides* grows, wind, particularly in the form of localized dust devils, may contribute to dispersing seed. While seeds may also be dispersed by water during rain showers and storms, Jennings (1996) suggested that this was unlikely given the species' habitat. No evidence of either arthropod or mammalian granivory has been documented, but granivores typically have a significant impact on desert seed banks (Kemp 1989). It is not known whether limited seed dispersal is a significant reason for the small amount of apparently suitable habitat that is actually occupied.

Available information indicates that *Chenopodium cycloides* is an annual species that reproduces by seed and does not exhibit any type of vegetative reproduction. These characteristics and its occurrence in an unstable habitat suggest that the species fits the profile of a competitive-ruderal or r-selected species (MacArthur and Wilson 1967, Grime et al. 1988). The habitat is unstable in the sense that environmental conditions such as temperature and precipitation are unpredictable and the soils are highly erosive. Grime et al. (1988) described a persistent seed bank of numerous small, wind-dispersed seeds and seasonal regeneration in vegetation gaps as being important to the regenerative strategy of ruderal species. *Chenopodium cycloides* does not have small seeds relative to many species, and the importance of wind to their dispersal is debatable, but both a persistent seed bank and periods of regeneration in vegetation gaps appear to be important phases in its life cycle.

Demography

Chenopodium cycloides individuals grow at different densities and within a wide range in abundance. The numbers of *C. cycloides* plants counted at an occurrence range from four to more than 1,000 individuals (**Table 1**; see Distribution and abundance section). A combination of environmental variables and aspects of the species' biology (e.g., seed-dispersal distance) influences the distribution of individuals. The occurrence records suggest that *C. cycloides* plants form patches in a subdivided population, but it is unknown if there is a balance of frequent local extirpations and colonizations within a colonized area or whether, once established, microsites are occupied for long periods. Although the natural cycle of blowout formation and shifting sandy soils suggests that patches *C. cycloides* are spatially dynamic, the frequency of their creation and elimination and the distance between established and new patches of *C. cycloides* plants are not known.

The demographics of *Chenopodium cycloides* populations have not been studied, but some characteristics may be inferred from relatively casual observations. For example, there appears to be a degree of developmental synchrony within populations. That is, all individuals within an occurrence are usually reported to be at about the same stage, such as vegetative, early flowering, flowering and/or fruiting, at the same time. It is not known if all plants that survive the seedling stage go on to reproduce. The average size of individuals, rather than their fecundity, has been reported to differ between years. This difference in morphology might be due to different environmental conditions; for example, drought stunts vegetative growth and often leads to precocious flowering. Other factors, such as exposure to herbicides, can also influence morphology. Seedlings, which would likely be difficult to see, have not been reported at any of the occurrences, and there is no information on seedling mortality. Seedling mortality might be density-dependent (Puntieri and Hall 1996, Houle et al. 2001).

Population viability analyses for *Chenopodium cycloides* have not been undertaken. Because there are few details on germination and survivorship rates, fecundity, or dispersal of *C. cycloides* seeds, only a generalized life cycle diagram can be developed (**Figure 6**). Superficially, the life cycle diagram of this annual plant appears simple, but many questions need to be answered. The levels of recruitment and mortality at various stages of growth and development have not been identified. Seed abortion rates, recruitment of seeds to the seed bank, germination rates, and seedling mortality are all unknown. There are also no data on longevity of seed or seed bank dynamics. Transition probabilities between one life stage and the next have not been determined. Considering the large year-to-year variation in the abundance of the adult plants, these transition probabilities may vary between years. Transition probabilities may also vary between geographic region or community type (Lesica and Shelly 1995). Although there have been no documented analyses of population matrices, *C. cycloides*' annual growth habit suggests that important parts of its life cycle include seed production (fecundity) and seed longevity in a persistent seed bank. Understanding which stages in its life cycle are most important to species viability is useful in predicting the potential consequences of environmental stochasticity and management practices. For example, if a persistent seed bank is most important in maintaining occurrences, abnormally high levels of seed predation (e.g., by insects) or intense disturbance resulting in depletion of the seed bank can be predicted as being particularly detrimental.

Community ecology

Chenopodium cycloides has been described as an early successional species because a number of

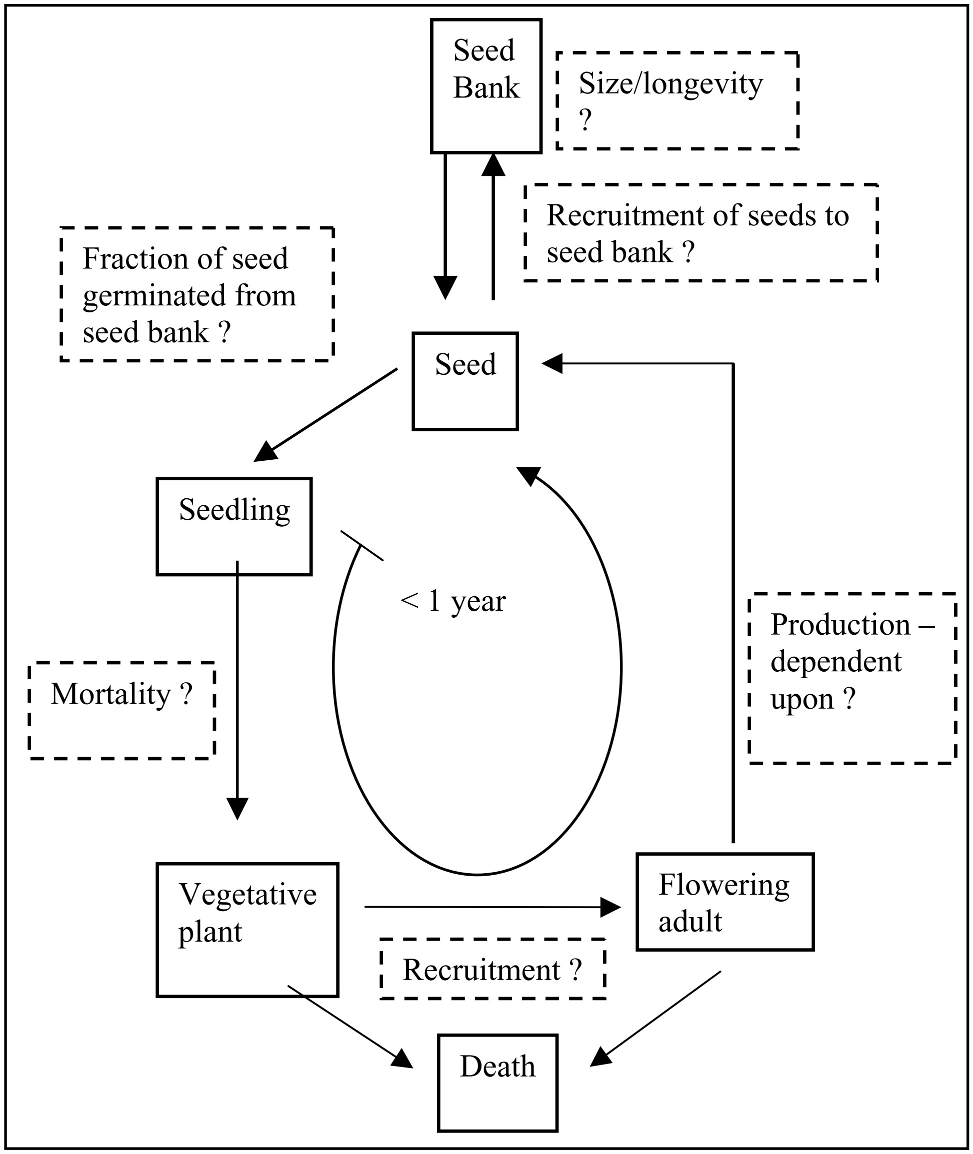

Figure 6. Proposed life cycle of the *Chenopodium cycloides*. The dotted boxes and question marks indicate stages and processes that need more information.

specimens have been collected from roadsides (Jennings 1996). After the initial highway construction, roadside sites are not necessarily highly disturbed. In areas where there is naturally low vegetation cover, only infrequent, low-level maintenance may be required. Another characteristic of highway right-of-ways (ROWs) is that they are unlikely to experience livestock grazing. There are numerous examples where populations of rare plants are of particularly high quality along fence lines and associated with highway ROWs (Ladyman 2000).

Chenopodium cycloides is found in sites characterized by sparse vegetative cover, but at least in some instances, the communities are likely to represent a permanent climax maintained by local edaphic and environmental factors. The *Quercus havardii* cover type is one such climax vegetation community and is not the ecological equivalent of overgrazed grasslands or depleted shrub steppe savannas (Brown et al. 1998, Rosiere undated). *Quercus havardii* as a species and/or species-dominated community is not an invader and is not an indicator of a deteriorated range (Brown et al. 1998, Rosiere undated). Therefore, *C. cycloides* may not represent an early successional species in the classical sense, but rather one that occupies a specialized ecological niche. This alternative view of the taxon may influence human perception of its position within the community. "Early successional" suggests a taxon that is eventually replaced whereas one that is "part of a climax community" suggests permanence. There is little information to suggest that *C. cycloides* relies on communities that are maintained by human or livestock disturbance. Such communities are referred to as disclimax communities (Gabriel and Talbot 1984, USDA Forest Service Pacific Northwest Region 2003, American Heritage Dictionary 2004).

The extent to which *Chenopodium cycloides* is used by herbivores is not known, but it is likely to be palatable. Ruderal species frequently have high palatability to unspecialized herbivores (Grime et al. 1988). No members of the Chenopodiaceae are known to be poisonous, and some make good forage, particularly when young (Swingle 1946, Stubbendieck et al. 1992). The seedlings, leaves, and seeds of many *Chenopodium* species, including linear-leaved ones such as *C. pratericola*, have been valued as human food (Moerman 1998). In fact, *C. album* was likely cultivated as a food crop in the Bronze Age and may owe its prevalence as a weed to its early domestication in Europe and the Middle East (Stokes and Rowley-Conwy 2002, Bogaard 2004). *Chenopodium cycloides* has a tendency to branch, and one response to early season herbivory may be to branch more profusely. Jennings (1996) remarked that the holotype has atypical basal branches that were likely caused by the upper stems being broken or browsed. *Chenopodium cycloides* plants in Las Animas County were reported browsed, but the animal using them was not identified (Jennings 1996). It was also noted that *C. cycloides* had multiple branches at occurrence CO-1 (**Table 1**), but the cause was not explained.

Interactions between *Chenopodium cycloides* and arthropods have not been documented. Crawford (1975) examined the flavonoid composition of several linear-leaved *Chenopodium* species for its taxonomic significance. He found the flavonoid profile of *C. cycloides* to be similar to *C. hians* but reduced as compared to other *Chenopodium* species. Only quercetin 3-O-rutinoside and quercetin 3-O-rhamnodiglucoside were found in *C. cycloides* material. No indication of their concentration was given. Flavonoids may have a role in defense against microbial and insect attack (Brignolas et al. 1995, Padmavati and Reddy Arjula 1998, Cowan 1999, Hammerschmidt 1999, Ndakidemi and Dakora 2003). The ecological significance of the reduced flavonoid complexity in *C. cycloides* is not known, but one can speculate that a reduced number of flavonoids might confer a greater vulnerability to introduced pathogens. Most studies of the impacts of non-indigenous pathogens on plants have focused on species with commercial value, for which losses are substantial (Pimentel et al. 2000). Except in a few instances (e.g., the devastation of *Castanea dentata* (North American chestnut) and *Ulmus americana* (North American elm) trees by chestnut blight fungus (*Cryphonectria parasitica*) and Dutch elm disease (*Ophiostoma ulmi*) respectively), impacts from introduced pathogens on native plant species are not well documented but may be substantial (Pimentel et al. 2000).

