Mead's Milkweed
(Asclepias meadii)

5-year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Missouri Ecological Services Field Office
Columbia, MO

March 2022

STATUS REVIEW: Mead's milkweed (*Asclepias meadii)*

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STATUS REVIEW
Mead's Milkweed (*Asclepias meadii*
GENERAL INFORMATION

Species: Mead's milkweed (*Asclepias meadii)*

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Date of listing publication: September 1, 1988

FR citation(s): 53 FR 33982-33996

Classification: Threatened

Methods used to complete the review:

In accordance with section 4(c)(2) of the Endangered Species Act of 1973, as amended (Act), the purpose of a status review is to assess each threatened species or endangered species to determine whether its status has changed and if it should be classified differently or removed from the Lists of Threatened and Endangered Wildlife and Plants. The U.S. Fish and Wildlife Service (Service) evaluated the biology and status of the Mead's milkweed (*Asclepias meadii*) to inform this status review.

This status review was completed by Gabriela Wolf-Gonzalez with the assistance of Vona Kuczynska and Kris Budd in the Missouri Field office. The review was conducted in coordination with Malissa Briggler from the Missouri Department of Conservation (MDC), Scott Namestnik and Matthew Beaty from the Indiana Department of Natural Resources, Stephen Tillman from the Illinois Department of Natural Resources, Jennifer Deslisle from the Kansas Natural Heritage Inventory, John Pearson from Iowa Department of Natural Resources, Kevin Doyle from the Wisconsin Department of Natural Resources, and Richard Henderson from The Prairie Enthusiasts (Wisconsin), who provided data required to compile the status review. In February 2022, the Missouri Field Office solicited peer review of this draft 5-year review from those who provided data and recognized Mead's milkweed experts: Christy Edwards and Paul

McKenzie. We received comments from Malissa Briggler, Scott Namestnik, John Pearson, Christy Edwards, and Kevin Doyle and have incorporated their recommendations in this revised document.

FR Notice citation announcing the species is under active review: 86 FR 61286 - 61287. (November 05, 2021) Endangered and Threatened Wildlife and Plants; Initiation of 5-Year Status Reviews of Six Listed Animal and Plant Species.

Review History: USFWS. 2012. Mead's milkweed (*Asclepias meadii*) 5-Year Review: Summary and Evaluation. Chicago, Illinois Field Office, Barrington, Illinois.

REVIEW ANALYSIS

RECOVERY CRITERIA:

U. S. Fish and Wildlife Service. 2003. Mead's milkweed (*Asclepias meadii)* Recovery Plan. U.S. Fish and Wildlife Service, Fort Snelling, Minnesota. 120 pp.

The Mead's Milkweed Recovery Plan (USFWS 2003) contains the following delisting criteria:

Criterion 1. Twenty-one populations are distributed across plant communities and physiographic regions within the historic range of the species.

Criterion 2. Each of these 21 populations is highly viable. A highly viable population contains: more than 50 mature plants; seed production is occurring and the population is increasing in size and maturity; the population is genetically diverse with more than 50 genotypes; the available habitat size is at least 125 acres (50 hectares); the habitat is in a late successional stage; the site is protected through long-term conservation easements, legal dedication as nature preserves, or other means; and the site is managed by fire in order to maintain a late successional graminoid vegetation structure that is free of woody vegetation (Bowles and Bell 1998).

Criterion 3. Monitoring data indicates that these populations have had a stable or increasing trend for 15 years.

The 2003 Recovery Plan criteria remain appropriate based on our current level of understanding of the species. Criterion 1 has been partially met as there are currently greater than 21 populations; however, populations are not distributed across plant communities and physiographic regions within the historical range of the species. Criterion 2 has not been met. Of the 371 known, natural and introduced, population sites, only 3 are considered highly viable. Genetic diversity estimates have also not been completed for the majority of sites. Criterion 3 has not been met as most known sites have not been consistently monitored for 15 years. Monitoring that has been completed suggests that populations are declining or disappearing in some areas. Reviewers have expressed the need for an updated status of all known populations and more accurate analysis of population viability.

UPDATED INFORMATION RELEVANT TO THE CURRENT SPECIES' STATUS

Mead's milkweed has been a federally listed threatened species since September 1, 1988 (53 FR 33982-33996). Its listing pre-dates the species status assessment (SSA) process and therefore no SSA is available for the species. It was also included in a cursory 5-year review conducted for all species listed before 1991 (56 FR 56882). It also has one 5-year review (USFWS 2012) which recommended no status change because none of the three delisting criteria in the recovery plan had been met (USFWS 2012).

BIOLOGY AND HABITAT:

Range and distribution:

Mead's milkweed historically occurred in 46 counties throughout Kansas, Missouri, Illinois, Iowa, Indiana, and Wisconsin (Figure. 1; USFWS 2003). At the time of listing, it was considered extirpated from Wisconsin and Indiana, and from 7 counties in Illinois. The previous 2012 status review reported 330 populations of Mead's milkweed throughout the range in Kansas (258), Missouri (60), Iowa (8), and Illinois (4). Before 2012, nineteen reintroductions occurred in Illinois (7), Indiana (1), and Wisconsin (11). Since then, additional plantings have occurred in Missouri and Illinois, resulting in a total of 375 recorded populations across 15 physiographic regions and two plant community types (Table 1).

Although several populations have been discovered since 2012, many of these are small, located within the Osage Plains, and have a limited contribution to the range wide recovery criteria for the species (USFWS 2012, p. 18). The disappearance of previously known populations is possible as 56% of sites have not had observations in at least 10 years and 23% have not been observed in the last 30 years. Additionally, approximately 29% (106 sites) of all known populations have been surveyed since 2010.

Population demographics:

Determining range-wide, species-wide, and population demographics status for Mead's milkweed is difficult because many of the population sites are not regularly monitored or do not have long-term data. In 2012, less than one third of sites had been visited in the previous decade. A majority of sites have not been visited in at least 10 years (USFWS 2012, MDC 2021, IL-DNR 2022, IN-DNR 2022, IA-DNR 2022, KS-DNR 2022). Additionally, many sites have been surveyed without any observations for multiple years. However, incomplete detection is not uncommon due to dormancy, observation error, or herbivory. This species spreads clonally, likely leading to an overestimate when determining population size through the use of ramets. Because of the long lifespan and ability for clonal spread, it is possible that plants can persist but remain undetected (Alexander et al. 2012, Hoffpauir et al. 2021).

In the 2003 Recovery Plan and 2012 status review, a preliminary population viability index (PVI) was conducted for the known populations (Appendix 1). An explanation of the variables used to calculate PVI are in Appendix 2. Recovery Criterion 2 calls for 21 highly viable populations across physiographic regions. In 2012, only 3 of the 330 known populations were considered highly viable. We recalculated PVI for 106 sites that were discovered or surveyed from 2010 to 2021 (Appendix 1); however, we discuss these results within the context of all known populations, natural and reintroduced, (n = 375). Of the known populations, a majority (259) have a low viability, 113 are considered moderately viable, and only 3 highly viable (Table 1). Although several populations experienced changes across one or more variables, the magnitude of these changes was not sufficiently large enough to shift viability statuses. However, many sites (269) were not surveyed, and the overall status of the species is unknown. Additionally, variables used to calculate PVI have not been routinely monitored or are overly optimistic and thus may overestimate PVI. A majority of the populations, natural (346) and introduced (29), across the range are considered to have moderate (113) and low viability (259); only three populations are considered highly viable (Table 1). A majority of populations have an average of 10 ramets (a clone or individual member) or fewer in the last 10 years (Appendix 1) and are often spread across a highly fragmented landscape (Figure 1).

One of the qualifications for a "highly viable" population is having more than 50 mature plants and 50 genotypes with seed production occurring (USFWS 2003). Mead's milkweed may take 25 to 30 years to reach reproductive maturity; however, small populations may not have reproductive individuals either due to a lack of diversity or mate availability (USFWS 2012). Few populations across the range meet this requirement, as 282 populations have less than 25 individuals and only 12 report flowering in the last 10 years (Appendix 1).

The 2012 5-year review lists 19 plantings of Mead's milkweed seedlings (USFWS 2012, pp. 10-11). Most reintroductions have initially shown signs of success but precipitously decline in the long-term. For example, in Indiana 33 seeds and 81 juvenile plants were reintroduced in 1994, an additional 78 seeds were planted in 1995, and an additional 90 seeds and 36 tubers were planted in 1996. The Indiana population peaked in 1996 when 111 individual plants were observed; however, by 2011 less than 10 plants were observed (S. Namestnik – Indiana DNR, pers. comm. 2022). Emergence rates of seedlings in greenhouses are higher than field sown seedlings (Roels 2013). Reintroductions have reported low survival rates of both seedlings (4.43%) and juvenile plants (10.3%), but greater genotypic persistence indicates the importance of successful reintroductions (Bowles et al. 2015). Long-term survival rates are very low, as demonstrated in an 11-year study where only 5.7% seedlings germinated survived throughout the period of the study (Hoffpauir et al. 2021).

