Species Status Assessment for the Prairie Bush-Clover (*Lespedeza leptostachya*)

Photo: Phil Delphey, USFWS

U.S. Fish and Wildlife Service
Midwest Region
Bloomington, Minnesota

August 2021. Version 1.0

Acknowledgements

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Suggested Citation:

U.S. Fish and Wildlife Service. 2021. Species Status Assessment Report for Prairie Bush-Clover (*Lespedeza leptostachya*). September 2021 (Version 1.0). Midwest Region, Bloomington, Minnesota. 59pp. + appendices.

EXECUTIVE SUMMARY

This report summarizes the results of the species status assessment (SSA) conducted for prairie bush-clover (*Lespedeza leptostachya*). The prairie bush-clover is a hardy Midwestern prairie plant species with naturally low genetic diversity that is capable of self-fertilization. The species both historically and currently occurs in Illinois, Iowa, Minnesota, and Wisconsin. Primary threats to the species include land conversion and the encroachment of dominant vegetation and non-native, invasive plant species. Conservation actions that protect land from conversion and that foster appropriate management strategies to promote seedling establishment have the greatest influence on population status.

The Service listed the species as threatened under the Endangered Species Act in 1987. At that time there were 26 known extant occurrences across Illinois, Iowa, Minnesota, and Wisconsin. As of 2020, prairie bush-clover occurs in all four states, with 113 extant populations (Figure 1.2). The species is listed as endangered in Illinois and Wisconsin and threatened in Iowa and Minnesota.

We used the best available information, including peer-reviewed scientific literature, survey data provided by state agencies and non-governmental organizations from Illinois, Iowa, Minnesota, and Wisconsin, and first-hand accounts from state biologists and other species experts. We defined prairie bush-clover populations based on known occurrence locations defined by state agencies.

We considered prairie bush-clover's ecological requirements for survival and reproduction at the individual, population, and species levels and described the factors influencing species viability. We used the three conservation biology principles of resiliency, representation, and redundancy (collectively the 3Rs) to describe the species' current and plausible future condition.

We evaluated resiliency at the population level using element occurrence (EO) rank, which incorporates population size, habitat quality, amount of contiguous suitable habitat, and protection status. We used the calculated EO rank to categorize each population as being in excellent, good, fair, or poor condition. To evaluate representation, we defined representative categories based on the prairie type. Prairie bush-clover is found in dry prairie, dry-mesic prairie, bedrock prairie, and mesic prairies. Each prairie type has subtle differences and may be influenced by natural or human processes differently. We examined prairie bush-clover redundancy across the 113 extant populations found in Illinois, Iowa, Minnesota, and Wisconsin by the spatial distribution of calculated EO ranks.

Of the 113 extant prairie bush-clover populations, 37 (33%) currently exhibit excellent or good resiliency. The majority, 76 populations (67%), of populations rangewide currently exhibit fair or poor resiliency. Twelve populations are currently considered extirpated. Across all four states, 54 prairie bush-clover populations or 48% of extant populations are owned by a conservation organization (federal, state, or non-profit) or are permanently protected for the purpose of conservation. Twenty-eight protected populations are in excellent or good condition and 26 are in fair or poor condition.

We evaluated two plausible scenarios to assess the future viability of prairie bush-clover. Both scenarios were examined at 2060 and 2100 or 40 and 80 years into the future. This time frame was selected due to the relative longevity of the species, a single plant can live 30 years and feedback from species experts indicated that the viability of a population was unlikely to change within 30 years for that reason. We used protection status and management coupled with habitat quality as metrics for assessing population resiliency at 2060 and 2100 as a result of the two scenarios. Consistent with current condition, we used the calculated EO ranks to assess future resiliency conditions for each population.

The number of extant populations is projected to decline from 113 to 78-84 in 2060 and to 65-71 in 2100. In general, future resiliency is anticipated to decrease at all sites that are currently unprotected or those with no ongoing habitat management in place. Approximately, 40-45 (35-40%) of populations are anticipated to decline in resiliency by 2060 and 73-76 (65-67%) are anticipated to decline in resiliency by 2100. In 2060 we project there will be 11-12 populations in excellent condition and 19-20 populations in good condition; 48-52 populations will be in fair to poor condition and 29-35 populations are projected to be extirpated (Table 4.1). By 2100, we project there will be 9 populations in excellent condition, 16-17 in good condition, 40-45 populations in fair to poor condition (with the majority of those in poor condition), and 42-48 populations extirpated.

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CHAPTER 1. BACKGROUND AND SPECIES ECOLOGY AND RESOURCE NEEDS (v. July 15, 2021)

Background

This report summarizes the results of a species status assessment (SSA) conducted for prairie bush-clover (*Lespedeza leptostachya*). This SSA report, the product of conducting an SSA, is intended to be a concise review of the species' biology and factors influencing the species, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. For a more detailed description of the analytical approach and framework used for this SSA, see Appendix A.

Prairie bush-clover was recommended for federal listing in the Smithsonian Institute report on endangered, threatened, or extinct plants submitted to Congress on January 9, 1975. The species was identified as threatened in the report. Prairie bush-clover was included as a category-1 species in a notice of review for plants published in the Federal Register (45 FR 82480) December 15, 1980. Category 1 includes taxa for which the Service had sufficient biological information to support their being proposed to be listed as endangered or threatened (45 FR 82480). The Service listed prairie bush-clover as threatened January 9, 1987 in the Federal Register (52 FR 781-784). At that time, there were 26 known extant populations in Illinois, Iowa, Minnesota, and Wisconsin. As of 2020 (over 30 years later), there are 113 known extant populations across the four states. Because of the apparent change in rangewide status of prairie bush-clover, the Service initiated a discretionary species status assessment in July 2020 to inform the upcoming 5-year review and to compile and analyze the best available scientific data regarding the species' biology, species viability, and current status.

Species Ecology and Resource Needs

Description and Taxonomy

Prairie bush-clover is an herbaceous, perennial member of the pea family (Fabaceae) with erect stems that may grow up to 1 meter (3 feet) tall (USFWS 1988, p. 1). The plant has linear or narrow oblong-shaped leaflets that are in clusters of three. The leaflets are often 2-4 cm (0.8-1.6 inches) long and 2-8 mm (0.1-0.3 inches) wide with green coloration on the top of the leaflet and silvery-white, silky hairs beneath (Fox 1945, p. 225). Longer terminal leaflets are less than half as wide as they are long with petioles that range from 2-10 mm (0.1-0.4 inches) in length (USFWS 1988, p. 1). Prairie bush-clover flowers occur individually or paired on spikes 2-4 cm (0.8-1.6 inches) long and 5-8 mm (0.2-0.3 inches) thick (Fernald 1950, p. 927). Later in the growing season, the species produces white, wooly fruit pods that are 3-4 mm (0.1-0.2 inches) long, which is approximately equal to or barely exceeding the length of the calyx, or the outermost portion of a flower (Gleason 1952, p. 436).

Prairie bush-clovers produce both chasmogamous (open, potentially outcrossing) and cleistogamous (closed, self-pollinating) flowers. A single plant can have both types of flowers, and thus be able to reproduce through cross-pollination, or it may produce only closed, self-pollinating flowers (USFWS 1988, p. 1). Flower type can be differentiated by appearance. Chasmogamous flowers are showy and rely on pollinators for cross-pollination. They range in color from white or yellow-white (Fox 1945 p. 224; Gambill 1953, p. 78; Clewell 1966a, p. 382;)

to light pink with a magenta mark in in the center (Sather 1986; Smith 1986; Figure 1.1). Petals are approximately between 4 and 6 mm (approximately 0.2 inches) long (USFWS 1988, p. 1). Cleistogamous flowers never open and have cream-colored, pale petals. They develop in and are surrounded by the calyx, which is generally 4.5 to 5 mm (0.18-0.20 inches) when fully developed (Gleason and Cronquist 1963, p. 415). Within the closed petals, the reproductive parts of the flower, filaments and styles, are smaller and allow pollen to be transferred directly without the aid of a pollinator (Cole and Biesboer 1992, p. 568).

Figure 1.1 Mature plant with chasmogamous flowers (light pink). Photo credit: Phil Delphey USFWS

Reproduction and Gene Flow

Prairie bush-clovers are capable of self-pollination but may also rely on cross pollination via wind or pollinators. All prairie bush-clover plants are capable of self-pollination with cleistogamous flowers, but some are able to reproduce sexually by having both chasmogamous and cleistogamous flowers. Chasmogamous flowers are showy and rely on pollinators for cross-pollination. Pollinators are relatively unknown for prairie bush-clover; however, the following species have been documented on individual plants, hairstreak butterfly (*Satyrium* sp.), western honeybee (*Apis mellifera*), weevil species, goldenrod soldier beetle (*Chaliognathus pennsylvanicus*), skeletonizing leaf beetle (*Scelolyperus* sp.) or flea beetle (*Altica* sp.), halictid bee (Halictidae), snout moth (Pyralidae), Pennsylvania ambush bug (*Phymata pennsylvanica*), and common walking stick (*Diapheromera femorata*) (Banai 2008, p. 11). Gene flow in the species appears to be limited due to the dominance of cleistogamous flowers in prairie bush-clover populations; however sites in Illinois were not included in the study (Cole and Biesboer 1992, p. 573; Bowles and Bell 1998, p. 6).

Habitat and Ecology

Prairie bush-clover is endemic to Midwestern prairies in Illinois, Iowa, Minnesota, and Wisconsin. The majority of populations at the time of listing were found on gentle, north-facing slopes of 10-15 degrees. Surveys conducted over the last thirty years have found that the species can occur on north, west, and east-facing slopes. Plants are usually found around the edges of slopes or within barely concave areas that are not subject to nutrient or herbicide input from drain-tile discharge (Nancy Sather, Minnesota Department of Natural Resources (MNDNR), retired, pers. comm, June 30, 2021). Soil types include, but are not limited to fine silty loam, sand, fine sandy loam, or clay loam (USFWS 1988, p. 2; Cole and Biesboer 1992, p. 567). Prairie bush-clover also occurs at bedrock outcrop sites interspersed with upland prairie (USFWS 1988, p. 8).

The species occurs on disturbed sites or prairie habitats that have been previously mowed, burned, cultivated, or grazed, in addition to undisturbed remnant prairie sites (USFWS 1988, p. 7, Nancy Sather, MNDNR, retired, pers. comm., June 30, 2021). Prairie bush-clover can thrive in great numbers on actively grazed sites (Nancy Sather, MNDNR, retired, pers. comm., June 30, 2021). The known range of prairie bush-clover overlapped with the bison (*Bison bison*) range and, as a result, the species co-evolved with grazing (Todd Bittner, Cornell Botanical Garden, pers. comm., June 22, 2021). Many sites that are currently protected in Minnesota are former pastures where the species was discovered only when systematic grassland surveys targeted them as potential habitat. At one heavily grazed pasture site in Minnesota, 1,117 prairie bush-clover plants shorter than 10 cm (3.9 inches) were discovered. The population was similar to other formerly grazed sites where flowering prairie bush-clover plants are visible approximately three years after the cessation of grazing (Nancy Sather, MNDNR, retired, pers. comm., June 30, 2021). At formerly cultivated sites, the species was visible and widely dispersed across the site, rather than the patchy distribution common at southwestern Minnesota sites, a few years after cultivation ended. It is likely that prairie bush-clover seeds in the seed bank were spread across the site due to cultivation practices (Nancy Sather, MNDNR, retired, pers. comm., June 30, 2021).

Historical and Current Range and Distribution

Prairie bush-clover has been found across four states: Illinois, Iowa, Minnesota, and Wisconsin (Figure 1.2). Populations considered historical around the time of listing (1988) were documented in 28 counties across all four states (USFWS 1988, p. 4). The number of known extant populations has increased in Iowa, Minnesota, and Wisconsin. Additional populations were found in Minnesota as a result of increased survey effort post-listing. For example, seven new prairie bush-clover populations were discovered in 1990 (Sather 1991, p. 1). The collection history of the species suggests that the plant was more common in Iowa than anywhere else in its geographic range (Table 1.1) (Watson 1983; Kurz and Bowles 1981; Alverson 1981; Smith 1986; USFWS 1988, p. 2). The species is abundant in a centralized area on the drift of the Des Moines Lobe of the Wisconsin glaciation in northern Iowa and southern Minnesota (USFWS 1988, p. 2). The status of two populations in Iowa (near Hottes Lake WMA and Spring Run Wetland Complex) is currently unknown, as the sites have not had a confirmed prairie bush-clover observation since 1982. Both sites were surveyed in 1988 and no prairie bush-clover plants were observed; however, they are included as extant populations because they have not been confirmed as extirpated or historical.

Table 1.1 The number of historical prairie bush-clover populations in 1988, the number of known extant populations in 1988, and the number of known extant populations in 2020 by state.

State	Historical Populations (1988)	Extant Populations (1988)	Extant Populations (2020)
Iowa	31	13	32
Illinois	6	7	6
Minnesota	2	14	56
Wisconsin	8	5	19
Total	**47**	**39**	**113**

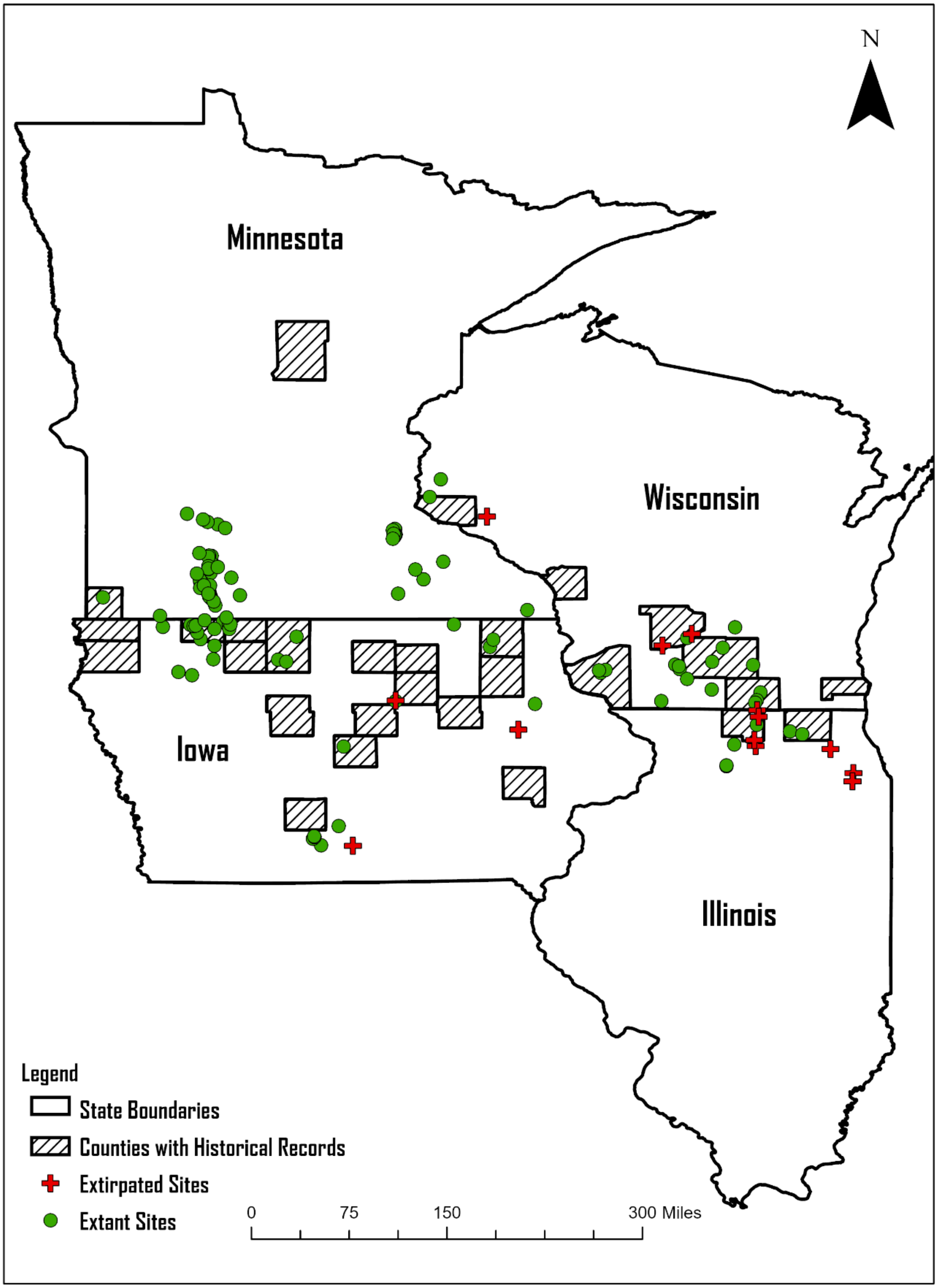

Figure 1.2 Current and historical distribution by county of prairie bush-clover (*Lespedeza leptostachya*). Extant sites have had at least one prairie bush-clover plant observation since 1970 and are not otherwise known to be extirpated or historical.

Life History and Individual-level Ecology

Individual prairie bush-clover plants are reliant on ecological requisites for survival and reproductive success at each life stage. These ecological requisites are described in this section based on the best available information and summarized in Table 1.2. Prairie bush-clover is a perennial species that is capable of flowering in the year it germinates or emerges from seed in a controlled lab setting. On the landscape, wild plants may take five or more years to reach maturity. Once mature, adult plants may flower annually, and a single plant may persist on the landscape for thirty years (Derek Anderson, MNDNR, pers. comm. 2020, Figure 1.3). For example, 15% of individual prairie bush-clover plants observed at a site in Minnesota in 2010 were first observed in 1983, when monitoring at the site started (Nancy Sather, MNDNR, retired, pers. comm., June 30, 2021). Plants often have a single stem that extends from the roots, but multiple stems may extend from a single plant or root system as the plant ages or as a result of damage to the main stem (USFWS 1988, p. 11; Nancy Sather, MNDNR, retired, pers. comm., June 30, 2021). As a plant ages, the distance from the original main stem increases (MN DNR unpublished data; Nancy Sather, MNDNR, retired, pers. comm., June 30, 2021). The number of individual plants that compose a population is based on the number of stems, or ramets, present. Multiple ramets may extend from a single root system, but it is difficult to understand this without a history of the population or an excavation (Nancy Sather, MNDNR, retired, pers. comm., June 30, 2021).

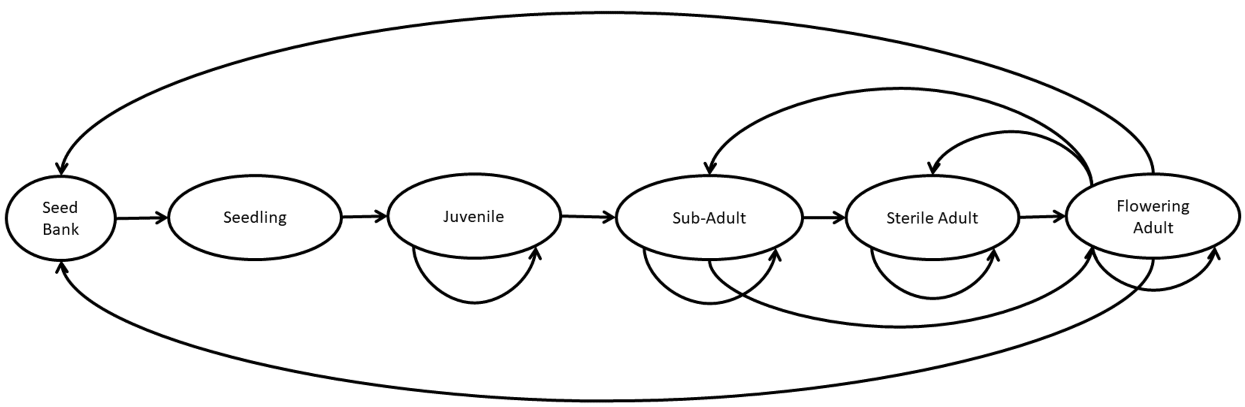

Figure 1.3 Life cycle diagram for the prairie bush-clover (*Lespedeza leptostachya*).

The species reproduces by seed and seed production can be as low as 2% of the mature pods containing seeds (Sather 1986; USFWS 1988, p. 11). A single plant can produce up to 560 pods, but average pod production for a single plant is 265 (Sather 1986; USFWS 1988, p. 11). A two-year study found individual plants with both cleistogamous and chasmogamous flowers may have three times as many cleistogamous flowers than chasmogamous flowers; however, the ratio of observed cleistogamous to chasmogamous flowers reported in any study is dependent, in part, on the time of year the observation was made (Sather 1986; Nancy Sather, MNDNR, retired, pers. comm., June 30, 2021). In this particular study, the cleistogamous flowers persisted throughout the season, but the chasmogamous flowers aborted, likely due to drought conditions during the growing season. This led to a higher ratio of observed cleistogamous to chasmogamous flowers (Nancy Sather, MNDNR, retired, pers. comm., June 30, 2021). Of the cleistogamous flowers examined in the study, approximately 75% produced seed pods. In contrast, approximately one out of every six chasmogamous flowers produce mature seed pods (Sather 1986; USFWS 1988, p. 11). This dominance of cleistogamous flowers in plants with both flower types may be the result of high competition from other plant species or from limited resources (Bowles and Bell 1998, p. 3).

Individual plants appear to be capable of both forms of reproduction. Plants with only cleistogamous flowers tend to be short-statured plants in their first flowering year or older plants with expanded roots systems. Both young and old plants that appeared to have been restricted to cleistogamy at three Minnesota populations exhibited one or two inflorescence branches and produced fewer than 10 flowers. Generally, if the plants were present in subsequent years, they formed inflorescences with chasmogamous and cleistogamous flowers. This strongly suggests that distinction between whether a given plant manifests as chasmogamous or cleistogamous at a given time and place is not genetically fixed but is a plastic response to environmental conditions that the plant is experiencing at the time of observation (Nancy Sather, MNDNR, retired, pers. comm., June 30, 2021). Seed dispersal mechanisms for prairie bush-clover are largely unknown; however, seeds are thought to be dispersed by either gravity or animal activity (for example, voles, small rodents) (Bockenstedt 2002, p. 4).

A prairie bush-clover seedling is distinguishable by a single leaf that forms above the cotyledon leaves. The small, single leaf, or pro-leaf, persists after the cotyledon leaves have fallen off the plant (Minnesota Natural Heritage Program 1995, p. 3; Figure 1.4). Juvenile prairie bush-clovers can be characterized as individuals that are 15 cm (5.9 inches) or less in height and have a stem diameter less than 0.5 mm (0.02 inches). A sub-adult prairie bush-clover plant is any non-flowering individual that is greater than 15 cm tall (5.9 inches) and greater than 0.5 mm (0.02 inches) in diameter. Adult plants may bear buds, flowers, fruits, or are greater than 30 cm (11.8 inches) in height (Minnesota Natural Heritage Program 1995, p. 3).

Figure 1.4 Prairie bush-clover seedling with diagnostic pro-leaf. Photo Credit: Shelley Olson

Dormancy and Germination

Prairie bush-clover seeds are hard shelled and require physical scarification for germination (USFWS 1988, p. 12; Vitt *et al.* 2017, p. 162). Seeds from other *Lespedeza* species remained viable after passing through the digestive system of bobwhite quail implying that prairie bush-clover seeds may be resilient and/or moved across the landscape by wildlife (Clewell 1966b; USFWS 1988, p. 12). Seed germination begins in May and continues through July (USFWS 1988, p. 12; Figure 1.5). The longevity of prairie bush-clover seeds in the soil is relatively unknown; however, a study examining seed germination and the seed bank of prairie bush-clover found that the large majority (about 95%) of seeds germinated during the second year. Therefore, the seed bank of the species is likely small and short-lived (Menges and Quintana-Ascensio 1998, p. 11).

Individual prairie bush-clover plants have been documented entering a period of dormancy that may last 1-2 years. Individual plants may enter dormancy in response to increased competition and/or lack of disturbance (grazing) (Bockenstedt 2002, p. 45). In at least two studies, most plants in one and 13-42% of plants in another entered a period of dormancy (Menges and Quintana-Ascensio 1998, p. 8; Bowles and Bell 1998, p. 4; Bockenstedt 2002, p. 43). The length of time spent dormant has not been widely examined, but at least one study observed that individual plants were dormant for two years or less, as relatively few plants returned from dormancy after two years of being dormant (Bockenstedt 2002, p. 43). The majority of plants return from dormancy after only one year. Dormancy may be a challenge for plants within populations along the southern edge of the prairie bush-clover range where the growing season is longer and therefore more energy is required for base respiration. Prairie bush-clover has a small root system that may not be able to adequately produce the high amount of energy reserves required for base respiration during dormancy in areas with longer growing seasons (Bockenstedt 2002, pp. 43-44).

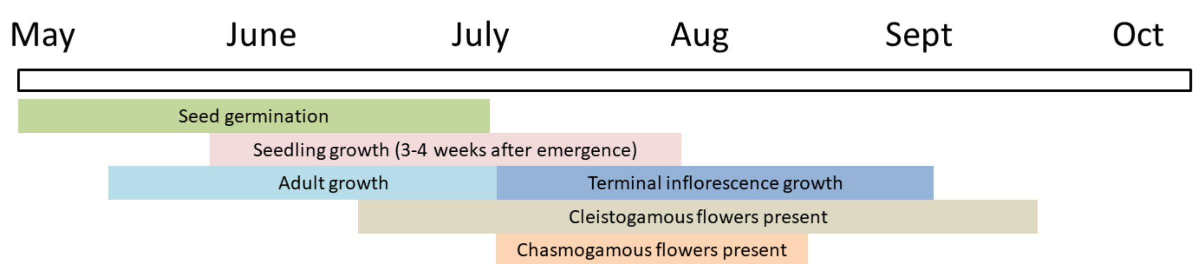

Figure 1.5 A timeline of prairie bush-clover growth stages throughout the growing season, May through September.