The role of disturbance in *Chenopodium cycloides*' life history is unknown. Considerable disturbance from wind and other environmental processes occurs naturally in its sandy habitat (see Habitat section). Historically, small vertebrate species such as pocket gophers, rabbits, and prairie dogs, and large mammals such as bison, pronghorn, mule deer, and wapiti (elk) grazed parts of its range (Benedict et al. 1996). These animals contributed to blowout formation and browsed, or grazed, the sand dune communities. Many of these species have declined in abundance or are extirpated and only exist as reintroductions (Benedict et al. 1996). As well as modifying habitat physically, these animal species exhibit feeding preferences that affect the vegetation community structure (Benedict et al. 1996). There is no information to indicate how the altered assemblage of animal species has impacted the abundance or life history of *C. cycloides*.

The role of fire in maintaining *Chenopodium cycloides* populations is also not documented. Estimates of the frequency with which fire occurred in pre-settlement times in short grass prairie range from five to ten years (Joern and Keeler 1990). Historically, fires in the Nebraska Sandhills, which extend into Kansas, may have occurred as frequently as every four or five years (Bragg and Steuter 1996). Direct evidence of fire history in the sand sage prairie community type of New Mexico, northern Texas, and Kansas is lacking. Based on accounts of European-American settlers and analyses of the growth rates of woody shrubs such as mesquite, fire is estimated to have had a 7- to 10-year return interval (Schmutz et al. 1991, McPherson 1995). The inference from studies on these other woody shrubs is that similar fire-return intervals were experienced in the sand sage community type. The impact of fire suppression due to post-settlement management practices over the last century or more is unknown.

An envirogram is a graphic representation of the components that influence the condition of a species and reflects its chance of reproduction and survival. Envirograms have been used particularly to describe the conditions of animals (Andrewartha and Birch 1984) but may also be applied to describe the conditions of plant species. Those components that directly affect the species make up the centrum, and the indirectly acting components comprise the web. Envirograms are useful as they graphically display how much is understood about a taxon's ecology and biology. The information needed to make a comprehensive envirogram for *Chenopodium cycloides* is unavailable. The envirogram in Figure 7 is constructed to outline some of the components that are believed to have a positive impact on the species. Resources include sandy soils, fire, a combination of temperature and precipitation to promote seed germination, and certain animals that may contribute to seed dispersal, seed caches, and habitat maintenance. The dotted boxes indicate the speculative nature of these resources. Fire, wind, and habitat modification by small mammals have been included because it is likely that some type of disturbance is needed to maintain the sandy communities. Large mammals at historic levels may also be important. However, unqualified disturbance has not been included in the envirogram because the precise types that are beneficial are not known. Natural disturbances, such as those caused by rodents and rainstorms, and human-induced disturbance, such as that caused by all-terrain vehicles, have vastly different consequences.

CONSERVATION

Threats

Loss of habitat is a significant threat throughout the range of *Chenopodium cycloides*. The agents of habitat loss include urbanization, activities related to resource extraction, and land conversion for agriculture and forage production. Recreation activities and livestock grazing cause disturbance, which at certain

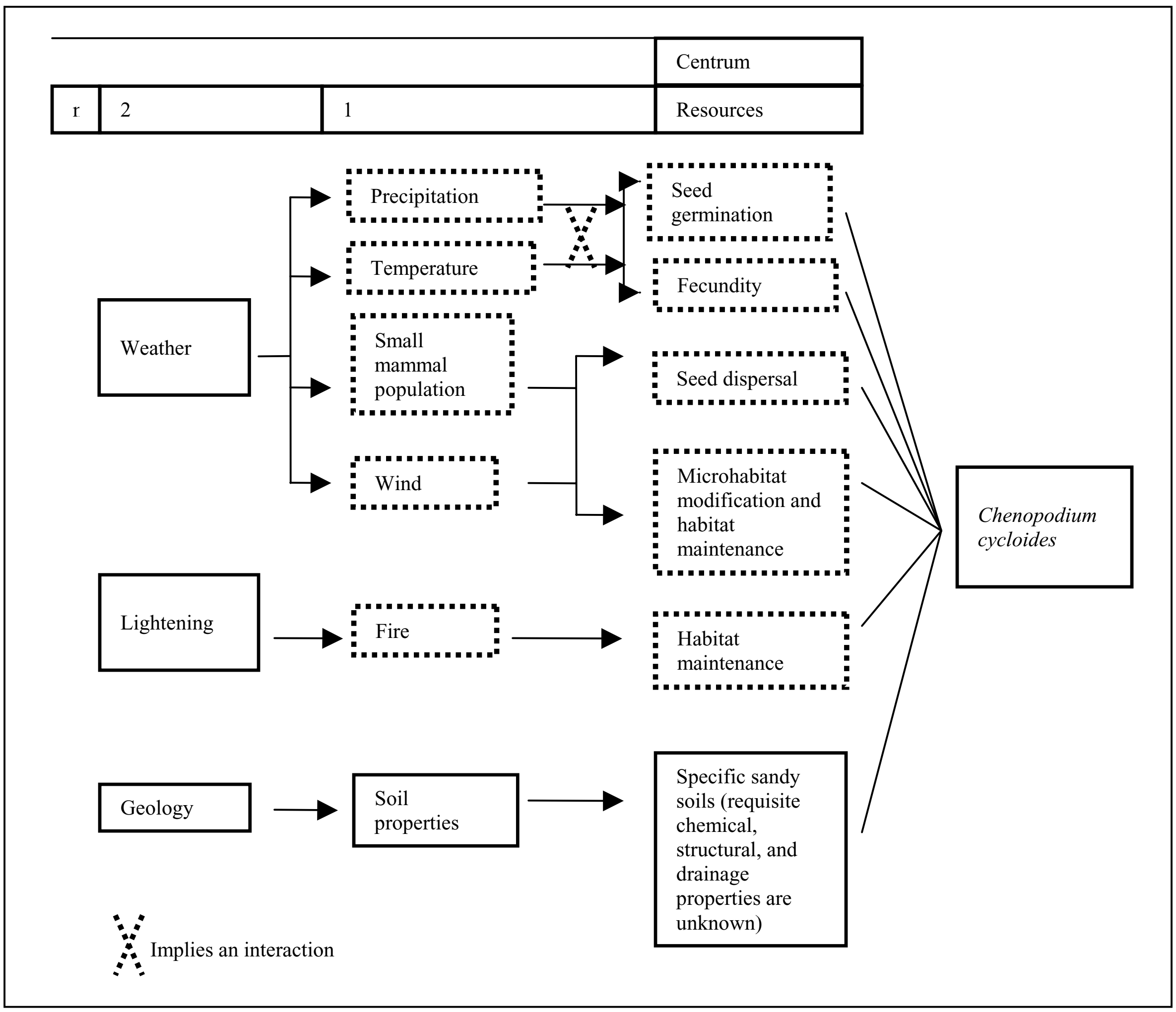

Figure 7. Envirogram of the resources of *Chenopodium cycloides* (see Community ecology section). Those components that directly impact *C. cycloides* make up the centrum, and the indirectly acting components comprise the web. Dotted boxes indicate that these resources are likely but not proven.

but as yet unknown levels may provide dune habitat for *C. cycloides* (Freeman 1989, Jennings 1996). However, disturbance beyond that level may contribute to habitat degradation or loss. High levels of disturbance may also destroy the seed bank or bury the seeds too deeply for germination. No information is available specifically for *C. cycloides*, but in general, seeds in desert soils are distributed near the ground surface, and seeds below 7 cm of the surface are considered lost from the seed bank (Kemp 1989). Livestock also have the potential of directly affecting plants through grazing. Invasive non-native plant species (weeds) contribute to habitat loss and may directly out-compete *C. cycloides* plants for resources. Anthropogenic activities and livestock also facilitate the spread of weeds (Sheley and Petroff 1999). Environmental, demographic, and genetic stochasticities are also potential threats to species' viability, but no details of their potential impact to specific *C. cycloides*' occurrences are available. Each threat is discussed in the following paragraphs.

Urbanization

Urbanization is a slow but enduring process. One Colorado occurrence (CO-9 in **Table 1**) may have been lost to the expansion of the city of Pueblo (Jennings 1996). Another Colorado occurrence (CO-6 in **Table 1**) is near a proposed 35-acre development, which may eventually extend into occupied habitat. CO-8 (**Table 1**) is on a military installation near Pueblo. Access to this installation, which has only a few private enterprises leasing space, is currently restricted (Colorado Natural Heritage Program 2004). However, the installation is facing decommissioning within the next 15 years, and the suboccurrences of CO-8, which are currently both east and west of the existing business center, may be affected by privatization (Colorado Natural Heritage Program 2004).

Resource development

Mineral, oil, and gas resources development is active in most parts of *Chenopodium cycloides*' range. Gas resources include both helium and natural gas. Oil and natural gas exploration and development are particularly active throughout the species' range. All occurrences on the Cimarron National Grassland are within areas open to natural gas and oil development. This area overlies one of the worlds' largest known accumulations of natural gas (USDA Forest Service 1984). *Chenopodium cycloides* plants at KS-19 (**Table 1**) were specifically described as being near producing wells. NM-11 (**Table 1**) is within the federally owned extractable mineral zone of the Todd Oil Field. Oil and gas fields extend through the Monahans Sandhill regions, north and south of Kermit, and west of Crane in Texas (TX-3, 4, and 5 in **Table 1**). Damage and modifications to habitat associated with resource extraction developments extend beyond the well sites. Features associated with resource development include, but are not limited to, road construction, pipe installation, pad construction, installation of associated buildings and holding tanks, and the multiple informal tracks and turn-around sites made by exploration, construction, and maintenance vehicles. All these features contribute to direct soil disturbance and to habitat degradation, loss, and fragmentation. Construction and maintenance of the Longhorn pipeline may have affected *C. cycloides* in New Mexico and West Texas.

There is evidence of other ongoing forms of resource development within the habitat of *Chenopodium cycloides*. CO-6 and NM-1 (**Table 1**) were found near existing gravel pits. Gypsum and several other minerals are mined extensively in Culberson County, Texas. Both the physical damage to the area and the disturbance caused by day-to-day operations have the potential to affect plants directly and to degrade habitat. The specific locations of these mining operations relative to known *C. cycloides* occurrences are not clear from the available documentation. Potential extractable minerals on the Cimarron and Comanche national grasslands include potassium, sodium, and alunite (USDA Forest Service 1984).

Agriculture and range-conversion

Conversion of potential *Chenopodium cycloides* habitat to agricultural land and grass-dominated range for livestock production is common throughout its range and has contributed to habitat modification and fragmentation. Shinnery oak communities, of which *C. cycloides* is part, historically covered between 5 and 7 million acres within the southern Great Plains (Peterson and Boyd 1998). Of this amount, 3.5 million acres were in Texas, 1.5 million acres in New Mexico, and one million acres in Oklahoma (Nellessen 2000). Approximately 30 percent of the Texas acreage and 10 percent of the acreage in both Oklahoma and New Mexico have been converted to cropland and farmland (Nellessen 2000). In addition, the vegetation in these areas has been altered by broad-spectrum herbicides, such as 2,4-D, 2,4,5-T, benzoic acids, picloram, and Tebuthiuron. These chemicals were applied to convert shrub lands dominated by shinnery oak, mesquite, or sand sage to grassland for improved livestock forage potential (Nellessen 2004). It is estimated that at least 100,000 acres of land have been treated with herbicide in eastern New Mexico alone (Nellessen 2000). Negative impacts of herbicide treatment on *C. cycloides* are likely to be primarily due to habitat modification; although *C. cycloides* is a dicot (broadleaf) and is sensitive to these herbicides, the seed bank is unlikely to be affected. On the other hand, herbicide treatments made over multiple years when conditions are favorable for *C. cycloides* reproduction could disrupt seed bank replenishment.