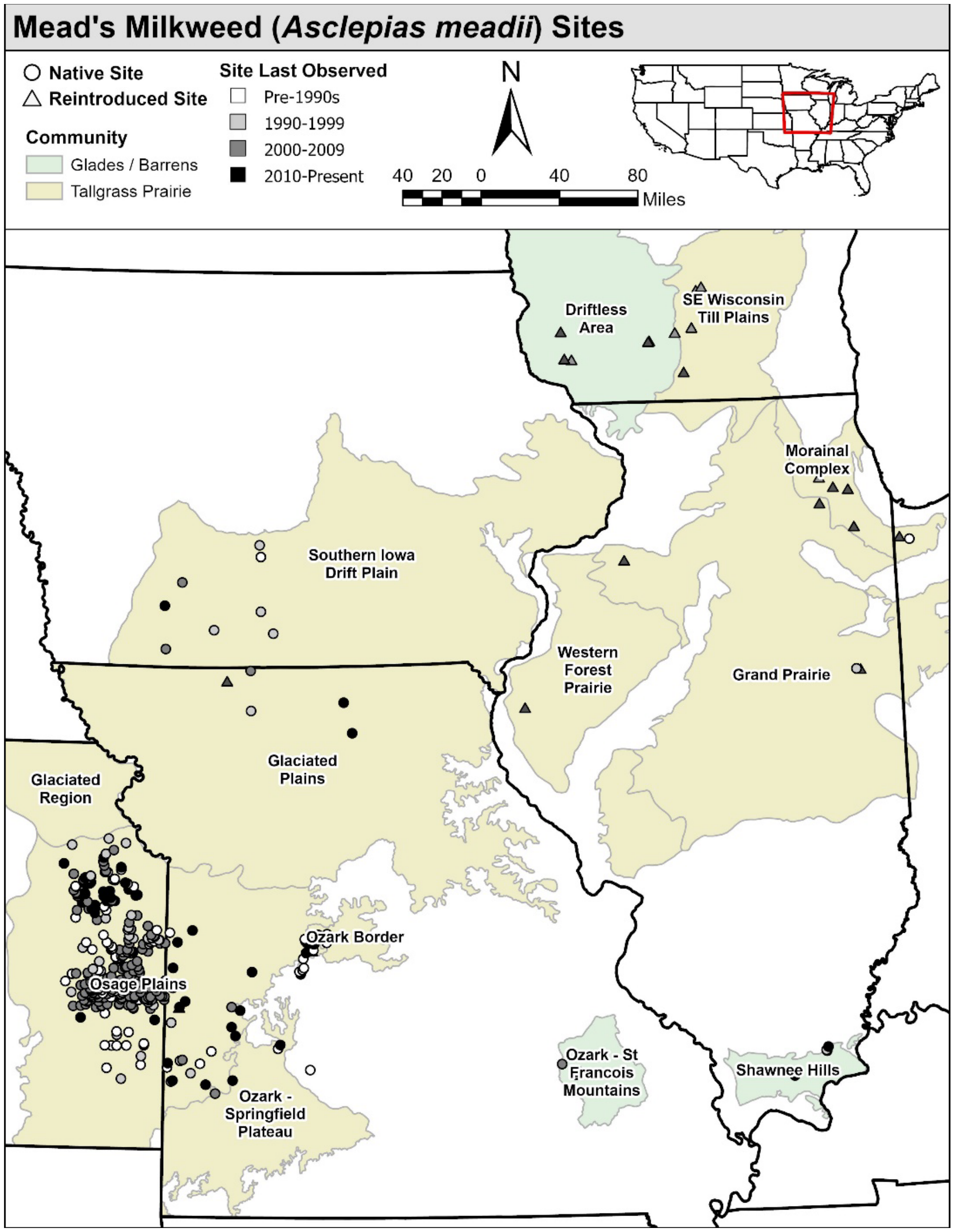

Figure 1: Distribution of Mead's Milkweed sites and habitat communities across its range. Triangles indicate sites where plantings (i.e., seeds, juveniles, tubers) have been reintroduced. Circles indicate remnant native sites. Opacity indicates the recency of observations where darker shapes have been most recently observed and white shapes have not been observed in over 30 years.

Since 2012, several reintroductions or augmentations have occurred throughout the range (Table 2). Monitoring of the reintroductions is sporadic, and although many sites indicated population growth, recent surveys show a precipitous decline and absence of flowering. Thus, no reintroduced populations are considered highly viable, 16 are considered moderately viable, and 13 of low viability (Table 2). As previously stated, the viability of these is likely over-optimistic. Initial establishment and later declines are evidence of both heterosis (improved or increased function of any biological quality in a hybrid offspring) and outbreeding depression (crosses between highly genetically differentiated individuals results in reduced fitness) (Bowles et al. 2015). Recent research suggests that flowering in reintroduced Mead's milkweed may be influenced by proximity to large natural populations. Initial survivorship of planted seeds and juvenile plants is low, and recruitment of individuals in reintroduced populations has not been recorded. After individuals become established, they are more likely to persist despite slow growth and maturation rates (Roels 2013, Bowles et al. 2015). Surveys of some reintroduced populations have been discontinued after multiple years of zero observations (R. Henderson – The Prairie Enthusiasts, pers. comm. 2022). For remnant natural populations, further information and surveys are needed to determine if populations persist or have disappeared.

A major issue for the continued management and restoration of Mead's milkweed across its range is the lack of long-term data and regular surveys. Nearly one-third of all populations have not had observations or have not been surveyed in 30 years (Figure 1). Given poor recruitment, previous population declines, and changing environmental conditions, it's likely some populations have disappeared.

There is not a readily apparent decision framework for determining when a population becomes a "historical" observation. Some states use Element Occurrence (EO) ranking to categorize populations. Using NatureServe's ranking guidance (2002), depending on the species' biology, a plant population would be considered historical if no observations or surveys have occurred in 20-40 years. Without up-to-date monitoring of all populations EOs become of limited use for conservation efforts (NatureServe 2002). The application of the suggested range of years without observation on the currently available data would result in up to 198 (~ 53%) being labeled as "Historical" (> 40 years: 4 populations, > 30 years: 82 populations, > 20 years: 112 populations; See Appendix 1). Additionally, 255 (68%) have not had an observation in 10 years. Of the sites that have been surveyed since 2010, 16 populations (~ 15%) could also be considered historical (> 40 years: 4 population, > 30 years: 1 population, > 20 years: 14 populations; See Appendix 1). Only 40% (42) of sites surveyed post 2010, have not had an observation in 10 years. Sites that are considered degraded to the point of no restoration potential would be labeled as extirpated. Surveys are necessary to update EO rankings of all populations and to prioritize conservation efforts.

Table 1: Summary of recovery progress for Mead's milkweed. The number of Mead's milkweed populations per the recovery criteria, past and current number of extant populations in the United States. Viability of extant populations is preliminary. Modified from (USFWS 2003, 2012). * Indicates physiographic regions that were not included in the 2003 Recovery plan, - indicates no data for this time period. These values are for extant populations in 2021 and does not include reintroduced populations.

Physiographic Region	State	Community	Recovery Criteria	Known Natural Populations			Viability of All Populations (PVI)		
				2003	2012	2021	High	Moderate	Low
Coastal Plain*	Illinois	Tallgrass Prairie	-	-	-	0	0	0	0
Middle Mississippi River Border*	Illinois	Tallgrass Prairie	-	-	-	0	0	0	0
Northeastern Morainal*	Illinois	Tallgrass Prairie	-	-	-	0	0	0	0
Shawnee Hills	Illinois	Glades / Barrens	1	4	4	4	0	0	4
Grand Prairie	Illinois / Indiana	Tallgrass Prairie	3	0	0	1	0	0	1
Northwestern Morainal*	Indiana	Tallgrass Prairie	-	-	-	0	0	0	0
Western Forest-Prairie	Iowa / Illinois	Tallgrass Prairie	2	0	0	0	0	0	0
Southern Iowa Drift Plain	Iowa	Tallgrass Prairie	2	7	8	8	0	2	6
Glaciated Region	Kansas	Tallgrass Prairie	2	8	18	18	1	0	17
Osage Plains	Kansas / Missouri	Tallgrass Prairie	4	129	277	291	1	85	205
Glaciated Plains	Missouri	Tallgrass Prairie	2	3	3	4	0	2	2
Ozark Border	Missouri	Tallgrass Prairie	1	3	3	3	0	0	3
Ozark-Springfield Plateau	Missouri	Tallgrass Prairie	2	10	9	9	1	1	7
Ozark-St. Francis Mountains	Missouri	Glades / Barrens	1	7	8	8	0	7	1
Driftless	Wisconsin	Glades / Barrens	1	0	0	0	0	0	0
SE Wisconsin Till Plains*	Wisconsin	Tallgrass Prairie	-	-	-	0	0	0	0
		Totals	21	171	330	346	3	97	246

Table 2: The number of Mead's milkweed reintroductions and augmentations by state and physiographic Region. Updated from USFWS (2012). All plantings listed here have an up-to-date Population Viability Index (Appendix 1). *Missouri had two reintroductions after 2012 review, all other plantings were pre-2012.