Seedlings and Mature Plants

Seasonal growth occurs in the first 3 to 4 weeks post-emergence for seedlings, juvenile, and sub-adult prairie bush-clover plants. Adult plants grow rapidly until flowering in mid-July (Figure 1.5). The growth and development of flowers occurs from mid-July until early September. The production of chasmogamous flowers lasts until mid-August and the production of cleistogamous flowers occurs into September. Seed pods mature from late August to early October (USFWS 1988, p. 12). Adult prairie bush-clover plants often drop their leaves earlier than sub-adult or juvenile plants, which may keep their leaves later into autumn (USFWS 1988, p. 13).

Seed production in prairie bush-clover plants may be negatively impacted by herbivory from small mammals (rabbits). Heavy herbivory at sites may result in reduced plant height and seed production the following year, especially if plant growth is repeatedly removed during seed maturation. This ultimately could lead to long-term, negative impacts on prairie bush-clover reproductive success (USFWS 1988, p. 12). Rabbit grazing on leafy prairie-clover (*Dalea foliosa*) plants prevented seed production in a study conducted by Schwegman (1990, p. 113). At sites with active grazing, seed herbivory from grazing cattle may have long-term impacts on prairie bush-clover reproductive success (Todd Bittner, Cornell Botanic Garden, pers. comm., June 22, 2021). In addition to mammals, Cuclionid or Brucid beetles may negatively impact plants, by laying eggs in seed pods, as evidenced by larval exit holes on seed pods in southwestern Minnesota (USFWS 1988, p. 13).

Low seedling survival rates in prairie bush-clover populations may influence site demographics. At one population in Minnesota, seedling survival averaged less than 50% from the first to the second year. At this site, sub-adult plants did not reach maturity and flower until year eight or nine (Menges and Quintana-Ascensio 1998, p. 18). Therefore, reduced seedling recruitment at sites may have long-lasting consequences. Management that replicates natural processes (prescribed burns) has been studied as a method to increase seedling recruitment; however, recruitment did not increase in the years following prescribed burns at the study site (Menges and Quintana-Ascensio 1998, p. 21). A similar response was documented at Nachusa Grasslands in Illinois. It is suspected that the removal or alteration of the duff layer decreased the amount of soil moisture the following growing season and the area was no longer conducive for seedling germination and survival. Therefore, prescribed fire as a management tool to replicate natural disturbance processes may be used sparingly to minimize negative impacts to prairie bush-clover seedlings (Todd Bittner, Cornell Botanic Garden, pers. comm., June 22, 2021).

Seed Bank

Prairie bush-clover seeds may persist in the seed bank for approximately 2-3 years. In a Minnesota study, not conducted in the field, about 95% of viable seeds germinated the second year (Menges and Quintana-Ascensio 1998, p. 11). Because of the species' relatively short-lived seed bank, conditions for germination and seedling establishment must occur at least every few years (2-3 years) to maintain healthy prairie bush-clover populations on the landscape (Vitt *et al.* 2017, p. 167).

Table 1.2 Individual prairie bush-clover requisites by life stage.

Life Stage	**Resource Need**	**Reference**
Seed	Adequate light levels Soil (Sand, loam) Physical scarification	Vitt *et al.* 2017, p. 167; Jensen and Gutekunst 2003, p. 584 USFWS 1988, p. 2 USFWS 1988, p. 12; Vitt *et al.* 2017, p. 162
Seedling	Lack of competing woody or non-native vegetation and/or reduced natural vegetation and thatch to allow adequate light levels to reach seedlings Presence of hemi-parasitic associated species such as bastard toadflax (*Comandra umbellata*) to reduce competition from dominant vegetation such as little bluestem (*Schyzocharium scoparium*) Presence of herbivores (rabbits and other small mammals) or grazers (bison, cattle) to promote seedling growth by limiting dominant vegetation.	USFWS 1988, p. 10; Sather and Anderson 2014, p. 6 Todd Bittner, Cornell Botanic Gardens, pers. comm., June 22, 2021. USFWS 1988, p. 12; Bowles and Bell 1998, p. 12
Juvenile, Sub-adult, Sterile Adult	Lack of competing woody or non-native vegetation Presence of hemi-parasitic associated species such as bastard toadflax (*Comandra umbellata*) to reduce competition from dominant vegetation such as little bluestem (*Schyzocharium scoparium*) Moderate presence of herbivores (rabbits and other small mammals) or grazers to promote seed production and reproductive success through the reduction of dominant vegetation at sites.	USFWS 1988, p. 10 Todd Bittner, Cornell Botanic Gardens, pers. comm., June 22, 2021. USFWS 1988, p. 12; Bowles and Bell 1998, p. 12
Dormant Juvenile, Sub-adult, Sterile adult	Soil (sand, loamy)	Bockenstedt 2002, p. 43; USFWS 1988, p. 2

	Decrease in environmental stressors (woody vegetation encroachment and extreme drought) Adequate energy reserves for base respiration	Bockenstedt 2002, p. 45 Bockenstedt 2002, p. 44
Flowering Adult	Pollinators to fertilize chasmogamous flowers Presence of hemi-parasitic associated species such as bastard toadflax (*Comandra umbellata*) to reduce competition from dominant vegetation such as little bluestem (*Schyzocharium scoparium*) Lack of competing woody or non-native vegetation Seed dispersal via wind or animal activities (prairie voles caching seeds)	USFWS 1988, p. 11 Todd Bittner, Cornell Botanic Gardens, pers. comm., June 22, 2021. USFWS 1988, p. 10 USFWS 1988, p. 12; Bockenstedt 2002, p. 4

Population-level Ecology

In this section we review the demographic and habitat requirements for the prairie bush-clover at the population level (Table 1.3, Figure 1.6). In general, population viability, or the ability for a population to sustain itself over time, requires healthy demographics, genetic diversity, suitable habitat, and limited threats or stressors.

Resiliency

Resiliency describes the ability of populations to withstand environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature, rainfall), periodic disturbances within the normal range of variation (fire, floods, storms), and demographic stochasticity (normal variation in demographic rates such as mortality and fecundity) (Redford *et al.* 2011, p. 40). This can be measured through population level characteristics such as demography (abundance and the components of population growth rate –survival, reproduction, and dispersal), genetic health (effective population size and heterozygosity), connectivity (gene flow and population rescue), and habitat quantity, quality, configuration, and heterogeneity. In general, the likelihood of sustaining populations over time increases as the number of healthy populations that can occupy a variety of habitats increases. Therefore, the greater the number of individuals within habitat of adequate quantity and quality, the greater the resiliency of individual populations.

Previous efforts to define viable prairie bush-clover populations were based solely on population size and the amount of contiguous suitable habitat present. Bowles and Bell (1998, p. 7) defined a highly viable population as having more than 500 plants with a stable or growing population dispersed over a minimum area of 50 hectares (125 acres) and a moderately viable population as having more than 100 plants with a stable or growing population across 10 hectares (25 acres) of suitable habitat over a 10-year period. Because the quality of the habitat greatly influences population health, we also incorporate habitat quality and protection status of the land into our assessment of population resiliency.

Genetic Diversity

Genetic diversity in plant species is largely dependent on the ability of the species to disperse pollen and seeds. Prairie bush-clover relies heavily on self-fertilization through the production of cleistogamous flowers, which may result in genetic isolation. This may be especially pronounced at locations where the populations are geographically isolated (USFWS 1988, p. 14). Inbreeding in plants often results from a species reliance on autogamy for reproduction. This ultimately results in populations with little genetic diversity (Cole and Biesboer 1992, p. 567). According to one study that examined populations in Iowa, Minnesota, and Wisconsin, there is little phenotypic variation among individual prairie bush-clover plants, which may be due to the dominance of cleistogamous flowers in prairie bush-clover populations (Cole and Biesboer 1992, p. 570). The lack of genetic diversity and dominance of cleistogamous flowers in prairie bush-clover populations suggests that the species is a poor competitor and as a result, pathogens, predators, or environmental changes may pose a greater threat to the species (Coles and Biesboer 1992, p. 573; Bowles and Bell 1998, p. 6).

Habitat Factors

Prairie bush-clover appears to tolerate disturbances at sites with known populations (Bowles and Bell 1998, p. 3). Disturbances that replicate natural prairie processes are necessary to control encroaching woody and non-native vegetations that often crowd out prairie bush-clover populations (USFWS 1988, p. 10; Bowles *et al.* 1999, p. 11). A higher rate of dormancy or death of prairie bush-clover was documented in plots where the species was crowded out by competitive, native plant species including, white heath aster (*Aster ericoides*), candle anemone (*Anemone cylindrica*), prairie coneflower (*Ratibida pinnata*), Indian grass (*Sorghastrum nutans*), and big bluestem (*Andropogon gerardii*) (Bockenstedt 2002, p. 54, 56). Plants that did survive and did not enter dormancy, were generally shorter with fewer inflorescences (Bockenstedt 2002, p. 54).

Population trends may be influenced by precipitation. A positive correlation between population size and precipitation departure from the annual average precipitation was documented in a study by Bowles and Bell (1998, p. 6); however, Menges and Quintana-Ascensio (1998) did not detect any significant patterns between precipitation (annual, seasonal, or monthly) and demographic data (p. 18-19). Similarly, the influence of fire on population demographics is unknown, as many studies have been conducted but the results have been inconclusive (Bockenstedt 2002, p. 48; Bittner and Kleiman 1999, p. 4). Grazing at sites with prairie bush-clover populations may benefit the species by reducing competition and shifting plant community composition (Bockenstedt 2002, p. 52), but grazing may also have a negative impact on populations if grazing pressure is too intense. After cattle and horse grazing ended at a site in Illinois, prairie bush-clover numbers increased but subsequently declined as the plant community composition changed in response to other management practices (removal of invasive plants species and prescribed fire) (Bittner and Kleiman 1999, p. 3).

Table 1.3 Prairie bush-clover requisites for long term viability of populations.

Population Health Factor	**Requisites for Long-term Viability**	**Description**
Demography	Population growth	$\lambda \geq 1$, which is a function of survivorship, recruitment, and population structure, and is dependent on seed production (Bowles and Bell 1998, p. 3).
Demography	Survivorship	Seedling survival is needed to promote population longevity.
Demography	Recruitment	Healthy flowering adult plants that produce large quantities of viable seeds annually via out-crossing and cleistogamous means to compensate for short-lived seedbank and seedling mortality rates (Bowles *et al.* 1999, p. 11). The species' short-lived seed bank underscores the importance of germination and seedling establishment for maintaining populations (Vitt *et al.* 2017, p. 167).
Demography	Population structure	Representation from each life stage to maintain populations into the future.
Demography	Population size	Populations with excellent resiliency have a population size of 1000 or more individual plants with no evidence of significant decline over the last 20 years; populations with good resiliency have 100-999 individual plants or 1000 or more individual plants that have shown significant recent decline.
Demography	Genetic diversity	Prairie bush-clover has limited genetic diversity (Cole and Biesboer 1992, p. 571). Genetic diversity increases populations' resiliency to pathogens, predators, or changes in the environment (Cole and Biesboer 1992, p. 571).
Habitat	Sufficient suitable habitat	Prairies with variable loam soil types ranging from silt to sand to clay loam (Cole and Biesboer 1992, p. 567); high quality prairie sites have no threats or threats are minimized by persistent management activities that replicate natural disturbance processes (for example, grazing).
Habitat	Connectivity among microhabitats	Maintaining connections between subpopulations prevents reducing the limited genetic variation in prairie bush-clover (USFWS 1988, p. 14; Cole and Biesboer 1992, p. 571).
Habitat	Disturbance processes	Low levels of interspecific competition from competitive associates to allow for establishment and growth (Bowles *et al.* 1999, p. 11; Bockenstedt 2002, p. 52).

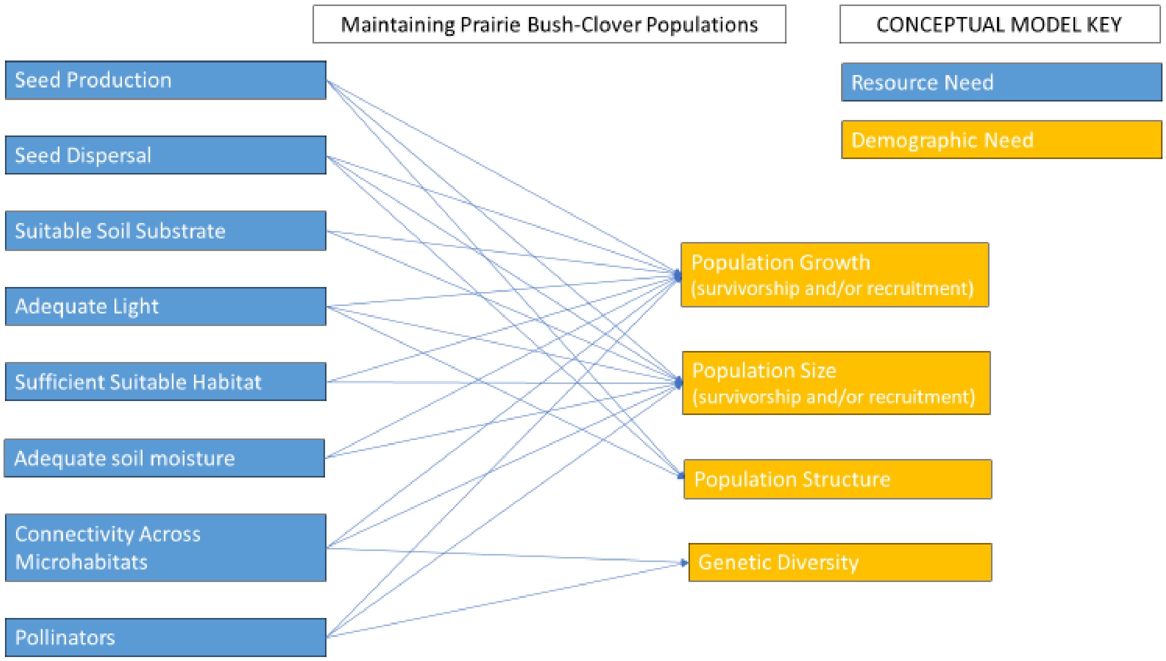

Figure 1.6 Conceptual model of prairie bush-clover resource needs and how they influence demographic needs.

Species-level Ecology

Viability is the ability of a species to maintain populations in the wild over time. To assess viability, we use the conservation biology principles of resiliency, redundancy, and representation (Shaffer and Stein 2000, pp. 308-311). To sustain populations over time, a species must have the capacity to withstand environmental and demographic stochasticity and disturbances (resiliency), catastrophes (redundancy), and novel changes in its biological and physical environment (representation). A species with a high degree of resiliency, representation, and redundancy is better able to adapt to novel changes and to tolerate environmental stochasticity and catastrophes (Smith *et al*. 2018, p. 306). We describe prairie bush-clover's requirements for resiliency at the population level (above) and redundancy and representation below. Key aspects are summarized in Table 1.4.

Table 1.4 Ecological requirements for species-level viability in the context of resiliency, representation, and redundancy.

3 Rs	Requisites for long-term viability	Description
Resiliency *(populations able to withstand stochastic events)*	Self-sustaining populations across a diversity of conditions	Self-sustaining populations are demographically, genetically, and physiologically robust, and have enough high-quality habitat that is free of threats.
Representation *(genetic & ecological diversity to maintain adaptive potential)*	Maintain adaptive diversity of the species	Populations are maintained across (4) prairie types to maintain the ecological and genetic diversity of prairie bush-clover.
Representation	Maintain evolutionary processes	Maintain evolutionary drivers (gene flow, natural selection) to mimic historical patterns.
Redundancy *(number & distribution of populations to withstand catastrophic events)*	Sufficient number and distribution of populations	Sufficient number and distribution across representative categories to guard against catastrophic events, that is, to reduce covariance among populations; spread out geographically but also ecologically (different ecological settings)

Representation
The prairie bush-clover's ability to withstand ongoing and future novel changes is influenced by its capacity to adapt (referred to as adaptive capacity) (Nicotra *et al.* 2015, p. 1269). This ability can best be measured by examining the breadth of genetic, phenotypic, and ecological diversity found within a species and its ability to disperse and colonize new areas.

Because the genetic diversity of the species rangewide is limited because of the species' reliance on self-fertilization (USFWS 1988, p. 14), we identified representative categories based on habitat type. Prairie bush-clover is adapted to a wide variety of prairie soil conditions that include glacial till underlain by limestone, sandstone, gneiss, or quartzite (Bowles and Bell 1998, p. 3). As a result, the species occurs at sites that can be categorized into four types of prairies: dry, dry-mesic, mesic, and bedrock. Each of these is described below.

<u>Dry Prairie:</u> The majority of prairie bush-clover populations (52) occur in habitat that can be described as dry prairie. This habitat type includes dry barrens prairie, dry sand-gravel prairie, dry bedrock bluff prairie, and dry hill prairie. Minnesota has the most prairie bush-clover populations that are included in this representative category, 45 populations or 87% of populations in dry prairie habitat. Dry prairie communities are often limited in size by physiographic factors, woody vegetation encroachment, and habitat conversion for development. Prairie habitat types, including dry prairie, rely on periodic fire to prevent successional changes on the landscape (Epstein 2017, p. H-143). Threats to this habitat type include the encroachment of woody vegetation and/or non-native, invasive species, the absence of periodic fire, and habitat fragmentation due to residential and agricultural development. Non-native, invasive plant species

documented at dry prairie sites include spotted knapweed (*Centaurea stoebe*) and leafy spurge (*Euphorbia esula*) (Epstein 2017, p. H-144).

Dry-Mesic Prairie: Prairie bush-clover populations at sites that are described as dry-mesic have features of both dry and mesic prairies in close proximity to the population. For example, a dry-mesic prairie site with a documented prairie bush-clover population in Iowa was described as, "relatively mesic, sandy prairie below a xeric prairie on a limestone ridge" (Iowa Department of Natural Resources 2018). The majority of prairie bush-clover populations in Wisconsin, 16 out of 19 populations, are at dry-mesic prairie sites. Dry-mesic prairie habitat in Wisconsin is often converted to agricultural cropland, developed areas, or tree plantations. As a result, patches of this habitat type are often surrounded by areas where the dominant land use is agricultural rowcrop (Epstein 2017, p. H-148). Active management is needed to limit woody vegetation encroachment from native species including sumacs (*Rhus spp*.), cherries (*Prunus spp*.), eastern red cedar (*Juniperus virginiana*), and box elder (*Acer negundo*). Non-native, invasive species also pose a threat to this habitat type. Common invasive species found in dry-mesic prairies include, Kentucky bluegrass (*Poa pratensis*), Canada bluegrass (*P. compressa*), smooth brome (*Bromus inermis*), Canada thistle (*Cirsium arvense*), white sweet-clover (*Melilotus albus*), and yellow sweet-clover (*M. officinalis*), autumn olive (*Elaeagnus umbellata*), Eurasian honeysuckle (*Lonicera tatarica*), common buckthorn (*Rhamnus cathartica*), and multiflora rose (*Rosa multiflora*) (Epstein 2017, p. H-148).

Mesic Prairie: Mesic prairie habitat is currently considered one of the rarest grassland community types because the high soil fertility at these sites made them ideal for crop production (Epstein 2017, p. H-150). Mesic prairie sites are characterized by loamy soils, gently rolling topography, adequate moisture and drainage, and rely on natural disturbance processes including fire, periodic drought, and grazing by ungulates. Today, these mesic prairie remnants are often found along linear transportation or utility corridors (Epstein 2017, p. H-149). Fourteen prairie bush-clover populations still exist at mesic prairie sites today. Without natural disturbance processes or active management, mesic prairie sites are overtaken by woody vegetation (sumacs, dogwoods (*Cornus* spp.), common buckthorn, and glossy buckthorn (*R. frangula*), honeysuckles, and multiflora rose) (Epstein 2017, p. H-149). Incompatible use of herbicides, intense grazing, mowing, tree planting, and fire suppression all pose threats to mesic prairie populations. Non-native, invasive plant species found at mesic prairie sites include, smooth brome, Kentucky bluegrass, Canada bluegrass, timothy (*Phleum pratense*), orchard grass (*Dactylis glomerata*), and reed canary grass (*Phalaris arundinacea*) (Epstein 2017, p. H-150).

Bedrock Prairie: The habitat type currently with the fewest, six, prairie bush-clover populations is bedrock prairie. These sites are characterized by level to sloping exposures of bedrock with sparse woody vegetation (Minnesota Department of Natural Resources 2003, p. 1-2). Prairie plant species, like prairie bush-clover, are found in areas interspersed among exposed bedrock where deep soil is present (Minnesota Department of Natural Resources 2003, p. 1). Bedrock prairie habitat is relatively drought tolerant and plant communities found in this habitat type are subjected to fluctuating temperatures, low substrate moisture-holding capacity, exposure to direct sunlight, and limited nutrient availability. Similarly, to the other representative categories, bedrock prairie relies on fire to limit encroaching woody vegetation and non-native, invasive plant species (Minnesota Department of Natural Resources 2003, p. 2).

Redundancy

Redundancy influences the ability of a species to withstand catastrophic events. Redundancy is achieved by having multiple, widely distributed populations that are beyond the spatial impact of catastrophic events. Having multiple, healthy populations widely distributed will also preserve the range of adaptive diversity. The ability of the species to withstand catastrophic events is enhanced by the species having a sufficient number of populations that are distributed across and within representative categories (prairie types).

Possible catastrophic events that could impact prairie bush-clover populations include prolonged drought or habitat conversion at a population-wide level. While the species is relatively adapted to seasonal drought conditions, a prolonged drought over multiple consecutive growing seasons may have long lasting impacts on populations. If conditions are not favorable, the species may enter a state of dormancy for a year; however, if unfavorable conditions persist for two or more years, the dormant plant may not survive. In addition, prairie bush-clover populations located on unprotected sites are at risk of extirpation due to conversion of the entire site to incompatible land use, such as agricultural or urban development or gravel mines.

CHAPTER 2. PRIMARY INFLUENCES ON VIABILITY (v. July 15, 2021)

This chapter provides a summary of past, current, and plausible future factors that are affecting or could be affecting the current and future condition of prairie bush-clover throughout some or all of its geographic range.

Risk Factors

For prairie bush-clover, we identified six main threats or stressors that directly impact prairie bush-clover resource and demographic needs (Figure 2.1).

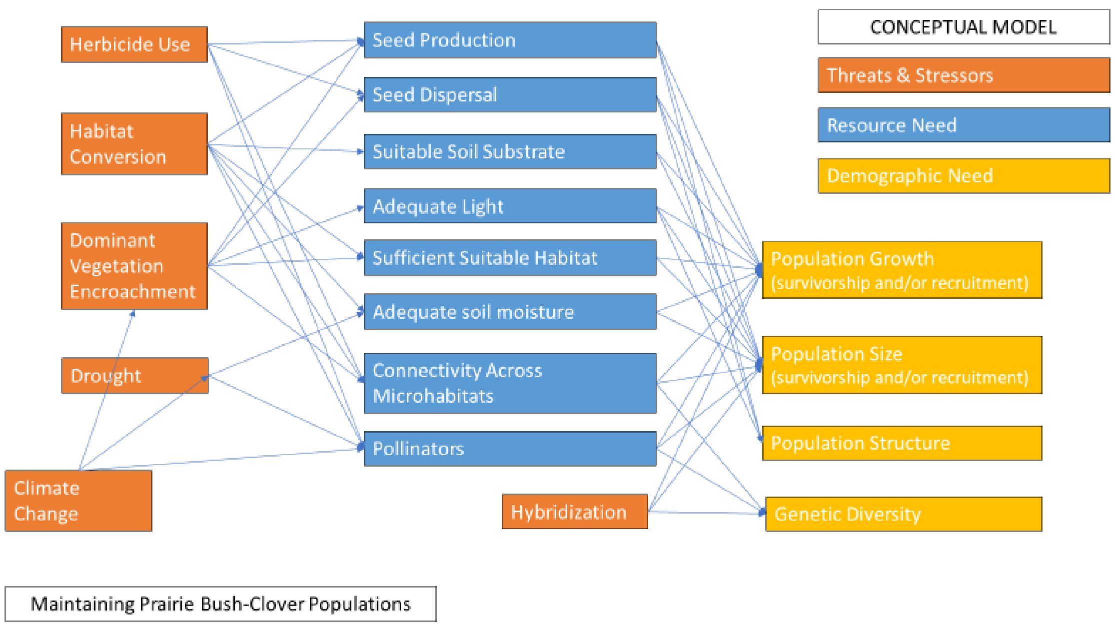

Figure 2.1 Conceptual model of prairie bush-clover (*Lespedeza leptostachya*) threats and stressors and how they influence resource and demographic needs of the species.

