Todsen's Pennyroyal
(*Hedeoma todsenii*)
5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service

New Mexico Ecological Services Field Office
Albuquerque, New Mexico

August 2022

5-YEAR REVIEW
Todsen's pennyroyal (*Hedeoma todsenii*)

1.0 GENERAL INFORMATION

1.1 Reviewers:

Lead Regional or Headquarters Office: Southwest Regional Office, Region 2
Janess Vartanian, Recovery Biologist, Recovery and Restoration, Ecological Services, (505) 248-6657

Lead Field Office: New Mexico Ecological Services Field Office
Shawn Sartorius, Field Supervisor
Chuck Hayes, Collaborative Conservation Services Branch Supervisor
Tim Ludwick, Supervisory Fish and Wildlife Biologist
Lauren Rangel, Fish and Wildlife Biologist

1.2 Purpose of 5-Year Reviews:

The U.S. Fish and Wildlife Service (Service or USFWS) is required by section 4(c)(2) of the Endangered Species Act (ESA) to conduct a status review of each listed species once every 5 years. The purpose of a 5-year review is to evaluate whether or not the species' status has changed since it was listed (or since the most recent 5-year review). Based on the 5-year review, we recommend whether the species should be removed from the list of endangered and threatened species, be changed in status from endangered to threatened, or be changed in status from threatened to endangered. Our original listing as endangered or threatened is based on the species' status considering the five threat factors described in section 4(a)(1) of the ESA. These same five factors are considered in any subsequent reclassification or delisting decisions. In the 5-year review, we consider the best available scientific and commercial data on the species and focus on new information available since the species was listed or last reviewed. If we recommend a change in listing status based on the results of the 5-year review, we must propose to do so through a separate rule-making process including public review and comment.

1.3 Methodology used to complete the review:

In conducting this 5-year review, we relied on the best available information pertaining to historical and contemporary distributions, life histories, genetics, habitats, and threats of this species. This review includes information from the previous 5-year review (USFWS 2011) that is still applicable to the species, with updated or new information incorporated, as appropriate. We announced initiation of this review and requested information in a published Federal Register notice (87 FR 5834). We used a variety of information resources, including monitoring reports, surveys, and other scientific and management information, augmented by conversations and comments from biologists familiar with the species. The review was conducted by a biologist in the New Mexico Ecological Services Field Office. Literature and documents used for this 5-year review are on file at the New Mexico Ecological Services Field Office. All recommendations resulting from this review

are a result of thoroughly reviewing the best available information on Todsen's pennyroyal. The Service did not seek additional peer review for this updated 5-year review.

1.4 Background:

1.4.1 FR Notice citation announcing initiation of this review:

87 FR 5834; February 2, 2022

1.4.2 Listing history:

Original Listing
FR notice: 46 FR 5730
Date listed: January 19, 1981
Entity listed: Species, *Hedeoma todsenii*
Classification: Endangered, with critical habitat

Revised Listing, if applicable
FR notice: N/A
Date listed: N/A
Entity listed: N/A
Classification: N/A

1.4.3 Associated Rulemakings:

Critical habitat, January 19, 1981.

Two parcels of approximately 1 square kilometer (0.39 square miles) each on White Sands Missile Range in Rhodes Canyon of the San Andres Mountains, Sierra County, New Mexico; described as UTM Zone 13 between 76,000 and 77,000-meters N and 39,000 and 40,000-meters E; and between 74,000 and 75,000-meters N and 40,000 and 41,000-meters E (46 FR 5730-5733; January 19, 1981).

1.4.4 Review History:

A 5-year review was initiated on November 6, 1991 (56 FR 56882), for all species listed before 1991, but no document was prepared for this species. In 2001, Sivinski completed a Section 6 progress report on Todsen's pennyroyal (Sivinski 2001). A 5-year review was initiated for this species on April 21, 2006 (71 FR 20714) and completed on August 22, 2011 (USFWS 2011). This review recommended no change in status (remain as endangered). In 2015, Charles Britt completed a status review at the request of White Sands Missile Range (Britt 2015).

1.4.5 Species' Recovery Priority Number at start of 5-year review:

RPN 8

A Recovery Priority Number of 8 indicates a full species with a moderate degree of threat and a high recovery potential.

1.4.6 Recovery Plan or Outline

Name of plan or outline: Todsen's Pennyroyal (*Hedeoma todsenii*) Recovery Plan
Date issued: March, 1985
Dates of previous plans/amendment or outline, if applicable: August, 2001

2.0 REVIEW ANALYSIS

Section 4 of the Act (16 U.S.C. 1533) and its implementing regulations (50 CFR part 424) set forth the procedures for determining whether a species meets the definition of "endangered species" or "threatened species." The Act defines an "endangered species" as a species that is "in danger of extinction throughout all or a significant portion of its range," and a "threatened species" as a species that is "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." The Act requires that we determine whether a species meets the definition of "endangered species" or "threatened species" due to any of the five factors described below.

The identification of any threat(s) does not necessarily mean that the species meets the statutory definition of an "endangered species" or a "threatened species." In assessing whether a species meets either definition, we must evaluate all identified threats by considering the expected response of the species, and the effects of the threats—in light of those actions and conditions that will ameliorate the threats—on an individual, population, and species level. We evaluate each threat and its expected effects on the species, then analyze the cumulative effect of all of the threats on the species as a whole. We also consider the cumulative effect of the threats in light of those actions and conditions that will have positive effects on the species—such as any existing regulatory mechanisms or conservation efforts. The Service recommends whether the species meets the definition of an "endangered species" or a "threatened species" only after conducting this cumulative analysis and describing the expected effect on the species now and in the foreseeable future.

2.1 Distinct Population Segment (DPS) policy (1996):

The Distinct Population Segment Policy does not apply to Todsen's pennyroyal because it is not a vertebrate animal.

2.2 Updated Information and Current Species Status

2.2.1 Biology and Habitat

Hedeoma todsenii is an edaphic specialist which grows on gypseous soils on north-facing slopes within piñon-juniper communities in the San Andres Mountains and Sacramento Mountains (USFWS 2001). It also occurs in scattered ponderosa pine and Douglas-fir woodlands in the Sacramento Mountains (USFWS 2001). The plant was known from only two populations at the time of listing in 1981. Between the time of

listing and completion of the second Recovery Plan revision in 2001, 16 additional populations had been discovered, forming a total of three populations in the San Andres Mountains on White Sands Missile Range, and 15 sites in the Sacramento Mountains on Bureau of Land Management and Lincoln National Forest lands. The Sacramento Mountains are situated 75 kilometers (45 miles) to the east of the San Andres Mountains, and both ranges have an overall north to south orientation that straddles the lower and drier Tularosa Basin. As of 2022, 47 Todsen's pennyroyal populations have been documented: 32 populations in the Sacramento Mountains and 15 populations in the San Andres Mountains. Nearly all known populations occur on Federal lands, with 19 populations on Bureau of Land Management lands; 5 populations on Bureau of Land Management and the Lincoln National Forest lands; 7 populations on the Lincoln National Forest; and 15 populations on White Sands Missile Range. One population occurs on land administered by the New Mexico State Land Office, and one population on Bureau of Land Management land crosses over into private land (Britt 2020). Populations in the San Andres Mountains are numbered P16 to P30, and populations in the Sacramento Mountains are numbered P1 through P15 and P31 through P49 (Table 1).

The species grows at elevations between 1,883 meters to 2,257 meters (6,178 feet to 7,405 feet) and is generally found at higher elevations in the Sacramento Mountains than populations in the San Andres Mountains (Table 2) (Britt 2021). Populations grow on a variety of slopes (1 degree – 44 degrees; Figure 1) (Britt 2021). Most populations occur on slopes near 30 degrees. Populations in the Sacramento Mountains have the most variation in slopes, with slopes ranging from 1-44 degrees, while slopes in the San Andres Mountains range from 4-34 degrees.

Nearly all populations grow on north-facing slopes. In the Sacramento Mountains, populations are predominantly found on both northwest to northeast facing slopes and can sometimes include west-facing or east-facing portions. Populations in the San Andres Mountains can be found on north facing slopes that either extend northwest or northeast. Only one population (P13), in the Sacramento Mountains, has a portion that occurs on a southeast facing slope (Britt 2021).

Populations in the Sacramento Mountains are larger in size than populations in the San Andres Mountains. Populations in the Sacramento Mountains are as small as 194 square meters (P33), and as large as 288,421 square meters (P11) (Britt 2021). The smallest population in the San Andres Mountain is 418 square meters (P25), and the largest is 5,692 square meters (P27).

Table 1. Populations of Todsen's pennyroyal with year discovered, mountain range, and land ownership. Populations in this table are grouped by survey year and land ownership. Populations P03 and P04 were combined into P03 and P11 and P12 were combined into P11 following re-mapping efforts.

Population	Discovered	Mountain Range	Ownership
P01	1988	Sacramento Mountains	Bureau of Land Management
P02, P03*	1990	Sacramento Mountains	Bureau of Land Management and Forest Service
P05	1990	Sacramento Mountains	U.S. Forest Service
P06	1990	Sacramento Mountains	Bureau of Land Management
P07	1990	Sacramento Mountains	Bureau of Land Management and Forest Service
P08	1990	Sacramento Mountains	Bureau of Land Management
P09	1990	Sacramento Mountains	Bureau of Land Management and Forest Service
P10, P11*	1990	Sacramento Mountains	Bureau of Land Management
P13	1990	Sacramento Mountains	Bureau of Land Management and Forest Service
P14, P15	1990	Sacramento Mountains	Bureau of Land Management
P16	1978	San Andres Mountains	Department of Defense
P17	1979	San Andres Mountains	Department of Defense
P18	1990	San Andres Mountains	Department of Defense
P19, P20, 21	2001	San Andres Mountains	Department of Defense
P22, P23	2006	San Andres Mountains	Department of Defense
P24, P25, P26, P27, P28, P29	2007	San Andres Mountains	Department of Defense
P30	2009	San Andres Mountains	Department of Defense
P31, P32	2017	Sacramento Mountains	U.S. Forest Service
P33	2017	Sacramento Mountains	Bureau of Land Management
P34	2017	Sacramento Mountains	New Mexico State Land Office
P35, P36, P37, P38, P39, P40, P41, P42, P43	2017	Sacramento Mountains	Bureau of Land Management
P44	2017	Sacramento Mountains	Bureau of Land Management and private land
P45	2017	Sacramento Mountains	Bureau of Land Management
P46, P47, P48, P49	2020	Sacramento Mountains	U.S. Forest Service

Table 2. Minimum and maximum elevations of populations on San Andres Mountains and Sacramento Mountains (Britt 2021).