			Population Viability Index		
State	**Physiographic Region**	**Total Number of Reintroductions**	**High**	**Moderate**	**Low**
Illinois	Shawnee Hills	0	-	-	-
	Northeastern Morainal	4	0	0	4
	Middle Mississippi River Border	1	0	0	1
	Coastal Plain	1	0	0	1
	Grand Prairie	3	0	0	3
	Western Forest-Prairie	0	0	0	0
Indiana	Grand Prairie	0	-	-	-
	Northwestern Morainal	1	0	1	0
Missouri*	Ozark Border	0	-	-	-
	Ozark-Springfield Plateau	0	-	-	-
	Ozark-St. Francis Mountains	0	-	-	-
	Osage Plains	8	0	4	4
Wisconsin	SE Wisconsin Till Plains	4	0	4	0
	Driftless	7	0	7	0
Totals		**29**	**0**	**16**	**13**

Genetics:

The mosaic agricultural landscape of the species' range currently presents a barrier to gene flow among populations of Mead's milkweed, preventing pollinator dispersal and reducing the likelihood that attempted dispersals will result in successful transport of gametes elsewhere. Efforts to increase genetic diversity have previously included population augmentation and reintroductions through seeding or transplanting individuals from a greenhouse environment.

Most research previously asserted that a lack of genetic diversity, high clonal rates, and self-incompatibility were the primary causes for a lack of sexual reproduction in Mead's milkweed populations (USFWS 2003, 2012, Bowles et al. 2015). Evidence against self-incompatibility and lack of mate availability being a main driver of reproductive failure was demonstrated by (Roels 2013) after failing to detect clones (Comer 2009). Comer (2009) provides evidence for high genetic diversity within small populations. Data derived from Mead's milkweed populations in Kansas and Missouri rejected the assertion that low genetic diversity leads to low rates of reproduction; instead, they indicate a significant relationship between the number of flowering plants and fecundity (Edwards et al. 2020). Comer (2009) also showed lower genetic diversity in Mead's compared to other *Asclepias* species, yet it still maintains 93% of its genetic variation within populations (Comer 2009), similar to Edwards et al. (2020) which indicated that small populations maintain high genetic diversity. High levels of genetic diversity are likely remnant from historical periods where habitat connectivity was high; however, this diversity may be eventually extinguished if reproduction declines due to low mate availability, pollinator/pollen limitation, or other resource constraints (Edwards et al. 2020). Edwards et al. (2020) reported a component Allee effect, a phenomenon occurring in small populations where population growth and demographics depend on population size and density. Regardless of which limitation is occurring, reaching a minimum threshold of flowering ramets (>50) or >25 flowering genets (a group of genetically identical individuals originating from the same seed; i.e., a group of ramets) is imperative to maintain or improve fecundity in Mead's milkweed populations (Edwards et al. 2020).

Taxonomic and nomenclature:

There has been no new information regarding taxonomic classification or nomenclature since the final listing rule, the issuance of the 2003 Recovery Plan, and 2012 5-year Review.

Habitat:

Mead's milkweed requires moderately wet-mesic to moderately dry-mesic upland tallgrass prairie or glade/barren habitat characterized by vegetation adapted to drought and fire. It persists in stable late-successional prairie; however, due to the suppression of fire and conversion of suitable habitat to agriculture throughout much of its range, remaining patches of habitat are highly fragmented.

The habitat condition and management status of many sites are unknown. Many sites are irregularly burned, frequently hayed, and have other types of damage (Appendix 1). Over 220 of all known sites are hayed annually or periodically, 46 sites are managed with fire, and 10 sites are regularly grazed. It should be noted that land use descriptions have not been updated since 2003 and it's likely some have changed. Of the 106 sites that were updated in this report, 23 are burned, 55 are hayed, and 3 have report feral swine presence. One population, Flaherty Prairie in Iowa, was previously mischaracterized as a preserve (Bowles et al. 1998), but has always been a pasture (J. Pearson - Iowa DNR, pers. comm. 2022).

Coordination across nearby sites to synchronize population phenology is recommended (Edwards et al. 2020). An adaptive management framework is also suggested to coordinate efforts, especially when uncertainty exists (Moore et al. 2011).

Additional information:

Although Mead's milkweed is a bee-pollinated species, a large number of monarch butterflies have been observed visiting plants and laying eggs (Bernhardt and Edens-Meier 2013).

Conservation efforts for Mead's milkweed may benefit monarchs and other candidate or listed species.

THREATS ANALYSIS (THREATS, CONSERVATION MEASURES, AND REGULATORY MECHANISMS):

THREATS:

New threats have been documented since the last 5-year review. A detailed description of previously recorded threats can be found in the Recovery Plan (USFWS 2003) and the last 5-year review (USFWS 2012). Previously described threats including the wholesale destruction and alteration of tallgrass prairie and the use of herbicides and pesticides have contributed to the extirpation of Mead's milkweed at many sites. Here, we focus on describing new threats not previously described: the introduction and expansion of feral swine and declines in Mead's milkweed's pollinators.

Herbicide and Pesticide Use:

Aerial application of herbicides is an ongoing practice in some areas that eliminates forbs, making these sites unsuitable for Mead's milkweed. Indirect effects of increased pesticide use can result in the direct decline of the Mead's milkweed primary pollinators, which include miner bees (*Anthophora abrupta)*, western honeybees (*Apis mellifera)* and small bumblebees (*Bombus* spp).

Feral Swine:

Feral swine were originally introduced to the southeastern United States and California in the early 1500s, but their range has increased substantially over the last several decades across the United States. The distribution and abundance of feral swine varies with habitat type but is highly correlated with the presence of public lands. Feral swine damage natural resources by destroying native vegetation, causing soil erosion, degrading water quality, and acting as a vector for many diseases. Feral swine have contributed to substantial habitat destruction in Missouri including severe damage to Mead's milkweed plants at some locations (Mark Twain National Forest 2009, USFWS 2012). Feral swine have been reported in all states of the Mead's milkweed distribution; however, swine are believed to be eradicated from Wisconsin and Iowa, with near eradication achieved in Illinois and Indiana (USDA-APHIS 2020). Historically, feral swine have overlapped in the Mead's milkweed distribution in 4 counties in Kansas (accounting for 138 Mead's milkweed sites), 11 counties in Missouri (58 sites) and 1 county in Illinois (1 site; Figure 2).

Numerous lethal and nonlethal control techniques have been utilized to control feral swine and mitigate their damage following the establishment of the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) National Feral Swine Damage Management Program and USDA Natural Resources Conservation Service (NRCS) Feral Swine Eradication and Control Pilot Program, established in 2018. These programs consist of coordinated efforts including direct swine removal by APHIS, restoration of habitat following feral swine damage by NRCS, and assistance to non-federal partners through grants and funding opportunities. Populations of feral swine have since retracted southward in Missouri, limiting their range to 8 counties that overlap with 41 known Mead's milkweed populations (Figure 2). It is unknown how long impacts from feral swine on Mead's milkweed may last; however, they may have contributed to the extirpation of the plant in some sites.