Herbicide Use

Incompatible use of herbicides at known population sites would directly impact an individual plant's ability to produce seeds and may disrupt connectivity across microhabitats. Seed dispersal may also be impacted due to a decline in pollinators, which are largely unknown for prairie bush-clover. Prairie bush-clover populations located near agricultural fields or adjacent to existing roadways may be at increased risk of exposure to herbicide use (USFWS 1988, p. 15).

Habitat Conversion

Conversion of documented prairie bush-clover sites to row crops and gravel quarries has destroyed at least two sites in Wisconsin and Illinois (USFWS 1988, p. 14). Agricultural activity resulting in a direct conversion to row-crops destroyed at least one known prairie bush-clover site in Wisconsin (USFWS 1988, p. 14). Conversion of documented populations to rock or gravel quarries has occurred at least once in Illinois (USFWS 1988, p. 15). One unprotected Illinois population was lost due to commercial development (Todd Bittner, Cornell Botanic Garden, pers. comm., June 22, 2021). Extant prairie bush-clover populations located on private land are at risk of conversion to row crop or rural residential development (USFWS 1988, p. 14), and populations located adjacent to existing rights of way are at risk due to potential roadway expansion in the future (USFWS 1988, p. 15).

Climate Change

Climate change may act as a stressor on the species by promoting non-native vegetation growth and exacerbating drought conditions. Changes in precipitation regimes are anticipated with fewer, but larger events followed by prolonged dry periods and drought stress (Knapp *et al.* 2008, p. 816). These alterations may create novel ecosystems that suppress native plant species and promote expansion of invasive, non-native species into prairie bush-clover habitat (Knapp *et al.* 2008, p. 817). Climate change may also promote dominant, non-native vegetation growth and encroachment with the increase in CO_2 and subsequent increase in plant biomass (Blumenthal *et al.* 2013, p. 1161). Increased biomass at sites with prairie bush-clover populations may lead to increases in thatch, or layer of organic plant matter, which makes seed germination increasingly difficult.

Altered precipitation and temperature regimes may influence when management activities in prairie habitat can occur by increasing or reducing opportunities for the use of prescribed fire. Prolonged periods of warmer temperatures may allow for more opportunities for prescribed burning, while increased precipitation in the spring or early summer may constrain when prescribed burns may occur. Ultimately, the timing of prescribed burns may become increasingly unpredictable due to variable temperatures and changes in precipitation regimes (Wisconsin Initiative on Climate Change Impacts 2017).

Dominant Vegetation Encroachment

Prairie systems are reliant on natural disturbance regimes to maintain the structure of the prairie. Without fire, grazing, or other natural disturbances, prairie communities may transition to scrub-shrub or early successional habitat types. Mature prairie bush-clover plants can succumb to prolonged competition with woody vegetation encroachment. This has been documented at populations in Wisconsin and Minnesota (Nancy Sather, MN DNR retired, pers. comm., June 30, 2021). There are a number of invasive, non-native plant species, including buckthorn, that currently pose a threat to prairie bush-clover populations with no active management or management plans in place. Native dominant woody plant species documented at sites include: Buckthorn species (*Ceanothus* species), Hawthorn species (*Crataegus* species), eastern red cedar (*Juniperus virginiana*), quaking aspen (*Populus tremuloides*), cherry species (*Prunus* species), burr oak (*Quercus macrocarpa*), black oak (*Quercus velutina*), smooth sumac (*Rhus glabra*), staghorn sumac (*Rhus typhina*), western snowberry (*Symphoricarpos occidentalis*), and riverbank grape (*Vitis riparia*) (USFWS 1988, p. 10).

Drought

Prairie bush-clover predominantly occurs in habitats with dry soil types (dry prairie, bedrock prairie) or characteristics (dry-mesic prairie), which makes the species relatively drought-tolerant; however, populations at sites with mesic soil types (mesic prairie) may be subjected to additional stress from prolonged drought periods (Knapp *et al.* 2008, p. 816). Prolonged drought events lasting multiple consecutive growing seasons may have long lasting impacts on populations. If conditions are not favorable, the prairie bush-clover may enter a state of dormancy for a year; however, if unfavorable conditions persist for two or more years, dormant plants may not survive. Non-dormant plants may produce fewer chasmogamous flowers which may further impact the genetic diversity of a population. A prolonged drought may also have a significant impact on seedling survival (Kevin Doyle, Wisconsin Department of Natural Resources, pers. comm., June 22, 2021).

Hybridization

There have been numerous documented reports of hybridization between prairie bush-clover and round-headed bush clover (*Lespedeza capitata*) in all four states (Fant *et al.* 2010, p. 2197). Both species are found in remnant prairie habitats and have overlapping flowering periods (USFWS 1988, p. 16). Hybrids have been documented at Minnesota sites since the early 1980s (Nancy Sather, MNDNR, retired, pers. comm., June 30, 2021). Numerous hybrid plants were observed at Jeffers Petroglyphs National Monument in 1995 (MN Natural Heritage Program 1995, p. 4). The number of prairie bush-clover populations with hybrids and the number of hybrid plants within populations has steadily increased since 1987, when only two Minnesota populations had documented hybrids (Nancy Sather, MNDNR, retired, pers. comm., June 30, 2021). Now hybrids are present in all four states in the prairie bush-clover range (Fant *et al.* 2010, p. 2197). No systematic documentation of hybrids has been conducted in Minnesota; however, biologists recently discovered that one of the first populations to support hybrids had been completely swamped by morphological hybrids (Nancy Sather, MNDNR, retired, pers. comm., June 30, 2021).

Hybrid plants have vegetative traits (stem circumference, leaf width, and petiole length) that often are intermediate between the round-headed bush clover and the prairie bush-clover. Genetic testing indicated that prairie bush-clover acts as the seed-bearing parent (Fant *et al.* 2010, p. 2202). The hybrid plants may also be capable of self-fertilization, as both parent species produce cleistogamous flowers. At least one instance of back-crossing has been observed at a site in Minnesota. This occurs when a hybrid individual crosses with one of the hybridizing species (round-headed bush clover or prairie bush-clover) and produces an offspring that is morphologically and genetically similar to the parent, in this case, prairie bush-clover (Nancy Sather, MNDNR, retired, pers. comm., June 30, 2021). Prairie bush-clover is not a genetically diverse species, so genetic assimilation to round-headed bush clover may serve as a threat to the genetic diversity of prairie bush-clover (Fant *et al*. 2010, pp. 2203). For this report, we considered the potential impacts of hybridization qualitatively, rather than quantitatively as it’s unclear how many populations have documented hybrid plants.

Conservation Efforts

Prairie bush-clover is listed as endangered in Illinois and Wisconsin (Illinois Endangered Species Protection Board 2020; Wisconsin Department of Natural Resources 2019) and threatened in Iowa and Minnesota (Iowa Department of Natural Resources 2009; Minnesota Department of Natural Resources 2013). Across all four states, 54 prairie bush-clover populations or 48% of extant populations are owned by a conservation organization (federal, state, or non-profit) or are permanently protected for the purpose of conservation (Table 2.1). The Minnesota Department of Natural Resources considered delisting prairie bush-clover to legalize incidental harvest of the species during prairie restoration efforts within Minnesota (Sather 2006, p. 3).

Table 2.1 Number of permanently protected prairie bush-clover (*Lespedeza leptostachya*) populations by state and prairie type.

Prairie Type	**Illinois**	**Iowa**	**Minnesota**	**Wisconsin**
Dry	3	0	12	2
Dry-Mesic	1	14	0	11
Mesic	1	4	3	0
Bedrock	1	1	1	0

CHAPTER 3. CURRENT CONDITION (v. July 15, 2021)

Introduction

Current viability is the ability of the prairie bush-clover to sustain healthy populations into the future given the current demographic condition of the species and the current state of the influences. We assessed the current condition of prairie bush-clover in the context of its resiliency, representation, and redundancy (see Appendix A), using the best available information.

Methods for Assessing Current Condition

We used survey and monitoring data provided from state agencies in Minnesota, Wisconsin, Illinois, and Iowa, unpublished information from species experts, and other available information to assess the current condition of each prairie bush-clover population. The majority, 80 sites or 71%, of known, extant population sites have not been surveyed in over 10 years. For these populations, the current condition of the population is based on the best available information, data collected from the last survey conducted at the site.

In Minnesota and Wisconsin, populations are surveyed and assigned an element occurrence[1] (EO) rank based on the definitions developed by NatureServe (Hammerson *et al.* 2020). These ranks are based on a population's viability or ability to persist at least 20-30 years into the future and the ecological integrity of the site. While NatureServe's definition of an element occurrence rank can be used to assess current condition, a method to standardize ranks across the geographic range of the species was needed to directly compare populations, as not all states in the species' range had assigned element occurrence ranks to their prairie bush-clover populations.

We worked with species experts and state partners to calibrate and standardize how populations are classified using element occurrence ranks. To assess the current condition of extant prairie bush-clover populations, we used population size, habitat quality, size of contiguous habitat in acres, and protection status to inform a calculated resiliency score (Appendix B, Tables B-1 and B-2). Population size was identified as the most influential factor for current condition and was considered to be twice as influential as habitat quality, which was the second most influential factor. Habitat quality incorporates management that is targeted toward reducing dominant vegetation encroachment and maintaining the overall quality of the prairie. Protected status was identified as the least meaningful indicators of current population health, because, regardless of protected status, the habitat will continue to degrade absent appropriate management. (Protected status does, however, play a larger role in the future condition of populations, due to the risk of conversion in unprotected locations.) These four factors, when weighted (see Appendix B for specific weights per factor), result in an element occurrence rank of A, B, C, or D. An A ranked population represents a population with excellent viability, a B ranked has good viability, a C ranked has poor viability, and a D ranked population represents a population with poor viability. (See Appendix B for more details on the methodology for assessing current condition).

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[1] An element occurrence (EO) is an area of land and/or water in which a species or natural community is, or was, present. An EO should have practical conservation value for the element as evidenced by potential continued (or historical) presence and/or regular recurrence at a given location. The EO often corresponds with the local population, but when appropriate may be a portion of a population (e.g., long distance dispersers) or a group of nearby populations (e.g., metapopulation). For this SSA, an EO corresponds to a population.

Current Resiliency of Populations

Resiliency describes the ability of a population to withstand environmental or demographic stochastic disturbances and stressors. We used EO ranks to assess prairie bush-clover resiliency and ranked populations as having excellent (A), good (B), fair (C), or poor (D) resiliency. Appendix C includes current resiliency ranks for all 113 extant prairie bush-clover populations, lists the 12 extirpated populations, and provides the basis for our analyses of the species' current condition. Table 3.1 summarizes the number of populations categorized under each rank.

Table 3.1 Current resiliency based on calculated EO rank for prairie bush-clover (*Lespedeza leptostachya*) populations and the percent of extant populations in each resiliency category (excellent, good, fair, poor, extirpated).

Resiliency	EO Rank	Number of Populations (%)
Excellent	A	12 (11%)
Good	B	25 (22%)
Fair	C	41 (36%)
Poor	D	35 (31%)
Extirpated	X	12
Total		**125**

Thirty-seven prairie bush-clover populations or 33% currently exhibit excellent or good resiliency across all four states in the geographic range. The 12 populations that are in excellent condition all have over 1000 individual prairie bush-clover plants and no evidence of significant and recent (defined as occurring over the last 20 years) decline. The majority (8 or 67%) of the populations ranked as excellent are composed of high-quality prairie with minimal threats due to persistent management and 10 or more acres of contiguous suitable habitat. Ten populations with excellent resiliency are owned by a conservation organization or are permanently protected for purposes of conservation. One population is owned privately or by an organization that is currently interested in conservation and one population is currently not protected.

The 25 prairie bush-clover populations currently ranked as having good resiliency all have at least 10 individual plants, with the majority of those populations having 100 or more. All but two of these populations occur in areas with high or fair quality prairie habitat with minimal threats and/or persistent management. Two populations occur at sites with degraded prairie habitat and inconsistent management. The amount of suitable contiguous habitat at populations with good resiliency varies from less than 1 acre to 10 or more acres. The majority (18 or 72%) of prairie bush-clover populations exhibiting good resiliency are owned by a conservation organization and are permanently protected for purposes of conservation. Five populations are currently unprotected with no informal agreement in place. One population is owned privately or by an organization that is currently interested in conservation and one population has an informal agreement in place.

The majority, 76 populations or 67%, of prairie bush-clover populations rangewide currently exhibit fair or poor resiliency. Populations with fair resiliency have 99 or fewer plants or have shown significant recent decline (as determined by state biologists and species experts), degraded habitat due to high impact grazing, brush encroachment and/or non-native, invasive species, with inconsistent management. These populations are generally characterized as having one to four acres of contiguous suitable habitat and the landowner has an informal conservation agreement in place.

Thirty-five populations currently have poor resiliency. Populations exhibiting poor resiliency generally have fewer than 10 plants or have shown significant recent decline and are present in low quality habitat with no management. Non-native, invasive species are the dominant vegetation at these sites and suitable contiguous habitat is less than one acre. The sites are not protected from future land conversion. In addition, 12 populations are currently considered extirpated.

Current Representation and Redundancy

Representation describes the ability of a species to adapt to both near-term and long-term changes in its physical and biological environments and is characterized by the breadth of environmental diversity within the species. We used the four prairie habitat types described in Chapter 1 to assess representation across the geographic range of prairie bush-clover (Table 3.2, Figure 3.1).

Redundancy describes the ability of a species to withstand catastrophic events by maintaining multiple, resilient populations across the species' geographic range. The redundancy of prairie bush-clover is based on its 113 extant populations distributed across Illinois, Iowa, Minnesota, and Wisconsin and the four prairie habitat types that we define as representative categories. Individual populations in each of the four prairie habitat types (representative categories) are dispersed throughout the species' overall range, and, therefore, are distributed geographically. Thus, the number and resiliency of populations in each representative category also characterizes current distribution (redundancy) in terms of the spatial impact of a catastrophic event.

Table 3.2 The distribution of extant prairie bush-clover (*Lespedeza leptostachya*) by representative category.

Representative Category	Number of Extant Populations	% of Populations
Dry Prairie	52	46%
Dry-Mesic Prairie	41	36%
Mesic Prairie	14	12%
Bedrock Prairie	6	5%
Total	**113**	

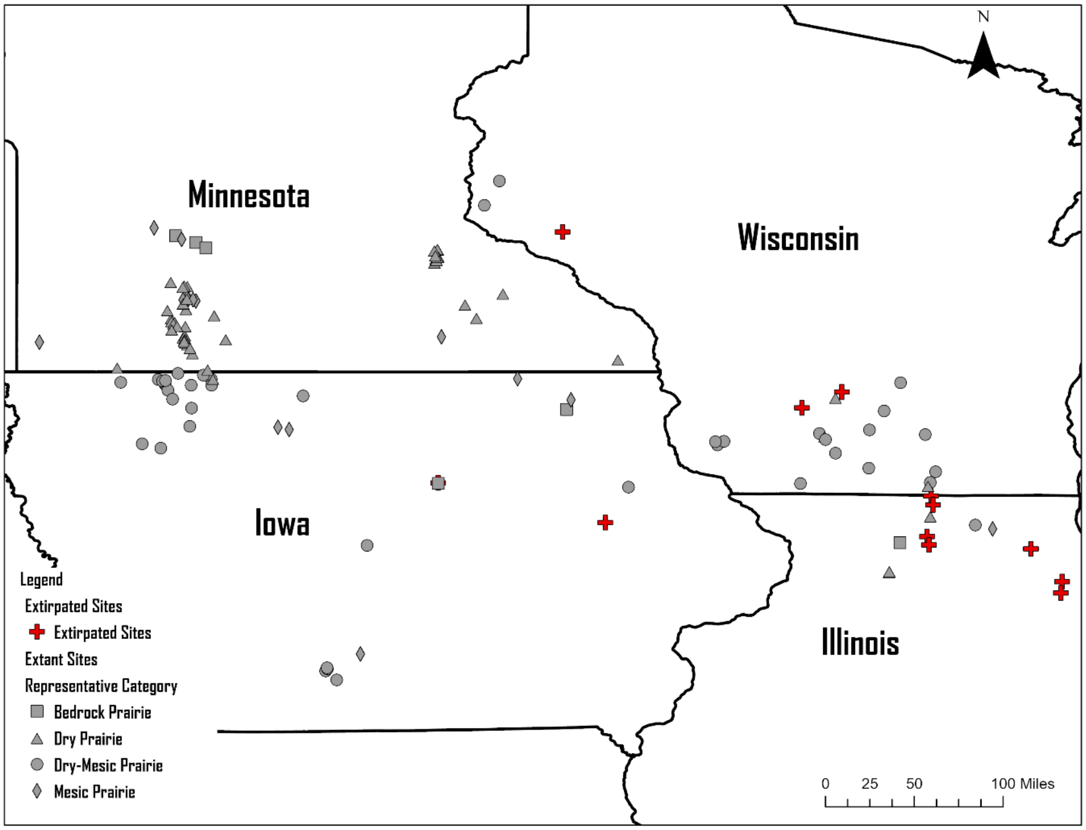

Figure 3.1 Map of extant prairie bush-clover (*Lespedeza leptostachya*) populations by representative category across the geographic range of the species. Extirpated populations are also depicted.

The current condition of the populations in each of the four prairie habitat types is shown in Table 3.3. The distribution and resiliency of the populations is depicted in Figure 3.2. Details of the current condition of populations for each representative category are presented below.

Table 3.3 Prairie bush-clover (*Lespedeza leptostachya*) resiliency by representative category (bedrock prairie, dry prairie, dry-mesic prairie, mesic prairie). Resiliency is characterized by calculated element occurrence (EO) rank.

Resiliency	Bedrock Prairie (% of Extant)	Dry Prairie (% of Extant)	Dry-Mesic Prairie (% of Extant)	Mesic Prairie (% of Extant)	Total (% of Extant)
Excellent (A)	0 (0%)	7 (13%)	3 (7%)	2 (14%)	12 (11%)
Good (B)	1 (17%)	10 (19%)	14 (34%)	0 (0%)	25 (22%)
Fair (C)	2 (33%)	19 (37%)	13 (32%)	7 (50%)	41 (36%)
Poor (D)	3 (50%)	16 (31%)	11 (27%)	5 (36%)	35 (31%)
Extirpated	0	7	5	0	12
Total Extant	**6**	**52**	**41**	**14**	**113**

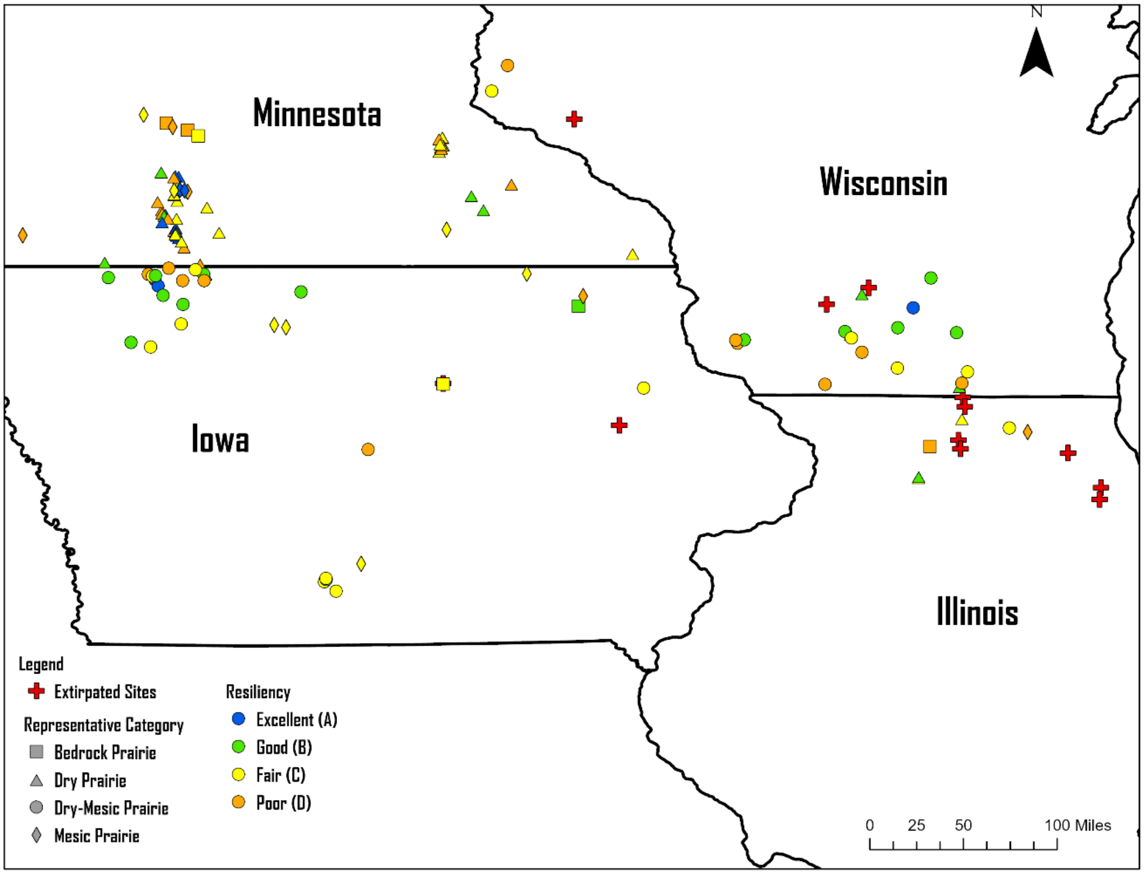

Figure 3.2 Map of prairie bush-clover (*Lespedeza leptostachya*) resiliency by representative category (bedrock prairie, dry prairie, dry-mesic prairie, mesic prairie) across the geographic range of the species.

Details of the current condition of populations for each representative category are presented below.

Dry Prairie

Most prairie bush-clover populations occur in the dry prairie habitat type. Table 3.4 shows the current condition of each population in the dry prairie habitat type. The distribution of these populations is depicted in Figure 3.3.

Table 3.4 Table of extant and extirpated prairie bush-clover (*Lespedeza leptostachya*) populations in dry prairie habitat. Resiliency is characterized by calculated element occurrence (EO) rank.

Resiliency	EO Rank	Number of Dry Prairie Populations	Percent (%) of Dry Prairie Populations
Excellent	A	7	12%
Good	B	10	17%
Fair	C	19	32%
Poor	D	16	27%
Extirpated	X	7	12%
Total		59	

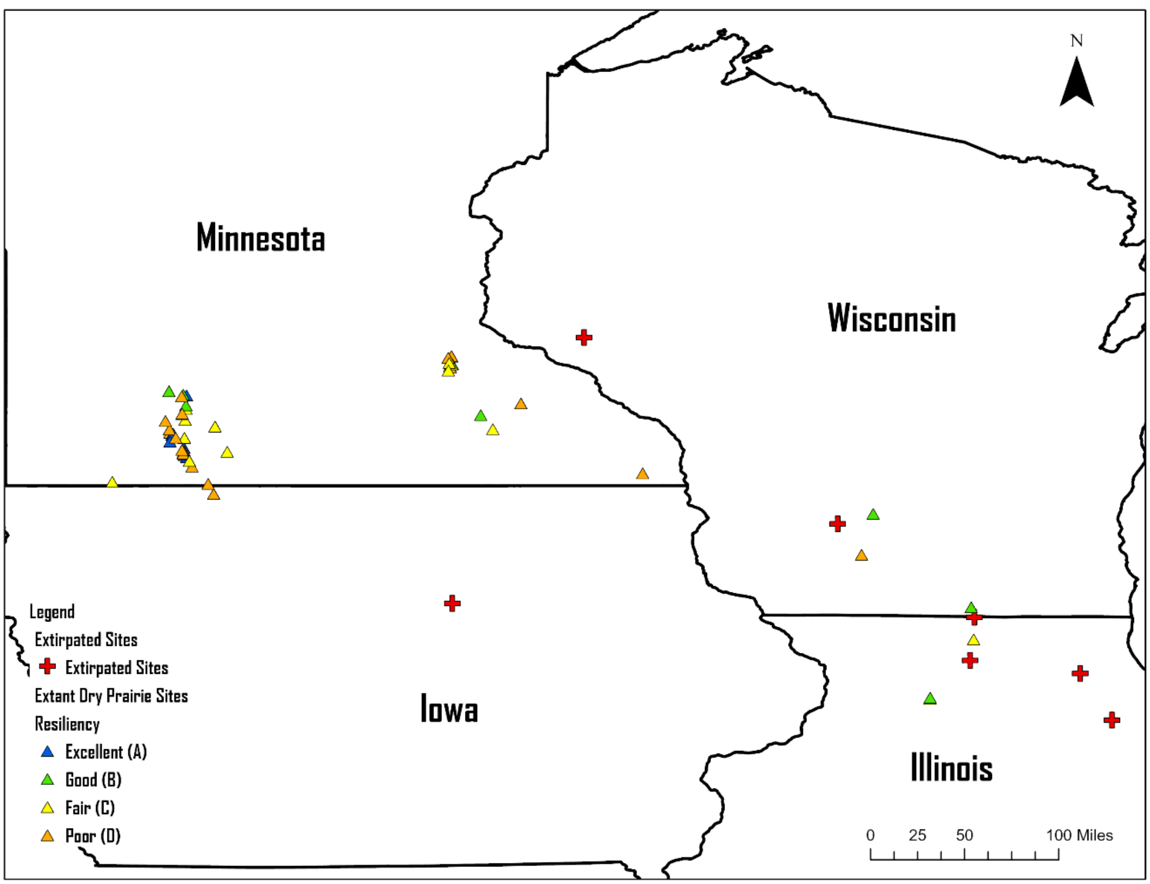

Figure 3.3 Map of extant and extirpated prairie bush-clover (*Lespedeza leptostachya*) populations in dry prairie habitat.