Occurrences of *Chenopodium cycloides* near cropland may be impacted. Cropland on the Great Plains frequently needs to be irrigated, which may have both short-term and long-term consequences. Overspray, leaks, fertilizer run-off, and disturbance by maintenance vehicles associated with the irrigation units often impact areas outside of the actual area of cultivation by substantially changing habitat conditions and the assemblage of plant species that inhabit the area. The installation of a center pivot for irrigation near NE-1 (**Table 1**) may affect that occurrence by altering its habitat conditions. The extensive use of irrigation across this species' range has considerably lowered the water table under the sandy soils that support *C. cycloides* populations (Samson and Knopf 1996). The impacts of fundamental changes in water availability on the life cycle of *C. cycloides* are not known, but they are likely to change the ecological conditions in which the plant has evolved.

Livestock

Livestock grazing is a major economic industry throughout the range of *Chenopodium cycloides*. All of the *C. cycloides* occurrences on the Cimarron National Grassland are within grazing allotments (USDA Forest Service 1984, Brewer personal communication 2004). Sheep grazing has declined, but cattle use has increased over the last 50 years (USDA Forest Service 1984). Livestock grazing on the Cimarron National Grassland is expected to increase to approximately 240,000 animal units per month by 2030 (USDA Forest Service 1984). The extent to which livestock use *C. cycloides* habitat probably depends on how much alternative forage is available. If there are sites with more palatable and abundant forage in the vicinity, livestock are likely to pass through the areas with low vegetation cover in search of the better forage. Use is also likely to depend on the community type. *Chenopodium* species are likely to be preferred when they are more palatable than other available species (Goatcher and Church 1970, Krueger et al. 1974, Vavra et al. 1977, Mayland and Shewmaker 1999; see Community ecology section). If grazing occurs early in the season, *C. cycloides* plants may be able to recover by growing new shoots and completing their life cycle. However, seed set may be limited or prevented in any year when grazing occurs during seed production.

The long-term effects of changes in the assemblage of large mammals on the functioning of *Chenopodium cycloides* habitat have not been studied. Historically, bison, pronghorn, elk, and mule deer roamed over much of *C. cycloides*' range, but the specific use of its habitat type is not known. Pronghorn and mule deer are still free-ranging, but bison and elk are now only reintroduced in certain areas (Samson and Knopf 1996). Cattle may be considered as having replaced bison since both are large bovine ungulates. However, cattle have not provided a direct substitute. Bison generally utilize different species of plants than cattle and exhibit different foraging and social behaviors (Peden et al. 1974, Plumb and Dodd 1993). Pronghorn and bison are complementary in their grazing habits whereas cattle are more similar to pronghorn. Pronghorn antelope and cattle typically use forbs and cool season grasses whereas bison use predominately warm season grasses (Mack and Thompson 1982).

Herbivory is only one consequence of grazing. Animals disturb vegetation and soil, and overgrazing contributes to increased soil erosion and desertification. Jennings (1996) and Freeman (1989) suggested that livestock might benefit *Chenopodium cycloides* habitat by opening up areas and creating dune conditions. This may be true, but as for the case of feeding habits, cattle and bison's use of habitat is different (Knapp et al. 1999). Compared to bison, livestock grazing at one site is typically of longer duration, with a larger number of individual grazers per unit area (Laurenroth and Milchunas 1995, Benedict et al. 1996, Ostlie et al. 1997). Cattle also do not create an environment that is as spatially or temporally diverse (Laurenroth and Milchunas 1995, Benedict et al. 1996, Ostlie et al. 1997). Disturbance needs to be in a delicate balance with revegetation rate; the extent and intensity of the disturbance are likely critical factors in habitat maintenance. A simple example is that after a drought in pre-settlement times, the revegetation rate was low, but drought also decreased the animal population so the potential for disturbance and herbivory also declined.

The significance of the changes in faunal assemblages on maintaining a functional Great Plains ecosystem is being investigated (Knapp et al. 1999, Manske 2000, Donlan et al. 2005, Stoltzenburg 2006). The relationships between vegetation and fauna depend upon many environmental and biological factors, and generalizations lead to over-simplification of the situation. However, the preceding observations on the differences between domestic cattle and historical species of wildlife have been made to encourage consideration of the different and disparate processes that may be involved with *Chenopodium cycloides*' viability.

Recreation

Threats associated with recreation to *Chenopodium cycloides* are not documented. The disturbance caused by motorized vehicles needs to be considered a potential threat. Recreational off-road vehicle (ORV) traffic and all-terrain vehicles (ATVs) have gained popularity within the last decade (e.g., ATV Source 1999-2004, OffRoadDirectory.net 2004). Dunes are popular destinations for mechanized vehicle recreation and are under heavy pressure for unrestricted use by ORV enthusiasts (ATV Source 1999-2004, Grant and Gorman 2004). Snowmobiles may also be used in the northern parts of *C. cycloides*' range. Both forms of recreation can severely disturb vegetation, cause accelerated soil erosion, increase soil compaction, and add to pollution (Ryerson et al. 1977, Keddy et al. 1979, Aasheim 1980, Belnap 2002, Misak et al. 2002, Gelbard and Harrison 2003, Durbin et al. 2004).

Competitive, non-native plant species

Invasive non-native species are highly competitive and may threaten some *Chenopodium cycloides* occurrences. While there are no data to indicate an imminent invasion of competitive species at any of the known occurrence sites, invasive species pose a general threat as a significant agent of habitat modification. Some invasive weeds also affect the fire regime (Sheley and Petroff 1999). For example, cheatgrass (*Bromus tectorum*), a common invader of sandy soils, can significantly increase fire frequency. Another example is Lehman lovegrass (*Eragrostis lehmanniana*), which has spread widely since its introduction as a forage plant (McClaran and Anable 1992). Lehman lovegrass alters fire regimes by producing much more aboveground biomass than native grasses. Since fire enhances its reproduction, Lehman lovegrass creates an environment that perpetuates itself to the exclusion of native species (Biedenbender et al. 1995). The importance of fire in *C. cycloides*' life cycle is not known, but historically fires likely occurred at intervals of four to ten years depending upon the community type (see Community ecology section).

Environmental stochasticity

Environmental stochasticity includes random, unpredictable changes in weather patterns or in biotic members of the community (Frankel et al. 1995). Specific environmental uncertainties that likely affect survival and reproductive success of *Chenopodium cycloides* include variation in temperature, soil water availability, soil erosive forces (e.g., wind, precipitation), and variable populations of native animal species. *Chenopodium cycloides* occurrences tend to be geographically clustered. This could be due to observation bias or may reflect an ecological or biological basis. If *C. cycloides* occurrences are geographically clustered, they are vulnerable to any natural or man-made event that is localized where they are most abundant. For example, non-selective herbicide spraying for shrub and forb control could have a significant impact on a large proportion of total *C. cycloides* habitat even though the impact on the total land area in a particular management unit is relatively small.

Global climate change is also an element of environmental stochasticity. Based on projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom Hadley Centre's climate model (HadCM2), by 2100 temperatures in Colorado could increase by 3 to 4 °F (1.7 to 2.2 °C) in spring and fall and 5 to 6 °F (2.8 to 3.4 °C) in summer and winter, and precipitation is predicted to decrease slightly in summer but increase by 10 to 30 percent in spring, fall, and winter (U.S. Environmental Protection Agency 1997a). In Texas, the same HadCM2 model predicts temperatures could increase by about 3 °F (1.7 °C) in spring and about 4 °F (2.2 °C) in other seasons, while precipitation may decrease by 5 to 30 percent in winter but increase by about 10 percent in the other seasons (U.S. Environmental Protection Agency 1997b). Similar predictions have been made for South Dakota (U.S. Environmental Protection Agency 1998a) and New Mexico (U.S. Environmental Protection Agency 1998b). Other climate models may show different results. However, four of the five most widely used General Circulation Models indicate that future climate in the High Plains region is likely to include higher average temperatures, an increase in the frequency and severity of droughts, and an increase in the frequency of heavy precipitation events (Committee on the Science of Climate Change - National Research Council 2001, U.S. Global Climate Change Research

Program 2006). More information on the potential consequences of climate change can be found in Alley (2002), Christy (2000), Pew Center (2005), US Global Climate Change Research Program (2006), Committee on the Science of Climate Change - National Research Council (2001), and the New Zealand Climate Change Office (2006).

Climate change may also cause weather to become more extreme; for example, the amount of precipitation on extreme wet or snowy days in winter may increase, and the frequency of extreme hot days in summer is likely to increase because of the general warming trend (U.S. Environmental Protection Agency 1997a, 1997b, 1998a, 1998b). It is unclear how such climate changes may affect *Chenopodium cycloides*. Constant higher temperatures and prolonged droughts within its range may eventually lead to irrevocable disruption of the seed bank replacement-depletion cycle. Limited dispersal due to short seed dispersal distances may prevent the species from moving and exploiting suitable habitat and climate conditions that may become available outside of the current range of *C. cycloides*. Frequent and heavy rainstorms may cause increased soil erosion that might disrupt the seed bank. On the other hand, increased variation in weather conditions may not profoundly affect *C. cycloides* because it appears to be adapted to unstable environmental conditions. As long as abundant seed is produced in some years and the seed bank can be maintained, periodic years when no seed is produced may not be detrimental. This theory is supported by results of Meyer et al. (2006) who used data from an 11-year artificial seed bank experiment to show that actually increasing environmental variance substantially decreased the risk of extinction of the desert ephemeral *Lepidium papilliferum*. This was thought to be because *L. papilliferum* relies on exceptionally good years to restock the seed bank, while exceptionally bad years have little impact (Meyer et al. 2006). In fact, if every year were "average" without the exceptionally favorable years, the species could not persist in its desert environment and might become extinct within time frames as short as 15 years (Meyer et al. 2006).

Demographic and genetic stochasticity

Intrinsic or biological stochasticities also contribute to the vulnerability of *Chenopodium cycloides*. These intrinsic uncertainties, which a population viability analysis typically addresses, include elements of demographic stochasticity and genetic stochasticity (Shaffer 1981).

Demographic stochasticity refers to chance events independent of the environment that may affect the reproductive success and survival of individuals (Menges 1991). In small populations, demographic stochasticity may have an important influence on the survival of the whole population (Pollard 1966, Keiding 1975). For example, a certain percentage of the population may abort seeds, with the percentage becoming bigger and perhaps reaching 100 percent as the population size becomes smaller. Since many *Chenopodium cycloides* occurrences are small, the fate of an individual may be important to species viability in some areas (Kendall and Fox 2003).

Genetic stochasticities are associated with random changes, such as inbreeding and founder effects, in the genetic structure of populations. It is not clear whether the clumped distribution of *Chenopodium cycloides* plants within occurrences is solely due to limited seed dispersal. However, if seed dispersal is limited, pollen transfer between occurrences is critical to maintain gene flow. Depending upon the extent of gene flow, small populations of *C. cycloides* may be vulnerable to inbreeding depression, which is a lack of fitness due to the expression of one or more recessive genes for unfavorable traits. For example, germination, competitive ability, over-wintering ability, or reproductive effort may be compromised in some way. On the other hand, inbreeding is not always detrimental in small populations since it can purge deleterious recessive mutations (Byers and Waller 1999). Life history traits appear to influence the extent of purging; annuals, such as *C. cycloides*, are more likely to exhibit purging than perennials (Byers and Waller 1999). However, evidence also indicates that purging depends upon a wide range of factors and that it is an inconsistent force within populations (Byers and Waller 1999).

The substantial geographic separation and isolation of *Chenopodium cycloides* occurrences may have led to the development of ecotypes adapted to local conditions. Outbreeding depression can result when crosses are made between widely spatially separated plants and local adaptations are disrupted after non-local genotypes are introduced (Waser and Price 1989). However, the potential threat of outbreeding depression for *C. cycloides* appears to be low. Movement of genotypes outside their natural range appears to be remote at the present time because the taxon is unlikely to be used for horticultural or restoration purposes and it appears to be too rare for significant transport to occur via vehicle tires or other artificial long-distance mechanisms.