Mountain	Minimum elevation	Maximum elevation
San Andres Mountains	1,883 meters (6,178 feet)	2,094 meters (6,870 feet)
Sacramento Mountains	1,909 meters (6,263 feet)	2,257 meters (7,405 feet)

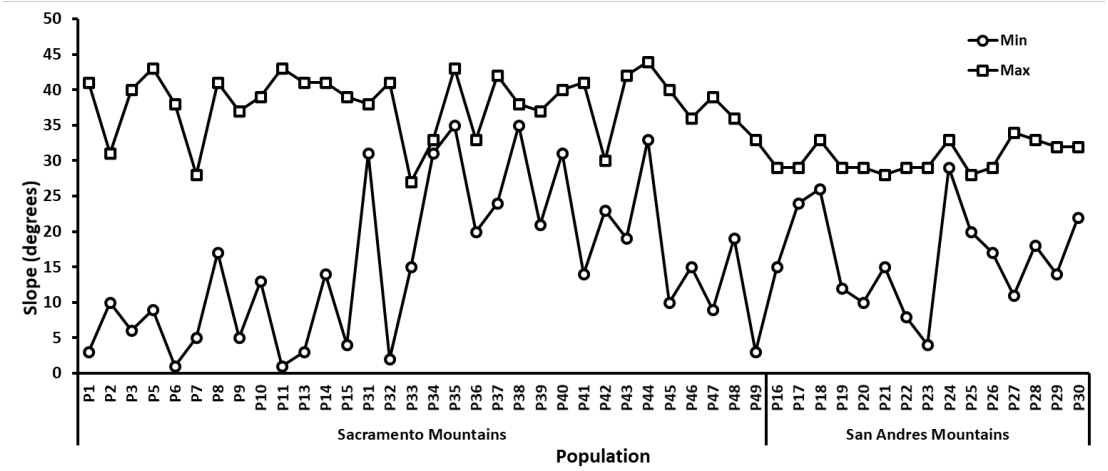

Figure 1. Minimum and maximum slope at each population in the San Andres and Sacramento Mountains (Britt 2021).

2.2.1.1 New information on the species' biology and life history:

Hedeoma todsenii exhibit two periods of reproduction, both in the summer, and both are influenced by precipitation (Britt 2017). The first reproductive period occurs in early summer, especially in years with favorable winter and spring precipitation, and the second occurs in late summer, coinciding with summer monsoons. While conducting phenological monitoring in 2017, Britt observed the first flower on May 9th, during the first reproductive period, and the last flower on September 20th, during the second reproductive period. While monitoring populations in the Sacramento Mountains in 2017 and 2020, reproductive effort was observed to occur during both reproductive periods, but most reproductive effort occurred in the early reproductive period (Britt 2021).

Funding from the Department of Defense was allocated in 2009 to initiate a pollinator study of Todsen's pennyroyal populations on White Sands Missile Range, Lincoln National Forest, and Bureau of Land Management lands in both the San Andres Mountains and the Sacramento Mountains ranges. The study was designed to assess the structure and function of the pollinator community

and evaluate Todsen's pennyroyal's breeding success. Tonne (2009) only completed the first year of this pollinator study but found that broad-tailed hummingbirds are the likely pollinator and primary visitor to Todsen's pennyroyal in all areas.

Efforts to study pollination and reproductive success in San Andres Mountains populations found that broad-tailed hummingbirds (*Selasphorus platycercus*) use the flowers of Todsen's pennyroyal and are relatively frequent visitors (Sikula 2009, Tonne 2009). Tonne (2009) has also identified broad-tailed hummingbirds as being the primary visitors of Todsen's pennyroyal flowers in the Sacramento Mountains. Britt (2017) observed broad-tailed hummingbirds visiting Todsen's pennyroyal populations while conducting phenological monitoring on White Sands Missile Range in 2016, and during population monitoring in 2017 and 2018 (Britt 2018c, 2019a). While monitoring populations in the Sacramento Mountains in 2017, Britt observed broad-tailed hummingbirds more frequently than he did in the San Andres Mountains, and attributed this to increased connectivity and noted that single adults often visit 15-20 clumps of flowers (Britt 2018b). Tonne (2009) observed two wasp visitors (Sphecidae). No other pollen vectors have been seen at the flowers of Todsen's pennyroyal. Based on this field data, hummingbirds appear to be the primary pollinators of this plant.

2.2.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, birth rate, seed set, germination rate, age at mortality, mortality rate, etc.), or demographic trends:

2.2.1.2.1. San Andres Mountains

Long-term monitoring in the San Andres Mountains has occurred sporadically since 2005. Monitoring has demonstrated that reproductive effort varies by year and location.

The reproductive effort of two San Andres Mountains populations was monitored in 2019 (Britt 2019d), and five San Andres populations in 2018 (Britt 2019a), during the early and late reproductive seasons. The seven plots monitored in 2018 and 2019 are from different locations within the San Andres Mountains and include Big Gyp Mountain (P23 monitored), Granddaddy Peak (P16, P17, and P20 monitored), Big Gap (P19 monitored), and Loma Vista (P25 and P26 monitored). Long term monitoring has occurred since 2005 for P16 and since 2009 for P17. Long term monitoring has occurred since 2006 for P20 and P19, since 2007 for P23, and since 2009 for P25 and P26. Both populations monitored in 2019, and four of the populations monitored in 2018, were between the high and low stem counts (Table 3). One of the populations (P26) monitored in 2018 was below the previous low stem count.

While conducting monitoring in 2019 and 2018, Britt found that reproductive effort was higher in the late season than in the early reproductive season. One of the populations (P20) monitored in 2018 was not observed to exhibit reproductive effort and has not exhibited reproductive effort since first monitored in 2006. Of the four populations that did exhibit reproductive effort in 2018, reproductive effort was highest in P23 with 30% of clumps exhibiting reproductive effort, and reproductive effort in the other three plots ranged between 10 to 25%.

All other populations in Big Gyp Mountain (P22), Granddaddy Peak (P30), Big Gap (P18, P21), and Loma Vista (P24, P27, P28, P29) were last monitored in 2016 (Britt 2017). Most (6) of the populations monitored in 2016 experienced an increase in stem count compared to the last time they were monitored, however four of the populations were still below the high stem counts of 2009 (Table 3). Two populations reached an all-time high stem count, while two populations reached an all-time low stem count. Reproductive effort was higher in the early period than the later period (Britt 2017). The largest reproductive effort observed during this monitoring period was observed in P17 during the late season when 50-75% of individuals were noted to have calyces, considerably greater than the next largest reproductive output observed at P26 in the early season (25% of individuals in flower).

Table 3. Most recent stem count, high stem count, and low stem count in White Sands Missile Range plots (Britt 2017; 2019a; 2019d).

Area	Population	Year last surveyed	Most recent count	High count	Low count
Granddaddy Peak	P16	2019	86	367 (2007)	18 (2012)
Granddaddy Peak	P17	2019	13	32 (2009)	4 (2012 and 2016)
Granddaddy Peak	P20	2018	25	44 (2006)	20 (2012)
Granddaddy Peak	P30	2016	49	49 (2016)	33 (2012)
Big Gyp Mountain	P22	2016	106	314 (2009)	56 (2012)
Big Gyp Mountain	P23	2018	68	94 (2007)	45 (2012)
Big Gap	P18	2016	450	539 (2009)	304 (2006)
Big Gap	P19	2018	406	725 (2014)	296 (2006)
Big Gap	P21	2016	163	289 (2007)	136 (2012)
Loma Vista	P24	2016	56	202 (2009)	18 (2012)
Loma Vista	P25	2018	177	214 (2009)	171 (2012)
Loma Vista	P26	2018	159	222 (2016)	159 (2018)
Loma Vista	P27	2016	35	65 (2012)	35 (2016)
Loma Vista	P28	2016	139	292 (2012)	139 (2016)
Loma Vista	P29	2016	128	128 (2016)	79 (2014)

Density was sporadically monitored at the 15 populations of Todsen's pennyroyal in the San Andres Mountains on White Sands Missile Range in 2006, 2007, 2009, 2012, and 2014 (Sikula 2009; Britt 2015). Between 2006 and 2012 there was a general decline in densities, with the lowest density recorded occurring in 2012 (0.25 individuals per square meter in P17 and P20). Populations saw an increase in density in 2014, with the highest density recorded in P19 (14.25 individuals per square meter).

While collecting samples between 2015-2019, Philpott et al. (2022, in prep) observed population sizes between "less than 50 individuals to thousands of stems". This provides some general corroboration for the variability in population sizes among plots and over time. Trends among plots are not entirely consistent, but Todsen's pennyroyal has persisted at all known plots, despite some observations of plots with no evidence of reproductive effort. While the mechanism for this variation is not well understood, Britt (2019d) noted that declines in vegetative growth observed in 2011-2012 likely resulted from extreme drought conditions, as indicated by Standardized Precipitation Index values.

2.2.1.2.2. Sacramento Mountains

Long-term monitoring plots were established in 2017, at all populations known at the time in the Sacramento Mountains, with the intention of monitoring each population every three years. Twenty plots have been re-visited since establishment. Ten plots (P10-P15, P31-32, P38, P41) have not been monitored in the five years since establishment. Long-term monitoring plots have not been established at the four populations discovered in 2020 (P46-49). Monitoring has demonstrated that reproductive effort varies by year and location.

Britt (2021) assessed the reproductive effort, defined here as the sum of flower buds, flowers, or calyces (including those recently dropped), of 9 populations (at 10 plots) in the Sacramento Mountains in 2021, and 10 populations in the Sacramento Mountains in 2020. Reproductive effort was monitored in the early and late season. Phenology was also recorded during monitoring. The ten plots monitored are from different locations within the Sacramento Mountains and include Cat Mountain (P42, P43, 44 and P45 monitored), Mountain Lion Peak (P09, P33, P34, P35, P36, P37, and P40 monitored), and Domingo Peak (P01, P02, P03N, P03S, P05, P06, P07, P08, and P39 monitored). Trends in maximum stem count, reproductive effort, and estimated population reproductive effort varied compared to 2017 (Table 4). Ten populations experienced an increase in maximum stem count since 2017, while ten populations experienced a decrease in stem count. Most plots (13) experienced a decrease in reproductive effort, including all plots monitored in Mountain Lion Peak. Additionally, a visual population reproductive effort was estimated for each of the populations, a majority of populations experienced a decline in estimated population reproductive effort.

To study density, abundance, and recruitment trends of Todsen's pennyroyal, six study plots were established in October of 1991, in two unnamed canyons west of Nogal Canyon and south of Mountain Lion Peak of the Sacramento Mountains on Bureau of Land Management land. Study plots were monitored each autumn until 1995, and were subsequently visually assessed in 2009, although two plots were not able to be located. Plant density was fairly consistent from 1991 to 1994, but showed a decrease of approximately 15 percent in 1995 (Sivinski 2001). Densities between 1991 and 1995 ranged from 12 individuals per square meter (1.1 individual per square foot) in one plot in 1991 to 41 individuals per square meter (3.8 per square foot) in the same year but at a different plot (Britt 2015). The populations appeared to be healthy and occupying the same area of habitat observed in 1995, and occur at much higher densities than populations monitored in the San Andres Mountains (Sivinski 2009; Britt 2015).

Table 4. Maximum stem count, reproductive effort, and estimated population reproductive effort of populations monitored in 2020 and 2021 compared to 2017 (Britt 2021). Asterisk indicates only the late reproductive season was monitored. Red shading indicates a decrease, green shading indicates an increase, and grey shading indicates no change.