The seven populations with excellent resiliency are found in Minnesota. These populations have at least 1000 or more individual prairie bush-clover plants with no evidence of significant and recent decline over the last 20 years. These populations also have at least 10 or more acres of contiguous suitable habitat. Of the seven populations, five are permanently protected for the purposes of conservation, one is privately owned or owned by an organization that is currently interested in conservation but not permanently protected, and one is not protected. Many of these populations consist of high-quality prairie or fair quality habitat with consistent management.

The ten dry prairie populations with good resiliency are found in Illinois, Minnesota, and Wisconsin. These populations have at least 10 individual prairie bush-clover plants, with nine populations having over 100 individual plants documented. All 10 of these populations consist of high-quality prairie or fair quality habitat with consistent management. The amount of contiguous suitable habitat present ranges from five to ten or more acres. Of the ten populations, five are permanently protected for the purposes of conservation, two populations have informal agreements in place, and four are not protected.

The 19 populations with fair resiliency are found in Minnesota and Illinois. Population sizes range from fewer than ten individual plants to fewer than 1000. Only two populations have high quality habitat with either no threats or threats kept minimal due to persistent management, while the other populations occur in degraded dry prairie habitat with inconsistent management, encroaching woody vegetation and non-native invasive plant species. The amount of contiguous suitable habitat present ranges from one to ten or more acres. The protection status of these populations varies, with five permanently protected for the purposes of conservation, six privately owned or owned by an organization that is currently interested in conservation but not permanently protected, two with informal agreements in place, and six unprotected.

The 16 dry prairie populations with poor resiliency occur in Iowa and Minnesota. Most populations with poor resiliency (10) have fewer than 10 individual prairie bush-clover plants and six populations have fewer than 99 individual plants. All 16 populations occur in degraded dry prairie habitat with inconsistent management, encroaching woody vegetation and non-native invasive plant species. The amount of contiguous suitable habitat present ranges from less than one to ten or more acres. Nine populations have one to four acres of contiguous suitable habitat for the species. Thirteen (81%) of the 16 populations in dry prairie habitat are unprotected. One population is privately owned or is owned by an organization that is currently interested in conservation but not permanently protected, and two are permanently protected for the purposes of conservation.

Dry-Mesic Prairie

Prairie bush-clover populations in dry-mesic prairie are the second most common representative category for the species, with 41 extant populations in Illinois, Iowa, and Wisconsin. Table 3.5 shows the current condition of each population in the dry-mesic prairie habitat type. The distribution of these populations is depicted in Figure 3.4.

Table 3.5 Table of extant and extirpated prairie bush-clover (*Lespedeza leptostachya*) populations in dry-mesic prairie habitat. Resiliency is characterized by calculated element occurrence (EO) rank.

Resiliency	EO Rank	Number of Dry-Mesic Prairie Populations	Percent (%) of Dry-Mesic Prairie Populations
Excellent	A	3	7%
Good	B	14	30%
Fair	C	13	28%
Poor	D	11	24%
Extirpated	X	5	11%
Total		46	

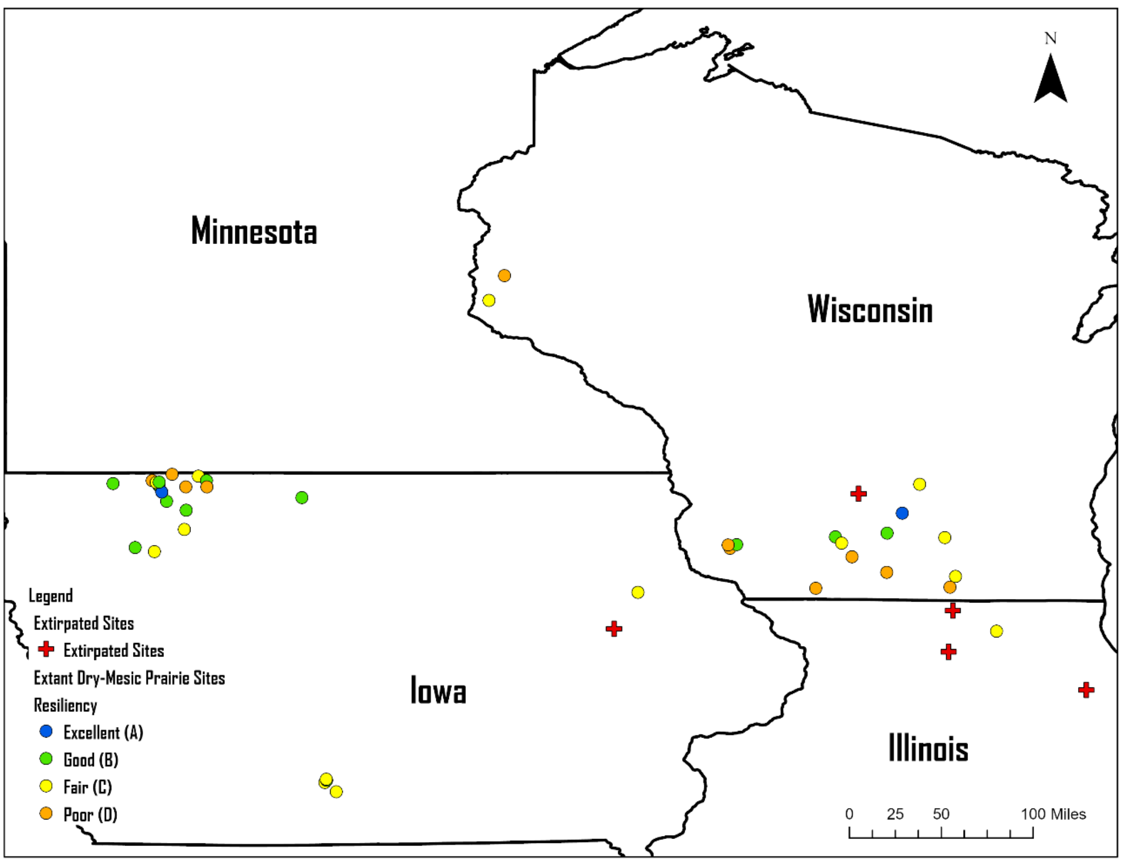

Figure 3.4 Map of extant and extirpated prairie bush-clover (*Lespedeza leptostachya*) populations in dry-mesic prairie habitat.

The three populations with excellent resiliency are found in Iowa and Wisconsin. All these populations have at least 1000 or more individual prairie bush-clover plants with no evidence of significant and recent decline over the last 20 years. These populations also have at least five or more acres of contiguous suitable habitat. All three populations are permanently protected for the purposes of conservation and consist of high-quality prairie with no threats or threats are kept minimal by persistent management.

Populations in dry-mesic prairie with good resiliency are found in Iowa and Wisconsin. These populations have at least 10 individual prairie bush-clover plants, with ten populations having over 100 individual plants documented. Twelve out of fourteen of these populations consist of high-quality prairie or fair quality habitat with consistent management. The amount of contiguous suitable habitat present ranges from one to ten or more acres. Of the 14 populations, 12 are permanently protected for the purposes of conservation, 1 population is privately owned or owned by an organization that is currently interested in conservation but not permanently protected, and one is not protected.

The 13 populations with fair resiliency are found in Illinois, Iowa, and Wisconsin. Population sizes range from fewer than ten individual plants to fewer than 1000. Four populations have high quality habitat with either no threats or threats kept minimal due to persistent management, while the other populations occur in degraded dry-mesic prairie habitat with inconsistent management, encroaching woody vegetation and non-native invasive plant species. The amount of contiguous suitable habitat present ranges from one to ten or more acres. Seven populations are permanently protected for the purposes of conservation and six are unprotected.

Dry-mesic prairie populations with poor resiliency occur in Iowa and Wisconsin. Nearly all, 10 out of 11, of the dry-mesic prairie populations with poor resiliency have fewer than 10 individual prairie bush-clover plants and all populations have fewer than 99 individual plants. Six populations are found in high quality habitat with inconsistent management or fair quality habitat with consistent management, while the remaining five populations occur in degraded dry-mesic prairie habitat with inconsistent management, encroaching woody vegetation and non-native invasive plant species. The amount of contiguous suitable habitat present ranges from less than one to ten or more acres. Of the 11 dry-mesic prairie populations with poor resiliency, 4 are permanently protected for the purposes of conservation, 1 population is privately owned or owned by an organization that is currently interested in conservation but not permanently protected, 1 has an informal agreement in place, and 1 is not protected.

Mesic Prairie

The second fewest number of prairie bush-clover populations are found in mesic prairie. Table 3.6 shows the current condition of each population in the mesic prairie habitat type. The distribution of these populations is depicted in Figure 3.5.

Table 3.6 Table of extant prairie bush-clover (*Lespedeza leptostachya*) populations in mesic prairie with current resiliency based on calculated element occurrence (EO) rank. Resiliency is characterized by calculated element occurrence (EO) rank.

Resiliency	EO Rank	Number of Mesic Prairie Populations	Percent (%) of Mesic Prairie Populations
Excellent	A	2	14%
Good	B	0	0%
Fair	C	7	50%
Poor	D	5	36%
Extirpated	X	0	0%
Total		14	

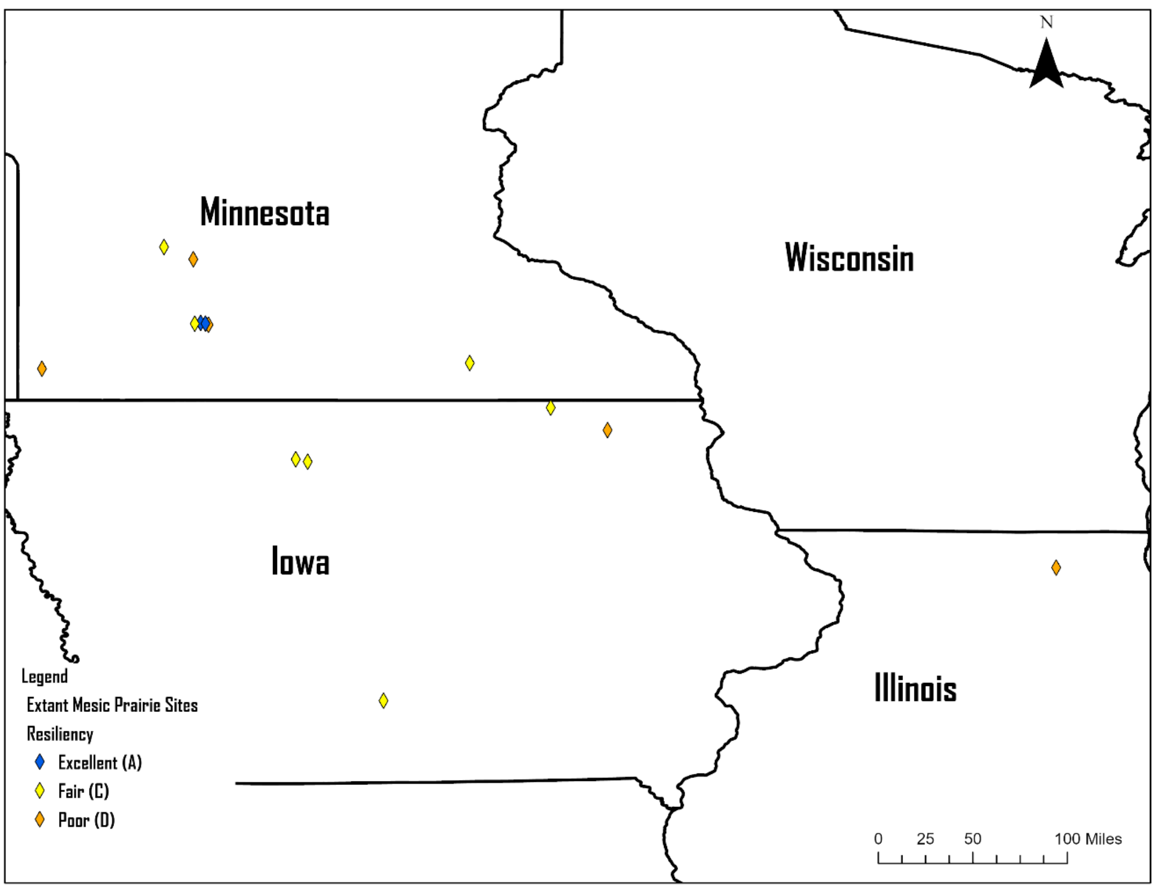

Figure 3.5 Map of extant prairie bush-clover (*Lespedeza leptostachya*) populations in mesic prairie habitat.

The two populations with excellent resiliency are both found in Minnesota. Both populations have at least 1000 or more individual prairie bush-clover plants with no evidence of significant and recent decline over the last 20 years and have at least 10 or more acres of contiguous suitable habitat. Both of these populations are permanently protected for the purpose of conservation and consist of high-quality prairie with no threats or threats kept minimal by persistent management.

The seven mesic prairie populations with fair resiliency are found in Minnesota and Iowa. Population sizes range from fewer than ten individual plants to fewer than 1000. Three populations have high quality habitat with either no threats or threats kept minimal due to persistent management, while the other four populations occur in fair mesic prairie habitat with persistent management or degraded mesic prairie habitat with inconsistent management, encroaching woody vegetation and non-native invasive plant species. The amount of contiguous suitable habitat present ranges from one to ten or more acres. The protection status of these populations varies, with three permanently protected for the purposes of conservation, one privately owned or owned by an organization that is currently interested in conservation but not permanently protected, and three unprotected.

Prairie bush-clover populations at mesic prairie sites with poor resiliency occur in Illinois, Iowa, and Minnesota. Nearly all mesic prairie populations with poor resiliency have fewer than 10 individual prairie bush-clover plants and one population has fewer than 99 individual plants. Four out of the five populations occur in degraded dry prairie habitat with inconsistent management, encroaching woody vegetation and non-native invasive plant species. One population occurs in high quality habitat with no threats or minimal threats due to persistent management. The amount of contiguous suitable habitat present ranges from less than one to ten or more acres. Three populations are permanently protected for the purposes of conservation and two are unprotected.

Bedrock Prairie
The fewest number of prairie bush-clover populations are found in bedrock prairie. Table 3.7 shows the current condition of each population in the bedrock prairie habitat type. The distribution of these populations is depicted in Figure 3.6.

Table 3.7 Table of extant prairie bush-clover (*Lespedeza leptostachya*) populations in bedrock prairie. Resiliency is characterized by calculated element occurrence (EO) rank.

Resiliency	EO Rank	Number of Bedrock Prairie Populations	Percent (%) of Bedrock Prairie Populations
Excellent	A	0	0%
Good	B	1	17%
Fair	C	2	33%
Poor	D	3	50%
Extirpated	X	0	0%
Total		6	

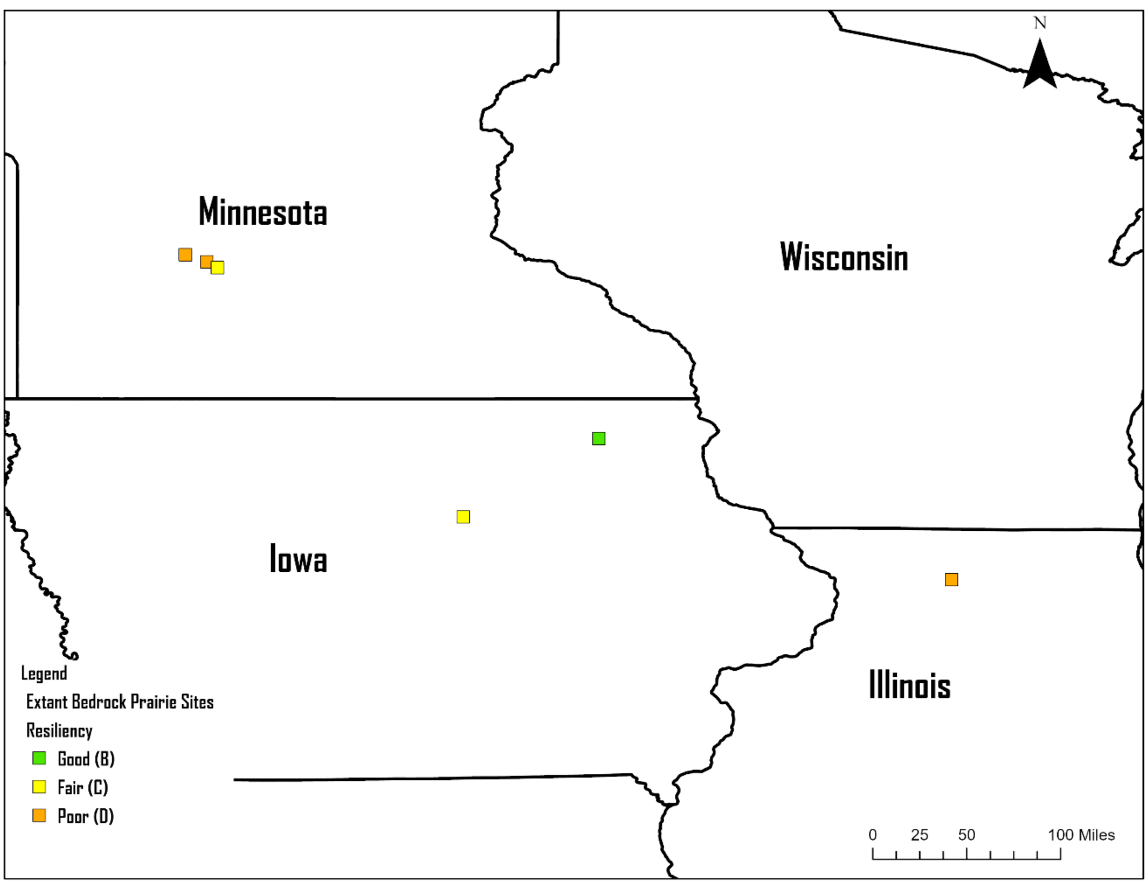

Figure 3.6 Map of extant prairie bush-clover (*Lespedeza leptostachya*) populations in bedrock prairie habitat.

The single bedrock prairie population with good resiliency is found in Iowa. This population has at least 100 individual prairie bush-clover plants, high quality habitat or persistent management, and is permanently protected for the purposes of conservation. However, less than one acre of contiguous suitable habitat is present.

The two populations with fair resiliency are unprotected, have at least one acre of contiguous suitable habitat, and at least ten individual prairie bush clover plants. One population has high quality habitat with either no threats or threats kept minimal due to persistent management, while the other population occurs in degraded bedrock prairie habitat with inconsistent management.

Bedrock prairie populations with poor resiliency have fewer than 99 individual prairie bush-clover plants. Two populations are permanently protected for the purposes of conservation, while the other population is unprotected. Contiguous suitable habitat at a site ranges from one to ten or more acres, with most having one to four acres. In general, the habitat quality at these sites is fair or degraded due to inconsistent management and the prevalence of non-native, invasive plant species or encroaching woody vegetation.

CHAPTER 4. FUTURE CONDITIONS AND VIABILITY (v. July 15, 2021)

Introduction

This chapter summarizes our assessment of the ability of the prairie bush-clover to sustain healthy populations into the future given plausible future changes in threats and stressors and their effects on the demographic condition of the species. We assessed the future condition of the prairie bush-clover in the context of its resiliency, representation, and redundancy, using the best available information. The future resiliency of each population is directly related to the EO rank (excellent, good, fair, or poor) and was used to evaluate the projected future prairie bush-clover viability across its geographic range.

Future Threats and Stressors

Our assessment of future condition included plausible future effects from habitat conversion and indirect effects of climate change (dominant vegetation encroachment). We also considered the potential impacts from herbicide use, climate change, and hybridization, as described below; however, we did not include these in our assessment of future condition because we lacked sufficient information at an appropriate scale to do so.

Herbicide Use

We did not assess the potential impacts of increased or new herbicide use at agricultural fields or other locations adjacent to extant prairie bush-clover populations. We are aware of the potential for additional, new herbicides to be used in agricultural fields close to populations across the species' range. Populations that are not currently permanently protected are at greater risk of negative impacts from increased or incompatible use of herbicides; however, herbicidal drift also has the potential to negatively impact populations currently protected.

Drought

Changes to precipitation regimes are anticipated due to climate change. Prolonged drought events lasting over 2-3 consecutive growing seasons may have long lasting impacts on populations. If conditions are not favorable, the prairie bush-clover may enter a state of dormancy for a year; however, if unfavorable conditions persist for two or more years, the plant may not survive. The 14 extant populations in mesic prairies may be at greater risk of negative impacts due to prolonged drought periods because of changes in soil moisture (Knapp *et al.* 2008, p. 816).

Hybridization

While we did not assess future impacts of increased hybridization, we anticipate hybrids will continue to increase at sites where hybridization has already been documented. The number of sites where hybridization is occurring is currently unknown, but the range of round-headed bush clover overlaps the entire prairie bush-clover range. Climate change may be contributing to hybridization at sites by altering the flowering times of the two parent species and associated pollinators, resulting in greater overlap and additional opportunities for hybridization (Kramer and Havens 2009, p. 605). Prairie bush-clover is not a genetically diverse species, so genetic assimilation to round-headed bush clover may serve as a threat to the genetic integrity of prairie bush-clover (Fant *et al*. 2010, p. 2203) and its distinctness as a species may be lost.

Methods for Evaluating Future Condition

To assess plausible future scenarios, we built off the current condition metrics identified by species experts as having the most influence on species viability. The metrics likely to have the greatest influence on a population's ability to persist into the future include maintenance of habitat quality and protection status. Habitat conversion and the pressure of encroaching woody vegetation are the main drivers that influence species presence at a site into the future (Figure 4.1). Given the longevity of individual plants, in some cases 30 years or more, it is reasonable to consider these stressors at a 40- and 80-year interval, to 2060 and 2100, respectively.

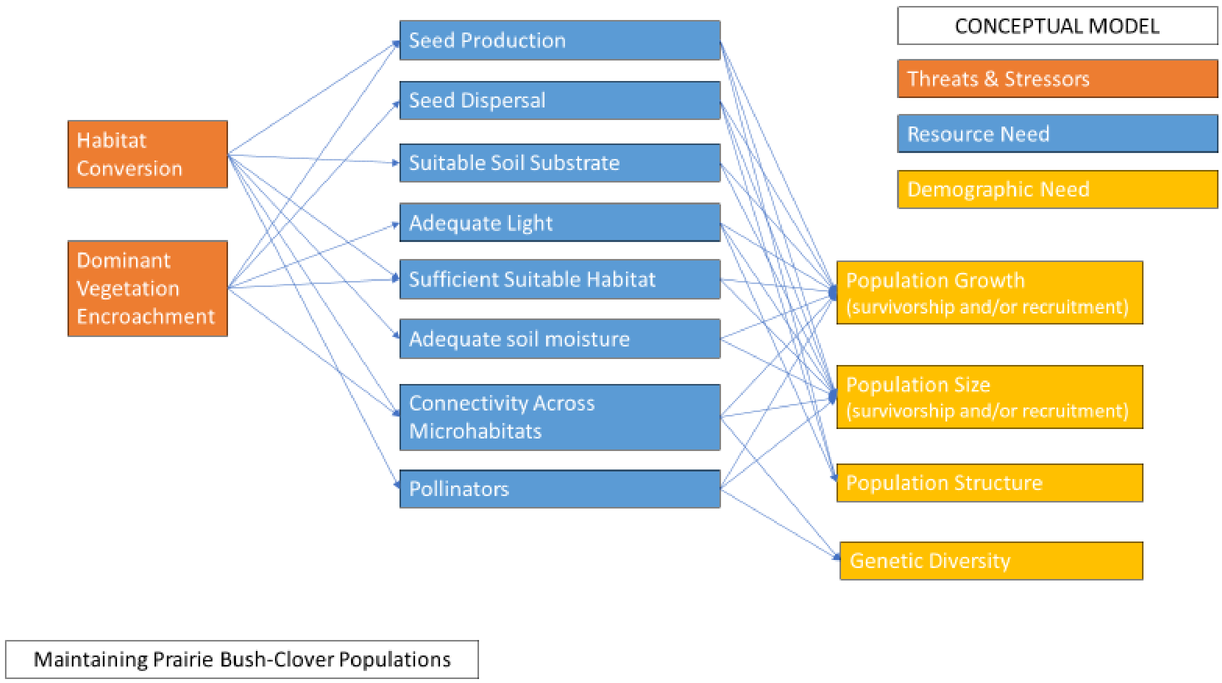

Figure 4.1 Conceptual model for maintaining prairie bush-clover (*Lespedeza leptostachya*) populations with the threats and stressors (habitat conversion and dominant vegetation encroachment) selected for assessing plausible future scenarios.

Habitat conversion at unprotected populations could lead to the extirpation of populations in the future. To assess plausible habitat conversion scenarios, we used the Conterminous United States Land Cover Projections – 1992 to 2100 from the U.S. Geological Survey. Projected changes are based on the 2000 Special Report on Emission Scenarios by the Intergovernmental Panel on Climate Change (Nakićenović *et al.* 2000, entirety) and the four climate change storylines (A1B, A2, B1, and B2). Each storyline represents a different set of demographic, social, economic, technological, and environmental scenarios that may occur in the future. We examined the location of each extant prairie bush-clover population not permanently protected for the purposes of conservation under each climate change storyline and documented the projected land cover type in 2060 and 2100.

