BEFORE THE SECRETARY OF THE INTERIOR

PETITION TO LIST THE SOUTHERN PLAINS BUMBLE BEE AS ENDANGERED UNDER THE ENDANGERED SPECIES ACT AND CONCURRENTLY DESIGNATE CRITICAL HABITAT

Photo credit: Bumble Bee Watch / Kellie Hayden

CENTER FOR BIOLOGICAL DIVERSITY

July 27, 2022

NOTICE OF PETITION

Deb Haaland, Secretary
U.S. Department of the Interior
1849 C Street NW
Washington, D.C. 20240
exsec@ios.doi.gov

Martha Williams, Director
U.S. Fish and Wildlife Service
1849 C Street NW
Washington, D.C. 20240
martha_williams@fws.gov

Gary Frazer, Assistant Director for Endangered Species
U.S. Fish and Wildlife Service
1840 C Street NW
Washington, D.C. 20240
gary_frazer@fws.gov

Amy Lueders, Regional Director
Region 2 U.S. Fish and Wildlife Service
P.O. Box 1306
Albuquerque, NM 87103-1306
amy_lueders@fws.gov

Charles Wooley, Regional Director
Region 3 U.S. Fish and Wildlife Service
5600 American Blvd. West, Suite 990
Bloomington, MN 55437-1458
charles_wooley@fws.gov

Leopoldo Miranda-Castro, Regional Director
Region 4 U.S. Fish and Wildlife Service
1875 Century Blvd. NE
Atlanta, GA 30345
leopoldo_miranda@fws.gov

Wendi Weber, Regional Director
Region 5 U.S. Fish and Wildlife Service
300 Westgate Center Dr.
Hadley, MA 01035
wendi_weber@fws.gov

Noreen Walsh, Regional Director
Region 6 U.S. Fish and Wildlife Service
134 Union Boulevard, Suite 650
Lakewood, CO 80228
noreen_walsh@fws.gov

Pursuant to Section 4(b) of the Endangered Species Act (ESA), 16 U.S.C. § 1533(b); Section 553(e) of the Administrative Procedure Act, 5 U.S.C. § 553(e); and 50 C.F.R. § 424.14(a), the Center for Biological Diversity (Center) hereby petition the Secretary of the Interior, through the United States Fish and Wildlife Service (FWS, Service), to list the Southern Plains bumble bee (*Bombus fraternus*) as endangered under the ESA.

FWS has jurisdiction over this petition. This petition sets in motion a specific process, placing definite response requirements on the Service. Specifically, the Service must issue an initial finding as to whether the petition "presents substantial scientific or commercial information indicating that the petitioned action may be warranted." 16 U.S.C. § 1533(b)(3)(A). FWS must make this initial finding "[t]o the maximum extent practicable, within 90 days after receiving the petition." *Id*.

Petitioners also requests that critical habitat be designated for the Southern Plains bumble bee concurrently with the species being listed, pursuant to 16 U.S.C. § 1533(a)(3)(A) and 50 C.F.R. § 424.12.

The Center is a nonprofit, public interest environmental organization dedicated to the protection of imperiled species and the habitat and climate they need to survive through science, policy, law, and creative media. The Center is supported by more than 1.7 million members and online activists throughout the country. The Center works to secure a future for all species, great or small, hovering on the brink of extinction. The Center submits this petition on its own behalf and on behalf of its supporters, members and staff who share an interest in protecting the Southern Plains bumble bee and its habitat.

Please contact me at 406-366-4872 or email me at jtyler@biologicaldiversity.org if you have any questions or need any clarification on the information in this petition.

Sincerely,

Jess Tyler, M.S.
Staff Scientist
Center for Biological Diversity

Abbreviations

AMNH_BEE	American Museum of Natural History-Bee Database
AOO	Area of Occupancy
APHIS	Animal and Plant Health Inspection Service
BBSL	Bee Biology and Systematics Lab
BIML	Native Bee Inventory and Monitoring Lab
BLM	Bureau of Land Management
BMEC_ENT	Bohart Museum Entomology Collection
CRP	Conservation Reserve Program
DWV	Deformed Wing Virus
EMEC	Essig Museum Entomology Collection
EOO	Extent of Occurrence
EQIP	Environmental Quality Incentive Program
ESA	Endangered Species Act
FWS	United States Fish and Wildlife Service
FLPMA	The Federal Land Policy and Management Act
GBIF	Global Biodiversity Information Facility
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
ITIS	Integrated Taxonomic Information System
IUCN	International Union for the Conservation of Nature
LACM-ENTB	Los Angeles County Museum-Entomology Bee Database at U.C. Riverside
NEPA	National Environmental Policy Act
NFMA	National Forest Management Act
NPS	National Park Service
SGCN	Species of Greatest Conservation Need
SWAP	State Wildlife Action Plan
UCRC_ENT	University of California Riverside Collection-Entomology
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
WWF	World Wildlife Fund

Suggested Citation

Tyler J. 2022. PETITION TO LIST THE SOUTHERN PLAINS BUMBLE BEE AS ENDANGERED UNDER THE ENDANGERED SPECIES ACT AND CONCURRENTLY DESIGNATE CRITICAL HABITAT. Center for Biological Diversity, Portland, Oregon.