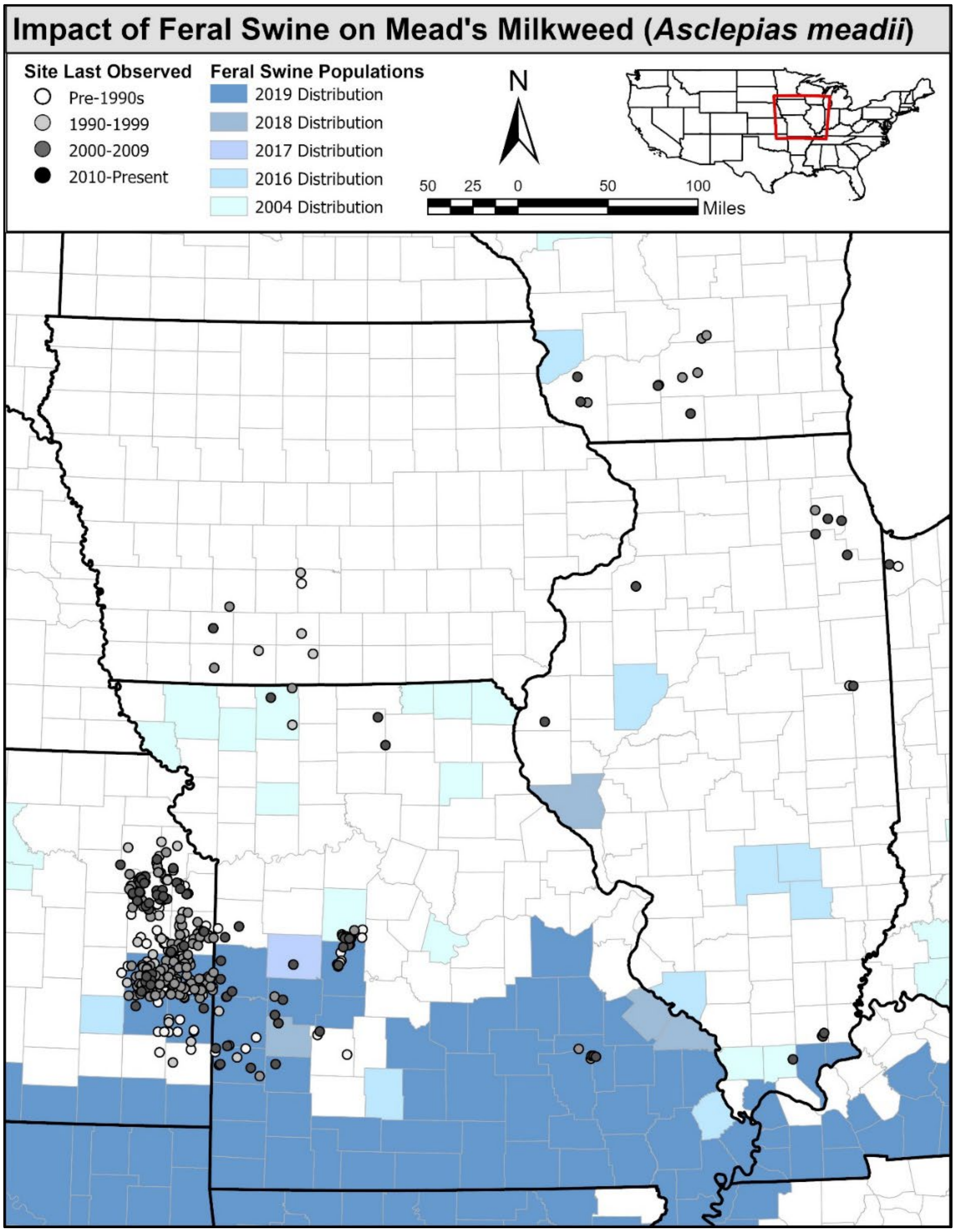

Figure 2: Feral swine reported distribution by APHIS throughout the distribution of Mead's milkweed. There is active overlap between counties with feral swine populations and known Mead's milkweed sites in Kansas and Missouri, but also previously in Illinois. Opacity of circles indicates recency of observations (darker being more recent). County shading indicates distribution of feral swine across different years.

Overutilization for commercial, recreational, scientific, or educational purposes:

No past or current demand exists for Mead's milkweed plants for commercial, recreational or educational purposes. Occasionally, permitted research activities collect Mead's milkweed.

Disease or predation:

In 2012, Brown et al. (2015) documented fungal hyphae on the floral organs of Mead's milkweed. Upon further review of plants from Missouri and Kansas, the authors discovered fungal-packed stigmatic slits (Brown et al. 2015). Stigmatic slits are small openings or crevices on a flower where a pollinator's leg may slip inside while drinking the flower's nectar, inside of the stigmatic slits are pollinia, a collection of pollen that attaches to a pollinator's leg and is then transferred while foraging on another flower. Fungal-infected pollinia were discovered in as many as 90% of the plant specimens inspected by researchers in Missouri and Kansas (Brown et al. 2015). Although the relationship between Mead's milkweed and the fungi discovered is unknown at this time, there is potential that the fungus is causing significant infections and could limit the reproductive success of milkweed plants by causing increased plant stress, tissue necrosis, and floral abortion (Brown et al. 2015). The authors recommend that Koch's postulates be applied to verify if fungi isolated from milkweed plants are pathogenic or mutualistic.

Inadequacy of existing regulatory mechanisms:

Land ownership within Mead's milkweed habitat is likely the primary factor that limits the effectiveness of existing regulatory mechanisms. Recovery options are often limited on private lands, and most of the populations occur on private land without a management agreement. A majority (309) of populations either have no protection status or the status is unknown. Sixty-two populations have formal protections (59 legal and 3 formal but not legal). For a detailed description of protection categories see Appendix 2.

Other natural or manmade factors affecting its continued existence:

Climate Change:

Long-term changes in environmental conditions (e.g., patterns of temperature and precipitation) have had observable impacts on plants, wildlife, ecosystems, and the ecosystem services they provide to society (Groffman et al. 2014, USGCRP 2018). Mead's milkweed may be directly impacted by the changes to water quality, drought and flooding, and the spread of invasive species. Such changes are projected to continue. Without substantial and sustained reductions in global greenhouse gas emissions, extinctions and transformative impacts on some ecosystems cannot be avoided in the long term. More frequent and intense extreme weather and climate-related events, as well as changes in average climate conditions, are expected to continue to damage infrastructure, ecosystems, and social systems that provide essential benefits to communities (USGCRP 2018). The frequency of flood events has increased across the southeastern region and across most of the Midwestern U.S. over the past two or more decades (Neri et al. 2019). Climate change projections predict warming average temperatures, more days with extreme heat, increased extreme precipitation events, and longer periods of drought (IPCC 2014, USGCRP 2018).

Across the Midwest, predicted extremely wet late springs (April – May) and extremely dry late summers (July – August; Zhou et al. 2022) overlap with key Mead's milkweed reproductive periods (USFWS 2003). Climate change vulnerability models are useful in identifying potential refugia and prioritizing conservation actions while planning for future conditions (Molano-Flores et al. 2019). Decision making frameworks can be developed at range-scale, facilitating conservation and recovery efforts across states (Morelli et al. 2020, Balantic et al. 2021). Temperatures are expected to increase in the Midwest indicating longer periods of extreme heat, and longer periods of drought (Pryor et al. 2014). Accordingly, most of the federally listed plant species in the Midwest are vulnerable to climate change (Molano-Flores et al. 2019). Specifically, Mead's milkweed populations in Illinois are within the plant's southern range where environmental changes linked to climate change are occurring with greater intensity and are thus considered moderately vulnerable to climate (Pryor et al. 2014, Molano-Flores et al. 2019).

Pollinator Declines:
Mead's milkweed are primarily pollinated by large bees, including the species European honeybee (*Apis melifera*)*,* rusty patched bumblebee (*Bombus affinis*)*,* brown-belted bumblebee (*B. griseocollis*)*,* Southern Plains bumblebee (*B. fraternus*) and the chimney bee (*Anthrophora abrupta*), (Betz et al. 1994, Edens-Meier et al. 2017). Hallmann (2017) reported severe losses of flying insects across the globe, with several taxa of pollinators (e.g., butterflies, wild bees, and moths) experiencing large declines. In most ecosystems, bees are the dominant pollinators; however, compounding stressors (e.g. habitat loss, food stress, exposure to pesticides, pathogens, and climate change-related impacts) have led to wide scale declines (Rhodes 2018). In North America, losses of bees in grasslands commenced in the early 19th century (Samson and Knopf 1994), while a largescale bee decline in the U.S. Midwest occurred as agriculture practices intensified between the 1940s and 1960s (Grixti et al. 2009). Mead's milkweed pollinators, particularly bumblebees, have declined throughout the United States.

Matching other largescale declines in Midwestern pollinators, 50% of bumblebee species in Illinois have been extirpated or have severely declined, most of which occurred at the edges of their ranges (Grixti et al. 2009). The Southern Plains bumblebee suffered population declines across 70% of its range and is considered at high risk for extinction due to its small geographic range (Colla et al. 2012, Rhodes 2018). The brown-belted bumblebee remains in only 72% of its historical range (Colla et al. 2012). Furthermore, rusty-patched bumblebee, previously identified as a pollinator of Mead's milkweed (Betz et al. 1994), has experienced a large decline across its range and was listed as endangered in 2017 (82 FR 3186 3209). Recovery efforts for pollinators are ongoing through a variety of partnerships across the nation, and maintaining pollinator populations will be essential for the recovery of Mead's milkweed.

In addition, phenological shifts have been reported in several plant-pollinator relationships which can affect both social and ecological systems (Rhodes 2018, Gómez-Ruiz and Lacher 2019). Anecdotal evidence of asynchrony between Mead's milkweed flowering and pollinator activity was reported in 2012 when plants flowered and withered before chimney bees emerged (Edens-Meier et al. 2017). Although long-term shifts in Mead's milkweed phenology are not completely understood due to a lack of data, phenological shifts in other species of pollinators have previously been reported in Midwestern states where Mead's milkweed occurs emerged (Edens-Meier et al. 2017). Additionally, small populations of Mead's milkweed may not attract the appropriate pollinators; therefore, population augmentation is necessary to benefit both plant and pollinator communities (Edens-Meier et al. 2017).