From this we developed two habitat conversion scenarios to illustrate the range of plausible future conditions based on two assumptions of potential changes in land use under the four climate change storylines. In scenario A, if a population that was not permanently protected had a projected land cover type of either developed or cropland under at least one of the four climate change storylines, the population was considered to become extirpated. Under scenario B, an unprotected population was considered to become extirpated if the projected land cover under all four climate change storylines was developed or cropland. Under both scenarios (A and B), populations that were not considered to become extirpated based on the above rule-set were evaluated under a set of assumptions based on the metrics used to calculate resiliency and current condition.

Our assumptions for assessing plausible future conditions at extant prairie bush-clover sites:

- If a site is currently permanently protected for the purposes of conservation, the site will remain protected into the future and is not at risk of being converted for the purpose of development, quarry, or agricultural field.
- If a site is not currently protected, there is a plausible chance that in 40 or 80 years the site may be converted. This assumption is further supported by the projected land cover data from USGS (see the preceding paragraph).
- If a site is not anticipated to be converted due to protection status or projected land cover, then the habitat quality, population size, and amount of contiguous suitable habitat may be negatively impacted by dominant encroaching vegetation (native and/or non-native, invasive plant species), depending on management. Thus, based on the management at a site, we made the following assumptions about the impacts of dominant encroaching vegetation into the future:
    - Sites with existing management plans and on-the-ground vegetation management are not likely to be negatively impacted by encroaching vegetation. Therefore, populations with excellent habitat quality currently will maintain population size and amount of contiguous suitable habitat (for example, if a populations' current population size and size of contiguous suitable habitat are A rank, those factors will continue to be A rank in both 40 and 80 years (see Table B-1 in Appendix B)).
    - Populations with high quality habitat, but where management is inconsistent, or where habitat is of fair quality (moderate abundance of brush or non- native species), but management is persistent will maintain the same resiliency in 40 years but decrease in population size and contiguous suitable habitat in 80 years (for example, if a populations' current population size and size of contiguous suitable habitat are B rank, those factors will continue to be B rank in 40 years, but decline to C rank in 80 years (see Table B-1 in Appendix B)). Inconsistent management can maintain high quality habitat in the short-term but will not be sufficient to maintain it in the long-term. Persistent management can maintain fair quality habitat for the short-term, but because the management is not improving the habitat beyond the fair condition, the population will deteriorate over time.
    - Sites with degraded prairie due to high impact grazing, brush encroachment, and/or non-native species with inconsistent management will decrease in population size and available contiguous suitable habitat in 40 years with no additional change in 80 years (for example, if a populations' current population size and size of contiguous suitable habitat are B rank, those factors will decline

to C rank in 40 years, but will then remain C rank in 80 years (see Table B-1 in Appendix B)). Populations at sites with degraded habitat and inconsistent management will decline more rapidly, but that decline may plateau in the longer-term.

  - Populations with low quality degraded habitat and no management will decrease in population size and amount of contiguous suitable habitat in the next 40 years and decline again in the following 40 years (2100) (for example, if a populations' current population size and size of contiguous suitable habitat are B rank, those factors will decline to C rank in 40 years, and decline again to D rank 80 years (see Table B-1 in Appendix B)). Due to the poor habitat quality and lack of management at these sites, they will continue to degrade over time.

Resiliency, Representation, and Redundancy under Future Scenarios

Future Resiliency

Resiliency describes the ability of a population to withstand environmental or demographic stochastic disturbances. We used the calculated EO ranks to assess future prairie bush-clover resiliency in 2060 and 2100, or 40 and 80 years into the future.

In general, future resiliency is anticipated to decrease at all sites that are currently unprotected or those that are protected but with no habitat management plans in place. Approximately, 40-45 (35-40%) of populations are anticipated to decline in resiliency by 2060 and 73-76 (65-67%) by 2100. Under each of our future scenarios, we anticipate at least 35% of prairie bush-clover populations will decline in resiliency. Thirty-seven populations will maintain the same resiliency under both habitat conversion scenarios in 2060 and 2100. The projected resiliency of populations is similar under the scenarios (see Tables 4.1, 4.2, and 4.2).

Table 4.1 Summary table of the range of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency in 2060 and 2100 under two scenarios. See Appendix C for the resiliency condition of each population.

Resiliency	**EO Rank**	**Number of Populations 2020**	**Number of Populations 2060**	**Number of Populations 2100**
Excellent	A	12	11-12	9
Good	B	25	19-20	16-17
Fair	C	41	24-25	14-16
Poor	D	35	24-27	26-29
Extirpated	X	12	29-35	42-48
Total Extant Populations by Year		**113**	**78-84**	**65-71**

The discussion below describes the projected resiliency under each of the two future habitat conversion scenarios.

Scenario A

In scenario A, prairie bush-clover sites where land cover projections under any of the four climate change storylines (A2, A1B, B2, and B1) included cropland or developed land were considered extirpated in 2060 and/or 2100. Under this scenario, we project that 23 additional populations will be extirpated by 2060 and by 2100 an additional 13 populations will be extirpated because of habitat conversion and changes in habitat quality due to climate change and management (Table 4.2). The majority (42 populations; 88%) of the populations that we project will become extirpated are currently in fair (C) or poor (D) condition. The number of populations exhibiting excellent resiliency under this scenario remains largely the same in 2060 (decreases from 12 to 11) and we project that nine populations will continue to exhibit excellent resiliency in 2100.

Table 4.2 Summary table of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency in 2060 and 2100 under habitat conversion **scenario A**. See Appendix C for the resiliency condition of each individual population.

Resiliency	**EO Rank**	**Number of Populations 2020 (% of Extant)**	**Number of Populations 2060 (% of Extant)**	**Number of Populations 2100 (% of Extant)**
Excellent	A	12 (11%)	11 (10%)	9 (8%)
Good	B	25 (22%)	19 (17%)	16 (14%)
Fair	C	41 (36%)	24 (21%)	14 (12%)
Poor	D	35 (31%)	24 (21%)	26 (23%)
Extirpated	X	12	35 (31%)	48 (42%)
Total Extant Populations by Year		**113**	**78**	**65**

Scenario B

In scenario B, prairie bush-clover sites where land cover projections under all the four climate change storylines (A2, A1B, B2, and B1) included cropland or developed land were considered extirpated in 2060 and/or 2100. Under this scenario, we project that 29 populations will be extirpated by 2060 and 42 populations will be extirpated by 2100 due to habitat conversion and changes in habitat quality as a result of climate change and management (Table 4.3). The number of populations exhibiting excellent resiliency under this scenario remains the same in 2060 (12) and we project that nine populations will continue to exhibit excellent resiliency in 2100. Under this scenario 29 extant prairie bush-clover populations in 2100 will exhibit poor resiliency.

Table 4.3 Summary table of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency in 2060 and 2100 under habitat conversion **scenario B**. In this scenario, See Appendix C for the resiliency condition of each individual population.

Resiliency	EO Rank	Number of Populations 2020 (% of Extant)	Number of Populations 2060 (% of Extant)	Number of Populations 2100 (% of Extant)
Excellent	A	12 (11%)	12 (10%)	9 (8%)
Good	B	25 (22%)	20 (18%)	17 (15%)
Fair	C	41 (36%)	25 (22%)	16 (14%)
Poor	D	35 (31%)	27 (24%)	29 (26%)
Extirpated	X	12	29 (26%)	42 (37%)
Total Extant Populations by Year		**113**	**84**	**71**

Future Representation and Redundancy

The projected resiliency of populations is similar under the two scenarios across representative categories. In 2060, the number of populations exhibiting excellent resiliency in each of the representative categories remains largely the same as it is currently. Under both scenarios, at least one prairie bush-clover population with excellent or good resiliency will exist in all four representative categories in 2060 (Tables 4.4 and 4.6). There will be 6-7 excellent populations in dry prairie, 3 in dry-mesic prairie, and 2 in mesic prairie. We anticipate that there will not be any excellent rated populations in bedrock prairies, but there will be one population with good resiliency. The number of extirpated populations increases in all categories: from 0 to 1 population in bedrock prairie, from 7 to 16-21 populations in the dry prairie, from 5 to 7-8 populations in the dry-mesic prairie, and from 0 to 5 populations in the mesic prairie.

In 2100, the number of populations with excellent resiliency decreases to four in the dry prairie and remains the same in the other representative categories (Tables 4.5 and 4.7). The bedrock prairie category has three extant populations, none with excellent or good resiliency. The number of extirpated populations increases between 2060 and 2100 in nearly all categories: from 1 to 3 in bedrock prairie, from 16-21 to 19-24 in the dry prairie, from 7-8 to 15-16 in the dry-mesic prairie, and 5 remain extirpated in the mesic prairie.

Below is a summary of the results for each scenario. For a more detailed description for each representative category, see Appendix D.

Scenario A: 2060

In scenario A, prairie bush-clover sites where land cover projections under any of the four climate change storylines (A2, A1B, B2, and B1) included cropland or developed land were considered extirpated in 2060. Under this scenario, the number of populations exhibiting excellent resiliency in each of the representative categories in 2060 remains largely the same as it is currently and at least one prairie-bush clover population with excellent or good resiliency will exist in all four representative categories (Table 4.4). The number of extirpated populations increases in all representative categories: from 0 to1 in bedrock prairie, 7 to 21 in the dry prairie, 5 to 8 in the dry-mesic prairie, and 0 to 5 in the mesic prairie.

Table 4.4 Summary table of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency by representative category (prairie type) across the geographic range of the species in 2060 under habitat conversion **scenario A**.

Resiliency (2060)	Bedrock Prairie	Dry Prairie	Dry-Mesic Prairie	Mesic Prairie	Total
Excellent (A)	0	6	3	2	11
Good (B)	1	6	12	0	19
Fair (C)	1	10	8	5	24
Poor (D)	3	9	10	2	24
Extirpated	1	21	8	5	35
Total Extant Sites	**5**	**31**	**33**	**9**	**78**

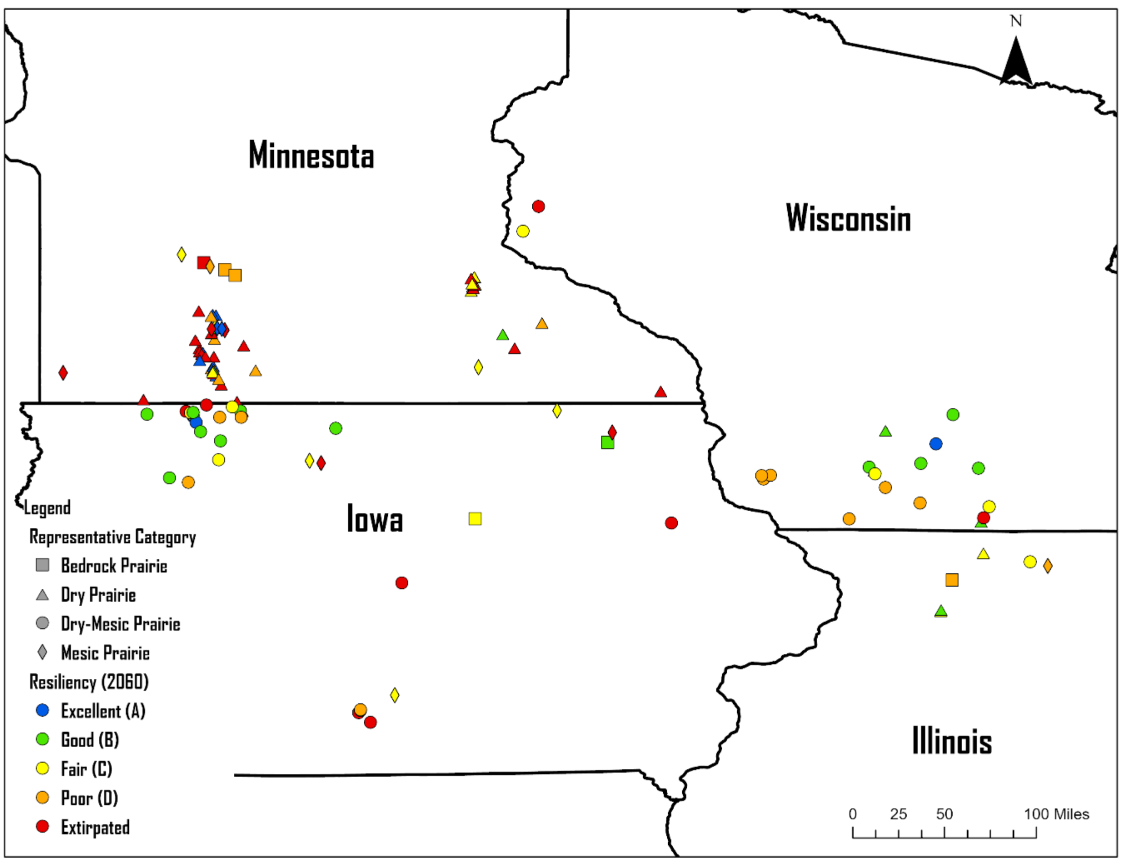

Figure 4.2 Summary map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency by representative category (prairie type) across the geographic range of the species in 2060 under habitat conversion **scenario A**.

Scenario A: 2100

In 2100, the number of populations with excellent resiliency decreases from six to four in the dry prairie and remains the same in the other representative categories (Table 4.5, Figure 4.3). The number of extirpated populations increases between 2060 and 2100 in nearly all representative categories: from 1 to 3 in bedrock prairie, from 21 to 24 in the dry prairie, from 8 to 16 in the dry-mesic prairie, and 5 remain extirpated in the mesic prairie. The bedrock prairie has three extant populations, none with excellent or good resiliency.

Table 4.5 Summary table of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency by representative categories (prairie type) across the geographic range of the species in 2100 under habitat conversion **scenario A**.

Resiliency (2100)	Bedrock Prairie	Dry Prairie	Dry-Mesic Prairie	Mesic Prairie	Total
Excellent (A)	0	4	3	2	9
Good (B)	0	7	9	0	16
Fair (C)	1	4	7	2	14
Poor (D)	2	13	6	5	26
Extirpated	3	24	16	5	48
Total Extant Sites	**3**	**28**	**25**	**9**	**65**

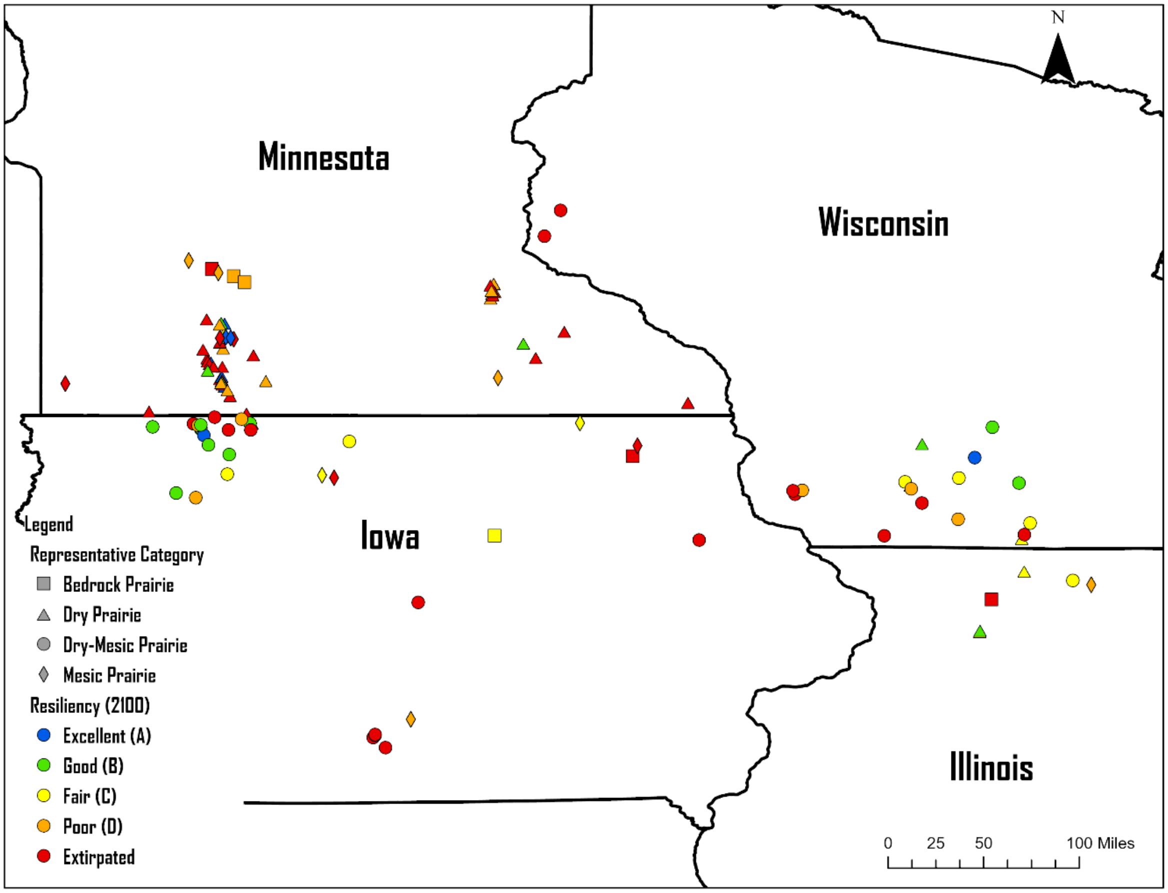

Figure 4.3 Summary map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency by representative category (prairie type) across the geographic range of the species in 2100 under habitat conversion **scenario A**.

Scenario B: 2060

In scenario B, prairie bush-clover populations were considered extirpated in 2060 if land cover projections under all four climate change storylines (A2, A1B, B2, and B1) were either cropland or developed land. Under this scenario, the number of populations exhibiting excellent resiliency in each of the representative categories remains the same as it is currently and at least one prairie-bush clover population with excellent or good resiliency will exist in all four representative categories in 2060 (Table 4.6 and Figure 4.4). The number of extirpated populations increases in all categories: from 0 to 1 in bedrock prairie, 7 to 16 in the dry prairie, 5 to 7 in the dry-mesic prairie, and 0 to 5 in the mesic prairie.

Table 4.6 Summary table of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency by representative category in 2060 under habitat conversion **scenario B**.

Resiliency	Bedrock Prairie	Dry Prairie	Dry-Mesic Prairie	Mesic Prairie	Total
Excellent (A)	0	7	3	2	12
Good (B)	1	7	12	0	20
Fair (C)	1	11	8	5	25
Poor (D)	3	11	11	2	27
Extirpated	1	16	7	5	29
Total Extant Sites	**5**	**36**	**34**	**9**	**84**

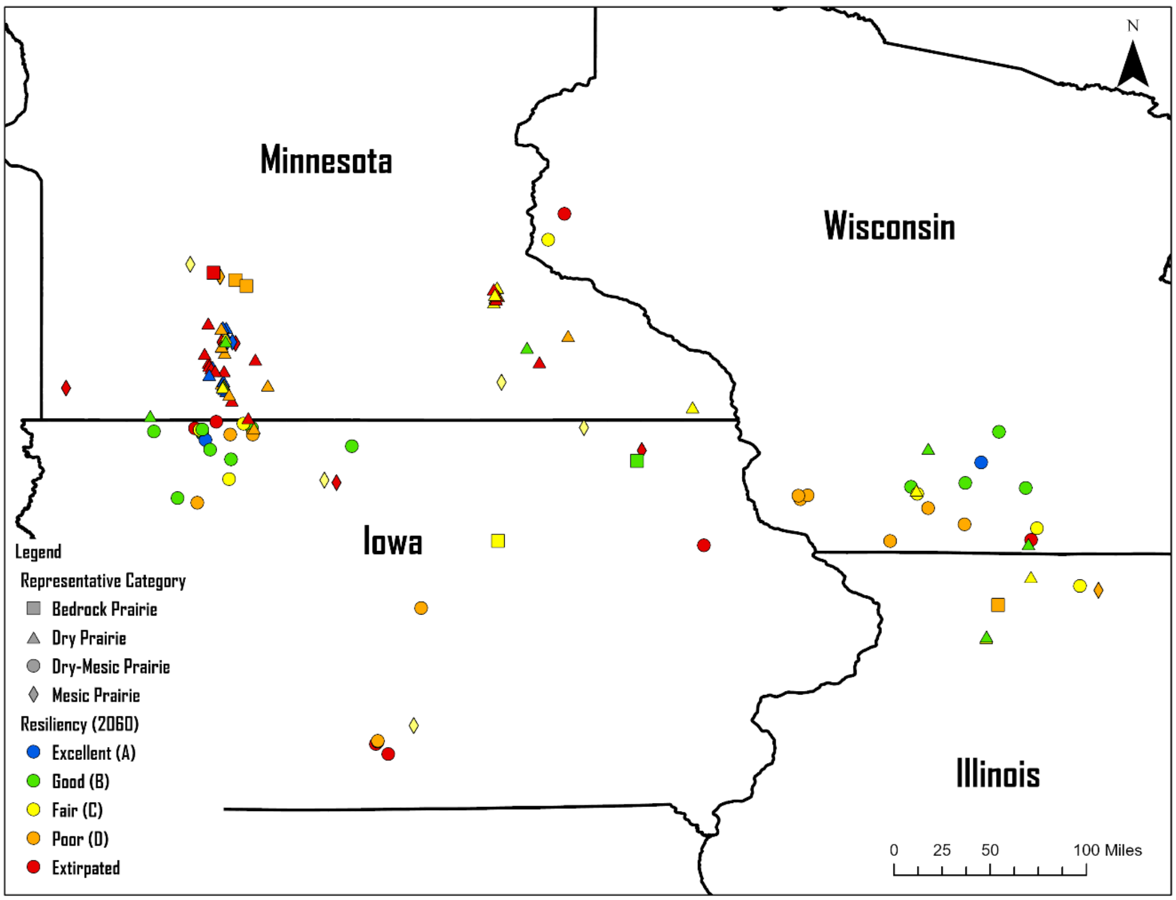

Figure 4.4 Summary map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency by representative category (prairie type) across the geographic range of the species in 2060 under habitat conversion **scenario B**.

Scenario B: 2100

Under scenario B, in 2100, the number of populations with excellent resiliency decreases to four in the dry prairie and remains the same in the other representative categories (Table 4.7). The number of extirpated populations increases between 2060 and 2100 in all representative categories: from 1 to 3 in bedrock prairie, from 16 to 19 in the dry prairie, from 7 to 15 in the dry-mesic prairie, and 5 remain extirpated in mesic prairie.

Table 4.7 Summary table of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency by representative category in 2100 under habitat conversion **scenario B**.

Resiliency	Bedrock Prairie	Dry Prairie	Dry-Mesic Prairie	Mesic Prairie	Total
Excellent (A)	0	4	3	2	9
Good (B)	0	8	9	0	17
Fair (C)	1	6	7	2	16
Poor (D)	2	15	7	5	29
Extirpated	3	19	15	5	42
Total Extant Sites	**3**	**33**	**26**	**9**	**71**

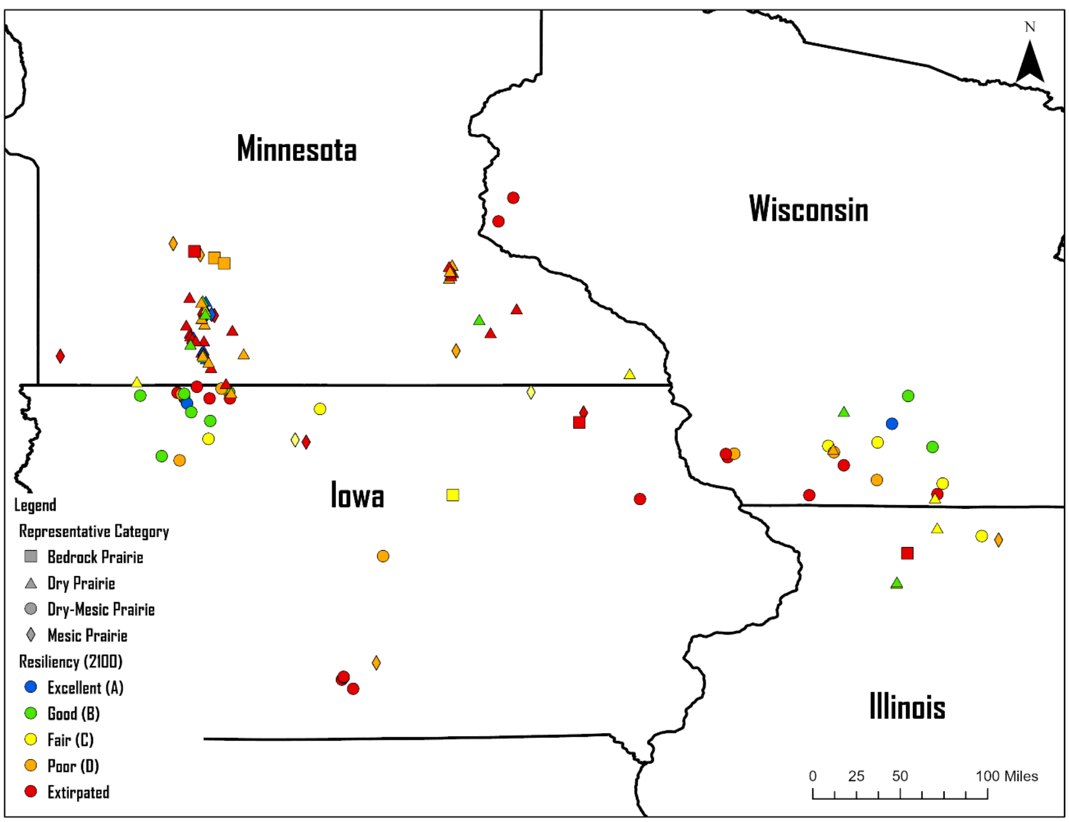

Figure 4.5 Summary map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency by representative category (prairie type) across the geographic range of the species in 2100 under habitat conversion **scenario B**.