Unintentional extirpation

Chenopodium cycloides appears to be subject to large fluctuations in aboveground population size from year to year (Freeman 1989). In fact, in some years it is likely that no plants will grow in areas where a seed bank of *C. cycloides* exists. This absence of aboveground evidence of occupation confers substantial vulnerability to unintentional extirpation. For example, on some managed areas where known occurrence sites and potential habitat are typically surveyed prior to substantial development, if no plants are found the project is likely to go ahead. Therefore, there is the potential that the seed bank will be unintentionally eliminated, and populations might be extirpated during development projects. The degree to which this has happened in the past, or might happen in the future, cannot be estimated with the available information.

Summary

The envirogram of **Figure 8** is constructed to outline some of the factors, termed malentities, that are likely to impact *Chenopodium cycloides* negatively. The primary threats to this taxon are those that contribute to habitat loss. Disturbance that leads to substantial habitat modification is included in the envirogram, but the type and levels that are deleterious to long-term

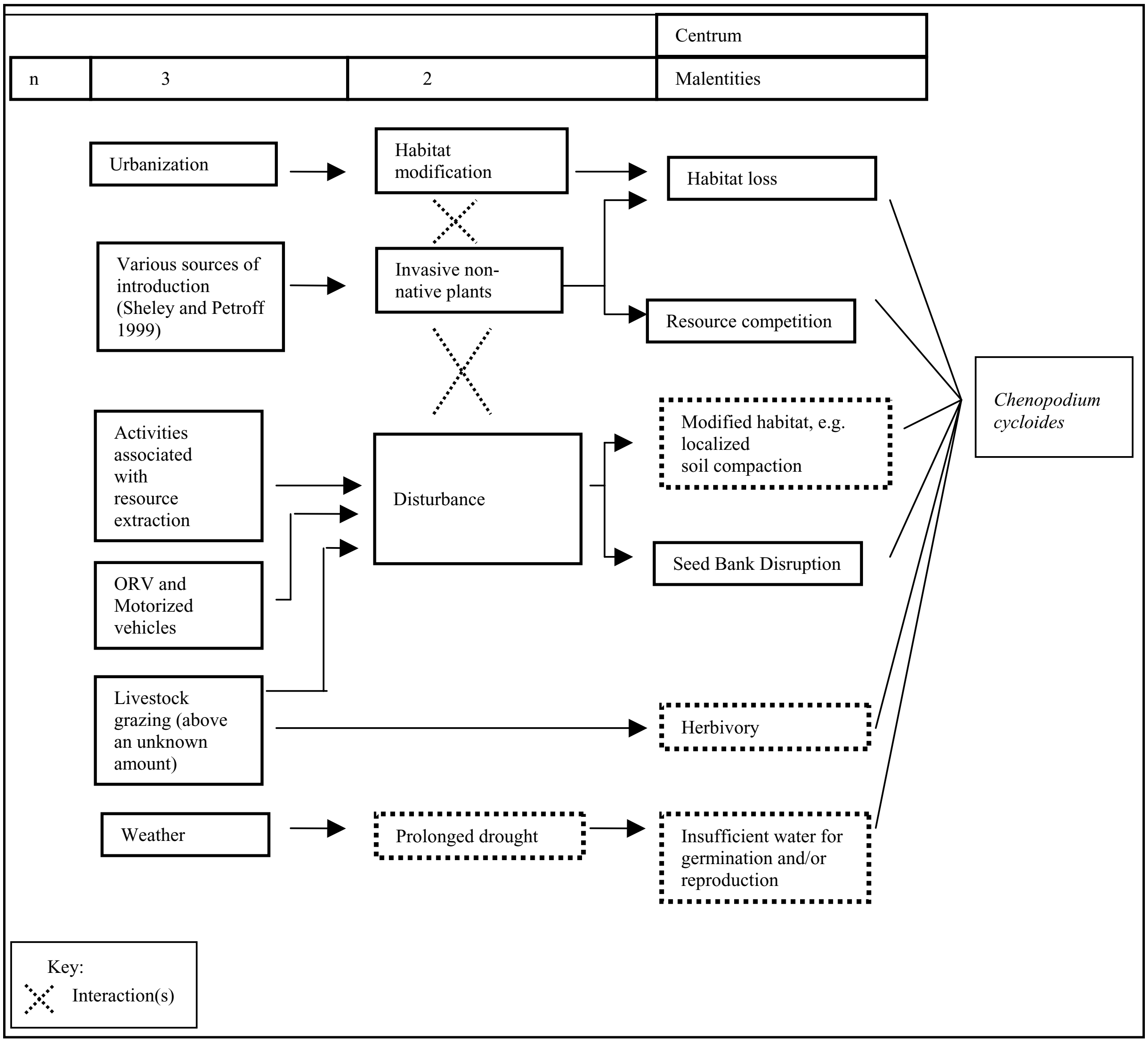

Figure 8. Envirogram outlining the malentities and threats to *Chenopodium cycloides*. Those components that directly impact *C. cycloides* make up the centrum, and the indirectly acting components comprise the web. Dotted boxes indicate factors that are likely but not proven. Dotted lines indicate likely interactions.

sustainability need to be defined. Disturbance can be of two types: direct impacts and consequences directly attributable to the initial disturbance. ORV traffic can directly crush and dislodge plants. Disturbance has also indirect consequences, such as contributing to soil erosion and increasing soil compaction. Although disturbance may open an area to colonization by *C. cycloides*, it can also lead to invasion by competitive non-native plant species that may eventually result in loss of habitat. Invasive plant species directly compete for resources and contribute to loss of habitat (Sheley and Petroff 1999). An important consideration, indicated by a faint dotted line in the envirogram, is the significant contributions that ORVs and large mammals make to the spread of weed species. Threats associated with herbivory by livestock and native ungulates have been included because there is the potential that overgrazing may negatively affect *C. cycloides*. Less easily managed potential threats also include global climate change and demographic and genetic stochasticity. Many such threats can only be mitigated through maintaining an adequate number of sustainable populations. No accurate, quantitative estimates on the number of individuals or occurrences that are adequate to maintain species' viability can be made with the currently available information.

Conservation Status of Chenopodium cycloides in Region 2

Chenopodium cycloides is recognized as a rare species and is designated a sensitive species by Region 2. As part of a 1988 inventory for rare plants, Freeman (1989) located approximately 12 *C. cycloides* occurrences, eight of which were on the Cimarron National Grassland. In 1991, McGregor collected a specimen (*R.L. McGregor #40194* KANU) from a site in the same general area where plants were found in 1988 (KS-13 in **Table 1**). An additional, previously unreported *C. cycloides* occurrence was found in 2003 on the Cimarron National Grassland (KS-19 in **Table 1**). However, the status of *C. cycloides* on the Cimarron National Grasslands is not clear. Although USFS personnel have conducted occasional surveys for *C. cycloides* in the last decade, they have not been able to locate any plants since 1988 (Brewer personal communication 2004). The significance of the paucity of plants over this 16-year period is not known, but it suggests that targeted surveys need to be conducted in order to clarify the status of *C. cycloides* on the Cimarron National Grassland.

The status of *Chenopodium cycloides* on the Comanche National Grassland is also uncertain. Hazlett (2004) describes the species as "rare in region" in an inventory of the Comanche National Grassland flora. There is a 1995 record a few miles south of Kim, near the boundary of the Comanche National Grassland, but there is no location information for specific occurrences within the grassland (Olson personal communication 2004).

Management of Chenopodium cycloides in Region 2

The only known *Chenopodium cycloides* occurrences on National Forest System lands in Region 2 are on the Cimarron National Grassland (**Figure 1**). Since all of these are in areas open to current and future oil and natural gas development and are within active cattle grazing allotments, they are potentially subject to substantial disturbance from anthropogenic sources (Brewer personal communication 2004). Disturbance from these sources may also contribute to habitat loss.

All known *Chenopodium cycloides* occurrences on the Cimarron National Grassland are in units where emphasis is placed on "management for livestock grazing, where intensive grazing management systems are favored over extensive systems" (USDA Forest Service 1984, Brewer personal communication 2004). Intensive grazing management is defined as "Grazing management that attempts to increase production or utilization per unit area or production per animal through a relative increase in stocking rates, forage utilization, labor, resources, or capital" and "Intensive grazing management is not synonymous with rotational grazing. Grazing management can be intensified by substituting any one of a number of grazing methods that utilize a relatively greater amount of labor or capital resources" (Forage and Grazing Terminology Committee 1991). Intensive grazing management is in contrast to extensive grazing management, defined as "Grazing management that utilizes relatively large land areas per animal and a relatively low level of labor, resources, or capital" (Forage and Grazing Terminology Committee 1991). There have been no studies to determine how *C. cycloides* responds to either management system.

Few other types of disturbance have the potential to affect known *Chenopodium cycloides* occurrences on the Cimarron National Grassland appear. There are no prescribed burns currently planned for the areas in which *C. cycloides* occurs, but these areas may be treated in the future (Brewer personal communication 2004). There is only one *C. cycloides* occurrence area with an established recreation facility; KS-13 (**Table 1**) in the Cottonwood Picnic area appears to be the most likely to be affected by recreational activities.

Implications and potential conservation elements

Chenopodium cycloides occurrences on USFS lands may be particularly important to maintaining the species' viability because these lands are more likely to be managed for conservation of the species. Conservation may be more difficult to achieve on private lands. *Chenopodium cycloides* is inconspicuous and may be overlooked during casual observation, particularly if only a few individuals are located in an occurrence of other similar species (Freeman 1989). In addition, because *C. cycloides* lacks attractive flowers and foliage, people unfamiliar with the taxon might dismiss it as a "weed." Although the weedy and unremarkable characteristics of *C. cycloides* may be neutral to its survival, they make it less likely that the general public will appreciate *C. cycloides* as a taxon worth conserving.

The temporal variability in *Chenopodium cycloides* occurrence size suggests that there are several important and related conservation issues. Since there are large differences in the abundance of *C. cycloides* from year to year, surveys of potential habitat need to be made over several consecutive years, even if the searches are negative. However, since the longevity of *C. cycloides* seed in the soil is not known, the number of years over which surveys need to be made cannot be recommended. The invasive *Chenopodium* species *C. album* has a large seed bank, and the seeds are viable for several decades (Telewski and Zeevaart 2002, Davis et al. 2005). However, it is almost certainly inaccurate to extrapolate the biology of an invasive species to that of a rare one.

If some *Chenopodium cycloides* occurrences need protection from anthropogenic activity, the patchy and temporally variable distribution of *C. cycloides* needs to be taken into account. It is important that the area delineated for protection be larger than that occupied by *C. cycloides* plants in any given year. Determining which *C. cycloides* occurrences are most appropriate to conserve is challenging. The abundance of this taxon in any one year is unlikely to be an accurate indicator of its abundance in subsequent years. In addition, even if an occurrence is determined to be potentially small, it may still be important to retain. Local adaptation and unique gene combinations in small populations are distinctly possible. Although small populations are often considered genetically depauperate because of changes in gene frequencies due to inbreeding or founder effects, alleles that are absent in larger populations may only be found in small populations (Karron et al. 1988, Menges 1991). Therefore, in order to conserve genetic variability in the absence of genetic data, it is likely most important to conserve as many occurrences as possible in as large a geographic area as possible and to keep in mind that a larger population does not automatically have better conservation value. The quality of habitat is another important consideration in choosing which *C. cycloides* occurrences are best to protect. Unless there are extenuating circumstances, occupied habitat that is free of non-native plant species, experiences low anthropogenic use, and is distant from roadways has more conservation value than does a degraded occupied habitat.