Area	Population	Monitored in	% change in stem count	Change in reproductive effort	Change in estimated population reproductive effort
Cat Mountain	P42	2020	22.1	Decrease (83 to 10)	Decrease (25-50% to <5%)
Cat Mountain	P43	2020	56.6	Increase (0 to 3)	No change (<5% to 5%)
Cat Mountain	P44	2021	-13.6	No change (0 to 0)	Increase (<5% to 5-10%)
Cat Mountain	P45	2021	-6.5	Increase (29 to 49)	Increase (10-25% to 25-30%)
Mountain Lion Peak	P09	2020	-31.2	Decrease (146 to 22)	Decrease (50-60% to 25%)
Mountain Lion Peak	P33	2020	-10.7	Decrease (5 to 0)	Increase (<5% to 10%)
Mountain Lion Peak	P34	2020	63.6	Decrease (272 to 149)	Decrease (75% to 50-75%)
Mountain Lion Peak	P35	2021	11.1	Decrease (217 to 13)	Decrease (25% to 10-15%)
Mountain Lion Peak	P36	2021	49.7	Decrease (10 to 0)	Increase (10-25% to 25%)
Mountain Lion Peak	P37	2021	32.5	Decrease (83 to 31)	Decrease (50% to 25%)
Mountain Lion Peak	P40	2021	2.8	Decrease (213 to 113)	Decrease (50-60% to 25-40%)
Domingo Peak	P01	2020	-25.8	Decrease (39 to 21)	Decrease (25-50% to <15%)
Domingo Peak	P02	2020	-41.2	Decrease (67 to 6)	Decrease (50-60% to 10-15%)
Domingo Peak	P03N	2021	-31.8	No change (0 to 0)	Decrease* (50% to 25%)
Domingo Peak	P03S	2021	-7.9	Increase (0 to 35)	Decrease* (75% to 25%)
Domingo Peak	P05	2021	-15.3	Decrease (56 to 0)	Decrease (25% to <1%)
Domingo Peak	P06	2021	-20.7	Decrease (53 to 0)	Decrease (50% to 25%)
Domingo Peak	P07	2020	76.6	Increase (20 to 137)	Increase (10-25% to 75%)
Domingo Peak	P08	2020	7.1	Decrease (124 to 70)	Decrease (75% to 25-50%)
Domingo Peak	P39	2020	47	Increase (1 to 30)	Decrease (50% to 25%)

2.2.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

Most genetic studies on Todsen's pennyroyal indicate genetic diversity within populations is generally low compared to other species, and increases as distance between populations increases. Several studies looking at genetics of Todsen's pennyroyal have been completed in the years since the last five-year review and are summarized chronologically below.

An initial genetic study using random amplification polymorphism DNA analysis of 12 Todsen's pennyroyal lines indicated there is less genetic diversity among lines established from plants that exist in close proximity to each other compared to lines that are separated by greater distance (Pence et al. 2007; Pence et al. 2009). Regardless, diversity between populations was still considered low. This is an expected result of the isolated pattern of distribution of this rhizomatous plant, which perpetuates patches of stems by asexual reproduction and sexual inbreeding. When comparing lines from populations with the greatest distance between each other, there were more genetic differences. Pence et al. (2009) also found that there were more genetic differences in plants that inhabited different slopes within the same population, while plants that inhabit the same slopes in the same population were very similar. Pence et al. (2009) came to the following conclusion in their study: "These preliminary results suggest a possible association of low genetic diversity within populations and greater diversity between populations."

Bailey and Donmez (2011) analyzed 43 Todsen's pennyroyal lines from populations in the San Andres and Sacramento Mountains and also found more genetic diversity between populations than within populations, with overall low genetic diversity. Bailey and Donmez (2011) found a relationship between geographic location and genetic relationship between individuals, and a level of diversity within and between populations indicating that there is some sexual reproduction.

Donmez et al. (2014) analyzed microsatellite loci from 125 Todsen's pennyroyal samples originating from four populations (two from White Sands Missile Range, collected in 2009 and 2012, and two from Lincoln National Forest, collected in 1998 and 2009). Donmez et al. (2014) also found evidence of genetic population structure, although there was no correlation between genetic differences and geographic distances.

Philpott (2018) collected leaf samples from seven populations (six from White Sands Missile Range, one from Lincoln National Forest) between 2015 and 2017. Philpott (2018) found increased genetic diversity between plants from White Sands Missile Range and Lincoln National Forest, and lower genetic diversity between plants within White Sands Missile Range populations. Philpott (2018) found higher genotypic and allelic diversity in Lincoln National

Forest populations, and that within the White Sands Missile Range the southern populations possess more genetic diversity than northern populations. Philpott (2018) suggests that for Todsen's pennyroyal, inbreeding and genetic drift play a role in fixation and reduced heterozygosity.

Philpott et al. (2022, in prep) analyzed the genetic diversity of microsatellite loci from Todsen's pennyroyal at ten populations from the San Andres Mountains (sampled between 2015 and 2019) and five populations from the Sacramento Mountains (sampled between 2017 and 2019). Philpott et al. (2022, in prep) found the Sacramento Mountain populations to have higher genotypic evenness and diversity, while genetic richness was observed to be similar in both ranges. Philpott et al. (2022, in prep) noted "fairly low levels of genetic diversity overall" with a "trend towards fixation within populations", likely as a result of both inbreeding and genetic drift.

2.2.1.4 Taxonomic classification or changes in nomenclature:

No changes in taxonomy are known at this time.

2.2.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, pollinator availability, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):

Hedeoma todsenii continues to occur in its historical range throughout the San Andres Mountains and the Sacramento Mountains. At the time of listing, Todsen's pennyroyal was only known from two areas on White Sands Missile Range in the San Andres Mountains, for a combined area of approximately 3,000 square meters. Since 1981 an additional 45 populations have been discovered, including 32 populations on the Sacramento Mountains. All of the new populations occur within habitats similar to known populations.

White Sands Missile Range has initiated a formal monitoring program and has recently conducted several field surveys to locate new populations (Britt 2012, 2019d, 2019e). No new populations have been discovered on the range since September 2009 (Britt 2018a). Discoveries of Todsen's pennyroyal populations in the Gyp Hills of the San Andres Mountains, and a regional distribution model for Todsen's pennyroyal, indicate high potential for populations on Chupadera Mesa, north of US 380. This area is shared between Bureau of Land Management and White Sands Missile Range. The suitable habitat on Chupadera Mesa is the only area in the San Andres Mountains that have not been extensively searched.

Additional searches for new populations have also occurred on Bureau of Land Management and United States Forest Service lands in the Sacramento Mountains in 2017, 2018, and 2020 (Britt 2018b, 2019c, 2020). The 2017

searches yielded 15 new populations, 11 on Bureau of Land Management lands, one on Bureau of Land Management and private land, two on United States Forest Service lands, and one on State lands. No new populations were discovered in 2018. The 2020 searches yielded four new populations, all on United States Forest Service lands. This brings the number of populations in the Sacramento Mountains to 32, for a total of 47 populations throughout the range of the species (Britt 2020). Prior to the 2017 searches, a regional distribution model was created to help identify potential Todsen's pennyroyal habitat.

2.2.1.5.1. San Andres Mountains

The revised Recovery Plan (2001) identified a total of three Todsen's pennyroyal populations in the San Andres Mountains of White Sands Missile Range and stated that one of the original populations used to describe the species (P17), near Rhodes Canyon, was revisited for the first time since its initial discovery in 1978 (USFWS 2001; Britt 2015). Field surveys throughout White Sands Missile Range have led to the documentation of an additional 12 Todsen's pennyroyal populations in the San Andres Mountains (TNC 2006, Sikula et al. 2007, Britt 2009).

All 15 of the Todsen's pennyroyal populations on White Sands Missile Range occur on gypseous strata of the Yeso Formation where it outcrops in the northern San Andres Mountains. Population sizes (occupied habitat) range from 418 square meters (4,500 square feet) to 5,692 square meters (61,268 square feet) (Britt 2021). Five populations (P16, P17, P18, P24, and P29) were remapped in 2019 (Table 5) (Britt 2019d). All re-mapped populations experienced a change in areal extent. Four populations experienced a decrease, with the largest decrease in population size seen in P16, followed by P29. Only one population (P24) experienced an increase in population size, this population experienced a retreat on its western slope and an expansion on the eastern slope.

Table 5. Change in spatial extent of five populations in the San Andres Mountains (Britt 2019d). Red shading indicates a decrease, and green shading indicates an increase.

Population	2006-2007 3D area (square meters)	2019 3D area (square meters)	Percent change in 3D area
P16	908	471	-48
P17	617	512	-17
P18	615	502	-18
P24	460	532	16
P29	4945	3740	-34

1.1.1.1.1 Sacramento Mountains

The revised Recovery Plan (USFWS 2001) identified a total of 15 Todsen's pennyroyal populations in the Sacramento Mountains, with eight sites near Domingo Peak and seven sites near Mountain Lion Peak. Since then, field surveys throughout the Sacramento Mountains have led to the documentation of 17 new Todsen's pennyroyal populations.

The Sacramento Mountain populations of Todsen's pennyroyal usually cover larger areas than the San Andres populations, likely as a result of moister soil conditions. The fifteen original populations (P01-P15) were remapped in 2018 (Table 6) in an effort to initiate long-term monitoring of population extent (Britt 2019c). Following this effort, it was discovered that P03 and P04 were in fact one population, now referred to as P03. P11 and P12 were also discovered to be one population, now referred to as P11. All populations that were re-mapped experienced a change in areal extent. Six populations experienced a decrease in two-dimensional areal extent, with the largest decrease (-82%) seen in P10. Seven populations experienced an increase in 2D areal extent, with the largest expansion (+186%) seen in P01.

Table 6. Change in spatial extent of 15 populations in the Sacramento Mountains (Britt 2019c). Slope is not accounted for in these areas. Red shading indicates a decrease, and green shading indicates an increase.

Population	Original 2D area (square meters)	2018 2D area (square meters)	Percent change in 2D area
P01	5,500	15,721	186
P02	45,683	26,077	-43
P03	39,906	89,137	123
P05	6,594	14,107	114
P06	4,865	11,851	144
P07	10,762	2,800	-74
P08	10,067	12,128	20
P09	36,790	34,482	-6
P10	32,461	5,862	-82
P11	302,544	288,421	-5
P13	169,813	90,010	-47
P14	8,932	11,234	26
P15	9,418	9,978	6

2.2.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

All populations in the San Andres Mountains and most of the populations in the Sacramento Mountains occur on outcrops of the Permian-age Yeso Formation. Several populations in the Sacramento Mountains occur on the San Andres Formation, but are likely influenced by the Yeso Formation, as they occur at the edge of the Yeso Formation. These habitats are associated with strata that produce gypseous, sandy loam soils, often with loose limestone gravel and cobble. The calcareous soils that form have high percentages of sand and silt, allowing for good water penetration and water holding capacity. Todsen's pennyroyal is restricted to these gypsum soils. Habitats are generally on steep slopes with northern exposures that limit the evaporation potential of direct sunlight during long periods of the day.

Most Todsen's pennyroyal populations occur within madrean piñon-juniper woodland, where the species may grow under the tree and shrub canopy or in grassy woodland openings without the presence of tree or shrub canopy (USFWS 2001). Populations can also occur in mosaics of madrean piñon-juniper woodlands and other vegetation types (Britt 2019c). While Todsen's pennyroyal can grow in areas with varying degrees of tree cover, they are less often seen in areas with dense shrub cover (Britt 2019c). The amount of canopy cover tends to be lower in populations growing in the San Andres Mountains (10-50% cover, mean = 42.7%) than the Sacramento Mountains (10-70% cover, mean = 60%) (Britt 2019b).