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Appendix A. Analytical Approach and Framework

Analytical Framework
For this SSA, we define viability as the ability of a species to maintain populations in the wild over time. To assess viability, we use the conservation biology principles of resiliency, redundancy, and representation (Shaffer and Stein 2000, pp. 308-311). To sustain populations over time, a species must have the capacity to withstand:

1) environmental and demographic stochasticity and disturbances (Resiliency),
2) catastrophes (Redundancy), and
3) novel changes in its biological and physical environment (Representation).

A species with a high degree of resiliency, representation, and redundancy (the 3Rs) is better able to adapt to novel changes and to tolerate environmental stochasticity and catastrophes. In general, species viability will increase with increases in resiliency, redundancy, and representation (Smith *et al.* 2018, p. 306).

Resiliency is the ability of a species to withstand environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature, rainfall), periodic disturbances within the normal range of variation (fire, floods, storms), and demographic stochasticity (normal variation in demographic rates such as mortality and fecundity) (Redford *et al.* 2011, p. 40). Simply stated, resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions.

Redundancy is an indicator of the ability of a species to withstand catastrophes. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population heath and for which adaptation is unlikely (Mangal and Tier 1993, p. 1083).

Representation is an indicator of the ability of a species to adapt to both near-term and long-term changes in its physical (climate conditions, habitat conditions, habitat structure, etc.) and biological (pathogens, competitors, predators, etc.) environments. This ability to adapt to new environments, referred to as adaptive capacity, is essential for viability, as species need to continually adapt to their continuously changing environments (Nicotra *et al.* 2015, p. 1269). Species adapt to novel changes in their environment by either moving to new, suitable environments or by altering their physical or behavioral traits (phenotypes) to match the new environmental conditions through either plasticity or genetic change (Beever *et al.* 2016, p. 132; Nicotra *et al* 2015, p. 1270). The latter (evolution) occurs via the evolutionary processes of natural selection, gene flow, mutations, and genetic drift (Crandall *et al.* 2000, p. 290-291; Sgro *et al.* 2011, p. 327; Zackay 2007, p. 1).

In summary, long-term species viability is enhanced by having multiple (redundancy), healthy populations (resiliency) distributed across the species' range to maintain the ecological and genetic diversity (representation).

Species Status Assessment Approach

Our analytical approach for assessing the viability of prairie bush-clover involved three stages (Figure A-1). In Stage 1 (Chapter 1), we describe the species' needs in terms of redundancy, resiliency, and representation. Specifically, we identified the ecological needs for survival and reproduction at the individual, population, and species levels. In Stage 2 (Chapter 3), we describe the current condition of prairie bush-clover using the ecological needs of the species identified in Stage 1. We assessed the species' current condition in terms of the 3 Rs and past and ongoing factors influencing (Chapter 2) (positively or negatively) the species' current condition. In Stage 3 (Chapter 4), we projected future conditions of prairie bush-clover using the baseline conditions established in Stage 2 and the predictions for future risk and beneficial factors. Lastly, we provide a status assessment summary of the species' viability over time, given our analyses of current conditions and projections of future conditions.

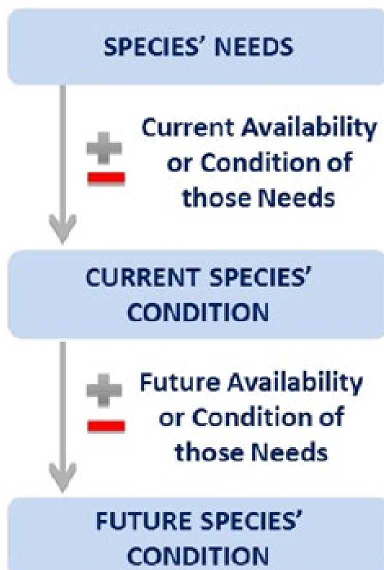

Figure A.1 Species Status Assessment Framework.

Appendix B. Current Condition Methods

To assess the current condition of extant prairie bush-clover populations, we used population size, habitat quality, size of contiguous habitat in acres, and protection status to inform a calculated resiliency score (Tables B-1 and B-2).

- Population Size – identified size as the most influential factor for current condition, twice as influential as habitat quality
- Habitat Quality – accounts for management at the site targeted towards reducing dominant vegetation encroachment and the overall quality of the prairie
- Size of Contiguous Suitable Habitat (acres) – examines greater landscape context of populations
- Protection Status – was identified as a less meaningful indicator of population health because a site can be protected but be of low quality if there is no management plan or active management to target natural succession. The weighting of this factor has very little influence over the overall calculated EO rank.

Table B-1. Factors and weights used to assess current resiliency of prairie bush-clover (*Lespedeza leptostachya*) populations.

Factor	Weight	A score (4)	B score (3)	C score (2)	D score (1)
Population Size	0.58	1000 or more individual plants with no evidence of significant decline over the last 20 years.	100-999 individual plants or populations with more than 999 plants that have shown significant decline over the last 20 years.	10-99 individual plants or populations with more than 99 plants that have shown significant decline over the last 20 years.	10 or fewer individual plants or populations with more than 10 plants that have shown significant decline over the last 20 years.
Habitat Quality	0.28	High quality prairie with no threats or persistent management that keeps threats minimal; grazing	Habitat is high quality, but management is inconsistent, or habitat is of fair quality (moderate abundance of brush or non-native species) but management is	Habitat is degraded due to high impact grazing, brush encroachment, and/or non-native species. Management is inconsistent.	Low quality habitat with no management (significant threats from brush, non-native species, high impact grazing,

		pressure is low or absent.	persistent. Grazing pressure is low or absent.		sedimentation, or erosion). Non-native species are dominant.
Size of Contiguous Suitable Habitat (Acres)	0.09	10 or more	5-9	1-4	Less than 1
Protection	0.05	Owned by conservation organization or permanently protected for purposes of conservation	Owned privately or by organization that is currently interested in conservation but no permanent protection in place	Informal agreement	Not protected

The element occurrence rank for each population was calculated by multiplying the score (1, 2, 3, or 4) for each factor (population size, habitat quality, size of contiguous habitat, and protection) by the assigned weight and then adding the scores together. The overall element occurrence rank (A, B, C, or D) was assigned based on the calculated score (Table B-2). Species experts or those familiar with individual prairie bush-clover populations assigned scores for each category.

Table B-2. Element occurrence ranks and the range of scores for each rank.

Rank	**Resiliency**	**Calculated Score**
A	Excellent	3.51-4
B	Good	2.8-3.5
C	Fair	2-2.79
D	Poor	0-1.99

Appendix C. Prairie Bush-Clover Populations and Element Occurrence Ranks

Table C-1. Prairie bush-clover (*Lespedeza leptostachya*) populations with calculated element occurrence (EO) scores and ranks in 2020 and EO ranks under both future scenarios in 2060 and 2100. Populations with cells in red with an "X" have become extirpated since the recovery plan (1988) and cells in gray with an "H" are historical populations and were considered extirpated before listing.

State	County	Site Name	EO Num.	Representative Category	EO Score	2020 EO Rank	2060 EO Rank Scenario A	2100 EO Rank Scenario A	2060 EO Rank Scenario B	2100 EO Rank Scenario B
Iowa	Dickinson	Cayler Prairie		Dry-Mesic Prairie	4	A	A	A	A	A
Iowa	Dickinson	Freda Haffner Kettlehole		Dry-Mesic Prairie	3.91	A	A	A	A	A
Minnesota	Brown	Cottonwood River Prairie SNA	15	Dry Prairie	4	A	A	A	A	A
Minnesota	Brown	Cottonwood River Prairie SNA (in part)	21	Dry Prairie	3.67	A	A	B	A	B
Minnesota	Jackson	Des Moines River Prairie SNA	34	Dry Prairie	4	A	A	A	A	A
Minnesota	Cottonwood	Great Bend 9 (not designated SNA yet)	32	Dry Prairie	4	A	A	A	A	A
Minnesota	Cottonwood	Jeffers Petroglyphs Historic Site	1	Mesic Prairie	4	A	A	A	A	A
Minnesota	Jackson	Kilen Woods State Park/Prairie Bush Clover SNA	6	Dry Prairie	4	A	A	A	A	A
Minnesota	Jackson	Private	13	Dry Prairie	3.57	A	X	X	A	B
Minnesota	Cottonwood	Red Rock Prairie	10	Mesic Prairie	4	A	A	A	A	A
Minnesota	Jackson	String Lake WPA	48	Dry Prairie	3.72	A	A	B	A	B
Wisconsin	Dane	Westport Drumlin Prairie		Dry-Mesic Prairie	4	A	A	A	A	A
Illinois	Lee	Nachusa Grasslands Stone Barn, Lee/Ogle, Lee, Carpenter		Dry Prairie	3.42	B	B	B	B	B

State	County	Site Name	EO Num.	Representative Category	EO Score	2020 EO Rank	2060 EO Rank Scenario A	2100 EO Rank Scenario A	2060 EO Rank Scenario B	2100 EO Rank Scenario B
Iowa	Emmet	Anderson Prairie		Dry-Mesic Prairie	3.24	B	B	B	B	B
Iowa	Dickinson	Cayler Prairie Addition		Dry-Mesic Prairie	3.33	B	B	B	B	B
Iowa	Clarke	Flaherty Prairie		Dry-Mesic Prairie	3.11	B	C	C	C	C
Iowa	Clay	Kirchner Prairie		Dry-Mesic Prairie	2.84	B	B	B	B	B
Iowa	Winneshiek	Ludwig Reserve		Bedrock Prairie	2.87	B	B	X	B	X
Iowa	Dickinson	Private Property Near Judd Wildlife Area (Dickinson Co.)		Dry-Mesic Prairie	3.42	B	B	B	B	B
Iowa	Dickinson	Santee Prairie ("Jensen Life Estate Prairie Pasture")		Dry-Mesic Prairie	2.84	B	B	B	B	B
Iowa	Kossuth	Union Slough NWR		Dry-Mesic Prairie	3.14	B	B	C	B	C
Iowa	O'Brien	Waterman Prairie - Fulk Tract		Dry-Mesic Prairie	3.42	B	B	B	B	B
Iowa	Osceola	Wolters Prairie		Dry-Mesic Prairie	3.33	B	B	B	B	B
Minnesota	Dodge	Pheasants Forever WMA	56	Dry Prairie	3.33	B	B	B	B	B
Minnesota	Cottonwood	Private	25	Dry Prairie	2.95	B	X	X	X	X
Minnesota	Dodge	Private	46	Dry Prairie	2.9	B	X	X	X	X
Minnesota	Jackson	Private	62	Dry Prairie	3.48	B	B	B	B	B
Minnesota	Redwood	Private	68	Dry Prairie	2.9	B	X	X	X	X
Minnesota	Nobles	Private	71	Dry Prairie	2.99	B	X	X	B	C
Minnesota	Cottonwood	Rock Ridge Prairie SNA	11	Dry Prairie	2.84	B	B	B	B	B
Wisconsin	Iowa	Barneveld Prairies		Dry-Mesic Prairie	3.14	B	B	C	B	C

State	County	Site Name	EO Num.	Representative Category	EO Score	2020 EO Rank	2060 EO Rank Scenario A	2100 EO Rank Scenario A	2060 EO Rank Scenario B	2100 EO Rank Scenario B
Wisconsin	Columbia	Hagen Prairie		Dry-Mesic Prairie	3.42	B	B	B	B	B
Wisconsin	Grant	Heather's Prairie Mount Ridge Prairie		Dry-Mesic Prairie	2.81	B	D	D	D	D
Wisconsin	Dane	Prairie Ridge Conservation Park		Dry-Mesic Prairie	3.14	B	B	C	B	C
Wisconsin	Rock	Rock River Prairie		Dry Prairie	3.05	B	B	C	B	C
Wisconsin	Sauk	Schluckebier Sand Prairie		Dry Prairie	3.42	B	B	B	B	B
Wisconsin	Dane	Smith Drumlin Prairie		Dry-Mesic Prairie	2.84	B	B	B	B	B
Illinois	Winnebago	Harlem Hills		Dry Prairie	2.26	C	C	C	C	C
Illinois	McHenry	HUM Railroad Prairie West		Dry-Mesic Prairie	2.66	C	C	C	C	C
Illinois	Lee	Nachusa Grasslands - Naylor Road		Dry Prairie	2.26	C	C	C	C	C
Iowa	Clarke	Bell Pasture		Dry-Mesic Prairie	2.62	C	X	X	X	X
Iowa	Dickinson	Christopherson Slough		Dry-Mesic Prairie	2.38	C	C	D	C	D
Iowa	Clarke	Flaherty Pasture		Dry-Mesic Prairie	2.16	C	X	X	X	X
Iowa	Buena Vista	Fox Run		Dry-Mesic Prairie	2.62	C	D	D	D	D
Iowa	Howard	Hayden Prairie		Mesic Prairie	2.26	C	C	C	C	C
Iowa	Clarke	Little Pasture		Dry-Mesic Prairie	2.34	C	D	X	D	X
Iowa	Clay	Little Sioux Wildlife Area		Dry-Mesic Prairie	2.75	C	C	C	C	C
Iowa	Dickinson	Long Prairie		Dry-Mesic Prairie	2.32	C	C	D	C	D
Iowa	Warren	Rolling Thunder Prairie		Mesic Prairie	2.47	C	C	D	C	D

State	County	Site Name	EO Num.	Representative Category	EO Score	2020 EO Rank	2060 EO Rank Scenario A	2100 EO Rank Scenario A	2060 EO Rank Scenario B	2100 EO Rank Scenario B
Iowa	Kossuth	Smith Prairie (Kossuth Co.)		Mesic Prairie	2.03	C	X	X	X	X
Iowa	Kossuth	Stinson Prairie		Mesic Prairie	2.26	C	C	C	C	C
Iowa	Delaware	Swanson Prairie		Dry-Mesic Prairie	2.23	C	X	X	X	X
Iowa	Butler	Washington Prairie		Bedrock Prairie	2.51	C	C	C	C	C
Minnesota	Jackson	Holthe Prairie SNA	47	Dry Prairie	2.56	C	C	D	C	D
Minnesota	Rice	Prairie Creek WMA	75	Dry Prairie	2.47	C	C	D	C	D
Minnesota	Brown	Private	16	Dry Prairie	2.71	C	C	C	C	C
Minnesota	Cottonwood	Private	17	Dry Prairie	2.62	C	D	D	D	D
Minnesota	Goodhue	Private	19	Dry Prairie	2.37	C	C	D	C	D
Minnesota	Cottonwood	Private	26	Dry Prairie	2.23	C	X	X	X	X
Minnesota	Houston	Private	44	Dry Prairie	2.12	C	X	X	C	C
Minnesota	Cottonwood	Private	49	Mesic Prairie	2.53	C	X	X	X	X
Minnesota	Redwood	Private	53	Mesic Prairie	2.32	C	C	D	C	D
Minnesota	Redwood	Private	54	Bedrock Prairie	2.62	C	D	D	D	D
Minnesota	Cottonwood	Private	59	Dry Prairie	2.04	C	X	X	D	D
Minnesota	Jackson	Private	61	Dry Prairie	2.05	C	D	D	D	D
Minnesota	Jackson	Private	63	Dry Prairie	2.42	C	C	D	C	D
Minnesota	Jackson	Private	64	Dry Prairie	2.62	C	D	D	D	D
Minnesota	Cottonwood	Private	65	Dry Prairie	2.72	C	X	X	X	X
Minnesota	Martin	Private	67	Dry Prairie	2.04	C	D	D	D	D
Minnesota	Rice	Private	69	Dry Prairie	2.42	C	C	D	C	D
Minnesota	Watonwan	Private	77	Dry Prairie	2.42	C	X	X	X	X
Minnesota	Goodhue	Private (Carleton College)	8	Dry Prairie	2.38	C	C	D	C	D
Minnesota	Mower	Private (RR)/MN DOT	52	Mesic Prairie	2.23	C	C	D	C	D

State	County	Site Name	EO Num.	Representative Category	EO Score	2020 EO Rank	2060 EO Rank Scenario A	2100 EO Rank Scenario A	2060 EO Rank Scenario B	2100 EO Rank Scenario B
Wisconsin	Pierce	Foster Hill		Dry-Mesic Prairie	2.29	C	C	X	C	X
Wisconsin	Rock	Green Belt Prairie		Dry-Mesic Prairie	2.66	C	C	C	C	C
Wisconsin	Iowa	Powell (Jones Valley) Prairie		Dry Prairie	2.46	C	C	D	C	D
Wisconsin	Green	Vale Prairie		Dry-Mesic Prairie	2.26	C	D	D	D	D
Wisconsin	Iowa	Williams Southeast Prairie Pasture		Dry-Mesic Prairie	2.56	C	C	D	C	D
Illinois	McHenry	HUM Railroad Prairie East		Mesic Prairie	1.99	D	D	D	D	D
Illinois	Ogle	Jarrett Prairie		Bedrock Prairie	1.98	D	D	X	D	X
Iowa	Emmet	Fort Defiance SP		Dry-Mesic Prairie	1.8	D	D	X	D	X
Iowa	Emmet	Johnson Tract		Dry Prairie	1.95	D	X	X	D	D
Iowa	Dickinson	Lake Park Prairie		Dry-Mesic Prairie	1.46	D	X	X	X	X
Iowa	Dickinson	Near Hottes Lake WMA (Dickinson Co.)*		Dry-Mesic Prairie	1.46	D	X	X	X	X
Iowa	Winneshiek	Prairie-Farmer Recreational Trail		Mesic Prairie	1.43	D	X	X	X	X
Iowa	Story	Raymond Prairie		Dry-Mesic Prairie	1.95	D	X	X	D	D
Iowa	Dickinson	Spring Run Wetland Complex (Dickinson Co.)*		Dry-Mesic Prairie	1.89	D	D	X	D	X
Minnesota	Jackson	Caraway WMA	76	Dry Prairie	1.98	D	D	X	D	X
Minnesota	Redwood	Cedar Rock WMA	72	Bedrock Prairie	1.52	D	X	X	X	X
Minnesota	Cottonwood	Cottonwood County Landfill	42	Dry Prairie	1.55	D	X	X	X	X
Minnesota	Olmsted	Oronoco Prairie SNA (in part)	50	Dry Prairie	1.89	D	D	X	D	X

State	County	Site Name	EO Num.	Representative Category	EO Score	2020 EO Rank	2060 EO Rank Scenario A	2100 EO Rank Scenario A	2060 EO Rank Scenario B	2100 EO Rank Scenario B
Minnesota	Goodhue	Private	2	Dry Prairie	1	D	X	X	X	X
Minnesota	Jackson	Private	3	Dry Prairie	1.86	D	X	X	X	X
Minnesota	Renville	Private	4	Bedrock Prairie	1.95	D	D	D	D	D
Minnesota	Cottonwood	Private	9	Dry Prairie	1.37	D	X	X	X	X
Minnesota	Jackson	Private	12	Dry Prairie	1.37	D	X	X	X	X
Minnesota	Brown/Cotto nwood	Private	29	Dry Prairie	1.95	D	D	D	D	D
Minnesota	Redwood	Private	33	Mesic Prairie	1.95	D	D	D	D	D
Minnesota	Rice	Private	35	Dry Prairie	1.95	D	D	D	D	D
Minnesota	Goodhue	Private	36	Dry Prairie	1.09	D	X	X	X	X
Minnesota	Goodhue	Private	40	Dry Prairie	1.95	D	X	X	X	X
Minnesota	Dakota	Private	45	Dry Prairie	1.46	D	X	X	X	X
Minnesota	Jackson	Private	60	Dry Prairie	1.67	D	D	X	D	X
Minnesota	Cottonwood	Private	66	Dry Prairie	1.28	D	X	X	X	X
Minnesota	Cottonwood	Private	73	Mesic Prairie	1.46	D	X	X	X	X
Minnesota	Cottonwood	Private	74	Dry Prairie	1.47	D	X	X	X	X
Minnesota	Rock	Touch the Sky Prairie NWR	70	Mesic Prairie	1.7	D	X	X	X	X
Wisconsin	Grant	Bush Clover Prairie		Dry-Mesic Prairie	1.71	D	D	X	D	X
Wisconsin	Lafayette	Dower Prairie		Dry-Mesic Prairie	1.79	D	D	X	D	X
Wisconsin	Rock	Happy Hollow Dry Prairie		Dry-Mesic Prairie	1	D	X	X	X	X
Wisconsin	Grant	Lancaster Prairie		Dry-Mesic Prairie	1.84	D	D	X	D	X
Wisconsin	St. Croix	New Richmond		Dry-Mesic Prairie	1	D	X	X	X	X
Wisconsin	Green	Weber Prairie (York Prairie SNA)		Dry-Mesic Prairie	1.98	D	D	X	D	X
Illinois	Winnebago	Beloit Gravel Prairie	10			X	X	X	X	X

State	County	Site Name	EO Num.	Representative Category	EO Score	2020 EO Rank	2060 EO Rank Scenario A	2100 EO Rank Scenario A	2060 EO Rank Scenario B	2100 EO Rank Scenario B
Illinois	Winnebago	Burr Oak Road Prairie	11			X	X	X	X	X
Illinois	DuPage	Hinsdale Prairie	1			X	X	X	X	X
Illinois	Winnebago	Rockview Stone Quarry	9			X	X	X	X	X
Illinois	Cook	Shoe Factory Road Prairie	15			X	X	X	X	X
Illinois	DuPage	Waterfall Glen	12			X	X	X	X	X
Illinois	Winnebago	Winquist Prairie	9			X	X	X	X	X
Iowa	Butler	Big Marsh WMA	1861			X	X	X	X	X
Iowa	Linn	Linn County Quarry	8303			X	X	X	X	X
Wisconsin	Sauk	Badger Army Ammunition Plant	13			X	X	X	X	X
Wisconsin	Pepin	EauGalle Sand Barrens	14			X	X	X	X	X
Wisconsin	Sauk	Spring Green Preserve	12			X	X	X	X	X
Iowa	Cerro Gordo	Buffalo Slough	3712			H	H	H	H	H
Iowa	Wapello	Fox Hill WMA	1889			H	H	H	H	H
Iowa	Kossuth	Historical 40th Ave Prairie	3877			H	H	H	H	H
Iowa	Emmet	Historical Armstrong Site	735			H	H	H	H	H
Iowa	Palo Alto	Historical Emmetsburg	4749			H	H	H	H	H
Iowa	Palo Alto	Historical Lost Island	2737			H	H	H	H	H
Iowa	Floyd	Historical Marble Rock	714			H	H	H	H	H
Iowa	Dickinson	Historical Terrace Park	1480			H	H	H	H	H
Iowa	Dickinson	Historical Wahpeton	4312			H	H	H	H	H

State	County	Site Name	EO Num.	Representative Category	EO Score	2020 EO Rank	2060 EO Rank Scenario A	2100 EO Rank Scenario A	2060 EO Rank Scenario B	2100 EO Rank Scenario B
Iowa	Dickinson	Historical Wahpeton 2	12431			H	H	H	H	H
Iowa	Dickinson	Iowa Lakeside Lab	260			H	H	H	H	H
Iowa	Marion	Pella WMA	142			H	H	H	H	H
Iowa	Lucas	Stephens State Forest	5137			H	H	H	H	H
Iowa	Emmet	Wolden Recreation Area	12432			H	H	H	H	H
Wisconsin	Dane	Blue Mounds	5			H	H	H	H	H
Wisconsin	LaCrosse	LaCrosse	3			H	H	H	H	H
Wisconsin	Grant	Potosi	6			H	H	H	H	H
Wisconsin	Racine	Racine	4			H	H	H	H	H

Appendix D. Representative Categories and Future Scenarios

Bedrock Prairie

Both Scenarios

For prairie bush-clover populations in bedrock prairie, projected future resiliency is the same under both of our scenarios. The land cover projections do not change across climate change storylines. Of the six populations that currently occur in this representative category, 67% and 83% are projected to exhibit poor resiliency or be extirpated in 2060 and 2100, respectively (Table D-1). Under this scenario, no prairie bush-clover populations in bedrock prairie are projected to be in excellent or good condition by 2100, with only 3 extant populations remaining (in fair and poor condition). In 2060, we anticipate only one bedrock prairie population will be considered extirpated and the two populations considered to have good or fair resiliency are in Iowa (Figure D-1). In 2100, the only bedrock prairie populations will be located in Minnesota and Iowa (Figure D-2).

Table D-1. Table of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at bedrock prairie sites in 2060 and 2100 under habitat conversion **scenarios A and B**.