Loss of *Chenopodium cycloides* habitat has occurred from a variety of causes. Clearly, *C. cycloides* has evolved in an environment that is maintained by certain types of periodic disturbance. The problem is that there is little information on which to base predictions as to the species' response to specific disturbance types or levels. A fundamental gap in knowledge is that it is not known how quickly disturbed areas are re-colonized or if plants are able to persist at frequently disturbed sites. The relative importance of seed rain and the seed bank to (re)colonization has important management implications. Management practices that either increase or decrease the frequency or intensity of natural perturbations or provide additional stresses to the seed bank may negatively affect population viability.

There is no information on the minimum size of a viable population, and therefore it is difficult to predict the consequences of actions that will reduce the size of any one population. The patchy and temporal variability in abundance also make understanding the impacts of management decisions particularly challenging.

Tools and practices

Species inventory

Formal inventory programs are needed for *Chenopodium cycloides* because there is little information on its abundance and distribution in any part of its range. Freeman conducted the most extensive *C. cycloides* inventory on Region 2 lands in 1988. This survey was more than 16 years ago, and the status of those occurrences is not known. It is important that *C. cycloides* surveys are conducted during late summer or fall when the plant has fruit, because they are needed for unequivocal identification. An example of a field survey form for endangered, threatened, or sensitive plant species can be viewed on the website of the Colorado Natural Heritage Program (URL: http://www.cnhp.colostate.edu/help.html#data). This form is appropriate to use for inventory purposes. The number of individuals and the area they occupy are important data for occurrence comparison. The easiest way to describe populations over a large area may be to count patches, making note of their extent, and to estimate or count the numbers of individuals within patches. A statement such as "many individuals" or "abundant" is subjective, and on the field survey form actual counts or an estimate of the number observed is more helpful in describing the condition of the occurrence. The estimate may be a range of values, such as "fewer than 10" or "between 50 and 100." Documenting that the plants are in flower or with fruit is important for future reference and may add more information about the phenology of the species.

Habitat descriptions are important for estimating the viability of a particular occurrence and are customarily recorded during surveys. In the case of new occurrences, it is useful to collect a voucher specimen and to deposit it in a herbarium. However, it is not appropriate to take specimens from small populations. The advisability of collecting a specimen always needs to be considered on a species-specific and a site-specific basis. A general guideline needs to be established for field technicians, such as limiting collections to occurrences with more that 50 plants. If there are fewer than 20 flowering individuals, a close-up color photograph of the fruit and an additional photograph of the plant to show its habitat need to be taken in order to document the occurrence. Even though a photograph is inadequate for taxonomic examination, it may be sufficient to confirm correct identification or for catching instances where gross misidentification has occurred. If there are doubts as to an occurrence's authenticity, the site needs to be re-visited and a suitable specimen collected. Collected specimens must have fruit, and a note of the fruit color needs to be made prior to pressing the specimen.

Habitat inventory

General characteristics of *Chenopodium cycloides* habitat have been described, but the precise conditions that are needed are unknown. Estimates of potential habitat may well be overestimated. For example, there is more than 8,000 square miles of the eolian derived soils in Colorado (Tweto 1989), but it is unlikely that all the area has an equal chance of being occupied. Some features, such as the presence of competitive non-native plant species, indicate poor habitat. Therefore, inventory of potential habitat where there are few or no competitive non-native plant species and evidence of low or no anthropogenic disturbance will provide information on where *C. cycloides* is most likely to occur. Geographic Information System (GIS) technology can be used to map and track the quality of potential habitat. Areas with stabilized vegetation at the edge of blowouts provide likely habitat, but other areas with sandy loamy soils also need to be considered. The irregular and clustered pattern of *C. cycloides* plants and the large amounts of unoccupied but ostensibly suitable habitat may mean that poor seed dispersal limits the species' distribution. Additionally, or alternatively, it may indicate that specific microclimate or edaphic conditions need to be met in order to support plant development.

There have been no studies to relate the abundance or vigor of populations to specific habitat conditions. Therefore, accurately defining the quality of the habitat or likelihood of colonization is limited by the currently available information.

Population monitoring

A formal, carefully documented monitoring program for *Chenopodium cycloides* would be valuable because the structure and persistence of occurrences and the colonization rate of unoccupied suitable habitat are unknown. Other than a survey by Freeman in 1988 in Kansas, additional relatively casual observations he made in the early 1990s, and a limited resurvey of sites in Colorado in 1994 and 1995, no monitoring activities have been undertaken in any part of its range (**Table 1**; Freeman 1989, Jennings 1996). Freeman (1989) observed that *C. cycloides* occurrences could be persistent for at least three years within a given area but that their size could vary considerably between years (KS-1, 6, and 13 in **Table 1**). Therefore, monitoring protocols for *C. cycloides* occurrences need to take into account the potentially dynamic nature of the occurrences and their temporally variable abundance.

Problems associated with spatial auto-correlation can occur when using permanent plots to monitor a dynamic population. If the size of the plot is too small or the establishment of new plots is not part of the original scheme, then when plants die and no replacement occurs, it is impossible to know the significance of the change without studying a large number of similar plots (Goldsmith 1991, Elzinga et al. 2001). Detailed discussions on monitoring protocols can be found in Elzinga et al. (2001). Other suitable observations to record during monitoring studies include evidence of disease or predation on *Chenopodium cycloides* plants and details of habitat conditions.

A demographic study, based on monthly visits through the growing season, may answer questions about the population dynamics and the life cycle of *Chenopodium cycloides*. Seedling mortality and transition probabilities between different life stages could be elucidated. However, it may be difficult to assess the flux of seedlings accurately because their life span may be shorter than one month, and visits at intervals on the order of several days may be needed. In conjunction with aboveground censuses, studies on the *C. cycloides* seed bank size and persistence would be very valuable in understanding the strengths and vulnerabilities of the taxon (e.g., Alexander and Schrag 2003, Adams et al. 2005). Because *C. cycloides* is an annual, colonizations and localized extirpations of small sub-occurrences are expected to occur among years. Just as for monitoring, the study design needs to take into account the potentially dynamic nature of the plants' distribution within an occurrence (Goldsmith 1991).

The use of photopoints and photoplots is recommended. Photographic documentation is useful in visualizing coarse-scale vegetation changes over time and is increasingly used to supplement but not replace quantitative monitoring records. Photopoints are collections of photographs with the same field of view that have been retaken from the same position over some given time period. Photoplots are usually relatively close-up photographs showing a birds-eye-view of the monitoring plot. In both cases, a rebar or some other permanent marker needs to be placed as a positional reference. Compass directions and field-of-view details need to be recorded to make sure the photograph can be re-taken accurately. Even though digital copies are convenient and easy to store, many museums and researchers suggest storing additional slides and hardcopies since the technology to read current digital media may not be available in the future.

Habitat monitoring

Elzinga et al. (1998) suggested that in the case of annual species that fluctuate in abundance from year to year, habitat monitoring might be more sensitive in detecting undesirable change than monitoring the plant species itself. Because there is some understanding of what areas represent suitable habitat, it may be possible to monitor habitat quality. Factors that indicate habitat quality include the abundance of non-native species, the level of fragmentation, and the type and amount of anthropogenic disturbances. Gross changes in erosion patterns in apparently appropriate habitat may also indicate degrading habitat. However, habitat monitoring has severe limitations when precise habitat requirements are unknown. In the case of *Chenopodium cycloides*, optimal habitat conditions are largely conjecture, derived from relatively few observations from several community types. Without periodic direct observations of *C. cycloides* plants or additional seed bank studies, it is impossible to know whether a population is persistent and if the land management practices are appropriate.

Habitat monitoring in known occurrences of *Chenopodium cycloides* needs to be associated with population monitoring protocols. Descriptions of habitat need to be recorded during population monitoring activities in order to link environmental conditions with abundance over the long term. Current land use designation and evidence of land use activities are important records to include with monitoring data. For example, it is useful to note if an occurrence is on an active grazing allotment even though no use by livestock is observed.

Population or habitat management approaches

Occurrences of sensitive plant species are often protected on National Forest System lands by land use designation, e.g. wilderness area or research natural area. In other circumstances, fencing, gates, or signs can be used to protect specific occurrences. Currently, *Chenopodium cycloides* is not known to occur in any area that is afforded special protection from anthropogenic activities. *Ex situ* conservation techniques (e.g., seed banking) are often employed to conserve plant species outside of their native habitats (Center for Plant Conservation Undated, Millennium Seed Bank Project undated). No evidence that *C. cycloides*' seed has been banked could be found for this report.

Monitoring programs are valuable in determining the conservation status of a taxon. There have been no systematic monitoring or inventory programs for *Chenopodium cycloides*, save for the single-year survey on the Cimarron National Grassland in 1988 (Freeman 1989, Olson personal communication 2004). The impacts of current management procedures on *C. cycloides* cannot be evaluated. Most of the areas on the

Cimarron National Grassland in which *C. cycloides* has been found have been subject to site-specific analysis prior to resource extraction activities and other projects, according to USFS sensitive species policy (Brewer personal communication 2004). Despite these surveys being conducted at the appropriate time, USFS have not (re)located any of the known or any new populations within the last 16 years (Brewer personal communication 2004).

Information Needs

Further inventory is needed to assess the status of *Chenopodium cycloides* in Region 2 in particular and range-wide in general. At the present time, *C. cycloides* appears to be a naturally uncommon species that is restricted to specific soil and community types within a limited geographic range, but that may be locally abundant in some years. Although in some instances *C. cycloides* may be overlooked, it is also likely that the species is naturally subject to large fluctuations in population size from year to year (Freeman 1989). The cause of the high variability in *C. cycloides* abundance needs to be identified and the characteristics considered in management strategy. Temporal and spatial differences in occurrence size may be most easily ascribed to environmental conditions and the size of the seed bank, but they also may be due to other factors (e.g., levels of past disturbance). The likely positive relationship between abundance and precipitation needs to be systematically confirmed.

Monitoring known *Chenopodium cycloides* sites is essential in order to understand the implications of existing and new management practices. Where management practices are likely to change, valuable information would be gained from collecting baseline data before, and then conducting periodic monitoring after, the new policy is initiated. In particular, *C. cycloides* colonies in high disturbance areas, such as those with ORV use or high levels of natural gas development, need to be monitored. Trend data to determine the likely long-term survival rate of occurrences at high-use sites are currently not available. The impacts of ungulate grazing are also not clearly understood, and the impact of intensive grazing practices on this taxon has not been assessed. Clarifying the levels at which *C. cycloides* plants may respond, positively or negatively, to disturbance or grazing pressure would be useful in designing management practices. Long-term monitoring is valuable because the impacts from accelerated soil erosion and disruption of seed bank depletion - replacement cycles may take several decades to become apparent. The taxon's ability to tolerate interspecies competition is thought to be low, but the threat from non-native invasive species needs to be better understood. Vigilance and action to minimize the invasion of aggressive, non-native plant species will preserve potential habitat and reduce habitat fragmentation.

Inventory and periodic monitoring of existing *Chenopodium cycloides* sites are important needs, but there are also unanswered questions about the species' biology and ecology that would influence its management. Observations that *C. cycloides* grows in areas such as road cuts suggest that it can act as a pioneer species. Additional studies need to be conducted to determine if the size of the seed bank or the fecundity of nearby populations is of greater importance for colonization ability. The rate at which *C. cycloides* colonizes potential habitat is unknown, and there may be a substantial difference between recolonizing an area from a pre-existing seed bank and colonizing an area through seed dispersal. These studies would entail examining seed longevity, seed bank persistence, and seed dispersal characteristics. The spatial dynamics of *C. cycloides* individuals within vegetation communities are also unknown.