One of two monitoring plots established in the San Andres Mountains was placed in relatively dense woodland (P22; 31.9 percent overstory cover) and the other plot was placed in an open area (P23; 0 percent cover). Todsen's pennyroyal densities at the woodland canopy and no canopy plots were roughly similar, but plants in the woodland canopy plot tended to have more stems than did plants growing in the open (Sikula et al. 2007). It is uncertain whether plants under trees live longer with more time to accumulate stems or if plants growing in open areas with greater insolation need fewer stems and leaves. Increased stem formation could be related to greater soil moisture retention in the plot with woodland canopy, due to less exposure to sunlight and soil moisture evaporation compared to conditions in the open plot.

A greater proportion of Todsen's pennyroyal may flower in open conditions compared to conditions with more overstory cover. In 2007, the woodland canopy plot had 23 percent of individual plants flowering while the no canopy plot had 69 percent flowering. None of the flowers in samples examined at each plot produced any seed (Sikula et al. 2007). Sikula (2009) stated there could be a relationship between canopy cover and reproductive effort, and this interaction may warrant further investigation.

2.2.1.7 Other:

1.1.1.1.2 Propagation and cryopreservation

Several institutions have successfully grown Todsen's pennyroyal in captivity. These include the University of New Mexico Herbarium, the Arboretum at Flagstaff, the Denver Botanic Gardens, and the Cincinnati Zoo and Botanical Garden (Pence et al. 2009; P. Tonne 2013, pers. comm.)

Pence et al. (2009) developed in vitro propagation techniques for the Todsen's pennyroyal for cryostorage and reintroduction. Following the development of in vitro propagation techniques, Pence et al. (2009) preserved shoot tips in liquid nitrogen for long-term storage. Pence et al. (2017) subsequently examined survival and genetic stability 13 years later, and found survival to range from 24.2% to 72.2%, with different cryopreservation methods influencing survival.

2.2.1.8 Conservation Measures:

The *Endangered Species Management Plan for Todsen's Pennyroyal (Hedeoma todsenii) at White Sands Missile Range, New Mexico*, which is part of the *White Sands Missile Range Integrated Natural and Cultural Resources Management Plan and Environmental Assessment 2015-2019* (WSMR 2015), specifically addresses the use of adaptive management for maintaining Todsen's pennyroyal populations, surveying potential habitat for additional populations, developing and implementing monitoring techniques, and measuring habitat change. Since development of the species management plan, conservation measures for Todsen's pennyroyal from the plan have been implemented on White Sands Missile Range when applicable. The management plan was updated in 2018 and includes the following objectives (Britt 2018a), and will be incorporated in the updated and revised Integrated Natural Resources Management Plan, which is scheduled for completion in 2022.

- Continue annual monitoring of known populations by authorized individuals following established protocols.
- Continue range wide searches for Todsen's pennyroyal in areas identified with moderate to highly suitable habitat.
- Continue to support research identified by the 2001 revised Recovery Plan.
- Minimize mission-related impacts on known Todsen's pennyroyal populations by maintaining 0.5-kilometer buffer areas.

On the Lincoln National Forest, Todsen's pennyroyal is managed according to the Service's programmatic biological and conference opinion for the *Continued implementation of the Land and Resource Management Plan for the Lincoln National Forest* (USFWS 2012, consultation #02ENNM00-2012-F-0048). This biological and conference opinion (USFWS 2012) included Todsen's pennyroyal in the comprehensive assessment for all threatened and endangered species on the Lincoln National Forest. The biological and conference opinion (USFWS 2012) concluded that continued implementation of the Lincoln

National Forest's management operations were not likely to adversely affect the Todsen's pennyroyal for the following reasons:

- Watershed health will be maintained through avoidance of potentially damaging activities.
- The species occurs where the grazing allotment has been withdrawn for many years, so there will be no permitted livestock in the occupied habitat.
- No prescribed fires or Wildland-Urban Interface fuel reductions will be carried out in areas where Todsen's pennyroyal exists (steep slopes with fragile soils).
- The Land and Resource Management Plan direct managers to use surface use stipulations in operating plans and permits to protect threatened and endangered species from minerals activity.

Additionally, Appendix C of the Lincoln National Forest Land and Resource Management Plan (USDA FS 1986) contains forest-wide standards and guidelines for federal and state threatened and endangered species. These standards and guidelines include the following:

- The protection and management of essential and critical habitats of threatened, endangered, and sensitive species, and; identify data needs for threatened, endangered, and sensitive species.
- The identification, protection, and enhancement of existing and potential habitat of all threatened, endangered, and sensitive species;
- The prohibition of activities likely to cause disturbance in the vicinity of any essential habitat for threatened and endangered species.

While a specific management plan for this species has not been developed by the Bureau of Land Management for Todsen's pennyroyal growing on Bureau of Land Management lands, 2,381 acres in the Sacramento Mountains have been nominated for Area of Critical Environmental Concern designation (R. Lister 2011, pers. comm.). The Sacramento Mountains Area of Critical Environmental Concern is still proposed and is included in the draft TriCounty Resource Management Plan Revision (M. Boyter 2022, pers. comm.).

Additionally, the following conservation measures were outlined in the 2013 biological opinion for the SunZia Southwest Transmission Line Project (USFWS 2001):

- Prior to the final design, engineering, and commencement of construction, any suitable habitat in Chupadera Mesa or the foothills of the Gallinas Mountains would be surveyed for gypseous soils and the Todsen's pennyroyal.
- The location and morphological characters of any plants provisionally identified as Todsen's pennyroyal would be reported promptly to the

Bureau of Land Management and to the Service. Identification would be verified by a species expert.

- If the Todsen's pennyroyal is found to be present within the Project area, the survey would be expanded as needed to determine the extent of that population, and the design of the Project would be modified to avoid as many individual Todsen's pennyroyals as is feasible.
- If the Todsen's pennyroyal is found to be present within the Project area, the following protective measures would be implemented during construction:
    - Where possible, ground disturbance would be avoided within approximately 300 feet of Todsen's pennyroyal plants.
    - Todsen's pennyroyal within 75 feet of any ground-disturbing activities would be flagged and physically protected during construction activities.
    - Biological monitors would be present to ensure that all avoidance and protective measures are implemented effectively.

2.2.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms):

2.2.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

1.1.1.1.3 Human disturbance

All Todsen's pennyroyal populations occur in rugged and remote areas that have no vehicle entry and receive very little land use by the managing agencies or the public. Additionally, White Sands Missile Range is closed to the public. Any human disturbance would likely be the result of monitoring and surveying activities.

1.1.1.1.4 Erosion

Erosion was noted as a potential human threat in the 2001 Recovery Plan. Erosion, as a natural disturbance, may occur within habitat occupied by Todsen's pennyroyal as a result of steep topography and loose, gravelly substrates. However, the very limited use of these sites by the public, outside of monitoring, does not appear to be exacerbating erosional impacts at this time.

1.1.1.1.5 Grazing

Livestock grazing was listed as a potential threat to Todsen's pennyroyal, though related more to the trampling of plants and exacerbation of erosion in fragile habitat than from direct herbivory (USFWS 2001). Populations on the Lincoln National Forest in the Sacramento Mountains are closed to grazing by livestock (Britt 2015). Heavy ground disturbance was observed at one

population (P15) in 2017, though the cause of the disturbance is not clear (Britt 2018b). Habitats on Bureau of Land Management land in the Sacramento Mountains are open to entry by cattle but are rarely used because of steep topography and lack of water (M. Howard 2010, pers. comm.; Britt 2015).

White Sands Missile Range is not open to cattle grazing, but trespass (feral) cattle were reported grazing in and around the San Andres populations in 1982 (USFWS 2001) and trespass cattle are occasionally reported grazing on or near some of the populations (Sikula et al. 2007). Two populations (P22 and P23) are located outside of the fence that restricts grazing on White Sands Missile Range. Grazing has been observed downslope of these populations, although they are likely protected from grazing by the steep gradient.

Mule deer and elk occur throughout the range of Todsen's pennyroyal, but these native species are not believed to concentrate around or threaten the plant through grazing. Oryx and feral hogs, two non-native species, have been noted near occupied habitat, but there is currently no data on how these species may impact Todsen's pennyroyal.

1.1.1.1.6 Mineral extraction

No economic minerals have been located or developed in or near any of the known occupied habitats.

1.1.1.1.7 Military activities

The prevailing land uses in and around the White Sands Missile Range populations are fly-overs and military weapons testing, which could cause impact-related wildfires. However, the Endangered Species Management Plan established that no ground disturbing activities can occur within 0.5 kilometers (0.3 miles) of any Todsen's pennyroyal population on White Sands Missile Range, and there is no evidence of fire scars within the immediate habitat of Todsen's pennyroyal populations. A piece of shrapnel was observed in P19 in 2015, suggesting the possibility of limited and localized impacts to individuals (Britt 2015). Populations on White Sands Missile Range lack fine fuel, so it is unlikely for a catastrophic wildfire to occur as a result of a weapons testing event (Britt 2015).

The impacts that a proposed action at White Sands Missile Range may have on Todsen's pennyroyal are considered through the National Environmental Policy Act review process as well as Section 7 of the Endangered Species Act.

1.1.1.1.8 Tree encroachment

Substantial increases in cover and extent of piñon-juniper woodlands in New Mexico have taken place within the last 150 years because of a warming climate, a period of heavy use by livestock, and a decrease in wildfire frequency

(Laycock 1999). Most Todsen's pennyroyal populations occur within piñon-juniper woodlands that were probably less dense in the past and could continue to expand in the future. Todsen's pennyroyal grows and flowers under piñon-juniper woodland canopy and in open areas without canopy. Increased canopy cover can contribute to increased asexual recruitment, but it has also been suggested to impair flowering (Sikula et al. 2007, 2009; Britt 2015). However, clumps located beneath cover have been observed flowering (Britt 2015). More information is needed to understand the relationship between canopy cover and reproductive effort.

Canopy cover is higher in the Sacramento Mountains (70%) than in the San Andres Mountains (50%) due to a higher density of trees and shrubs, potentially contributing to populations in the Sacramento Mountains being more susceptible to catastrophic wildfires (Britt 2015).

1.1.1.1.9 Fire suppression and catastrophic wildfire

All of the populations of Todsen's pennyroyal are susceptible to wildfire. The Bureau of Land Management and Lincoln National Forest both report heavy fuel loads in the areas of known plant populations. As woodland canopy increases and woody fuels accumulate, the potential and severity of wildfire also increases. The Mean Fire Return Interval, which "quantifies the average period between fires under the presumed historical fire regime", is one way to look at fire threats throughout the range of Todsen's pennyroyal. The Mean Fire Return Interval suggests that populations in the Sacramento Mountains (overall Mean Fire Return Interval = 51-60) are at higher risk of experiencing a wildfire than populations in the San Andres Mountains (Mean Fire Return Interval = 46-50), because the Sacramento Mountains have some populations with Mean Fire Return Intervals as lows 6-10 years (Britt 2015).

No known patches of Todsen's pennyroyal have been burned, and there is no information on how fire affects this plant. With its extensive underground rhizome system, Todsen's pennyroyal would be expected to resprout after fire removed above ground stems, if the fire did not kill the rhizomes. Burned habitats may have less competition for light, water and nutrients, resulting in increased vigor or reproductive success. Conversely, removing vegetation and exposing the soil could increase erosion and due to the reduction in shade, make the soil hotter and drier from greater insolation, which could potentially diminish a population (USFWS 2001).