Resiliency	EO Rank	Number of Populations 2020 (% of Extant)	Number of Populations 2060 (% of Extant)	Number of Populations 2100 (% of Extant)
Excellent	A	0 (0%)	0 (0%)	0 (0%)
Good	B	1 (17%)	1 (17%)	0 (0%)
Fair	C	2 (33%)	1 (17%)	1 (17%)
Poor	D	3 (50%)	3 (50%)	2 (33%)
Extirpated	X	0	1 (17%)	3 (50%)
Total Extant Populations by Year		**6**	**5**	**3**

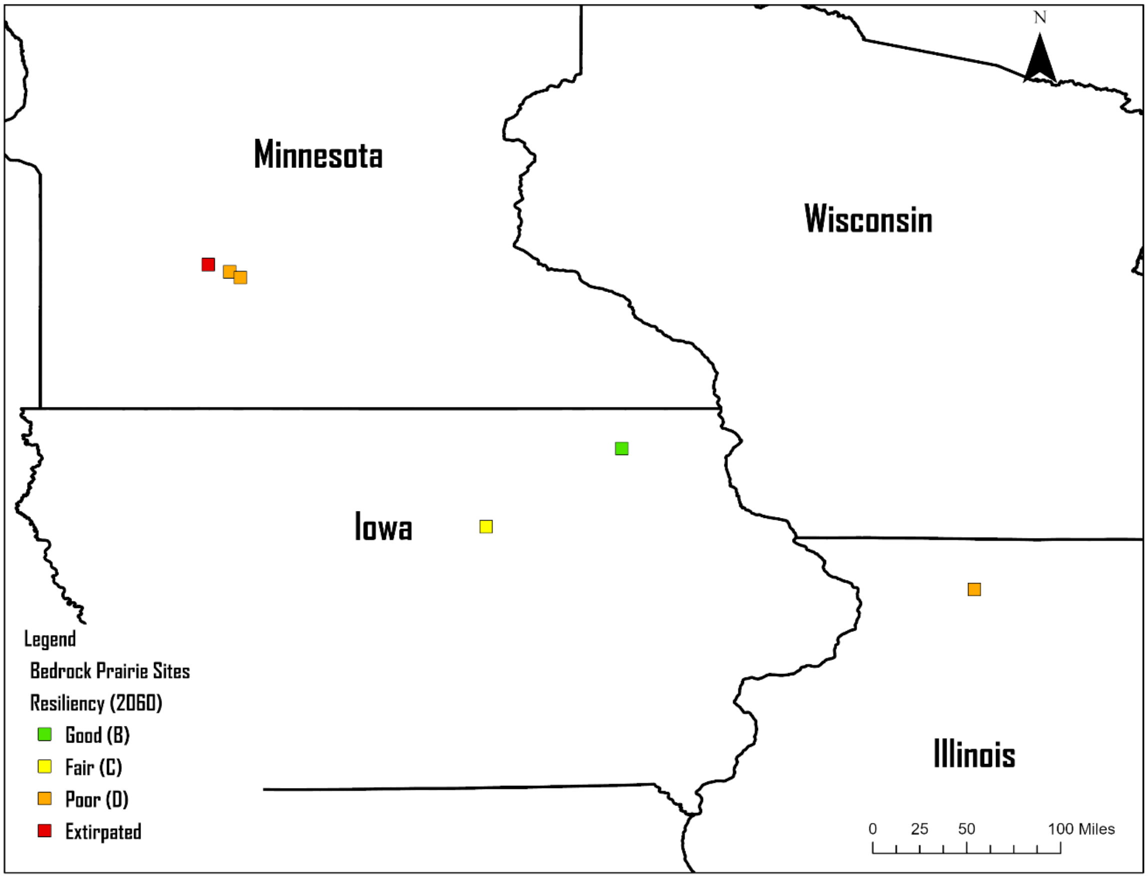

Figure D-1. Map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at bedrock prairie sites in 2060 under **both habitat conversion scenarios**.

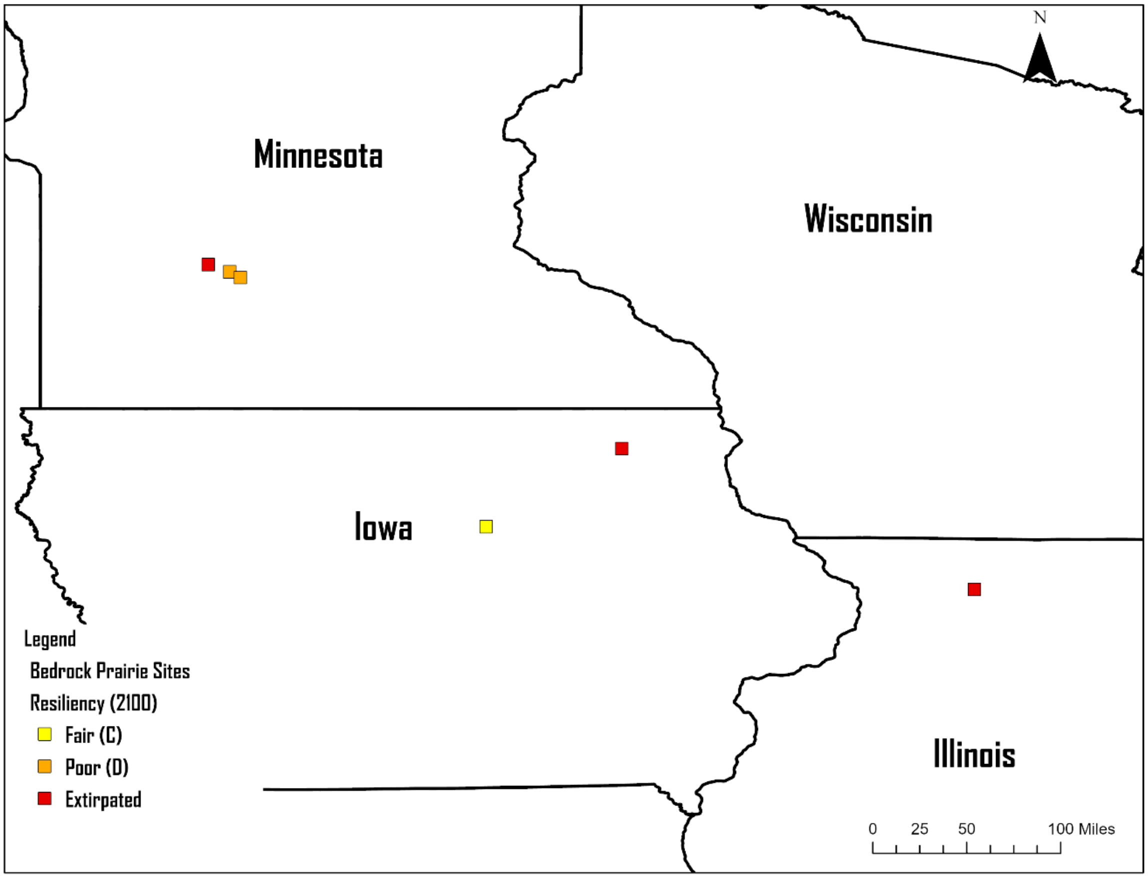

Figure D-2. Map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at bedrock prairie sites in 2100 under habitat conversion **scenario A**.

Dry Prairie

Scenario A

In scenario A, prairie bush-clover populations where land cover projections under any of the four climate change storylines (A2, A1B, B2, and B1) included cropland or developed land were considered extirpated in 2060 and/or 2100. Most prairie bush-clover populations are found at dry prairie sites. Of the 52 extant populations that occur in this representative category, we anticipate 23% (12) of documented extant populations in dry prairie will exhibit excellent or good resiliency in 2060, down from 33% (17) in 2020 (Table D-2, Figure D-3). The number of populations with fair or poor resiliency will decrease, as more sites become extirpated due to land conversion. Under this scenario, 14 dry prairie populations will become extirpated by 2060.

By 2100, 63% of documented dry prairie, prairie bush-clover populations are expected to exhibit poor resiliency or will be extirpated (Figure D-4). The 15 remaining populations will be in excellent (4 populations), good (7 populations), or fair (4 populations) condition. The populations that currently have fair resiliency may see the largest decline in the next 80 years, as these populations continue to degrade into poor condition or become extirpated.

Table D-2. Table of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at dry prairie sites in 2060 and 2100 under habitat conversion **scenario A**.

Resiliency	**EO Rank**	**Number of Populations 2020 (% of Extant)**	**Number of Populations 2060 (% of Extant)**	**Number of Populations 2100 (% of Extant)**
Excellent	A	7 (13%)	6 (12%)	4 (8%)
Good	B	10 (19%)	6 (12%)	7 (13%)
Fair	C	19 (37%)	10 (19%)	4 (8%)
Poor	D	16 (31%)	9 (17%)	13 (25%)
Extirpated	X	7	21 (40%)	24 (46%)
Total Extant Populations by Year		**52**	**31**	**28**

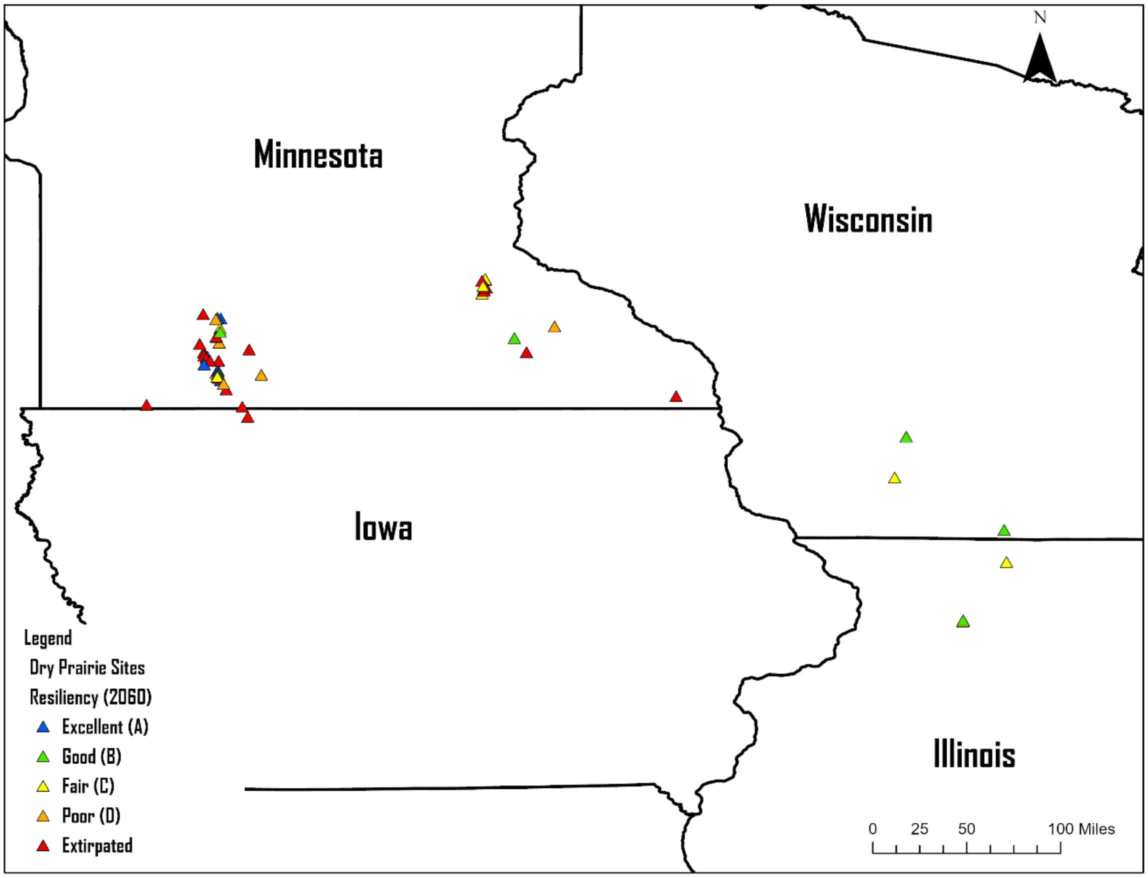

Figure D-3. Map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at dry prairie sites in 2060 under habitat conversion **scenario A**.

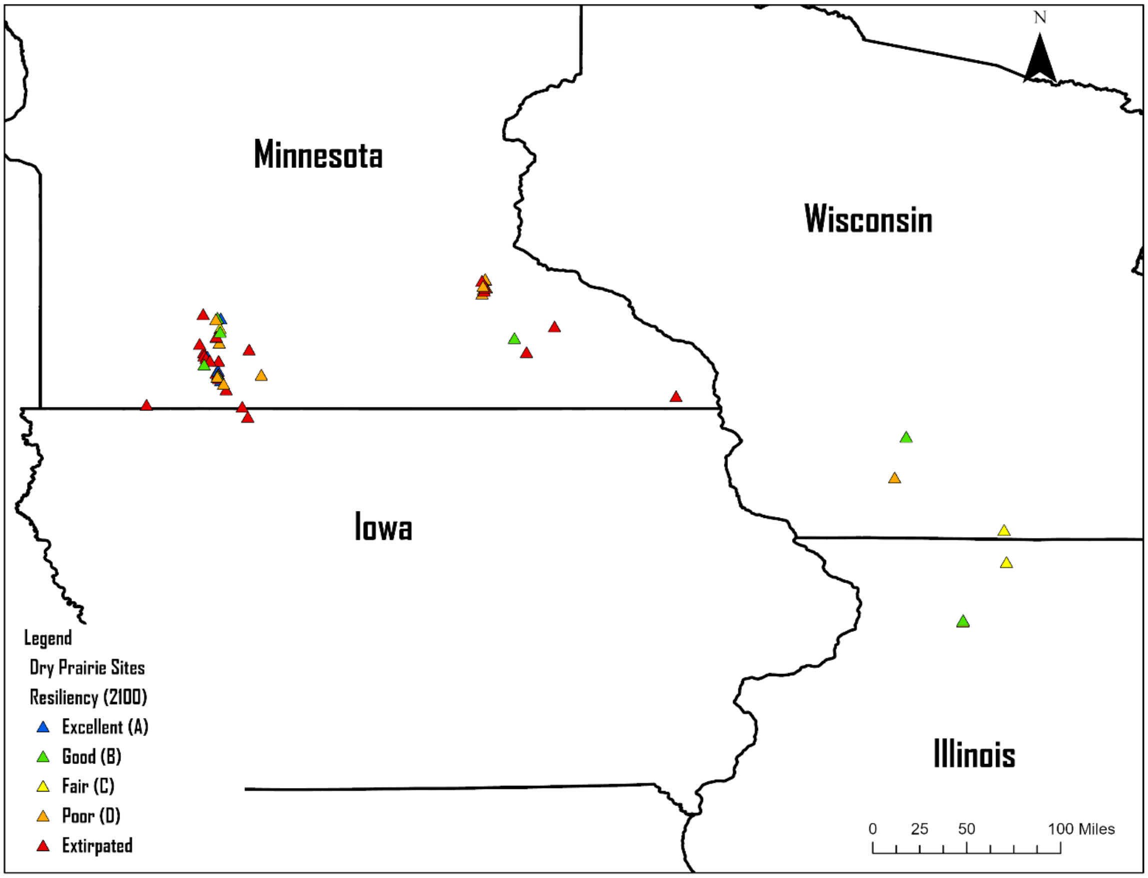

Figure D-4. Map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at dry prairie sites in 2100 under habitat conversion **scenario A**.

Scenario B

In scenario B, prairie bush-clover populations were considered extirpated in 2060 and/or 2100 if land cover projections under all four climate change storylines (A2, A1B, B2, and B1) were either cropland or developed land. Under this scenario, we anticipate 26% of documented dry prairie populations will exhibit excellent or good resiliency in 2060, down from 32% in 2020 (Table D-3). The number of populations with fair or poor resiliency will decrease between 2020 and 2060, as more sites become extirpated due to land conversion. Under this scenario, nine prairie bush-clover populations will be extirpated by 2060.

By 2100, 66% of documented dry prairie, prairie bush-clover populations are expected to exhibit poor resiliency or will be extirpated. The 18 remaining populations are of excellent, good, or fair condition. Of these, 8 may be in good condition. The populations that currently have fair resiliency may see the largest decline in the next 80 years. In 2020, 37% of dry prairie populations were considered fair, but in 2100 we project only 12% of populations will fall into this resiliency category.

Dry prairie populations located in Wisconsin and Illinois may be categorized as good or fair and the population in Iowa will be in poor condition by 2060 (Figure D-5). Minnesota has 45 prairie bush-clover populations in the dry prairie representative category, and at least one population falls under each of the four resiliency conditions. All 7 populations with excellent resiliency are located in Minnesota. By 2100, populations in Wisconsin will exhibit good, fair, and poor resiliency and the population in Iowa will remain in poor condition (Figure D-6). We do not anticipate a change in population status between 2060 and 2100 for prairie bush-clover sites in Illinois. In Minnesota, 19 or 42% of dry prairie sites in the state may become extirpated by 2100.

Table D-3. Table of plausible projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at dry prairie sites in 2060 and 2100 under habitat conversion **scenario B**.

Resiliency	**EO Rank**	**Number of Populations 2020 (%)**	**Number of Populations 2060 (%)**	**Number of Populations 2100 (%)**
Excellent	A	7 (13%)	7 (13%)	4 (8%)
Good	B	10 (19%)	7 (13%)	8 (15%)
Fair	C	19 (37%)	11 (21%)	6 (12%)
Poor	D	16 (31%)	11 (21%)	15 (29%)
Extirpated	X	7	16 (31%)	19 (37%)
Total Extant Populations by Year		**52**	**36**	**33**

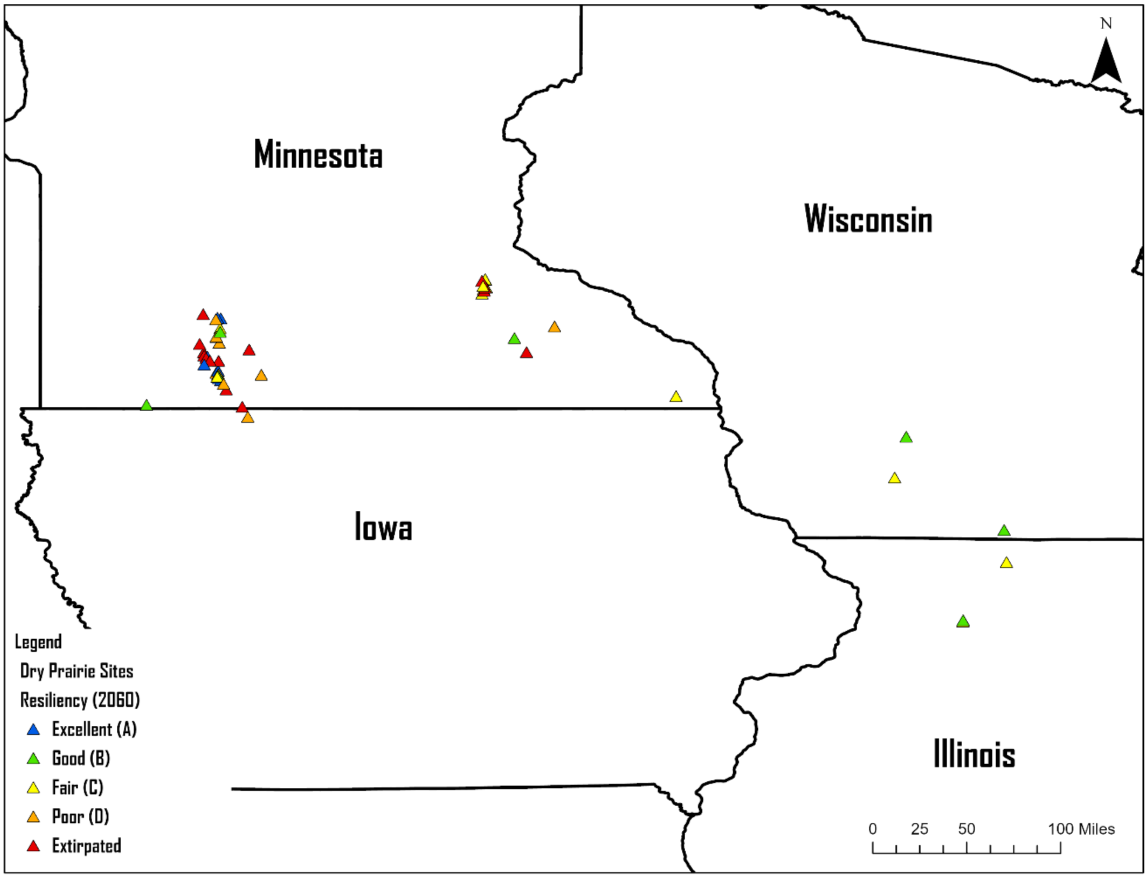

Figure D-5. Map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at dry prairie sites across the geographic range of the species in 2060 under habitat conversion **scenario B**.

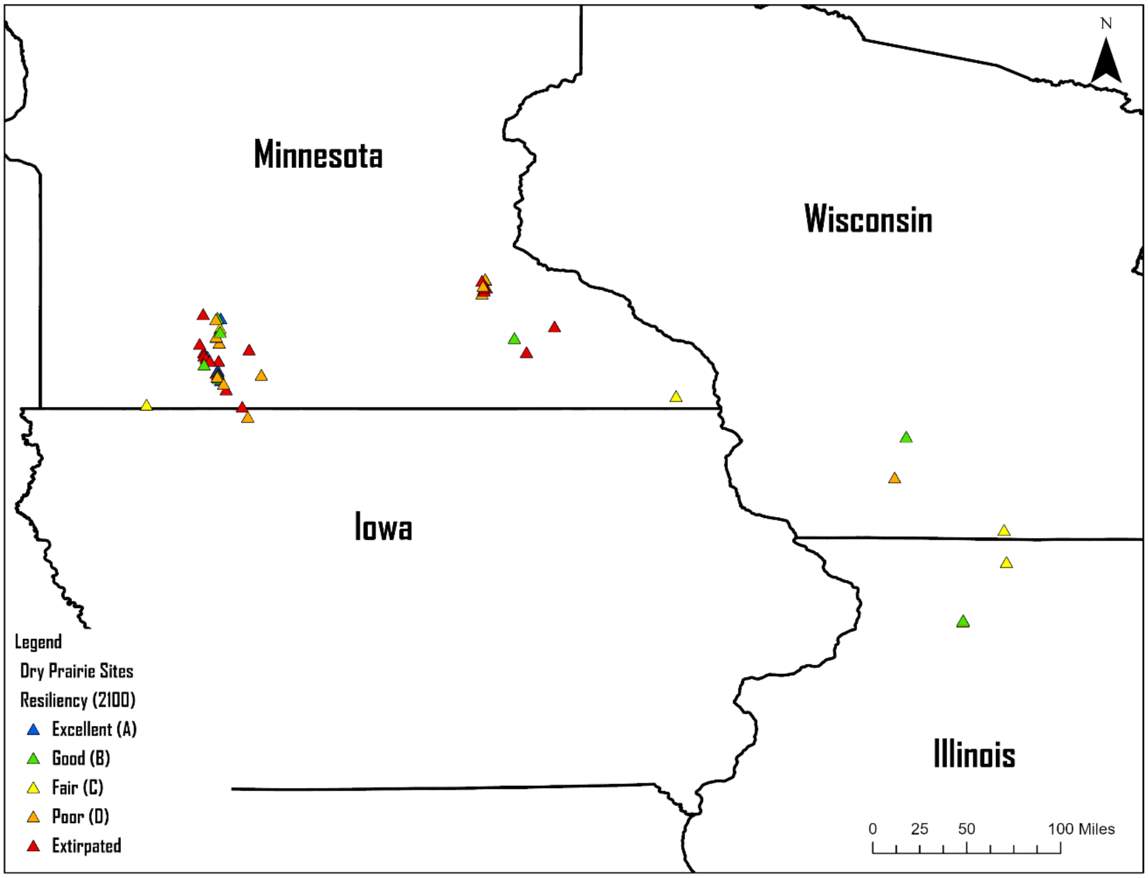

Figure D-6. Map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at dry prairie sites across the geographic range of the species in 2100 under habitat conversion **scenario B.**

Dry-Mesic Prairie

Scenario A

In scenario A, prairie bush-clover sites where land cover projections under any of the four climate change storylines (A2, A1B, B2, and B1) included cropland or developed land were considered extirpated in 2060 and/or 2100. The second highest number of prairie bush-clover populations occur at dry-mesic prairie sites in Illinois, Iowa, and Wisconsin. No populations are found at sites considered dry-mesic in Minnesota. We anticipate 36% of documented dry-mesic prairie populations will exhibit excellent or good resiliency in 2060, down from 41% in 2020 (Table D-4). The number of populations with fair or poor resiliency will decrease from 24 to 18 between 2020 and 2060, as more sites become extirpated due to land conversion or decline in resiliency. Under this scenario, three extant prairie bush-clover populations will be extirpated by 2060.

By 2100, 54% of populations at dry-mesic prairie, sites are expected to exhibit poor resiliency or will be extirpated. Of the remaining populations, we expect 29% will exhibit excellent or good resiliency. Sites with excellent resiliency in 2020 are expected to maintain this condition across the next 80 years. The populations that currently have fair resiliency may see the largest decline in the next 80 years. In 2020, 32% of dry prairie populations were considered fair, but in 2100 we project only 17% of populations will fall into this resiliency category.