Knowing the genetic variability of *Chenopodium cycloides* permits biologically informed decisions with respect to assessing the relative value of conserving different occurrences. The extent of genetic variability within and among occurrences is important when considering the potential genetic losses associated with loss of individual occurrences. If genetic variability exists among occurrences, it may be important to salvage local seed to mitigate or reseed impacted areas. In conjunction with such studies, research would have to be carried out to determine if establishment of sustainable occurrences from sown seed is feasible. The rarity of the species and its variation in abundance between years imposes significant challenges to seed collection and occurrence conservation.

More information is needed on the reproductive biology of *Chenopodium cycloides*. In particular, details of its seed production, seed longevity, seed germination rate, and seedling recruitment rate need to be clarified. More information about its development and about which of the stages in its life cycle are most important for viability is also needed to help guide management decisions. For example, the importance of annual seed production and a persistent seed bank, and *C. cycloides*' ability to recover from early season browsing are all factors that are useful to consider when selecting an appropriate grazing system.

In summary, information needs for *Chenopodium cycloides* include:

- ❖ inventorying *C. cycloides* occurrences, including known occurrence sites and areas that have not been surveyed
- ❖ monitoring existing *C. cycloides* occurrences, particularly to characterize the natural temporal variation in size
- ❖ characterizing and monitoring *C. cycloides* habitat so that proactive steps may be taken to mitigate habitat degradation and fragmentation
- ❖ determining the method of (re)colonization by *C. cycloides*
- ❖ determining the genetic diversity among and within *C. cycloides* occurrences
- ❖ understanding the reproductive biology of *C. cycloides*
- ❖ understanding the relative importance of the different stages in the life history of *C. cycloides*

Definitions

Achene – A small, usually single-seeded, dry fruit that remains closed at maturity; the simplest of any fruit.

Allergen – A substance, such as pollen, that causes an allergy.

Autogamous – Self-fertilizing.

Competitive-ruderal – plants that are annual, small in stature, grow potentially rapidly, have limited lateral spread, reproduce only by seed, and exhibit delayed flowering (Grime et al. 1988).

Disclimax – a climax community that has been disturbed by various influences, especially by humans and domestic animals, such as a grassland community that has been altered to desert by overgrazing (American Heritage Dictionary 2004). Disclimax has been variously defined: 1) A relatively stable ecological community, often including kinds of organisms foreign to the region and replacing the climax because of disturbance (Burns and Honkala 1990); 2) A vegetation community that is maintained at an earlier seral stage by continuing disturbance (i.e., fire and grazing) (USDA Forest Service Pacific Northwest Region 2003); 3) In monoclimax theory, a distinctive type of climax community that retains its character only under continuous or intermittent disturbance (e.g., heavy grazing, periodic burning) (Gabriel and Talbot 1984).

Edaphic – of or pertaining to the soil; resulting from or influenced by factors inherent in the soil or other substrate, rather than by climatic factors (Soil Science Society of America 2006).

Eolian – Pertaining to the wind, especially referring to deposits such as loess and dune sand (Bates and Jackson 1984).

Exine – The outer layer of the wall of a spore or pollen grain.

Fitness – Adaptive value; the balance of genetic advantages and disadvantages that determines the ability of an individual organism (or genotype) to survive and reproduce in a given environment (Allaby 1992).

Flavonoid – a class of plant secondary metabolites based around a phenylbenzopyrone structure.

Genotype – the genetic constitution of an organism.

Granivory – feeding on seeds/grain.

Habitat fragmentation – when continuous stretches of habitat become divided into separate fragments by land use practices such as agriculture, housing development, logging, other resource extraction, and road construction; eventually, the separate fragments tend to become very small islands isolated from each other by areas that cannot support the original plant and animal communities.

Hermaphrodite – Bisexual; having both stamens and carpels in the same flower (Abercrombie et al. 1973).

Holotype. The single specimen designated as the type of a species by the original author at the time the species name and description were published.

Innate dormancy – when the seed will not germinate even if conditions are favorable (Harper 1959); this is in contrast to "enforced dormancy" whereby the seed does not germinate because conditions are not favorable (Harper 1959).

Isotype – A duplicate specimen of the holotype; a specimen that was part of a single gathering made by a collector at one time.

Loam – Soil texture class; soil material that contains 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand (Soil Science Society of America 2006).

Pericarp – the fruit wall, often with three distinct layers: endocarp, mesocarp and the outer exocarp.

Phenology – the impact of climate on the seasonal occurrence of plant species (e.g. climate effect on flowering date.

Precocious – developing early (e.g., a plant or tree that blossoms before its leaves appear or that produces fruits only a few years after planting).

Ranks – NatureServe Ranking system. For further information see NatureServe at internet site: http://www.natureserve.org/explorer/granks.htm.

- **G3** Vulnerable – Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.
- **G4** **Apparently Secure –** Uncommon but not rare (although it may be rare in parts of its range, particularly on the periphery), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern. Typically more than 100 occurrences and more than 10,000 individuals.
- **S1** **Critically Imperiled –** Critically imperiled in state because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the subnation. Typically 5 or fewer occurrences or very few remaining individuals (<1,000).
- **S2** **Imperiled –** Imperiled in the state because of rarity or because of some factor(s) making it very vulnerable to extirpation from the nation or subnation. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000).
- **S3** **Vulnerable –** Vulnerable in the state either because rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.
- **SU** **Unrankable –** Currently unrankable due to lack of information or due to substantially conflicting information about status or trends.

Ruderal – plants that are annual, small in stature, grow potentially rapidly, have limited lateral spread, reproduce only by seed and flower precociously (Grime et al. 1988). In contrast, Allaby (1992) gave a more general definition of "a plant that colonizes waste ground." Allaby's definition cannot be applied to *Chenopodium cycloides*.

***r*-Selected Species –** A species that shows the following characteristics: short lifespan; early reproduction; low biomass; and the potential to produce large numbers of usually small offspring in a short period of time.

Semelparous – (semelparity) Reproducing once and then dying

Succession – "The sequential change in vegetation either in response to an environmental change or induced by the intrinsic properties of the plants themselves. Classically, the term refers to the colonization of a new physical environment by a series of vegetation communities until the final equilibrium state, the climax, is achieved" (Allaby 1992).

REFERENCES

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

Abercrombie, M., C.J. Hickman, and M.L. Johnson. 1973. A dictionary of biology. Sixth edition. Penguin Books Ltd, Middlesex, U.K.

Adams, V., D. Marsh, and J. Knox. 2005. Importance of the seed bank for population viability and monitoring of an endangered wetland herb. Biological Conservation 124:425–436.

Aellen, P. and T. Just. 1943. Key and synopsis of the American species of *Chenopodium* L. American Midland Naturalist 30:47-76.

Alexander, H.M. and A.M. Schrag. 2003. Role of soil seed banks and newly dispersed seeds in population dynamics of the annual sunflower, *Helianthus annuus*. Journal of Ecology 91:987-998.

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

Alley, R.B. 2002. The Two-Mile Time Machine: Ice Cores, Abrupt Climate Change, and Our Future. Princeton University Press, Princeton, NJ.

Allred, K.W. 1999. New plant distribution records. *Chenopodium cycloides*. The New Mexico Botanist 13:7.

American Heritage Dictionary. 2004. The American Heritage® Dictionary of the English Language, Fourth Edition. Houghton Mifflin Company, Boston, MA.

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

ATV Source. 1999-2004. Internet site: http://www.atvsource.com/ [Accessed December 2004].

Bailey, R.G. 1995. Description of the ecoregions of the United States. Originally published in 1978 and reprinted in 1980 by the USDA Forest Service, Washington, D.C., as Miscellaneous Publication No. 1391. Re-compiled in 1995 and available online at: http://el.erdc.usace.army.mil/emrrp/emris/emrishelp2/bailey_s_ecoregions_map.htm.

Barderas, R., M. Villalba, M. Lombardero, and R. Rodríguez. 2002. Identification and characterization of Che a 1 allergen from *Chenopodium album* pollen. International Archives of Allergy and Immunology 127:47-54.

Barderas, R., M. Villalba, C.Y. Pascual, E. Batanero, and R. Rodriguez. 2004. Profilin (Che a 2) and polcalcin (Che a 3) are relevant allergens of *Chenopodium album*. Journal of Allergy and Clinical Immunology 113:1192-1198.

Bassett, I.J. and C.W. Crompton. 1971. IOPB[2] Chromosome number reports. Taxon 20:786-787.

Bates, R.L. and J.A. Jackson. 1984. Dictionary of geological terms. Third edition. Anchor Books - Doubleday, New York, NY.

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

Benedict, R.A., P.W. Freeman, and H.H. Genoways. 1996. Prairie legacies – Mammals. *In*: Prairie Conservation. Island Press, Covela, CA.

Biedenbender, S.H., B.A. Roundy, and L. Abbott. 1995. Replacing Lehmann lovegrass with native grasses. Pages 52-56 *in* B.A. Roundy, E. McArthur, H. Durant, J.S. Haley, and D.K. Mann, compilers. Proceedings: Wildland shrub and arid land restoration symposium, Las Vegas, NV. USDA Forest Service, Gen. Tech. Rep. GTR-INT-315, pp. 52-56. Ogden, UT.

Biota of North America Program. 1998. Biota of North America Program (BONAP) database. Available online at: http://www.csdl. tamu.edu/FLORA/b98/check98.htm [Accessed June 2004].

[2]IOPB = International Organization of Plant Biosystematists

Bogaard, A. 2004. The nature of early farming in Central and south-east Europe. Documenta Praehistorica 31:49-58.

Bragg, T.B. and A.A. Steuter. 1996. Prairie ecology – the mixed prairie. Pages 53-66 *in* F.B. Samson and F.L. Knopf, editors. Prairie Conservation – preserving North America's most endangered ecosystem. Island Press, Covela, CA.

Brewer, N. 2004. USDA Cimarron National Grassland, Elkhart, Kansas. Personal communication.

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

Brown, D.E., F. Reichenbacher, and S.E. Franson. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City, UT.

Brown, J.S. and D.L. Venable. 1986. Evolutionary ecology of seed-bank annuals in temporally varying environments. American Naturalist 127:151-171.

Burns, R.M. and B.H. Honkala. 1990. Silvics of North America. Glossary. Agriculture Handbook 654, USDA Forest Service, Washington, D.C.

Butler, I. 2004. Information Technology Analyst, Oklahoma Biological Survey, Norman, OK. Personal communication.

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

Carter, M.R., G.R. Manglitz, M.D. Rethwisch, and K.P. Vogel. 1988. A seed midge pest of big bluestem. Journal of Range Management 41:253-254.

Center for Plant Conservation. Undated. National Collection of Endangered Plants Database. Available online at: http://www.centerforplantconservation.org/.

Christy, J.R. 2000. Written Testimony of John R. Christy, University of Alabama in Huntsville. To the Senate Committee on Commerce, Science and Transportation, 17 May 2000. Available online at: http://www.gcrio.org/OnLnDoc/pdf/pdf/christy000517.pdf [Accessed January 2006].

Clemants, S.E. and S.L. Mosyakin. 2003. *Chenopodium* Linnaeus, Chenopodiaceae. Pages 275-299 *in* Flora of North America Editorial Committee. Flora of North America Volume 4, Magnoliophyta: Caryophyllidae, part 1. Oxford University Press, New York, NY.

Colorado Native Plant Society. 1997. Rare Plants of Colorado. Second edition. Falcon Press Publishing Co., Helena, MT.

Colorado Natural Heritage Program. 2004. Data compilation for *JnJ Associates* LLC, completed 2004. Unpublished report. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Colorado Natural Heritage Program. 2006. Data compilation for *JnJ Associates* LLC, completed 2006. Unpublished report. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Committee on the Science of Climate Change - National Research Council. 2001. Climate Change Science: An Analysis of Some Key Questions. National Academy Press, Washington, D.C. Available online at: http://newton.nap.edu/books/0309075742/html/R1.html.