If the status quo of suppressing fires is maintained, dense woodland canopies may be suppressing many populations of Todsen's pennyroyal until fuel accumulations result in catastrophic fires. If even moderate fires diminish the suitability of habitat, then appropriate woodland management actions can be prescribed to protect them from burning.

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

There is no past or current demand for Todsen's pennyroyal for any commercial, recreational or educational purposes. This species has been collected under appropriate permits to establish garden populations at the Arboretum at Flagstaff in Arizona and the Cincinnati Botanical Garden in Ohio. The Arboretum at Flagstaff and Cincinnati Botanical Garden are plant research and preservation institutions that maintain conservation collections of threatened or endangered species.

Concern has been expressed that frequent monitoring of Todsen's pennyroyal populations may result in increased erosion due to the unstable nature of steep talus slopes (Sikula et al. 2007). It is unknown whether this impacts the species. To reduce potential impacts associated with monitoring Todsen's pennyroyal, monitoring should be planned to allow large periods of time between monitoring populations, and plots should be accessed using pedestrian routes to reduce ground disturbance.

2.2.2.3 Disease or predation:

No disease is presently known to be a threat to Todsen's pennyroyal. Although insect herbivory was observed in most plots during surveys in 2017 in the Sacramento Mountains (Britt 2018b), insect herbivory does not appear to be a threat to the species (Britt 2018a). Herbivory from rodents and native ungulates might occur, but the impact on Todsen's pennyroyal is unknown (USFWS 2001).

2.2.2.4 Inadequacy of existing regulatory mechanisms:

Hedeoma todsenii was federally listed as endangered with critical habitat in January 1981 (46 FR 5730). The plant is also listed as endangered in the state of New Mexico; however, the Endangered Species Act is the primary law providing protection for the species. Protections are afforded through sections 7 and 9 of the Act. Section 7 of the Act requires Federal agencies to ensure that any action authorized, funded, or implemented by them is not likely to jeopardize the continued existence of listed species or adversely modify their critical habitat. Section 7 also directs Federal agencies to use their authorities to carry out programs for the conservation of listed species. Section 9 of the Act prohibits the removal, damage, or destruction of listed plants on Federal lands and on other areas in knowing violation of any State law or regulation or State criminal trespass law.

The Service has addressed some projects through informal section 7 consultations with White Sands Missile Range and Bureau of Land Management. All Federal land managers of occupied Todsen's pennyroyal

habitat (Lincoln National Forest, Bureau of Land Management, and White Sands Missile Range) are aware of this endangered species and its populations within their jurisdictions.

The most recent informal section 7 consultations occurred in 2009, when White Sands Missile Range requested consultation on the Development and Implementation of Range-wide Mission and Major Capabilities (22420-2009-I-0087) and the Use of Yonder Airspace (22420-2009-I-0216). The most recent formal section 7 consultation occurred in 2013, when the Bureau of Land Management requested formal consultation on the proposed SunZia Southwest Transmission Line Project (02ENNM00-2013-F-0069). Other projects that include actions potentially involving Todsen's pennyroyal habitat are addressed through early coordination and technical assistance to confirm or achieve avoidance of adverse effects. A recent example of this is the Joint Directed Energy Test Center at White Sands Missile Range (02ENNM00-2022-TA-0156).

The National Environmental Policy Act provides some protection for Todsen's pennyroyal for projects with a Federal nexus (i.e., funding, authorization, or permitting). Under the National Environmental Policy Act the planning process for Federal actions must be analyzed to ensure that effects on the environment are considered. The National Environmental Policy Act process is intended to support public decision-making based on an understanding of the environmental consequences of their actions and to take actions to protect, restore, and enhance the environment (40 CFR 1500.1). Carrying out the National Environmental Policy Act process ensures that agency decision makers have information about the environmental effects of Federal actions and information on a range of alternatives that will accomplish the project purpose and need.

Additionally, the Sikes Act requires the development and implementation of Integrated Natural Resources Management Plans to address "conservation and rehabilitation" of fish and wildlife resources on all Department of Defense lands. This law is applicable on White Sands Missile Range. Other applicable regulatory guidance on White Sands Missile Range includes Army Regulation (AR) 200-1, or the Environmental Protection and Enhancement regulation, and DoDI 4715.03, or the Natural Resources Conservation Program.

Regulatory mechanisms seem adequate at this time, particularly because populations of Todsen's pennyroyal are located in areas either closed to the public or in remote habitats that receive little impact from human-induced threats. An approach to manage for tree encroachment for possible wildfire spread into occupied habitat would benefit this plant. As long as Todsen's pennyroyal remains protected under the Endangered Species Act, activities within its Federal jurisdiction must be reviewed and assessed through the National Environmental Policy Act and the Endangered Species Act section 7 consultation processes, which have served thus far to protect the species.

2.2.2.5 Other natural or manmade factors affecting its continued existence:

2.2.2.5.1. Reproduction, dispersal ability, and genetic diversity

Low genetic diversity has previously been identified as a threat to Todsen's pennyroyal (USFWS 2001). Sikula (2009) determined the 2009 sexual reproduction efforts in four San Andres Mountains populations to be relatively low in floriferous individuals (0 to 50 percent) that generally failed to produce any seed (0 to 5 percent fertile flowers). This finding confirms previous observations of Todsen's pennyroyal producing few seeds in other populations (Huenneke 1993, Sivinski 2001), and further substantiates the low level of sexual reproduction as characteristic of the species. There is some evidence that most seeds produced by Todsen's pennyroyal are not viable (Irving 1980, Sivinski 2001), which also indicates a genetic basis for most sexual reproduction failures.

An initial genetic study using random amplification polymorphism DNA analysis of 12 Todsen's pennyroyal lines indicated that there is less genetic diversity among lines established from plants that exist in close proximity in situ than among lines that are separated by greater distance (Pence et al. 2007; Pence et al. 2009). Bailey and Donmez (2011) observed a similar relationship between genetic diversity and geographic location. These results are anticipated due to the isolated pattern of distribution of this rhizomatous plant, which perpetuates patches of stems by asexual reproduction and sexual inbreeding.

Inbreeding depression in this species could be a contributing factor to the low level of seed set observed throughout all populations of Todsen's pennyroyal. If inbreeding and long-term asexual reproduction have caused an accumulation of lethal alleles in a population, many embryos would fail to survive and would be aborted. The possibility of increasing genetic variability by purposely out crossing more distant populations with pollen or seed transfers would run the risk of breaking up co-adapted gene complexes that confer adaptation to local environmental conditions, i.e., creating outbreeding depression.

Purposeful transfer of gene complexes between populations may further reduce embryo survival in ways that have not yet been identified. Huenneke (1993) showed that self-pollination and transfers of pollen between individuals within a patch and between nearby patches produced at least a few seeds. However, her hand-pollen transfers between two distant populations in canyons 1.2 kilometers (0.75 miles) apart failed to produce any seeds. Infrequent seed set likely may be a genetic characteristic of the species as a whole and probably cannot be modified by a few attempts to purposely transfer gene complexes between the various inbred populations. The continuing inability of Todsen's pennyroyal to produce an abundance of seeds will severely limit its ability to recolonize

habitats where populations may be extirpated or to migrate to new habitats if climate change renders current habitats unsuitable.

2.2.2.5.2. Drought and climate change

Periods of drought in the southwest are common. However, the frequency and duration of droughts may be altered by climate change. Global warming and associated effects on regional climatic regimes are not well understood, but weather predictions for the southwestern United States include less overall precipitation, longer periods of drought, and increased temperatures. Based on broad consensus among 19 climate models, Seager et al. (2007) predicted that the southwest will become drier in the 21st century and that this change to a drier climate is already occurring. Increased aridity will become the norm for the American southwest within a timeframe of years to decades if the models are correct.

In 2021 the Intergovernmental Panel on Climate Change published a report that outlines several scenarios with a high degree of certainty to occur in the 21st century. These include: 1) an increase in the frequency of warm spells/heat waves over most land areas; 2) an increase in the number of hot days and nights over most land; and 3) more regions will be affected by ecological drought. The 2018 Intergovernmental Panel on Climate Change report found that at a global scale, there has already been an overall increase in the number of warm days and nights, and that there is a high confidence that anthropogenic forcing has contributed to these changes. Additionally, the 2021 Intergovernmental Panel on Climate Change found that there has already been an increase in hot temperature extremes globally, as well as an increase in in agricultural and ecological drought across western North America.

The Intergovernmental Panel on Climate Change makes equally sobering predictions for ecosystems. Conditions are likely to exceed the resilience of many ecosystems during this century by an unprecedented combination of climate change, associated disturbances (e.g. flooding, drought, wildfire, insects), and other global drivers (IPCC 2007). With medium confidence, Intergovernmental Panel on Climate Change predicts that approximately 20 to 30 percent of plant and animal species assessed to date are likely to be at an increased risk of extinction if increases in global average temperature exceed 1.5 to 2.5ºC (IPCC 2007). The Intergovernmental Panel on Climate Change subsequently identified species with low dispersal rates that occupy isolated habitats as especially at risk of extinction (IPCC 2014). Almost certainly Todsen's pennyroyal, along with its habitat, will be affected in some manner by climate change; the magnitude and extent of the change cannot be quantified at this time.

Climate change also occurs with an increase in atmospheric carbon dioxide, which is commonly associated with increased temperatures and the greenhouse

gas effect. Since 2000, the observed emissions of greenhouse gases, which are a key influence on climate change, have been occurring at the mid- to higher levels of the various emissions scenarios developed in the late 1990s and used by the Intergovernmental Panel on Climate Change for making projections (e.g., Raupach et al. 2007, Pielke et al. 2008, Manning et al. 2010). At the plant level, adapting to drought involves the ability to balance carbon sequestration (the uptake and storage of carbon), carbon respiration (efflux back into the atmosphere), and maintain sustainable evapotranspiration rates (Huxman and Scott 2007). Adaptation would also require a plant to change its phenology (timing of life cycle events) to coincide successfully with extreme shifts in temperature, precipitation, and soil moisture (Walther et al. 2002) which are all part of the evapotranspiration equation. Rapid climate change could pose significant challenges for plants because they may not be able to adjust their phenology or photosynthetic mechanisms quickly enough.

The United States Geological Survey maintains the National Climate Change Viewer (USGS 2022, entire). The National Climate Change Viewer includes historical (1950-2005) as well as future (2006-2099) climate and water balance projections to model climate change effects based on increasing atmospheric carbon dioxide (CO_2) concentration over time. The National Climate Change Viewer uses 20 different climate models to predict atmospheric temperature and 6 precipitation variables as they are affected by a lower CO_2 emissions scenario and a higher CO_2 emissions scenario. The lower emissions scenario is identified as Representative Concentration Pathway 4.5, where atmospheric CO_2 concentrations are expected to equal approximately 650 ppm after the year 2100. The higher emissions scenario is identified as Representative Concentration Pathway 8.5, where atmospheric CO_2 concentrations aggressively increase to approximately 1,370 ppm after the year 2100. For comparison, current atmospheric CO_2 concentrations are around 419 ppm (NOAA 2022b).

Future climate scenarios for Otero and Sierra counties were assessed using the National Climate Change Viewer Mean Model for Representative Concentration Pathway 4.5. Climate projections under Representative Concentration Pathway 4.5 for Otero County, New Mexico and Sierra County, New Mexico includes increased monthly temperatures (Table 7 and 9), increased mean Summer and Autumn precipitation (Table 8 and 10), and decreased mean Winter and Spring precipitation (Table 8 and 10).