Dry-mesic prairie populations located in Wisconsin range from excellent to poor resiliency in 2060 (Figure D-7). Of these, two sites will become extirpated. The one dry-mesic population site in Illinois may be categorized as fair. Similarly, populations in Iowa will exhibit excellent, good, fair, and poor resiliency in 2060. Six populations in Iowa may be considered extirpated by 2060. By 2100, populations in Wisconsin will continue to exhibit excellent, good, fair, and poor resiliency and the population in Illinois will remain in fair condition (Figure D-8). In Iowa, 9 or 38% of dry-mesic prairie sites in the state may become extirpated by 2100.

Table D-4. Table of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at dry-mesic prairie sites in 2060 and 2100 under habitat conversion **scenario A**.

Resiliency	**EO Rank**	**Number of Populations 2020 (% of Extant)**	**Number of Populations 2060 (% of Extant)**	**Number of Populations 2100 (% of Extant)**
Excellent	A	3 (7%)	3 (7%)	3 (7%)
Good	B	14 (34%)	12 (29%)	9 (22%)
Fair	C	13 (32%)	8 (20%)	7 (17%)
Poor	D	11 (27%)	10 (24%)	6 (15%)
Extirpated	X	5	8 (20%)	16 (39%)
Total Extant Populations by Year		**41**	**33**	**25**

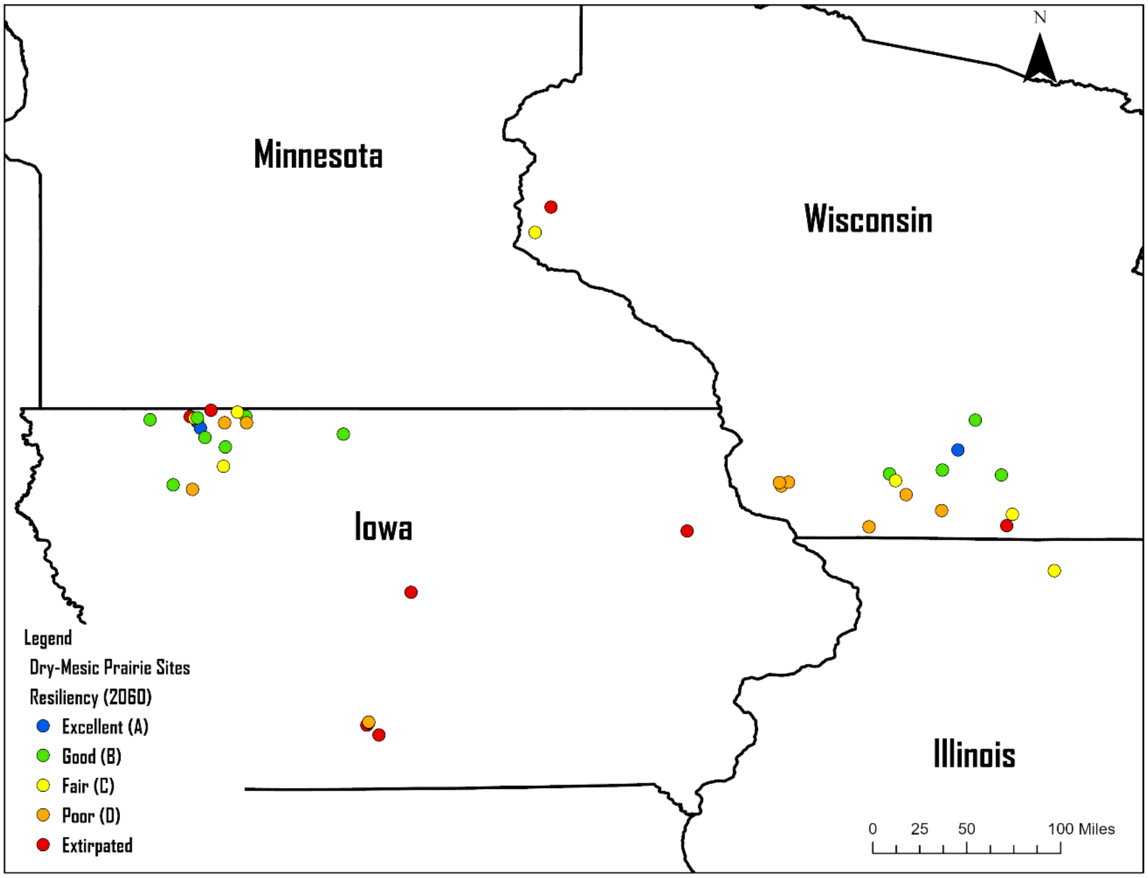

Figure D-7. Map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at dry-mesic sites across the geographic range of the species in 2060 under habitat conversion **scenario A**.

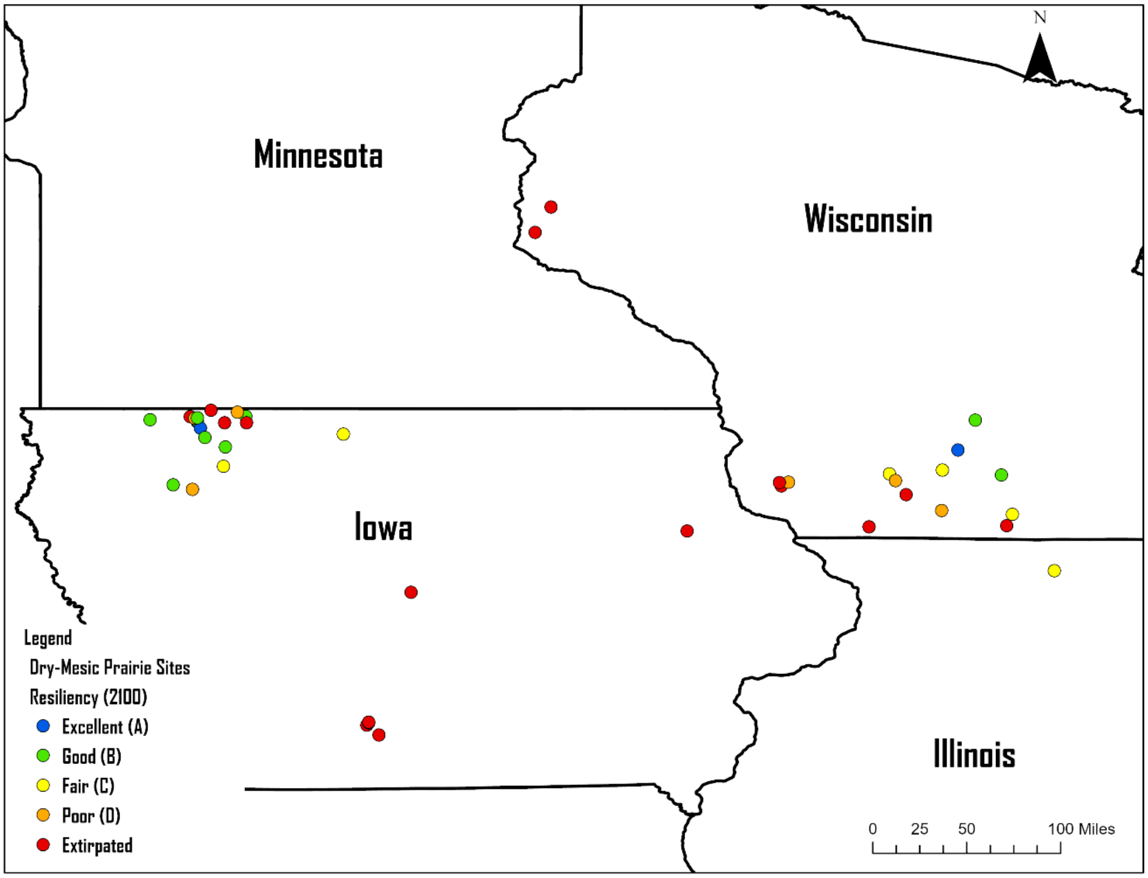

Figure D-8. Map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at dry-mesic prairie sites in 2100 under habitat conversion **scenario A**.

Scenario B

In scenario B, prairie bush-clover populations were considered extirpated in 2060 and/or 2100 if land cover projections under all four climate change storylines (A2, A1B, B2, and B1) were either cropland or developed land. The condition of populations at dry-mesic prairie sites was slightly better under this scenario when compared to scenario A, in that one fewer site was extirpated. We anticipate 36% of documented dry-mesic prairie populations will exhibit excellent or good resiliency in 2060, down from 41% in 2020 (Table D-5). The number of populations with fair or poor resiliency will decrease from 24 to 19 between 2020 and 2060, as more sites become extirpated due to land conversion or decline in resiliency. Under this scenario, two extant prairie bush-clover populations will be extirpated by 2060.

By 2100, 54% of populations at dry-mesic prairie, sites are expected to exhibit poor resiliency or will be extirpated. Of the remaining populations, we expect 29% will exhibit excellent or good resiliency. Sites with excellent resiliency in 2020 are expected to maintain this condition across the next 80 years. The populations that currently have fair resiliency may see the largest decline in the next 80 years. In 2020, 32% of dry prairie populations were considered fair, but in 2100 we project only 17% of populations will fall into this resiliency category.

Dry-mesic prairie populations located in Wisconsin range from excellent to poor resiliency in 2060 (Figure D-9). Of these, two sites will become extirpated. The one dry-mesic population site in Illinois may be categorized as fair. Similarly, populations in Iowa will exhibit excellent, good, fair, and poor resiliency in 2060. Five populations in Iowa may be considered extirpated by 2060. By 2100, populations in Wisconsin will continue to exhibit excellent, good, fair, and poor resiliency and the population in Illinois will remain in fair condition (Figure D-10). In Iowa, 8 or 33% of dry-mesic prairie sites in the state may become extirpated by 2100.

Table D-5. Table of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at dry-mesic prairie sites in 2060 and 2100 under habitat conversion **scenario B**.

Resiliency	**EO Rank**	**Number of Populations 2020 (% of Extant)**	**Number of Populations 2060 (% of Extant)**	**Number of Populations 2100 (% of Extant)**
Excellent	A	3 (7%)	3 (7%)	3 (7%)
Good	B	14 (34%)	12 (29%)	9 (22%)
Fair	C	13 (32%)	8 (20%)	7 (17%)
Poor	D	11 (27%)	11 (27%)	7 (17%)
Extirpated	X	5	7 (17%)	15 (37%)
Total Extant Populations by Year		**41**	**34**	**26**

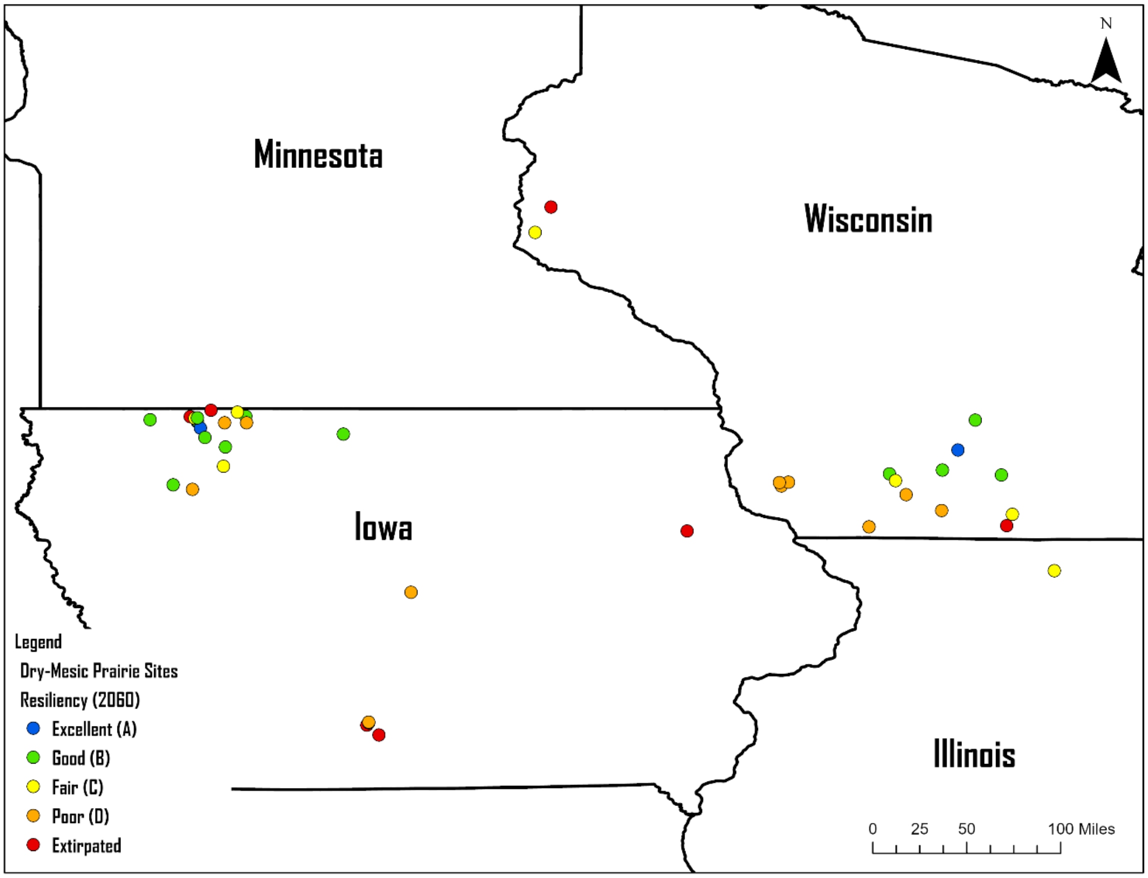

Figure D-9. Map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at dry-mesic prairie sites across the geographic range of the species in 2060 under habitat conversion **scenario B**.

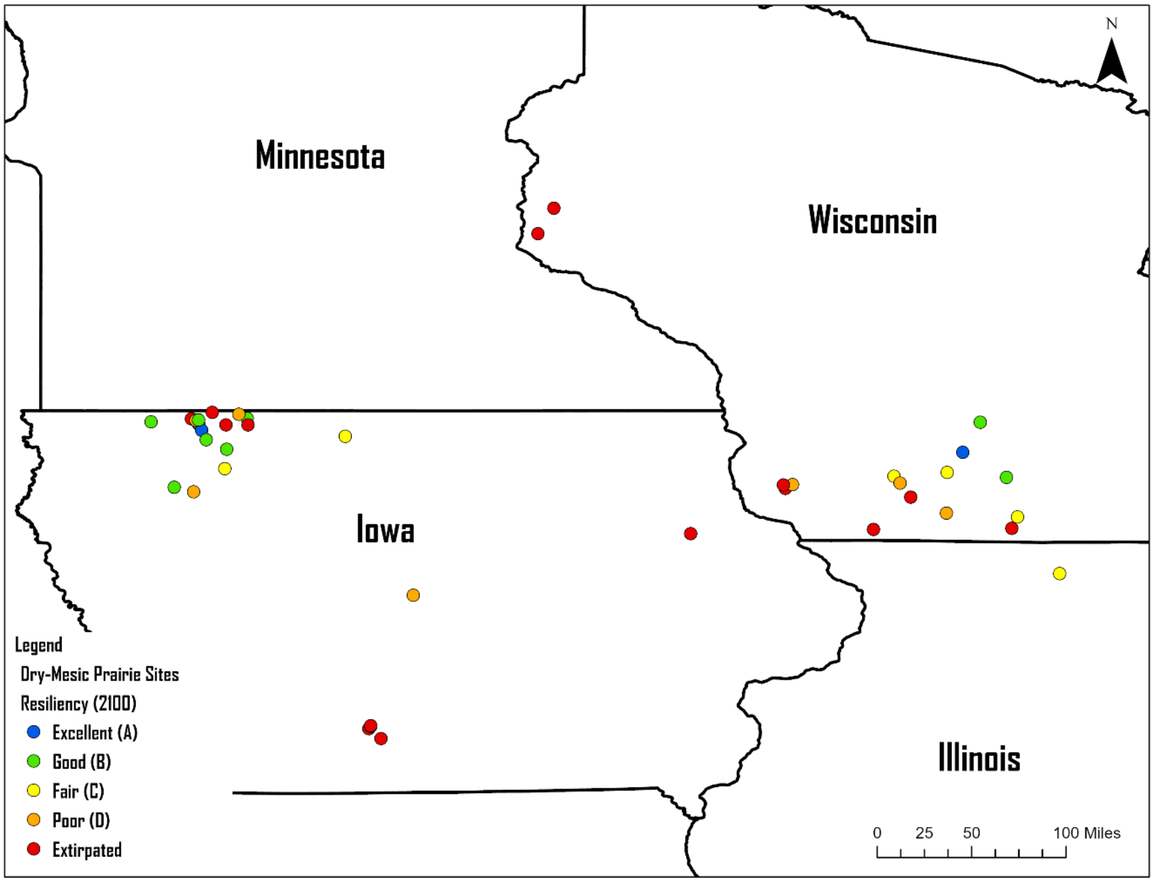

Figure D-10. Map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at dry-mesic prairie sites across the geographic range of the species in 2100 under habitat conversion **scenario B**.

Mesic Prairie

Both Scenarios

For prairie bush-clover populations in mesic prairie habitat, projected future resiliency is the same under both scenarios because the land cover projections for the mesic-prairie populations do not change across climate change storylines. Of the 14 extant prairie bush-clover populations in this representative category, 2 (14%) continue to exhibit excellent resiliency in 2060 and 2100 (Table D-6). No populations exhibit good resiliency in any time period. Half (50%) of the prairie bush-clover populations in mesic prairie are anticipated to be of poor resiliency or become extirpated by 2060 and the majority (72%) are anticipated to be of poor resiliency or become extirpated by 2100. Only two populations are anticipated to have fair resiliency by 2100, a decrease of five populations in 80 years.

The distribution of populations in the mesic prairie habitat type can be described by considering the number of populations in each state. There are no prairie bush-clover populations in Wisconsin that occur in mesic prairie habitat. Illinois has one mesic prairie population and that population has poor resiliency in 2060 and 2100 (Figure D-11). There are five populations in Iowa, and we project that 60% of them will have fair resiliency in 2060; none of the Iowa populations have good or excellent resiliency and 2 populations are projected to be extirpated in 2100. Minnesota has the most populations at mesic prairie sites and the only two sites with excellent resiliency. By 2100, populations in Minnesota will continue to exhibit excellent (2) and poor (3) resiliency, with three populations considered extirpated (Figure D-12). The population in Illinois will remain in poor condition.

Table D-6. Table of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at mesic prairie sites in 2060 and 2100 under both habitat conversion scenarios.

Resiliency	EO Rank	Number of Populations 2020 (%)	Number of Populations 2060 (%)	Number of Populations 2100 (%)
Excellent	A	2 (14%)	2 (14%)	2 (14%)
Good	B	0 (0%)	0 (0%)	0 (0%)
Fair	C	7 (50%)	5 (36%)	2 (14%)
Poor	D	5 (36%)	2 (14%)	5 (36%)
Extirpated	X	0 (0%)	5 (36%)	5 (36%)
Total Extant Populations by Year		**14**	**9**	**9**

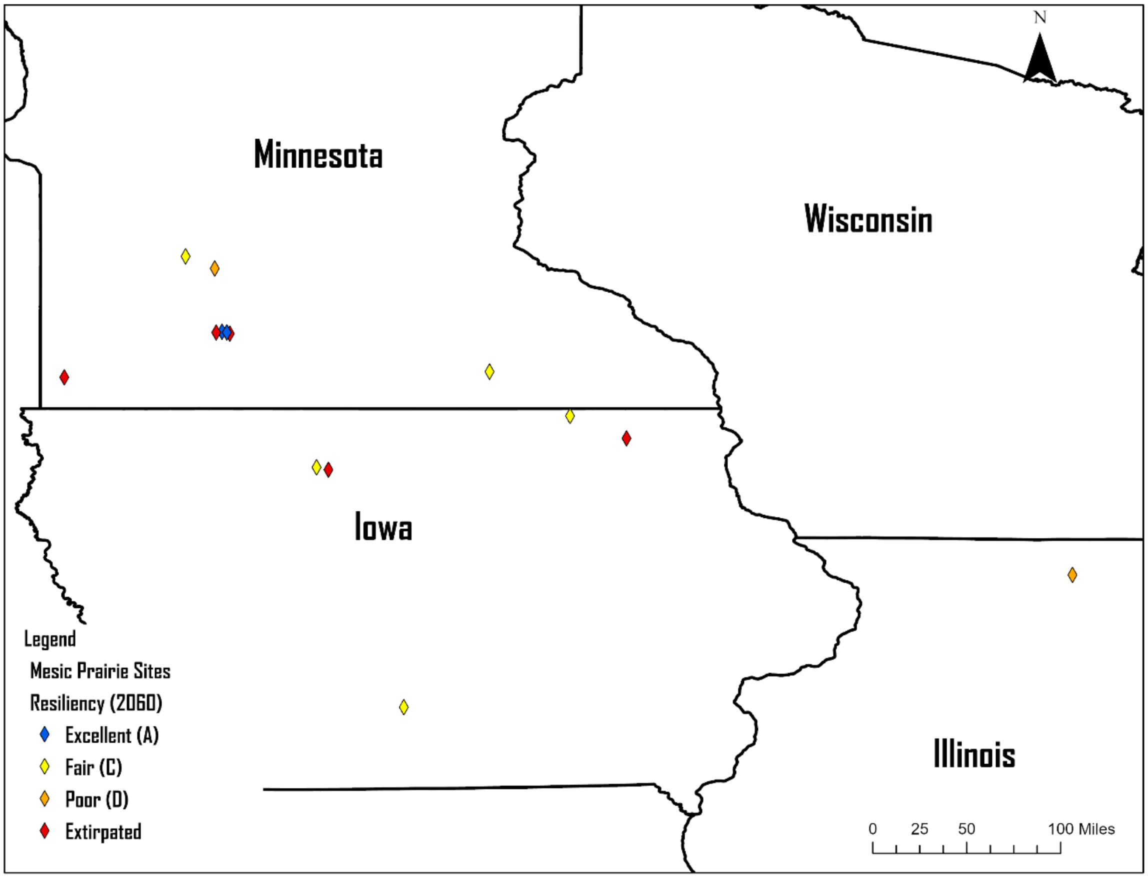

Figure D-11. Map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at mesic prairie sites in 2060 under both habitat conversion future scenarios.

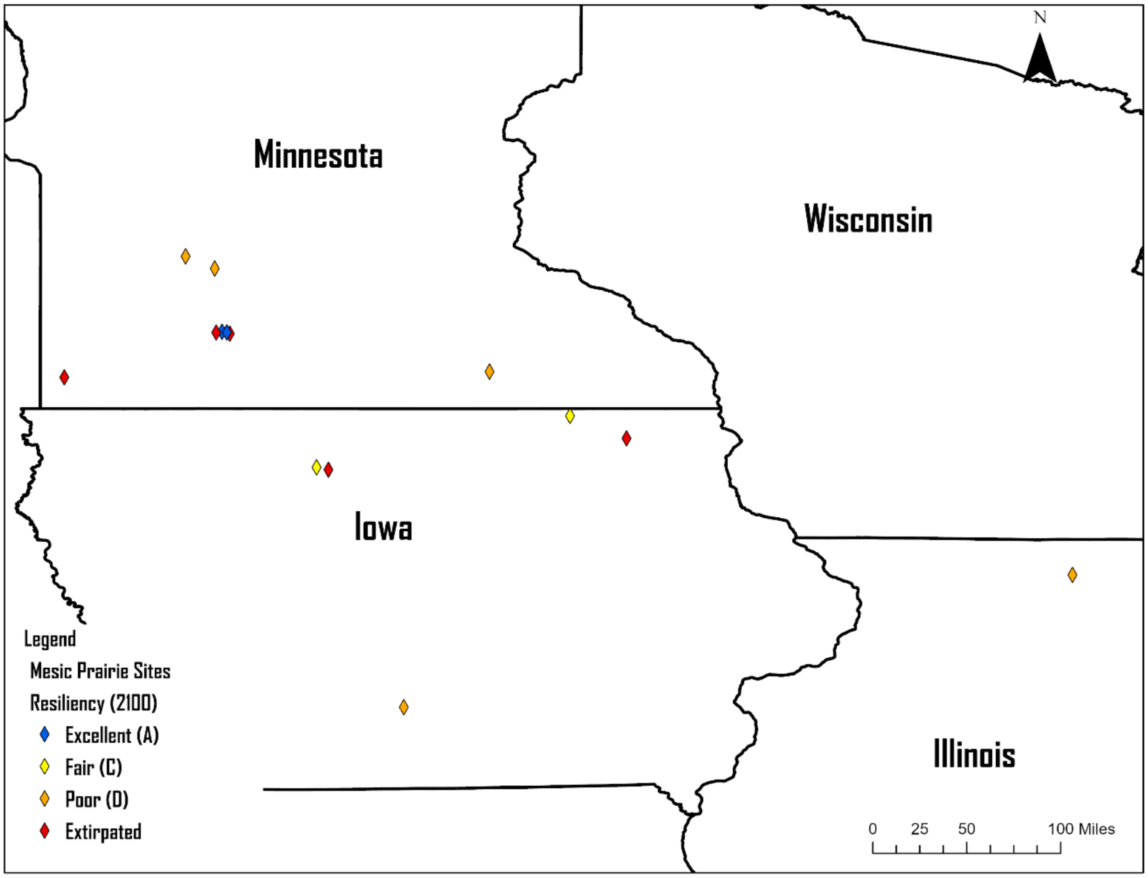

Figure D-12. Map of projected prairie bush-clover (*Lespedeza leptostachya*) resiliency at mesic prairie sites in 2100 under both habitat conversion scenarios.