Conrod, W. 2004. Natural Resource Specialist, White Sands National Monument, National Park Service, NM. Personal communication.

Correll, D.S. and M.C. Johnston. 1970. Manual of the Vascular Plants of Texas Research Foundation, Renner, TX.

Cousens, R. and M. Mortimer. 1995. Dynamics of weed populations. Cambridge University Press, Cambridge, UK.

Cowan, M.M. 1999. Plant Products as Antimicrobial Agents. Clinical Microbiology Reviews 12(4):564-582.

Crawford D.J. 1975. Systematic relationships in the narrow-leaved species of *Chenopodium* of the western United States. Brittonia 27:279-288.

Davis, A.S., J. Cardina, F. Forcella, G.A. Johnson, G. Kegode, J.L. Lindquist, E.C. Luschei, K.A. Renner, C.L. Sprague, and M.M. Williams, II. 2005. Environmental factors affecting seed persistence of annual weeds across the U.S. corn belt. Weed Science 53:860–868.

Dick-Peddie W.A. 1993. New Mexico Vegetation - past, present, and future. University of New Mexico Press, Albuquerque, NM.

Donlan , J., H.W. Greene, J. Berger, C.E. Bock, J.H. Bock, D.A. Burney, J.A. Estes, D. Foreman, P.S. Martin, W. Roemer, F.A. Smith, and M.E. Soulé. 2005. Re-wilding North America. Nature 436(18):913-914.

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

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

Elzinga, C., D. Salzer, J. Willoughby, and J. Gibbs. 2001. Monitoring Plant and Animal Populations. Blackwell Scientific Publishing, Boston, MA.

Endangered Species Act. 1973. As amended through the 100th Congress. US Code, Title 16 1531 et seq. U.S. Fish and Wildlife Service and US Department of Interior, Washington, D.C.

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

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

Freas, K.E. and P.R. Kemp. 1983. Some Relationships between Environmental Reliability and Seed Dormancy in Desert Annual Plants. Journal of Ecology 71:211-217.

Freeman, C.C. 1989. Rare plants of the Cimarron National Grassland, Kansas. Kansas Biological Survey Report No. 42, Lawrence, KS.

Freeman, C.C. 2004. Curator, R.L. McGregor Herbarium, Natural History Museum and Biodiversity Research Center, and associate professor, Department of Ecology and Evolutionary Biology, University of Kansas and scientist with the Kansas Natural Heritage Inventory. Personal communication.

Gabriel, H.W. and S.S. Talbot. 1984. Landscape and vegetation ecology for Alaska. Glossary. BLM-Alaska Technical Report 10. USDI Bureau of Land Management, Alaska State Office, Anchorage, AK.

Garvin S.C. and S.E. Meyer. 2003. Multiple mechanisms of seed dormancy regulation in shadscale (*Atriplex confertifolia*: Chenopodiaceae). Canadian Journal of Botany 81:301-310.

Gates, F.C. 1934. Wild flowers in Kansas. Report of the Kansas Board of Agriculture. Kansas State Printing Plant, Topeka, KS.

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

Goatcher, W.D. and D.C. Church. 1970. Taste responses in ruminants. IV. Reactions of pygmy goats, normal goats, sheep and cattle to acetic acid and quinine hydrochloride. Journal of Animal Science 31:373-382

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

Grant, G. and G. Gorman 2004. "Today the American Sand Association met with the Center for Biological Diversity (CBD) to discuss management options at The Imperial Sand Dunes Recreation Area (ISDRA)." Press Release – American Sand Association December 7, 2004, American Sand Association, La Verne, CA.

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

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

Guralnik, D. 1982. Webster's New World Dictionary. Simon and Schuster, New York, NY.

Hammerschmidt, R. 1999. Phytoalexins: What Have We Learned After 60 Years? Annual Reviews of Phytopathology 37:285-306.

Harper, J.L. 1977. Population Biology of Plants. Academic Press, London, U.K.

Harrington, H.D. 1964. Manual of the plants of Colorado. Second edition. Sage Books, Denver, CO.

Harrington, H.D. and L.W. Durrell. 1979. How to identify plants. Swallow Press, Athens, OH.

Hazlett, D.L. 1997. The Comanche National Grasslands: A preliminary survey for threatened and endangered plant species. Unpublished document. USDA Forest Service, Comanche National Grasslands, La Junta, CO.

Hazlett, D.L. 2004.Vascular Plant Species of the Comanche National Grassland in Southeastern Colorado. General Technical Report RMRS-GTR-130. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Hendrix, S.D. 1988. Herbivory and its impact on plant reproduction. Pages 246-263 *in* J. Lovett Doust, and L. Lovett Doust, editors. Plant Reproductive Ecology: Patterns and strategies. Oxford University Press, Oxford, U.K.

Hermann-Parker, S. 1976. Life history of *Psoralea esculenta* Pursh (Leguminosae): Reproductive biology and interactions with a curculionid weevil. Pages 86-91 *in* D.C. Glen-Lewin and R.Q. Landers Jr., editors. Proceedings of the fifth Midwest Prairie Conference. Iowa State University, Ames, IA.

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

Houle, G., M.F. McKenna, and L. Lapointe. 2001. Spatiotemporal dynamics of *Floerkea proserpinacoides* (Limnanthaceae), an annual plant of the deciduous forest of eastern North America. American Journal of Botany 88:594-607.

Integrated Taxonomic Information System. 2006. ITIS, the Integrated Taxonomic Information System - an authoritative taxonomic information on plants, animals, fungi, and microbes of North America and the world. Last Updated 06-Dec-2005. Interactive database available online at: http://www.itis.usda.gov [Accessed January 2006].

Jennings, W.F. 1996. Species Abstract for *Chenopodium cycloides*. Unpublished document prepared for the U.S. Fish and Wildlife, Albuquerque, NM.

Joern, A. and K.H. Keeler, editors. 1995. The changing prairie – North American Grasslands. Oxford University Press, New York, NY.

Kansas Biological Survey. 2004. Data compilation for *JnJ Associates* LLC. Unpublished report. Kansas Biological Survey, Lawrence, KS.

Karron, J.D., Y.B. Linhart, C.A. Chaulk, and C.A. Robertson. 1988. Genetic structure of geographically restricted and wide-spread species of *Astragalus* (Fabaceae). American Journal of Botany 75:1114-1119.

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

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

Kemp, P.R. 1989. Seed banks and vegetation processes in deserts. Pages 257-282 *in* M.A. Leck, V.T Parker, R.L. Simpson, editors. Ecology of soil seed banks. Academic Press, New York, NY.

Kendall, B.E. and G.A. Fox. 2002. Variation among individuals reduces demographic stochasticity. Conservation Biology 16:109-116.

Kettler S.M., N.D. Lederer, D. Bacher, and S. Spackman. 1993. Pike and San Isabel National Forests and Comanche and Cimarron National Grasslands, plants of special concern. Unpublished document. December. Colorado Natural Heritage Program, Boulder, CO.

Knapp, A.K., J.M. Blair, J.M. Briggs, S.L. Collins, D.C. Hartnett, L.C. Johnson, and E.G. Towne. 1999. The keystone role of bison in North American tallgrass prairie. BioScience 49:39-50.

Krueger, W.C., W.A. Laycock, and D.A. Price. 1974. Relationships of taste, small, sight, and touch to forage selection. Journal of Range Management 27:258-262.

Ladyman, J.A.R. 2000. Progress Report - Development of management strategies for protected plant species in highway right-of-ways. Unpublished report. Prepared for and submitted to the New Mexico State Highway and Transportation Dept., Santa Fe, NM.

Laurenroth, W.K. and D.G. Milchunas. 1992. Short-grass steppe. Pages 183-162 *in* R.T. Coupland, editor. Ecosystems of the world Vol. 8A: Natural grasslands, Introduction and western hemisphere. Elsevier, New York, NY.

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

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

Mack, R.N. and J.N. Thompson. 1982. Evolution in steppe with few large hooved mammals. The American Naturalist 119(6):757-773.

Manske, L.L. 2000. Prehistorical Conditions of Rangelands in the Northern Great Plains. Annual Report, Dickinson Research Extension Center, North Dakota State University, Dickinson, ND. Available online at: http://www.ag.ndsu.nodak.edu/dickinso/research/1999/range99e.htm & http://rangelandswest.org/db/az/template5.asp?level1=science&level2=ecology&level3=ecosystems.

Martin, W.C. and C.R. Hutchins. 1980. A Flora of New Mexico. Strauss and Cramer, Hirschberg, Germany.

Martin, J.H., W.H. Leonard, and D.L. Stamp. 1976. Principles of field crop production. Macmillan Publishing Co, Inc. New York, NY.

Mayland, H.F. and G.E. Shewmaker. 1999. Plant attributes that affect livestock selection and intake. *In*: K.I. Launchbaugh, K.D. Sanders, and J.C. Mosely, editors. Grazing behavior of livestock and wildlife. Idaho Forest, Wildlife and Range Experiment Station Bulletin #70, University of Idaho, Moscow, ID.

McClaran, M.P. and M.E. Anable. 1992. Spread of introduced Lehmann lovegrass along a grazing intensity gradient. Journal of Applied Ecology 29:92-98.

McGinnies, W.J., W.A. Laycock, T. Tsuchiya, C.M. Yonker, and D.A. Edmonds. 1988. Variability within a native stand of blue grama. Journal of Range Management 41:391-394.

McMahon, P.B., K.F. Dennehy, R.L. Michel, M.A. Sophocleous, K.M. Ellett, and D.B. Hurlbut. 2003. Water movement through thick unsaturated zones overlying the Central High Plains Aquifer, Southwestern Kansas, 2000–2001. U.S. Geological Survey Water-Resources Investigations Report 03–4171.

McPherson, G.R. 1995. The role of fire in the desert grasslands. Pages 130-151 *in* M.P. McClaran and R.T. Van Devender, editors. The desert grassland. The University of Arizona Press, Tucson, AZ.

Menges, E.S. 1991. The application of minimum viable population theory to plants. Pages 45-61 *in* D.A. Falk and K.E. Holsinger, editors. Genetics and conservation of rare plants. Oxford University Press, New York, NY.

Meyer, S.E., S.G. Kitchen, and S.C. Carlson. 1995. Seed germination timing patterns in intermountain *Penstemon*. American Journal of Botany 82:377-389.

Meyer S.E., S.L. Carlson, and S.C. Garvin. 1998. Seed germination regulation and field seed bank carryover in shadscale (*Atriplex confertifolia*: Chenopodiaceae). Journal of Arid Environments 38:255-267.

Meyer S.E., D. Quinney, and J. Weaver. 2006. A stochastic population model for *Lepidium papilliferum* (Brassicaceae), a rare desert ephemeral with a persistent seed bank. American Journal of Botany 93:891-902.

Millennium Seed Bank Project. Undated. Millennium Seed Bank Project - an international collaborative plant conservation initiative, Royal Botanic Gardens, Kew, UK. Available online at: http://www.kew.org/msbp/.

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

Moerman, D.E. 1998. Native American ethno-botany. Timber Press, Portland, OR.

Morrall, R.A.A. and R.J. Howard. 1974. Leaf spot disease of graminoids in native grassland. Matador Project Technical Report No. 48. University of Saskatchewan, Saskatchewan, Canada.

Moseley, R.K. 1989. Report on the conservation status of *Phacelia inconspicua* in Idaho. Unpublished report to the Idaho Department of Fish and Game, Boise, ID.

Mosyakin, S.L. and S.E. Clemants. 1996. New infrageneric taxa and combinations in *Chenopodium* L. (Chenopodiaceae). Novon 6:398-403.

NatureServe. 2004. NatureServe element occurrence guidelines. NatureServe, Arlington, VA. Available online at: http://www.natureserve.org/explorer [Accessed: November 2004].