CONSERVATION MEASURES:

Iowa:

Powell Prairie in Taylor County and Woodside Prairie in Adair County are sites where Mead's milkweed has been reliably located. After approximately 20 years without surveys, both sites were surveyed in 2020 with only 1 sterile plant observed at Woodside Prairie. While both sites are small, these highly diverse prairie remnants located on private property recently underwent active conservation management for Mead's milkweed. These sites were burned, and habitat improvements also included removal of red cedar (*Juniperus virginiana)* trees.

Indiana:

The Indiana Plant Conservation Alliance (INPCA) has recently identified rare plants for conservation prioritization, including Mead's milkweed. A Mead's milkweed conservation team has been formed, and conservation planning includes future monitoring, conducting a literature review, and identifying appropriate habitat for potential future reintroductions (V. Witting – Indiana Plant Conservation Alliance, pers. comm. 2022). Monitoring of reintroduced populations is ongoing and continues to be managed for prairie species including Mead's milkweed recovery (S. Namestnik – Indiana DNR, pers. comm. 2022).

Kansas:

The Grassland Heritage Foundation has purchased a 15-acre prairie in Anderson County with a small population of Mead's milkweed. In 2018, a conservation easement was placed on a privately-owned, 80-acre prairie in Anderson County with a large Mead's population (M. McNulty - USFWS, pers. comm. 2022). Managing agencies have initiated burns at the formerly hayed Lexington Lake Park site in Johnson County, Kansas (C. Edwards – Missouri Botanical Garden, pers. comm. 2022).

Missouri:

Missouri Department of Conservation (MDC) acquired Berrier (formerly known as South Fork upland and Winn's Prairie) in 2020 and has initiated burns on the site (C. Edwards – Missouri Botanical Garden, pers. comm. 2022). Together with Missouri Botanical Garden (MoBOT), MDC conducted an augmentation at Berrier in 2020 (C. Edwards – Missouri Botanical Garden, pers. comm. 2022).

Plantings occurred in 2011 and 2012, and these sites were monitored annually 2015-2017 to estimate establishment success and persistence. They continue to be monitored during the flowering season immediately after a prescribed burn. Remnant populations that are regularly managed and easily accessible are also surveyed immediately following a prescribed burn. Prescribed burns are predominately occurring during the dormant season.

Seed pods were collected in 2013, and used to establish a propagation plot in 2015 at Powell Gardens. As of 2022, there are approximately 50 individuals within the plot. A seed pod was produced in 2019 but succumbed to insect damage. There have been a few flowering individuals in recent years and the plot is expected to serve as a seed source for future propagation efforts.

Following recent studies that have provided better understanding of genetic diversity, future propagation efforts are expected, along with follow up studies to investigate the lack of seed production that is observed at several locations. Management activities (e.g., haying and burning) likely affect the height of individual plants and the number of observable plants, possibly contributing to low rates of fecundity (USFWS 2012). Another potential cause of low fecundity is a resource limitation. Upcoming research funded by MDC and conducted by the Missouri Botanical Garden is expected to evaluate these possibilities.

Wisconsin:

Three populations have been surveyed in the last 10 years and continued monitoring of these locations is planned. Interest has been expressed in identifying optimal habitat for future reintroductions (R. Henderson, pers. comm. 2022).

RECOMMENDATIONS FOR FUTURE ACTIONS:

1. Conduct surveys and monitoring. The PVI analysis conducted for Mead's milkweed was originally implemented as a preliminary calculation, and likely overestimates viability. It is important that more accurate analyses are conducted; however, to do so the current status of each population is needed with regular monitoring following.

2. Complete a Species Status Assessment. Since listing, many populations have not been monitored and their status remains unknown. Threats from feral swine, climate change, and a lack of appropriate management compound the risks to Mead's. Once sufficient data is gathered for a more accurate viability analysis, a species status assessment (SSA) may be helpful to determine if the species should remain the same or reclassified under the ESA.

3. Coordinate with partners on monitoring and management needs. Coordination among Federal, State, and private entities on monitoring and management needs to be enhanced and improved. As noted in Moore et al. (2011), an adaptive decision/management framework is recommended to assess various management actions, as well as augmentations to increase genetic diversity. The proliferation of virtual meeting platforms (e.g., Zoom, and Microsoft Teams) allows for collaboration at a distance, which can facilitate meetings and conservation planning. Federal, State, private conservation groups, species experts, geneticists, management experts, university researchers, expert ecologists, and invertebrate specialists (especially pollination experts) should be included in these discussions.

4. Prioritize populations for restoration efforts. After site surveys are updated, sites that are considered optimal habitat with low genetic diversity or ramet counts should be identified for future reintroductions.

5. Manage sites to improve fecundity in Mead's milkweed. Generally, high fruit set was found when populations had >50 ramets flowering at once. Therefore, populations with fewer than 50 flowering ramets should be augmented, though sites left fallow for several years and then burned may show a large increase in flowering ramets. Synchronous flowering among populations of Mead's milkweed may also improve fecundity. Coordinating the timing of controlled burns across multiple sites is one way to accomplish this (Wagenius et al. 2020). A study investigating the effects of fire return interval and seasonality on flowering is needed to test this hypothesis.

6. Conduct studies on the impacts of climate change. Climate change will likely alter future viability of many Mead's milkweed populations, and future viability analyses should adjust for changing environmental conditions. Studies like Molano-Flores et al. (2019) should be conducted throughout the range of the species.

7. Conduct pollination research studies to assess limitations. To test for pollen limitation, a pollen supplementation study is needed that compares fecundity in open and hand-pollinated treatments across populations with varying numbers of flowering ramets. Additionally, studies are needed to test for pollinator limitation.

8. Conduct genetic analysis to facilitate augmentations. Promote widespread gene flow across the range of Mead's milkweed. Future augmentations should focus on adding seedlings sourced from multiple different maternal plants to maintain levels of genetic diversity in populations. Additional genetic analyses of small populations are needed to test mate limitation and the presence of the Allee effect in Mead's milkweed.

9. Encourage voluntary management. Because the protection status of many populations is either unknown or the sites are unprotected, conservation organizations should encourage voluntary management strategies with landowners.

10. Evaluate the impacts of imperiled insect management. In managing Mead's milkweed habitat, we should also evaluate various management prescriptions on other listed and candidate species that co-occur with Mead's, especially invertebrates such as Rattlesnake master borer moth (*Papaipema eryngii*) and Monarch butterflies (*Danaus plexippus*).

SYNTHESIS:

After reviewing the best available scientific information, we conclude that a change in status for Mead's milkweed (*Asclepias meadii*) is not indicated at this time. A majority of populations have a low or medium population viability index (PVI) and only three populations have a high PVI. Most sites (56%) have not been visited in the last 10 years and many sites (23%) in the last 20 years and the indices calculated may not reflect the current status of these populations. Increased survey effort and populations updates are recommended. Major threats to Mead's milkweed habitat include a lack of burning, frequent haying or mowing, feral hog damage, and pollinator declines. Additionally, lack of reproduction is a major concern. It was previously thought that a lack of flowering was due to low genetic variability and high clonal rates; however, recent studies show that genetic diversity is retained in remnant populations and population size might be a critical factor in achieving flowering and seed production. Additional genetic studies are recommended in conjunction with population surveys to determine the amount of genetic variability in populations. Other recommendations include conducting pollinator studies, working with landowners on voluntary conservation measures, and prioritizing populations for management effort. Once population statuses are determined, we may conduct a status assessment within the SSA framework, including an assessment of the risk to the species from climate change and other threats.

RESULTS

U.S. FISH AND WILDLIFE SERVICE
STATUS REVIEW of Mead's Milkweed *(Asclepias meadii)*

Current Classification: Threatened

Status Recommendation resulting from Status Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist (Indicate reasons for delisting per 50 CFR 424.11):
  ____ The species is extinct
  ____The species does not meet the definition of an endangered or threatened species
  ____The listed entity does not meet the statutory definition of a species
__x__ No change needed

Lead Field Supervisor, Fish and Wildlife Service

Approve KAREN HERRINGTON Digitally signed by KAREN HERRINGTON Date: 2022.04.14 12:32:09 -05'00' Date _________

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APPENDIX 1: POPULATION VIABILITY INDEX (PVI)

The data for this analysis were provided by state agencies through the use of survey data, reports, or through personal communication.