Table 7. Historical (1981-2010) mean temperature and projected changes in mean temperature for three future time periods under Representative Concentration Pathway 4.5 for Otero County, New Mexico.

Month	1981-2010 Mean (°F)	2025 – 2049 Change (°F)	2050 - 2074 Change (°F)	2075 – 2099 Change (°F)
January	40.16	2.65	3.74	4.41
February	44.45	2.26	3.41	4.16
March	50.31	2.59	3.59	4.24
April	57.91	3	4.25	5.01
May	66.52	3.48	4.87	5.59
June	74.51	3.58	5.01	5.44
July	76.17	3.02	4.03	4.63
August	74.22	2.92	4.12	4.75
September	68.59	3.1	4.45	5
October	59.14	2.98	4.08	5.11
November	47.77	2.69	3.83	4.67
December	40.15	2.57	3.47	4.12

Table 8. Historical (1981-2010) mean monthly precipitation (inches per month) and projected changes in monthly precipitation for three future time periods under Representative Concentration Pathway 4.5 for Otero County, New Mexico.

Month	1981-2010 Mean (in/mo)	2025 – 2049 Change (in/mo)	2050 - 2074 Change (in/mo)	2075 – 2099 Change (in/mo)
January	0.67	-0.04	-0.06	-0.05
February	0.64	-0.03	-0.02	-0.06
March	0.47	-0.01	No change	-0.04
April	0.47	No change	-0.01	-0.04
May	0.8	-0.04	-0.03	-0.02
June	1.22	-0.05	No change	0.04
July	2.69	0.07	0.29	0.33
August	2.93	0.02	0.06	0.13
September	2.04	-0.07	0.08	0.03
October	1.27	0.09	0.05	0.11
November	0.69	-0.01	0.01	0.01
December	1.01	-0.05	-0.12	-0.08

Table 9. Historical (1981-2010) mean temperature and projected changes in mean temperature for three future time periods under Representative Concentration Pathway 4.5 for Sierra County, New Mexico.

Month	1981-2010 Mean (°F)	2025 – 2049 Change (°F)	2050 - 2074 Change (°F)	2075 – 2099 Change (°F)
January	40.02	2.69	3.81	4.49
February	44.49	2.25	3.44	4.14
March	50.16	2.6	3.6	4.29
April	57.5	3.02	4.27	5.01
May	66.36	3.51	4.9	5.68
June	74.79	3.63	5.11	5.55
July	76.81	3.08	4.09	4.65
August	74.64	2.98	4.19	4.81
September	68.8	3.13	4.47	5.13
October	58.87	3	4.15	5.19
November	47.42	2.7	3.88	4.72
December	39.75	2.51	3.49	4.16

Table 10. Historical (1981-2010) mean monthly precipitation (inches per month) and projected changes in monthly precipitation for three future time periods under Representative Concentration Pathway 4.5 for Sierra County, New Mexico.

Month	1981-2010 Mean (in/mo)	2025 – 2049 Change (in/mo)	2050 - 2074 Change (in/mo)	2075 – 2099 Change (in/mo)
January	0.62	-0.02	-0.04	-0.02
February	0.51	-0.01	-0.02	-0.04
March	0.39	-0.01	No change	-0.04
April	0.35	No change	No change	-0.04
May	0.6	-0.03	-0.03	-0.05
June	0.77	-0.04	0.04	0.06
July	2.42	0.06	0.28	0.34
August	2.71	0.11	0.02	0.1
September	1.79	0.03	0.11	0.08
October	1.08	0.06	0.03	0.12
November	0.71	-0.03	-0.01	0.02
December	1.01	-0.02	-0.12	-0.07

In the southwest region of the United States, the average annual temperature is predicted to rise by about 2.5 to 3.9 ºC (4.5 to 7 ºF) during this century (IPCC 2007). Since 2000, the southwestern United States has experienced higher than the long-term average temperatures. Compared to the mean temperature in New Mexico between 1901-2000, New Mexico was 2.5 ºF warmer in 2021, and 3.2

ºF warmer in 2020 (NOAA 2022a). Hydrologic trends are less clear except when considering snow. Less snowpack and earlier spring melt and runoff in the Intermountain West states is substantiated (Parmesan and Galbraith 2004; Udall and Bates 2007; Elias et al. 2021), yet the southwestern states show a long-term trend of increased precipitation since the 1970s (Parmesan and Galbraith 2004; Udall and Bates 2007; Enquist and Gori 2008). However, droughts throughout the southwestern United States are expected to increase in severity (Cook et al. 2015).

New Mexico precipitation changes show more variation than temperature changes, with increases in precipitation anticipated in Summer and Autumn and decreases in precipitation anticipated in Winter and Spring. The spatial heterogeneity of drought, as defined by temperature, and particularly precipitation, is extremely variable in the state of New Mexico (Enquist and Gori 2008). Since 2000, there have been four instances of Exceptional Drought Conditions in portions of Sierra County, New Mexico, where the San Andres Mountains populations are located, and four instances of Exceptional Drought Conditions in portions of Otero County, New Mexico, where the Sacramento Mountains populations are located (NDMC 2022). The most recent instance of Exceptional Drought Conditions to occur in Sierra County occurred between March and June of 2022, while the most recent instance of Exceptional Drought Conditions to occur in Otero County occurred between November 2020 and July 2021. Exceptional Drought Conditions (D4 Drought) surpass Extreme Drought Conditions (D3 Drought), and are considered to be 25 to 50 year recurrence events. Impacts from notable drought conditions anticipated by the 2005 Potential Effects of Climate Change on New Mexico report (Agency Technical Work Group 2005) include decreases in soil moisture availability, increases in evapotranspiration, and decreases in plant productivity.

Given the plant's positive response to more mesic conditions, drought impacts are likely not positive for the species as a whole. Monitoring data from 2020 and 2021 in the Sacramento Mountains show increases in stem counts in 2020, following favorable winter and spring precipitation, and a decrease in stem counts in 2021, following Exceptional Drought Conditions (see above paragraph) (Britt 2021). In the San Andres Mountains, where populations have been consistently monitored since 2006, drought conditions have been observed to influence vegetative growth. Number of population clumps drastically decreased between 2009 and 2012 in multiple populations following Extreme and Exceptional Drought Conditions that occurred throughout much of 2011 (Britt 2019d). Britt (2019d) suggests that the decrease in areal extent following remapping efforts of five populations is also likely attributed to drought conditions.

Finally, with broad-tailed hummingbird as the likely the primary pollinator of Todsen's pennyroyal, it is dependent on the broad-tailed hummingbird being able to adapt to a changing climate. The National Audubon Society (2022) used

bird observations and climate models to project the effects three warming scenarios would have on the range of the broad-tailed hummingbird. Under a warming scenario of 1.5 ºC, the overall species vulnerability of the broad-tailed hummingbird is moderate, with a reduction in 45% summer range. Under a warming scenario of 2.0 ºC and 3.0 ºC, the overall species vulnerability of the broad-tailed hummingbird is high, with a reduction in 55% summer range under the 2.0 ºC scenario and a reduction in 69% summer range under the 3.0 ºC scenario. Under the 1.5 ºC and 2.0 ºC scenarios, much of the broad-tailed hummingbirds' current range in the San Andres mountains are projected to be lost, and current habitat at the edges of habitat in the Sacramento Mountains are projected to be lost. Under the 3.0 ºC scenario, much of the broad-tailed hummingbird's current range in the San Andres and Sacramento mountains are projected to be lost.

Hedeoma todsenii is a relict species persisting as small, scattered patches of plants in a few places where gypseous soils and topographic aspect create cooler, moister microclimates in a relatively hot and arid region. These microclimate habitats and the Todsen's pennyroyal populations they contain would probably expand if the regional climate became cooler or wetter. Conversely, a climatic change that made these microclimate habitats drier could shrink or eliminate Todsen's pennyroyal populations. Seed set has been found to be lower in more arid sites in both the San Andres and Sacramento Mountains, meaning a reduction in precipitation and soil moisture can further reduce the already low levels of reproduction and seed set (Britt 2015). Localities in the San Andres Mountains may be vestiges of relict populations and incapable of spreading, whereas populations in the Sacramento Mountains inhabiting more mesic areas could hold more promise for the species' persistence, making their protection all the more imperative (P. Tonne 2011, pers. comm.). If predicted warming is accompanied by less precipitation over the longer term, or by no increase in precipitation, it is possible that Todsen's pennyroyal populations could be diminished. Thus, climate change poses a significant threat into the future for this plant.

2.3 Synthesis

Hedeoma todsenii is a rare, regionally endemic mint that occurs only in the San Andres and Sacramento mountains in Otero and Sierra counties of south-central New Mexico. This plant was listed as an endangered species with critical habitat in 1981. Only two populations of Todsen's pennyroyal were known at the time of listing. Critical habitat was identified as 1 square kilometer areas around each of the two original populations. Since the time of listing, 45 additional populations have been discovered, only 1 of which occurs within previously designated critical habitat. The additional populations in the San Andres Mountains on White Sands Missile Range have expanded the known range of Todsen's pennyroyal on White Sands Missile Range by approximately 13 kilometers (8 miles) and occur in habitats similar to previously known populations. There are now 32 known populations in the Sacramento Mountains and 15 populations in the San Andres Mountains.

Today, nearly all (45) known populations of this species occur entirely on Federal lands, including Bureau of Land Management, Lincoln National Forest, and White Sands Missile Range. Only one population occurs entirely outside of Federal lands, on lands administered by the New Mexico State Land Office, and part of one population occurs on private land. The total number of plants is unknown, but Todsen's pennyroyal populations range from a few thousand plants growing in patches that cover small areas of usually less than one acre, to localities supporting a few dozen plants. These small populations appear to be persisting as stable populations that are free of substantial impacts from diseases or predators. No invasive, non-native plant species have been found in Todsen's pennyroyal habitats.

Hedeoma todsenii reproduction appears to be predominantly asexual with most new individuals being clones arising from the rhizomes of existing plants. Individual clones flower infrequently and when they do bloom, few or no seeds are produced by the flowers. Seed set varies between years and between patches of plants indicating an environmental influence on seed production or an uneven or inadequate presence of pollinators. Initial field results did not suggest pollinator limitation by the primary pollinator (the broad-tailed hummingbird) However, seed set was found to be greater at more mesic sites in the Sacramento Mountains than at more arid sites in both the Sacramento and San Andres Mountains. Increased plant abundance and seed set found in association with moister habitats suggests a positive response to increased moisture and a potentially negative response to increased drought. Additionally, even the flowers that are purposely pollinated by hand generate few or no seeds, and most of the seeds that are produced are not viable, which points to a genetic basis for most failures in sexual reproduction.

A genetic study to determine the cause of Todsen's pennyroyal's low level of seed set would be unlikely to provide a remedy to limited sexual reproductive success. Infrequent seed set appears to be a genetic characteristic of the species as a whole and probably cannot be modified by a few attempts to purposely transfer gene complexes between the various inbred populations. The continuing inability of Todsen's pennyroyal to produce an abundance of seeds will severely limit its ability to recolonize habitats where populations may be extirpated or to migrate to new habitats if climate change renders current habitats unsuitable.