NatureServe. 2006. NatureServe Explorer: An online encyclopedia of life [web application]. Version 4.7. NatureServe, Arlington, VA. Available online at: http://www.natureserve.org/explorer [Accessed: June 6, 2006].

National Oceanic and Atmospheric Administration. 2004. CoRIS - NOAA's Coral Reef Information System (http://coris.noaa.gov/welcome.html). Glossary section. Internet site: http://www6.nos.noaa.gov/coris/glossary.lasso?letter=p [Accessed July 2004].

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

Nebraska Natural Heritage Program. 2004. Data compilation for *JnJ Associates* LLC, completed 2004. Unpublished report. Nebraska Natural Heritage Program Nebraska Game and Parks Commission, Lincoln, NE.

Nellessen, J. 2000. *Quercus havardii*. *In*: J.K. Francis, editor. Wildland Shrubs of the United States and its Territories: Thamnic Descriptions. General Technical Report IITF-WB-1. USDA Forest Service International Institute of Tropical Forestry and Shrub Sciences Laboratory, UT.

Nelson, A. 1902. Contributions from the Rocky Mountain Herbarium, IV. Some Chenopodiaceae. Botanical Gazette 34:355-364.

New York Botanical Garden. Herbarium records. Available online at: http://www.nybg.org/bsci/herb/ [Accessed September 2004; updated June 2006].

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

OffRoadDirectory.net. 2004.The online directory to the world of off-roading. . Internet site: http://offroaddirectory.net/atv.htm [Accessed December 2004].

Olson, S. 2004. Botanist, Pike and San Isabel National Forests and Comanche and Cimarron National Grasslands, Pueblo, CO. Personal communication.

Ostlie, W.R., R.E. Schneider, J.M. Aldrich, T.M. Faust, R.L.B. McKim, and S.J. Chaplin. 1997. The Status of Biodiversity in the Great Plains. The Nature Conservancy, Arlington, VA, and The U.S. Environmental Protection Agency under contract #X007803-01-3.

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

Peden, D.G. et al. The trophic ecology of *Bison bison* L. on shortgrass plains. Journal of Applied Ecology 11:489-498.

Peterson, R. and C.S. Boyd. 1998. Ecology and management of sand shinnery communities: a literature review. USDA Forest Service. RMRS-GTR-16. Rocky Mountain Research Station, Fort Collins, CO.

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

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 2000. Environmental and Economic Costs of Nonindigenous Species in the United States. BioScience 50(1):53-65.

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

Plumb, G.E. and J.L. Dodd. 1993. Foraging ecology of bison and cattle on northern mixed prairie: Implications for Natural Areas management. Ecological Applications 3:631-643.

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

Puntieri, J.G. and R.L. Hall. 1996. Density-dependent mortality, growth, and size inequality in roadside populations of the annual herb *Galium aparine* L. Ecological Research 11(2):121-137.

Rolfsmeier, S.B., R.F. Steinauer, and D.M. Sutherland. 1999. New floristic records for Nebraska-5. Transactions of the Nebraska Academy of Sciences 25:15-22.

Rosiere, R.E. Undated. Rangeland Management Notes. R.E. Rosiere, Professor of Range Management, Certified Professional in Rangeland Management (CP00-31), Tarleton State University, Texas A&M University System. Available online at: http://www.tarleton.edu/%7Erange/Historical%20Note/coverhist.html & http://www.tarleton.edu/%7Erange/Shrublands/Miscellaneous/miscshrub.html.

Rubin, J.M. and N.S. Weiss. 1974. Practical points in allergy. Medical Examination Publishing Company Inc., Flushing, NY.

Rydberg, P.A. 1932. Flora of the prairies and plains of central North America. New York Botanical Garden, New York, NY.

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

Ryke, N., L. McMartin, and D. Winters. 1993. Threatened, endangered, and sensitive species list for the Pike and San Isabel National Forests and Comanche and Cimarron grasslands. Unpublished document. USDA Forest Service, Pike and San Isabel National Forests and Comanche and Cimarron National Grasslands, Pueblo, CO.

Samson, F.B. and F.L. Knopf. 1996. Prairie Conservation – preserving North America's most endangered ecosystem. Island Press, Washington, D.C.

Samter, M. and O.C. Durham. 1955. Regional allergy of the United States, Canada, Mexico, and Cuba. C.C. Thomas, Springfield, IL.

Schmutz, E.M., E.L. Smith, P.R. Ogden, M.L. Cox, J.O. Klemmedson, J.J. Norris, and L.C. Fierro. 1991. Desert grassland. Pages 337–362 *in* R.T. Coupland, editor. Natural grasslands; introduction and Western Hemisphere. Ecosystems of the world. Volume 8A. Elsevier, Amsterdam, The Netherlands.

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

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

Sidle, J.G. 1998. Matrix of "Listed" Species in the Great Plains of North America and their Occurrence on National Grasslands. Great Plains National Grasslands USDA Forest Service, Chadron, NE. Document accessible on the Internet. Internet site: http://www.fs.fed.us/r2/nebraska/gpng/matrix/matrix.html [Accessed December 2004].

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

Sivinski, R. 1995. *Chenopodium cycloides* update. Unpublished communication to U.S. Fish and Wildlife Service, Albuquerque, NM.

Sivinski, R. 1996. New plant distribution records. *Chenopodium cycloides*. The New Mexico Botanist 3:6

Sivinski, R. and K. Lightfoot. 1995. Inventory of rare and endangered plants of New Mexico. Misc. Publication No. 4. New Mexico Forestry and Resources Conservation Division, Energy, Mineral and Natural Resources Department, Santa Fe, NM.

Society of Range Management. 2003. A glossary of terms used in range management. Second edition. Society for Range Management, Lakewood, CO.

Soil Science Society of America. 2006. Internet glossary of soil science terms. Available online at: http://www.soils.org/sssagloss/index.php. Also available as a hardcopy edition published 2001, Soil Science Society of America, Madison, WI.

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, USDA Forest Service, and the U.S. Fish and Wildlife Service by the Colorado Natural Heritage Program, Fort Collins, CO.

Stokes, P. and P. Rowley-Conwy. 2002. Iron Age cultigen? Experimental return rates for Fat Hen (*Chenopodium album* L.). Environmental Archaeology 7:95-99.

Stubbendieck, J.S., L. Hatch, and C.H. Butterfield. 1992. North American Range Plants. Fourth edition. University of Nebraska Press, Lincoln, NE.

Standley, P.C. 1916. Chenopodiaceae. North American Flora: 1-93.

Stoltzenburg, W. 2006. Where the Wild Things Were. The recent Nature paper proposing to bring cheetahs, lions, and elephants to North America raised a wild rumpus. But are the critics missing the point? Conservation in Practice 7(1):28-34.

Swingle, D.B. 1946. A textbook of systematic botany. McGraw-Hill Book Company, Inc., New York, NY.

Telewski, F.W. and J. Zeevaart. 2002. The 120th year of the Beal seed viability study. American Journal of Botany 89(8):1285-1288.

Texas Parks and Wildlife Department. 2004. Data compilation for *JnJ Associates* LLC. Unpublished report. Wildlife Diversity Database, Texas Parks and Wildlife Department, Austin, TX.

Tweto, O. 1978. Geologic map of Colorado. US Geological Survey, Denver, CO.

United States National Herbarium, Smithsonian Institution, Washington, D.C. The Type Specimen Register. Available online at: http://ravenel.si.edu/botany/types/ [Accessed December 2004].

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

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

U.S. Environmental Protection Agency. 1998a. Climate Change and South Dakota EPA 236-F-98-007x Office of Policy, Planning and Evaluation, Climate and Policy Assessment Division, Washington, D.C.

U.S. Environmental Protection Agency. 1998b. Climate Change and New Mexico. United States Environmental Protection Agency publication. EPA 236-F-98-007p. Washington, D.C.

U.S. Fish and Wildlife Service. 1993. Endangered and threatened wildlife and plants; review of plant taxa for listing as endangered or threatened species. Federal Register. September 30. 50CFR Part 17, Vol. 58, No. 188:51144-51190.

U.S. Fish and Wildlife Service. 1996. Endangered and threatened wildlife and plants; review of plant and animal taxa that are candidates for listing as endangered or threatened species. Federal Register. February 28. 50CFR, Part 17, Vol. 61, No. 40:7596-7613.

U.S. Fish and Wildlife Service. 2005. New Mexico Listed and Sensitive Species Lists – The webpage was last modified on: December 21, 2005.Available online at: http://www.fws.gov/ifw2es/NewMexico/SBC_intro.cfm.

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

USDA Forest Service. 1984. Pike and San Isabelle National Forest and Cimarron and Comanche Grasslands Land and Resource Management Plan. USDA Forest Service, Pueblo, CO.

USDA Forest Service. 1995. FSM 2600 – Wildlife, Fish and Sensitive Plant Habitat Management. Amendment No. 2600-95-6, effective 6/23/95. Chapter 2670 – Threatened, Endangered, and Sensitive Plants and Animals. Available online at: http://www.fs.fed.us/im/directives/fsm/2600/2670-2671.txt and http://www.fs.fed.us/im/directives/fsm/2600/2670_contents.txt.

USDA Forest Service. 1999. TES Plant Management Strategy, Grand Mesa, Uncompahgre and Gunnison, San Juan, Rio Grande, Pike-San Isabel National Forests and Comanche-Cimarron National Grasslands. Five year action plan 1999 to 2003. USDA Forest Service GMUG, Delta, CO.

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

USDA Forest Service Pacific Northwest Region. 2003. Wallowa-Whitman National Forest Comprehensive Management Plan FEIS - Hells Canyon National Recreation Area. Glossary. Wallowa-Whitman National Forest, Baker City, OR.

USDI Bureau of Land Management. 2001. BLM Manual 6840 – Special Status Species Management. Revised 1/17/01. Release 6-121. Available online at: http://www.blm.gov/ca/pdfs/pa_pdfs/biology_pdfs/6840_ManualFinal.pdf.

USDI National Park Service. 2001. Environmental Assessment/Assessment of Effect - Complete The Removal of African Oryx, White Sands National Monument, Otero and Doña Ana Counties, New Mexico. USDI National Park Service, White Sands National Monument, NM.

USDI National Park Service. 2002. Environmental Assessment/Assessment of Effect - Modify road alignment, parking areas, Otero County, New Mexico. Prepared by: USDI National Park Service, White Sands National Monument, NM.

Vavra, M., R.W. Rice, R.M. Hansen, and P.L. Sims. 1977. Food Habits of Cattle on Shortgrass Range in Northeastern Colorado. Journal of Range Management 30(4):261-263.

Venable, D.L. and L. Lawlor. 1980. Delayed germination and dispersal in desert annuals: Escape in space and time. Oecologia 46(2):272-282.

Wahl, H.A. 1952-53. A preliminary study of the genus *Chenopodium* in North America. Bartonia 27:1-46.

Warnock, B.H. 1974. Wildflowers of the Guadalupe Mountains and Sand Dune Country Texas. Sul Ross State University, Alpine, TX.

Warnock, B.H. 1977. Wildflowers of the Davis Mountains and Marathon Basin Texas. Sul Ross State University, Alpine, TX.

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

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

Whitson, T.D., L.C. Burrill, S.A. Dewey, D.W. Cudney, B.E. Nelson, R.D. Lee, and R. Parker. 1991. Weeds of the West. Western Society of Weed Science in cooperation with the Western US Land Grant Universities Cooperative Extension Service and the University of Wyoming, WY.

Willms, W.D. 1995. Grazing effects on germinable seeds on the fescue prairie. Journal of Range Management 48: 423-430.

Wisdom, C.S., C.S. Crawford, and E.F. Aldon. 1989. Influence of insect herbivory on photosynthetic area and reproduction in *Gutierrezia* species. Journal of Ecology 77:685-692.

Wodehouse, R.P. 1945. Hayfever plants. Chronica Botanica Company, Waltham, MA.