State	Physiographic Region	Site Name	Last Observed	Current Land Use	Pop. Size	Pop. Trend	Habitat Size	Habitat Condition	Protection	Management	PVI 2021	Viability 2021
IA	Southern Iowa Drift Plain	Adams County Pasture	2010	Pasture	0	1		1	0	1	0.20	Low
Il	Coastal Plain	Simpson Township Barrens	2015	Unknown	0	0		0	0		0.00	Low
Il	Grand Prairie	Pellville Cemetery	2020	Late-successional 0.2 ha prairie, mesic drainage	0	0	0	0	0		0.00	Low
Il	Grand Prairie	Munson Township Cemetery Prairie	2010	Mesic, black-soil prairie	0	0		0	0		0.00	Low
Il	Grand Prairie	Vermont Cemetery Prairie	2011	Mesic drainage, late-successional stage 0.4 ha prairie	0	0	0	0	0		0.00	Low
Il	Middle Mississippi River Border	Geissler Savanna	2010	Mesic to dry-mesic savanna	0	0		0	0		0.00	Low
Il	Northeastern Morainal	West Chicago Prairie	2006	Mid-successional 47 ha mesic prairie	0	0	2	0	0		0.13	Low
Il	Northeastern Morainal	Hickory Creek Barrens	2012	Early-successional 35 ha prairie, dry-mesic drainage	0	0	2	0	0		0.13	Low
Il	Northeastern Morainal	Morton Arboretum	2011	Dry-mesic/mid-successional prairie restoration site	0	0		0	0		0.00	Low
Il	Northeastern Morainal	Hinsdale Prairie	2010	Unknown	0	0		0	0		0.00	Low
IL	Shawnee Hills	Saline #2 (Cave Hill)	2008	National forest	0	2		2	0		0.33	Low

**Description of variables and calculations are in Appendix 2*

State	Physiographic Region	Site Name	Last Observed	Current Land Use	Pop. Size	Pop. Trend	Habitat Size	Habitat Condition	Protection	Management	PVI 2021	Viability 2021
IL	Shawnee Hills	Saline #4 (Dennison)	2008	National forest	1	2		2	0		0.42	Low
IN	Northwestern Morainal	Biesecker Prairie Nature Preserve	2020	Remnant tall grass prairie; burned periodically	0	0	1	2	3	3	0.50	Moderate
KS	Osage Plains	Friendly Cow Prairie/Paintbrush Prairie (Ksande)	2019-07	Haymeadow; possibly burning, Some past grazing.	3	3	2	2	3	2	0.92	High
KS	Osage Plains	Cec Survey Site Mmsa-Nw-1	2011-06	Pasture	0	0	1	0	0	1	0.00	Low
KS	Osage Plains	Mmsa-Nw-7	2011-06	Pasture	0	0	2	0	0	2	0.00	Low
KS	Osage Plains	Unnamed	1992-05	Haymeadow			0	0	0	0	0.00	Low
KS	Osage Plains	Anderson #2/Doering Place	1987-06	Haymeadow. 2009: Sprayed with herbicide			3	1	0	3	0.17	Low
KS	Osage Plains	Vinland Prairie Ne	6/12/2019	Unknown	1	1	1	2	0	1	0.33	Low
KS	Osage Plains	Hawks Prairie	6/6/2019	Unknown	0	1	1	2	0	1	0.25	Low
KS	Osage Plains	Pipeline Prairie	5/30/2019	Haymeadow	1	0	3	2	0	3	0.25	Low
KS	Osage Plains	Calhoun Bluffs Prairie/Oakwood Farm	5/17/2019	Haymeadow	0	0	1	3	3	1	0.50	Moderate
KS	Osage Plains	St. Louis And Emporia Railway Prairie	6/20/2018	Haymeadow	0	0	1	1	0	1	0.08	Low

**Description of variables and calculations are in Appendix 2*

State	Physiographic Region	Site Name	Last Observed	Current Land Use	Pop. Size	Pop. Trend	Habitat Size	Habitat Condition	Protection	Management	PVI 2021	Viability 2021
KS	Osage Plains	Maryland Road Prairie	6/16/2018	Haymeadow	2	1	3	3	0	3	0.50	Moderate
KS	Osage Plains	Leadplant Prairie/Bridge Repair Site	5/23/2018	Rested in 2020; hayed annually in prior years. Plan to manage with burn-hay-rest rotation.	3	2	1	1	3	1	0.75	Moderate
KS	Osage Plains	Kill Creek Prairie	5/17/2018	Dormant season fire/rest rotation	2	1	1	3	2	1	0.67	Moderate
KS	Osage Plains	Lexington Lake Park	5/17/2018	Dormant season fire/rest rotation	3	2	1	1	2	1	0.67	Moderate
KS	Osage Plains	Welda Prairie North/Anderson County Prairie Preserve (Unit 53)	7/7/2016	Patch burn-graze	0	0	3	1	3	3	0.33	Low
KS	Osage Plains	Unique Prairie	5/12/2016	Haymeadow	2	2	1	2	0	1	0.50	Moderate
KS	Osage Plains	Worden Prairie	6/18/2015	Haymeadow	0	0	1	3	0	1	0.25	Low
KS	Osage Plains	Fishermen's Prairie	6/11/2015	Haymeadow	0	2	0	2	1	0	0.42	Low
KS	Osage Plains	Gammagrass Prairie	6/11/2015	Haymeadow/pasture. Winter grazing prior to 2015	0	1	1	2	0	1	0.25	Low
KS	Osage Plains	Lecompton Prairie; One Of 5 Prairie Tracts	6/11/2015	Haymeadow	0	1	1	1	0	1	0.17	Low
KS	Osage Plains	Fence To Fence Prairie	6/9/2015	Haymeadow	1	2	1	3	0	1	0.50	Moderate

**Description of variables and calculations are in Appendix 2*

State	Physiographic Region	Site Name	Last Observed	Current Land Use	Pop. Size	Pop. Trend	Habitat Size	Habitat Condition	Protection	Management	PVI 2021	Viability 2021
KS	Osage Plains	Spring Valley Prairie	6/8/2015	Haymeadow	3	2	1	1	1	1	0.58	Moderate
KS	Osage Plains	The Day After Prairie	6/8/2015	Haymeadow	1	1	1	3	0	1	0.42	Low
KS	Osage Plains	Spring Creek Prairie West	6/6/2015	Haymeadow	1	0	1	3	3	1	0.58	Moderate
KS	Osage Plains	Clearfield Prairie	6/4/2015	Grazed (occasionally)	0	1	1	2	0	1	0.25	Low
KS	Osage Plains	Corner Prairie	6/4/2015	Haymeadow	0	1	1	3	0	1	0.33	Low
KS	Osage Plains	Blue Healer Prairie	6/3/2015	Haymeadow	3	1	1	2	0	1	0.50	Moderate
KS	Osage Plains	Eastlake Prairie	6/1/2015	Haymeadow	0	1	1	2	0	1	0.25	Low
KS	Osage Plains	Hang-Glider Prairie	5/28/2015	Haymeadow	1	1	1	3	0	1	0.42	Low
KS	Osage Plains	Twin Mounds Prairie Ne	5/28/2015	Haymeadow	0	1	1	3	0	1	0.33	Low
KS	Osage Plains	Vinland Prairie South	5/27/2015	Haymeadow	0	1	1	2	0	1	0.25	Low
KS	Osage Plains	Happy Prairie	5/26/2015	Haymeadow	1	1	1	2	1	1	0.42	Low
KS	Osage Plains	Rock Creek Prairie S	5/26/2015	Haymeadow	0	1	1	2	0	1	0.25	Low
KS	Osage Plains	Willow Springs Prairie	5/21/2015	Unknown	0	1	1	1	0	1	0.17	Low
KS	Osage Plains	Four-Piece Prairie	5/20/2015	Haymeadow. W parcel fenced	1	1	1	3	0	1	0.42	Low

**Description of variables and calculations are in Appendix 2*

State	Physiographic Region	Site Name	Last Observed	Current Land Use	Pop. Size	Pop. Trend	Habitat Size	Habitat Condition	Protection	Management	PVI 2021	Viability 2021
KS	Osage Plains	Jack's Prairie	5/19/2015	Haymeadow	1	1	1	3	0	1	0.42	Low
KS	Osage Plains	Leary Prairie	5/19/2015	Haymeadow	2	2	1	2	0	1	0.50	Moderate
KS	Osage Plains	Anderson County Prairie Preserve/Welda Prairie North	6/11/2014	Haymeadow	0	1	3	2	3	3	0.50	Moderate
KS	Osage Plains	Garnett Prairie	6/14/2013	Part haymeadow; part unmanaged	0	0	2	2	0	1.00	0.20	Low
KS	Osage Plains	Little Flower Prairie	5/16/2012	Haymeadow	1	1	1	2	0	1	0.33	Low
KS	Osage Plains	Allen #2	5/26/2011	Haymeadow	0	0	1	0	0	1	0.00	Low
KS	Osage Plains	Mound Prairie	6/23/2010	Haymeadow	1	1	1	3	0	1	0.42	Low
KS	Osage Plains	Allen #1	6/16/1986	Haymeadow/crop/grazed			1	0	0	1	0.00	Low
KS	Osage Plains	Hopewell Prairie/Katy Prairie	2015	Haymeadow	1	1	1	3	0	2.00	0.47	Low
KS	Osage Plains	The Prairie Center Site	2013	Unknown	0	1	1	0	3	1	0.33	Low
KS	Osage Plains	Violet Hill	2002	Unknown			1	3	0	1	0.50	Moderate
MO	Osage plains	Dunn Planting #1	*2011*	Unknown	3	2		0	3	2	0.67	Moderate
MO	Osage plains	Dunn Planting #2	*2011*	Unknown	3	2		0	3	2	0.67	Moderate
MO	Osage plains	Morton Planting	*2015*	Unknown	3	1		2	0	2	0.53	Moderate
MO	Osage plains	Paintbrush Planting	*2015*	Hay/burn	2	1		2	3	2	0.67	Moderate