Most Todsen's pennyroyal populations occur within piñon-juniper woodlands that are becoming denser due to a history of fire prevention, and more susceptible to wildfire due to increased drought conditions. The proximity of Todsen's pennyroyal populations to each other increases the chances that any given fire could affect multiple populations. However, the ground cover in more arid habitats, particularly in the San Andres Mountains, might not be dense enough to carry a fire a great distance. The underground rhizomes of Todsen's pennyroyal would probably survive a moderate intensity fire, but the suitability of burned habitat for this species is not known. Woodland canopy removal by fire might increase Todsen's pennyroyal vigor, or it could also result in a hotter and drier habitat with eliminated populations (depending on fire severity and on climatic conditions) or a smaller overall population.

Forty-seven populations of Todsen's pennyroyal are known to occur in very remote and inaccessible areas. With the exception of the White Sands Missile Range, none of the

Federal land management agencies have developed a species-specific management plan for Todsen's pennyroyal. The foreseeable threats to all Todsen's pennyroyal populations fall into three categories of: 1) a changing climate; 2) increasing piñon-juniper woodland densities within the habitats of this species, and the related increasing threat of wildfire; and 3) apparently inherent genomic constraints to sexual reproductive success and dispersal. Much-needed research on the reproductive potential and fire response of the species has yet to be conducted. It is foreseeable that wildfire could threaten a significant number of Todsen's pennyroyal populations, and if that happens the reproductive constraints may further endanger the continued existence of Todsen's pennyroyal in a significant portion of its range. Further, since the impacts of climate change and insufficient habitat protections are gradual and cumulative, it is likely that threats to this species will remain in the foreseeable future.

Of the three Federal agencies with Todsen's pennyroyal growing on their lands, the Department of Defense (White Sands Missile Range) is the only agency that has accomplished recovery criteria for downlisting by developing and implementing a detailed management plan for Todsen's pennyroyal. The 32 remaining populations on Bureau of Land Management, Lincoln National Forest, and New Mexico State Land Office lands have yet to be protected by a similar level of active management. The additional populations found since listing have notably enhanced the number of individuals of Todsen's pennyroyal; yet, their genetic distinctness remains unknown due to their tendency for vegetative reproduction and the lack of information on long-term fecundity and dispersal. Development of species-specific management plans for Bureau of Land Management and Lincoln National Forest areas, and continued management of Federal lands to protect this plant from threats, would promote recovery and move toward a status of threatened for this plant throughout its restricted range.

We do not understand the basis for observed genetic and reproductive limitations, the response of Todsen's pennyroyal to fire, and the effects of climate change in the range of the species. Therefore, more time is needed to analyze the response of this plant to changing conditions and to develop and enact long-term management. The increased potential for more frequent and severe fires, compounded by predicted effects from warmer and drier conditions could serve to contract suitable habitats of moist, upslope, north-facing areas with gypsum substrates, the only specialized habitat type that appears to support this species.

Threats to the species interact, can act cumulatively on the species, and are not adequately abated. We recommend the status of the Todsen's pennyroyal remain endangered due to a lack of understanding of the long-term effects of threats to the plant and means to ameliorate those threats, and the lack of permanent protection on Bureau of Land Management and Lincoln National Forest areas.

3.0 RESULTS

3.1 Recommended Classification:

____Downlist to Threatened
____ Uplist to Endangered
____ Delist (*Indicate reasons for delisting per 50 CFR 424.11):*
____ *Extinction*
____*Recovery*
____*Original data for classification in error*
__X__ No change is needed

3.2 New Recovery Priority Number (indicate if no change; see 48 FR 43098):

No change; remain at a recovery priority of 8.

Brief Rationale:

This indicates that Todsen's pennyroyal is a full species with a moderate degree of threat and a high recovery potential. No change is recommended at this time.

3.3 Listing and Reclassification Priority Number, if reclassification is recommended (see 48 FR 43098):

Reclassification (from Threatened to Endangered) Priority Number: N/A
Reclassification (from Endangered to Threatened) Priority Number: N/A
Delisting (Removal from list regardless of current classification) Priority Number: N/A

Brief Rationale:

N/A

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

Field Surveys: Recovery Action 3.0 in the Recovery Plan recommends using information from previous studies to identify potential habitat and search these areas (USFWS 2001). Suitable habitat in the San Andres Mountains has been extensively searched since 2001. The only areas that remain to be searched in the White Sands Missile Range vicinity include portions of the Chupadera Mesa north of highway 380. This area is shared between White Sands Missile Range and the Bureau of Land Management. In the Sacramento Mountains, there are potential habitats on private lands, the Mescalero Apache lands, and on other areas within the Lincoln National Forest. Additional searches in the Lincoln National Forest should occur within La Luz Canyon, Fresnal Canyon, and their associated tributaries. The Mescalero Apache Tribe should be engaged to assess the tribe's interest in a partnership to survey and manage any extant populations in a manner consistent with their sovereign authorities.

Long-term Monitoring: Recovery Action 1.7 prescribes establishing long-term monitoring (USFWS 2001). Long-term monitoring of all populations in the San Andres Mountains was established in 2006, and has subsequently been performed in 2007, 2009, 2012, 2014, 2015, 2016, 2017, 2018, and 2019. Long-term monitoring of most populations in the Sacramento Mountains was established in 2017, and has subsequently been conducted in 2020 and 2021.

Long-term monitoring plots have not been established in the four (P46-P49) populations discovered in 2020. Additional plots should be established and monitored at these populations, and any new populations. To achieve recovery criteria for downlisting, standardized monitoring should occur at regular intervals to detect any trends. Population trends need to be compared with climatic data obtained from the nearest permanent weather stations to investigate relationships to climate change. Monitoring dates should continue to coincide with flower maturation, for an assessment of sexual reproduction success. Research and monitoring should assess differences in plant density and vigor under varying degrees of piñon-juniper woodland canopy closure. These periodic assessments of canopy cover influences are prescribed by Recovery Actions 2.1.2 and 2.2.2 (USFWS 2001).

Fire Effects: Recovery Action 2.2.4 prescribes studying the effects of fire on Todsen's pennyroyal (USFWS 2001). At least one patch of Todsen's pennyroyal should be burned by prescribed fire to determine the effects of fire on plant density and vigor. This population should occur in woodlands of sufficient density to carry a fire of at least moderate intensity. Permanent monitoring plots should be established and assessed prior to the fire and for at least five years after being burned. Additionally, any permanent monitoring plots that are unexpectedly burned by wildfire should be monitored annually for five years to determine the effects of the fire.

At least one agency should prescribe a fire across monitoring plots in Todsen's pennyroyal habitat. If monitoring data indicate a need for active woodland treatments specific to Todsen's pennyroyal habitats, plans for woodland thinning or prescribed fire could be implemented by these agencies.

Reproductive Biology Studies: Recovery Action 2.1.1 recommends conducting studies on the reproductive biology of Todsen's pennyroyal including pollination, seed development, and seed dispersal. Low sexual reproduction, poor seed viability, and limited seed dispersal are considered to be inherent threats to this species. The only pollinators documented for this plant are broad-tailed hummingbirds.

Other undocumented pollinators could be important to reproduction or simply absent due to pollinator limitation or an overall lack of conspicuous flowering plants in the community. Field studies in each mountain range documenting pollinator species and activities should be undertaken with the goal of improving pollination, fertilization, and seed set.

Planning: Recovery Action 1.2 prescribes the development and implementation of management plans for Todsen's pennyroyal (USFWS 2001). The Federal permitting and consultation processes under the Endangered Species Act, along with NEPA, are adequate to protect known Todsen's pennyroyal habitats from significant land use impacts. Monitoring plans that are specific to this species need to be adopted by all three Federal agencies with Todsen's pennyroyal populations, these plans should commit agency time and personnel to establishing and monitoring permanent monitoring plots.

Recovery Plan: When workloads permit, a Species Status Assessment could be conducted to guide the development of a revised recovery plan to reflect the current number of populations, and status of threats.

5.0 REFERENCES

Agency Technical Work Group, State of New Mexico. 2005. Potential Effects of Climate Change on New Mexico, December 30, 2005. Report prepared by state agency personnel pursuant to Governor Richardson's Climate Change and Greenhouse Gas Reduction Executive Order 05-033, issued June 9, 2005.

Bailey, J., Donmez, O. 2011. Genetic Analysis of Distinct Populations of *Hedeoma todsenii* R. S. Irving (Lamiaceae). Submitted to: University of Cincinnati.

Britt, C. 2009. Search for New Populations of Todsen's Pennyroyal (*Hedeoma todsenii*) on White Sands Missile Range: 2009. Submitted to: Environmental Stewardship, White Sands Missile Range, NM.

Britt, C. 2012. Todsen's Pennyroyal (*Hedeoma todsenii* Irving) Population Monitoring and Searches on White Sands Missile Range: 2012. Submitted to: Environmental Stewardship, White Sands Missile Range, NM.

Britt, C. 2015. Todsen's pennyroyal (*Hedeoma todsenii*) Status Review: Summary and Evaluation. Submitted to: Environmental Stewardship, White Sands Missile Range, NM.

Britt, C. 2017. Climatic and Phenological Monitoring of Todsen's Pennyroyal (*Hedeoma todsenii*) on White Sands Missile Range in 2015 – 2016. Submitted to: Environmental Stewardship, White Sands Missile Range, NM.

Britt, C. 2018a. Endangered Species Management Component for Todsen's Pennyroyal (*Hedeoma todsenii*) at White Sands Missile Range, New Mexico. Submitted to: U.S. Army, White Sands Missile Range, Directorate of Public Works - Environment Division, White Sands Missile Range, NM.

Britt, C. 2018b. Population Searches and Monitoring of Todsen's Pennyroyal (*Hedeoma todsenii*) in Otero County, New Mexico: 2017. Submitted to: Bureau of Land Management – Las Cruces District Office, Las Cruces, NM.

Britt, C. 2018c. Summary of Monitoring Todsen's Pennyroyal (*Hedeoma todsenii*) on White Sands Missile Range: 2018. Submitted to: Environmental Stewardship, White Sands Missile Range, NM.

Britt, C. 2019a. Monitoring Todsen's Pennyroyal (Hedeoma todsenii) on White Sands Missile Range: 2018. Submitted to: U.S. Army, White Sands Missile Range, Directorate of Public Works - Environment Division, White Sands Missile Range, NM.

Britt, C. 2019b. Regional Distribution Model for Todsen's Pennyroyal (*Hedeoma todsenii*) in Southern New Mexico. Submitted to: Bureau of Land Management – Las Cruces District Office, Las Cruces, NM and Environmental Stewardship - White Sands Missile Range, NM.

Britt, C. 2019c. Searches and Mapping Todsen's Pennyroyal (*Hedeoma todsenii*) Populations in the Sacramento Mountains in 2018. Submitted to: Bureau of Land Management – Las Cruces District Office, Las Cruces, NM.

Britt, C. 2019d. Searches and Monitoring of Todsen's Pennyroyal (*Hedeoma todsenii*) on White Sands Missile Range in 2019. Submitted to: U.S. Army, White Sands Missile Range, Directorate of Public Works - Environment Division, White Sands Missile Range, NM.

Britt, C. 2019e. Summary of Search Efforts for Todsen's Pennyroyal (*Hedeoma todsenii*) on White Sands Missile Range. Submitted to: U.S. Army, White Sands Missile Range, Directorate of Public Works - Environment Division, White Sands Missile Range, NM.