**Description of variables and calculations are in Appendix 2*

State	Physiographic Region	Site Name	Last Observed	Current Land Use	Pop. Size	Pop. Trend	Habitat Size	Habitat Condition	Protection	Management	PVI 2021	Viability 2021
MO	Osage plains	Teel Planting # 1	*2015*	Unknown	3	2		3	0	2	0.67	Moderate
MO	Osage plains	Teel Planting # 2	*2015*	Unknown	3	2		3	0	2	0.67	Moderate
MO	Glaciated Plains	Dark Hollow Na	*2010*	1.5 year spring-fall burn rotation, invasive lespedeza present	0	1		2	3	2	0.53	Moderate
MO	Glaciated Plains	Williams Prairie	*2015*	Unknown	0	1		0	2	2	0.33	Low
MO	Osage plains	Amsterdam Prairie	*2015*	Annually hayed	0	0	1	1	0	1	0.17	Low
MO	Osage plains	Antique Prairie	*2014*	Annually hayed	0	0		1	0	1	0.13	Low
MO	Osage plains	Blue Mound Prairie	*2014*	Annually hayed, annually burned in spring	0	2		1	0	1	0.27	Low
MO	Osage plains	Bronaugh (Bushwhacker Conservation Area)	*2017*	Hay meadow	0	2	3	1	3	2	0.61	Moderate
MO	Osage plains	Cole Camp Junction Prairie	2016	Annually hayed	0	2	1	0	0	1	0.22	Low
MO	Osage plains	Friendly Prairie	*2008*	Hay/burn rotation	0	3	1	2	3	2	0.61	Moderate
MO	Osage plains	Grand River Bottoms (Hilltop Prairie-Truman Reservoir)	*2015*	Unknown	0	1		0	3	2	0.40	Low

**Description of variables and calculations are in Appendix 2*

State	Physiographic Region	Site Name	Last Observed	Current Land Use	Pop. Size	Pop. Trend	Habitat Size	Habitat Condition	Protection	Management	PVI 2021	Viability 2021
MO	Osage plains	Little Osage Prairie	*1978*	Natural area/former hay meadow	0	0	2	2	3	2	0.50	Moderate
MO	Osage plains	Teel Prairie (McGennis Prairie)	*2017*	Annual haying, periodic burning	2	2		3	0	2	0.60	Moderate
MO	Osage plains	Morey Prairie	*2017*	Fescue within the prairie, *Sericea lespedeza* along boundary, annually hayed	3	1		2	0	2	0.53	Moderate
MO	Osage plains	Morton Remnant Prairie (Root Ranch)	*2015*	Unknown	1	1		1	0	2	0.33	Low
MO	Osage plains	Old Rr Grade Prairie	*2018*	Hayed annually	1	2		1	0	1	0.33	Low
MO	Osage plains	Osage Prairie Natural Area	*2015*	Natural area, former hay meadow	0	1	3	3	3	2	0.67	Moderate
MO	Osage plains	Paintbrush Prairie Natural Area	*2015*	Hay/burn	3	2	3	3	3	2	0.89	High
MO	Osage plains	Paintbrush Prairie Vicinity South	*1989*	Hay/burn rotation	0	2		2	0	2	0.40	Low
MO	Osage plains	Polytaenia Prairie	*2015*	Prairie, tree removal occurring	1	2		0	0	0	0.20	Low
MO	Osage plains	Regal Prairie Natural Area	*2014*	Graze/burn rotation bison grazing	0	2	3	3	3	2	0.72	Moderate

**Description of variables and calculations are in Appendix 2*

State	Physiographic Region	Site Name	Last Observed	Current Land Use	Pop. Size	Pop. Trend	Habitat Size	Habitat Condition	Protection	Management	PVI 2021	Viability 2021
MO	Osage plains	Short Prairie	*2018*	Hayed annually S. Lespedeza present and needs control	0	2		1	0	1	0.27	Low
MO	Osage plains	Silverton Prairie	*2016*	Annually hayed, burned	0	2		1	0	2	0.33	Low
MO	Osage plains	Snowball Hill Prairie	*2016*	Unknown	0	2		2	3	2	0.60	Moderate
MO	Osage plains	Berrier / South Fork Prairie (Winn's Prairie)	*2013*	Purchased by MDC in 2020 Managed as conservation area, formerly idle	3	2	1	2	3	1	0.67	Moderate
MO	Osage plains	Taberville Prairie	*2015*	Patch/burn/graze rotation S section, control N section	0	1	3	2	3	2	0.61	Moderate
MO	Osage plains	Twenty-Five Mile Prairie Ca	*2018*	Unknown	0	2		2	3	2	0.60	Moderate
MO	Osage plains	Wah-Kon-Tah Prairie	*2015*	Patch/burn/graze; haying; spring burn; rest	3	1	2	2	3	2	0.72	Moderate
MO	Osage plains	Windmill Prairie	*2016*	Unknown	0	2		0	0		0.17	Low
MO	Osage plains	Windsor Junction Vicinity East	*2019*	Hay meadow	0	0	1	1	0	0	0.11	Low
MO	Osage plains	Wah-Kon-Tah Prairie (Mo-Ko Unit)	*2011*	Hay/burn rotation	0	0	3	2	3	2	0.56	Moderate
MO	Ozark-Springfield Plateau	Hi Lonesome Prairie Conservati on Area	*2008*	Hay meadow/pasture	1	2	3	1	0	1	0.44	Low

**Description of variables and calculations are in Appendix 2*

State	Physiographic Region	Site Name	Last Observed	Current Land Use	Pop. Size	Pop. Trend	Habitat Size	Habitat Condition	Protection	Management	PVI 2021	Viability 2021
MO	Ozark-Springfield Plateau	Niawathe Prairie	*2015*	S. Section - patch/burn/graze rotation, N. Section managed as prairie.	3	2	3	3	3	2	0.89	High
MO	Ozark-St. Francois mountains	Bell Mountain-West	*2008*	Natural area w/feral hogs	0	2	0	2	3	1	0.44	Low
MO	Ozark-St. Francois mountains	Ketcherside Mountain Conservation Area (Proffit Mountain)	*2009*	**Burn/natural area w/feral hogs**	3	2	1	2	3	1	0.67	Moderate
MO	Ozark-St. Francois mountains	St. Francois Mountains Natural Area	*2015*	Natural area	0	2		3	3	1	0.60	Moderate
MO	Ozark-St. Francois mountains	Taum Sauk Mtn State Park-Weimer Hill	*2015*	Natural area w/feral hogs	3	2	1	2	3	1	0.67	Moderate
MO	Ozark-St. Francois mountains	Taum Sauk Mountain State Park # 1	*2015*	Natural area	1	1		3	3	1	0.60	Moderate
WI	Driftless	Bushclover Prairie	2017	Dry Mesic; Original Prairie; last burned 2017	0	1	0	3	3	3	0.56	Moderate
WI	Driftless	Lancaster Prairie - North	2017	Dry Mesic; original prairie; no burns since 2013	0	0	0	3	3	3	0.50	Moderate
WI	Driftless	Nittany Knoll Prairies (Schurch-	2020	Dry Mesic; original prairie; no burns since 2020;Cleared of heavy brush	1	1	2	3	3	3	0.72	Moderate

**Description of variables and calculations are in Appendix 2*

State	Physiographic Region	Site Name	Last Observed	Current Land Use	Pop. Size	Pop. Trend	Habitat Size	Habitat Condition	Protection	Management	PVI 2021	Viability 2021
		Thomson Pr)		invasion winter 00-01, and mowed in summer 2002 & 2003								
WI	Driftless	Underwood Prairie	2009	Dry Mesic; Original Prairie; last burned 2013; prairie is being inter-seeded into old brome CRP w/ annual fire	0	0	2	3	1	3	0.50	Moderate
WI	SE Wisconsin Till Plains	Vale Prairie	2015	Dry Mesic; Original Prairie; last burned 2013 & 2015 (partial); formerly plowed (50+) years ago. Restoration work	0	0	1	3	3	3	0.56	Moderate

**Description of variables and calculations are in Appendix 2*

APPENDIX 2: METHODS TO CALCULATE PVI (FROM USFWS 2003; 2012):

Currently, only three populations should be viewed as preliminarily highly viable. The calculation of the Population Viability Index (PVI) (second to last column in Appendix 1) for each Mead's milkweed population relied upon measurements of several variables (Table 1) to assess the viability of each population (i.e., population size, whether the population trend is increasing, effective population size, habitat size, habitat condition, protection status, whether the habitat has long-term protection, and the need for management). For each variable, a ranking from 0 to 3 was assigned and the sum of all variable rankings was then divided by the number of variables (e.g., seven variables would yield a maximum sum of 21) to produce an index ranging from 0 to 1. When information about a variable was not available for a site, that variable was not used in the calculation of the PVI for that site. An index greater than 0.75 indicates populations of high viability, an index from 0.50 to 0.75 indicates populations of moderate viability, and an index less than 0.50 indicates populations of low viability.

Despite the lack of variable information for some populations, a preliminary Population Viability Index (second to last column in Appendix 1) was determined for each Mead's milkweed population using the number of ramets and protection status' from the recovery plan's element occurrence ranking observed 1970 to 2001 (USFWS 2003). Reports and lists of element occurrences for the populations were also used in order to update counts and add information about reproduction, habitat quality, habitat size, and management condition (Missouri Department of Conservation 2009, Delisle 2010, Pearson 2010). The method by which the PVI ranks were assigned for each variable is described below.

Population size: Although the number of ramets was used as a proxy for population size, this will almost certainly be an overestimate of the population size since Mead's milkweed spreads clonally. A single individual or genotype may be represented by two or more shoots or ramets with uncertainty as to how many genotypes or genets are actually represented. This is particularly problematic in sites where mowing occurs, since mowing cuts off the flower heads, inhibiting sexual reproduction and encouraging clonal spread (Bowles et al. 1998). The number of ramets listed in the recovery plan was updated using reports sent to the USFWS in response to requests for new information on Mead's milkweed for this 5-year review. An average ramet number from 2010 to 2021 was generally used if there were several counts over that period. For sites only visited sporadically, the most recent count was used. In a few cases where the most recent count was 0, but plants were observed at the site during 2010 to 2021, the highest count was used. Even though using the ramet number as a surrogate for the individual plant number, and using the highest plant count for the period 2010 to 2021, for populations where the most recent count is 0, might bias the preliminary Population Viability Index to be higher than it should, there are still only 3 populations that are highly viable. Populations with 0 to 9 ramets received a ranking of 0, 10 to 24 ramets received a ranking of 1, 25 to 49 ramets received a ranking of 2, and 50 or greater ramets received a ranking of 3 (See Appendix 1 Column: Population Size).

Population Trend: While it is recognized that the production of seed does not ensure that plant establishment will outpace plant loss, populations with seed production occurring received a rank of 3; populations with flowering but no seed production received a rank of 2; populations containing only nonflowering plants, or for which flowering was not recorded, received a rank of 1; and populations with no plants received a rank of zero (See Appendix 1 Column: Population Trend).

Effective population size/# of genotypes: The information required to determine the variable ranking of effective population size/# of genotypes is not available for approximately 93% of the populations (Tecic et al 1998; Hayworth et al. 2001; Comer 2009), hence this variable was not included in the PVI.

Habitat Size: The variable of habitat size was generally determined from the size reported for the prairie site, which would frequently overestimate the variable because the entire site would not necessarily be appropriate Mead's milkweed habitat. Large locations, defined as >50 ha (>125 ac) received a rank of 3; medium locations 25<50 ha (62.5<125 ac) received a rank of 2; small locations 1<25 ha (2.5<62.5 ac) received a rank of 1; and very small locations <1 ha (<2.5ac) received a rank of 0 (See Appendix 1 Column: Habitat Size).

Habitat Condition: Sites that were reported to have A-quality grade habitat, defined as having a high diversity of native species and located in undisturbed native areas received a habitat condition ranking of 3; populations reported to have B-quality grade habitat defined as moderate quality habitat experiencing rotated haying with rest or burn received a ranking of 2; populations reported to have C-quality grade habitat defined as marginal habitat which might include annual haying/grazing or home to feral pigs received a ranking of 1; and populations in poor quality habitat reported to be degraded, developed, or if the habitat condition was unknown, received a ranking of 0 (See Appendix 1 Column: Habitat Condition).

Protection Status: In the Recovery Plan, protection status of each population was ranked from 0 to 9. For the PVI, a different ranking was used. Populations with legally binding protection (dedication, fee title held by conservation entity, conservation easement, federal protection of listed species on public land) are ranked as 3; formal but not legal protection (remainder interest) are ranked as 2; informal but not legal protection (voluntary agreement, right-of-first refusal, management agreement) are ranked as 1; and no protection or no information on protection status are ranked as 0 (See Appendix 1 Column: Protection Status).

Management Condition: Fire management appears to be critical for enhancing survivorship, growth, and flowering of Mead's milkweed (Bowles et al. 2001a, Alexander et al. 2009). Betz (1989) found 77.1% flowering stems in annually burned prairies with Bowles et al. (1998) finding an increase in milkweed juvenile growth and survivorship in burned tracts (Bowles et al. 1998), therefore, natural areas that are reported to be well managed or fire managed, and that support low populations of exotic or woody species are ranked as 3; natural areas that are burned, but with moderate sized populations of exotic or woody species, or hay meadows that are burned, are ranked as 2; sites which support high populations of exotic or woody species, unburned hay meadows or sites disturbed by growing season grazing (including patch/burn/graze), feral pigs, or oil fields are ranked as 1; and degraded or developed sites are ranked as 0 (See Appendix 1 Column: Management Condition). Although it was suggested that the ranking for habitat effects from feral pigs and oil fields be 0 instead of 1, the ranking will remain 1 because this number (1) indicates that habitat recovery may be possible with intense management (i.e., successful feral pig eradication; Swanson 2011), whereas a ranking of 0 indicates an area of habitat that no longer exists or is so extremely degraded that even with intense management recovery would not be possible.

To obtain the PVI, ranks for all variables were summed and then divided by the maximum number of variables used for each population. Populations with an index greater than 0.75 are designated as having high viability, populations with an index from 0.51 – 0.75 have moderate viability, and populations with an index of 0.50 and less have low viability. Three populations are determined to be highly viable, one each in Glaciated (KS), Osage Plains (KS/MO), and Ozark-Springfield Plateau (MO) Physiographic Regions, and can be counted toward achieving Criterion 2.

Determination of the Population Viability Index (PVI). Values for each variable range from 0-3. PVI = [A+B+C+ D+E+F+G]/21. Low population viability $\leq$ 0.50 PVI, moderate population viability = 0.50-0.75 PVI, and high population viability $\geq$ 0.75 PVI (Bowles and Bell 1998). More detailed descriptions of these variables can be found in Appendix 2.

Variable	Range of Values			
	0	1	2	3
1. Population size (adult plants)[1]	< 10	10-< 25	25-< 50	> 50
2. Population growth trend[2]	no measure or < survivorship and < growth	either + survivorship or + growth	flowering\no seeds + survivorship > growth	seeds produced + survivorship > growth
3. Effective population size/# of genotypes[3]	< 10 genotypes	10-< 25 genotypes	25-< 50 genotypes	> 50 genotypes
4. Habitat size[4]	< 1 hectare	1-<25 hectares	25-<50 hectares	>50 hectares
5. Habitat condition/ successional stage[5]	very heavily disturbed	heavily disturbed/early successional	moderately disturbed/mid-successional	lightly disturbed/late-successional
6. Protection status[6]	none	informal	formal	legal
7. Management condition[7]	severe	moderate	low	none

[1]Size based on total population census.

[2]Trend based on occurrence of flowering, seed production, stable (+) or declining (<) cohort survivorship, and increasing (>), stable (=) or declining (<) life stage transitions.

[3]Based on allozyme or molecular measures of the number of genotypes present

[4]Area of potential habitat.

[5]Based on natural quality grades. Lightly or undisturbed = grade A, moderately disturbed = grade B, heavily disturbed = grade C, very heavily disturbed = grade D.

[6]Function of ownership and deed restrictions. None = private ownership with no protection, informal = private ownership without legally binding protection, formal = private or public ownership with formal but not legal protection, legal = private or public ownership with legally binding protection.

[7]Degree of management needed due to habitat degradation from fire protection and woody plant succession, exotic species invasion, hydrology alteration, and other land use impacts.