Britt, C. 2020. Searches and Mapping New Todsen's Pennyroyal (*Hedeoma todsenii*) Populations in the Sacramento Mountains in 2020. Submitted to: United States Fish and Wildlife Service, Region 2, Albuquerque, NM.

Britt, C. 2021. Population Monitoring of Todsen's Pennyroyal (*Hedeoma todsenii*) in Otero County, New Mexico: 2020-2021. Submitted to: Bureau of Land Management – Las Cruces District Office, Las Cruces, NM.

Cook, B., T. Ault, and J. Smerdon. 2015. Unprecedented 21st century drought risk in the American Southwest and Central Plains. Science Advances 1:1-7.

Donmez, O., Culley, T., Pence, V. 2014. Identification and characterization of microsatellite loci and levels of genetic variation in *Hedeoma todsenii*. Submitted to: University of Cincinnati.

Elias, E., J. Darren, S. Heimel, C. Steele, H. Steltzer, and C. Dott. 2021. Implications of observed changes in high mountain snow water storage, snowmelt timing and melt window. Journal of Hydrology: Regional Studies 35:1-14.

Enquist, C. and D. Gori. 2008. A climate change vulnerability assessment for biodiversity in New Mexico, Part I: Implication of recent climate change on conservation priorities in New Mexico. The Nature Conservancy and Wildlife Conservation Society. http://nmconservation.org/dl/NMClimateChange_report1_527.pdf

Huenneke, L.F. 1993. Interaction of breeding system and genetic structure in Hedeoma todsenii (Lamiaceae), a rare mint of New Mexico. Final Report to Center for Plant Conservation and New Mexico Division of Forestry, Santa Fe.

Huxman, T. and R. Scott. 2007. Climate change, vegetation dynamics, and the landscape water balance. Southwest Hydrology, January/February 2007:28-29, 37.

Irving, R.S. 1980. Status Report for *Hedeoma todsenii*. Report submitted to U.S. Fish &Wildlife Service, Region 2, Albuquerque, NM. 12 pp. Recommended federal status: Threatened.

IPCC (Intergovernmental Panel on Climate Change). 2007. Fourth Assessment Report Climate Change 2007: Synthesis Report Summary for Policymakers. Released on 17 November 2007. Available at: http://www.ipcc.ch/pdf/assessmentreport/ ar4/syr/ar4_syr_spm.pdf

IPCC (Intergovernmental Panel on Climate Change). 2018. Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Available at: https://www.ipcc.ch/sr15/

IPCC (Intergovernmental Panel on Climate Change). 2021. Weather and Climate Extreme Events in a Changing Climate. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter11.pdf

Irving, R.S. 1980. Status Report for Hedeoma todsenii. Report submitted to U.S. Fish & Wildlife Service, Region 2, Albuquerque, NM. 12 pp. Recommended federal status: Threatened.

Laycock, W.A. 1999. Ecology and management of pinyon-juniper communities within the Interior West: overview of the "Ecological Session" of the Symposium. pp. 7-11. In: S.B. Monsen and R. Stevens, comps. Proceedings: ecology and management of pinyon- juniper communities within the Interior West; 1997; Provo, UT. Proc. RMRS-P-9. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Manning, M.R., J. Edmonds, S. Emori, A. Grubler, K. Hibbard, F. Joos, M. Kainuma, R.F. Keeling, T. Kram, A.C. Manning, M. Meinshausen, R. Moss, N. Nakicenovic, K. Riahi, S.K. Rose, S. Smith, R. Swart, & D.P. van Vuuren. 2010. Misrepresentation of the IPCC CO2 emission scenarios. Nature Geoscience 3:376-377.

National Audubon Society. 2022. Guide to North American Birds: Broad-tailed Hummingbird. Retrieved on August 10, 2022 from https://www.audubon.org/field-guide/bird/broad-tailed-hummingbird.

NDMC (National Drought Mitigation Center). 2022. U.S. Drought Monitor: Time Series. Retrieved on August 10, 2022 from https://droughtmonitor.unl.edu/DmData/TimeSeries.aspx.

NOAA (National Oceanic and Atmospheric Administration). 2022a. National Centers for Environmental information, Climate at a Glance: Statewide Mapping. Retrieved on August 7, 2022 from https://www.ncei.noaa.gov/cag/.

NOAA (National Oceanic and Atmospheric Administration). 2022b. Trends in atmospheric carbon dioxide. Global Monitoring Laboratory. Earth Systems Research Laboratories. Retrieved on August 7, 2022 from https://gml.noaa.gov/ccgg/trends/global.html.

Parmesan, C. and H. Galbraith. 2004. Observed impacts of global climate change in the U.S. Pew Center on Global Climate Change, Arlington, VA. Prepared for the Pew Center on Global Climate Change, November 2004.

Pence, V.C., S.M. Charles, B.L. Plair, K. Lindsey, and G.D. Winget. 2007. Propagation and cryopreservation of Todsen's pennyroyal (Hedeoma todsenii) in vitro. Abstract of paper contributed to In Vitro Biology Meeting, June 13, 2007, Indianapolis, IN. Available: http://www.sivb.org/2007MeetingPDFs/PlantContributedPapers.pdf.

Pence, V., Winget, G., Lindsey, K., Plair, B., Charls, S. 2009. In Vitro Propagation, Cryopreservation, and Genetic Analysis of the Endangered *Hedeoma Todsenii* (Lamiaceae). Madroño 56(4): 221-228.

Philpott, M. 2018. The genetic consequences of ex situ conservation of exceptional plant species. University of Cincinnati, PhD dissertation. Cincinnati, OH.

Philpott, M., O. Donmez, S. Fening, C. Britt, T. Culley, and V. Pence. 2022. Collecting exceptional species for ex situ conservation: An investigation of the genetic diversity of the rare New Mexican species *Hedeoma todsenii*. Manuscript in preparation.

Pielke Jr., R., T. Wigley, and C. Green. 2008. Dangerous assumptions. Nature 452:531-532.

Raupach, M.R., G. Marland, P. Ciais, C. Le Quéré, J.G. Canadell, G. Klepper, and C.B. Field. 2007. Global and regional drivers of accelerating CO2 emissions. Proceedings of the National Academy of Sciences. cgi/doi/10.1073/pnas.0700609104

Seager, R., M. Ting, I. Held, Y. Kushnir, J. Lu, G. Vecchi, H. Huang, N. Harnik, A. Leetmaa, N. Lau, C. Li, J. Velez, and N. Naik. 2007. Model projections of an imminent transition to a more arid climate in southwestern North America. Science 316: 1181.

Sikula, N., C. Britt and C. Lundblad. 2007. Todsen's pennyroyal (Hedeoma todsenii): population monitoring and habitat searching on White Sands Missile Range. Submitted to: Environmental Stewardship, White Sands Missile Range, NM.

Sikula, N. 2009. Todsen's pennyroyal (Hedeoma todsenii): population monitoring on White Sands Missile Range. Annual progress report 2009. Submitted to: Environmental Stewardship, White Sands Missile Range, NM.

Sivinski, R.C. 2001. Todsen's pennyroyal (Hedeoma todsenii): 2000-2001 Section 6 progress report. Submitted to USDI-FWS, Region 2, Albuquerque, NM.

Sivinski, R.C. 2009. Todsen's pennyroyal (Hedeoma todsenii): Section 6 progress report. Submitted to USDI-FWS, Region 2, Albuquerque, NM.

TNC (The Nature Conservancy) White Sands Field Office. 2006. Todsen's pennyroyal searching and monitoring: annual progress report, 2006. Submitted to: Environmental Stewardship, White Sands Missile Range. Revised in 2007.

Tonne, P. 2009. Preliminary report on the Pollination Ecology of Hedeoma todsenii – year 1. Unpublished draft report for White Sands Missile Range. Natural Heritage New Mexico. Albuquerque, New Mexico.

Udall, B. and G. Bates. 2007. Climatic and hydrologic trends in the Western U.S.: A review of recent peer-reviewed research. Intermountain West Climate Summary 3(1): 2-8.

USDA FS (U.S. Department of Agriculture, Forest Service). 1986. Lincoln National Forest Land and Resource Management Plan. Lincoln National Forest.

USDA FS (U.S. Department of Agriculture, Forest Service). 2021. Lincoln National Forest draft environmental impact statement, Volume 2, Appendices A - G. Lincoln National Forest.

USFWS (U.S. Fish and Wildlife Service). 1981. Determination of two New Mexico plants, *Eriogonum gypsophilum* (gypsum wild buckwheat) and *Hedeoma todsenii* (Todsen's pennyroyal), to be threatened and endangered species, with critical habitat. Federal Register 46:5729-5733.

USFWS (U.S. Fish and Wildlife Service). 2001. Todsen's pennyroyal (*Hedeoma todsenii*), revised recovery plan. New Mexico Ecological Services Field Office, Albuquerque. 37 pp.

USFWS (U.S. Fish and Wildlife Service). 2012. Biological conference opinion: The continued implementation of the Land and Resource Management Plan for the Lincoln National Forest of the Southwestern Region. Region 2, Cons. #2012-F-0048.

USFWS (U.S. Fish and Wildlife Service). 2011. Todsen's Pennyroyal (*Hedeoma todsenii*) 5-Year Review: Summary and Evaluation. New Mexico Ecological Services Field Office, Albuquerque. 28pp.

USGS (U.S. Geological Survey). 2022. National Climate Change Viewer. Retrieved on August 6, 2022 from https://www2.usgs.gov/landresources/lcs/nccv/maca2/maca2_counties.html.

Walther, G., E. Post, P. Convey, A. Menzel, C. Parmesan, T. Beebee, J. Fromentin, O. Hoegh-Guldberg, and F. Bairlein. 2002. Ecological responses to recent climate change. Nature 416:389-395.

WSMR (White Sands Missile Range). 2015. Integrated Natural and Cultural Resources Management Plan and Environmental Assessment, 2015-2019. 2019. U.S. Army Garrison White Sands, White Sands, New Mexico. 568 pp. + 27 Appendices.

Personal Communications

Anderson, David. Botanist, Environmental Stewardship, White Sands Missile Range, NM. Provided information for the 2011 review in 2009 and 2011.

Boyter, Molly. Acting State Botanist, Bureau of Land Management, Santa Fe, NM. Provided information for this review in 2022.

Howard, Michael. Botanist, Bureau of Land Management, Las Cruces, NM. Provided information for the 2011 review in 2010.

Lister, Ray. Supervisory Natural Resource Specialist, Bureau of Land Management, Las Cruces, NM. Provided information for the 2011 review in 2011.

Salas, Danney. Forest Biologist, Lincoln National Forest, Alamogordo, NM. Provided information for the 2011 review in 2007.

Tonne, Phil. Collections Manager/Botanist, University of New Mexico, Museum of Southwestern Biology Herbarium, Albuquerque, NM. Provided information for the 2011 review in 2011 and for this review in 2013.

U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW of Todsen's pennyroyal (*Hedeoma todsenii*)

Current Classification:

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
___**X** No change needed

Appropriate Listing/Reclassification Priority Number, if applicable: N/A

Review Conducted By: Lauren Rangel, Fish and Wildlife Biologist

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service, New Mexico Ecological Services Field Office

Approve SHAWN SARTORIUS Digitally signed by SHAWN SARTORIUS Date: 2022.08.26 14:10:28 -06'00'