Acknowledgements

The author would like to thank Xerces Society staff Leif Richardson, Rich Hatfield, Sarina Jepsen, Aimee Code, Ray Moranz, Mace Vaughan, and Center for Biological Diversity staff Lori Ann Burd for their thoughtful review and feedback. Thanks also to Kara Clauser, at the Center, for making maps and conducting GIS analysis.

The author thanks the law students from the Vermont Law School's Environmental Advocacy Clinic who reviewed state wildlife action plans of 24 states for this petition

All bumble bee records referenced in this petition are from Leif Richardson's bumble bee database which is referred to as Richardson (2021) throughout.

Table of Contents

1. Executive Summary

The Southern Plains bumble bee (*Bombus fraternus* Smith 1854) faces extinction due to multiple threats. The relatively uncommon but highly recognizable Southern Plains bumble bee was once found in much of the Midwest, throughout the grasslands, savannas, and open woodlands of the Great Plains from Texas to North Dakota and along the southeastern coastal plain. However, the Southern Plains bumble bee now is in alarming decline due to threats to its habitat and health. Observational records show that the Southern Plains bumble bee has become less abundant, less widespread, and less persistent over time. Despite increasing interest in and surveys for bumble bees between 2011 and 2020, the relative abundance of the species is estimated to have declined by half and the bee has not been sighted in one third of all counties with historic records. This bee was historically found in 26 states, but has declined in relative abundance in most of the states within its range and has disappeared completely from six states including Indiana, Maryland, Michigan, New Jersey, North Dakota, and Ohio. Likewise, this species has experienced a 42% decline in modeled occupancy across its range.

The Southern Plains bumble bee faces multiple, concurrent, and interacting threats including degraded habitat and ongoing habitat loss due to agriculture and development, pesticide exposure, pathogens from commercial bees, climate change, and small population size. The Southern Great Plains lost nearly five million acres of perennial grassland habitat between 1982 and 2015,and agricultural interests in the Great Plains continue to convert grassland to cropland at the astounding rate of four football fields a minute. Agricultural intensification is decreasing crop diversity and increasing reliance on pesticides, particularly herbicides which have depleted agricultural land of nectar and pollen resources that once supported populations of the Southern Plains bumble bee. Moreover, cropland contaminated with neonicotinoid insecticides and other toxic insecticides produce acute mortality in addition to subacute mortality via chronic stress to bumble bees that reduce their foraging efficiency, reproduction, and overall health. Disease spillover and competition from managed pollinators, including honey bees and commercial bumble bees, likely adds additional stress to populations. The threats to this species are ongoing and widespread; and without protection under the Endangered Species Act, the future of this species is highly uncertain.

No existing regulatory mechanisms adequately address the threats to the Southern Plains bumble bee. While 30% of 2011-2020 observations of the bee were on public land, this is a lower percentage compared to bumble bees overall (37%) and less than a third of these public lands are protected and managed to prioritize biodiversity (i.e. wilderness areas, wildlife refuges, national parks). As such, current regulations offer insufficient protections for the Southern Plains bumble bee, and this species is not protected under any state endangered species statute.

Based on the best available science, this species is in decline and faces extinction due to ongoing and persistent threats. We have time to save it while effective regulatory and conservation measures are available. In light of the best available science, the Fish and Wildlife

Service must act to list the Southern Plains bumble bee as endangered under the Endangered Species Act.

2. Introduction

Pollinating insects are essential to the health of natural ecosystems and the agricultural systems on which humanity depends (Obama 2014 p. 1; IPBES 2016 p. 16). Animal pollination, the vast majority of which is done by bees, is required for successful production of around 90% of wild plants, 75% of leading global food crops, and 35% of the global food supply (Moisset & Buchmann 2011 p. 2; IPBES 2016 p. 16).

Bumble bees are critical pollinators for crops and native plants because they feed on the nectar and pollen of a wide variety of plants (Goulson 2010 p. 162-172). Bumble bees are among the best studied insect groups and the evidence is clear that populations of many species of bumble bees have declined across the country (Cameron et al. 2011 p. 665; Bartomeus et al. 2013 pp. 662–663; IPBES 2016 pp. 21–22). Roughly one out of every four species of bumble bees in North America is classified as vulnerable, endangered, or critically endangered according to the International Union for the Conservation of Nature (IUCN) (IUCN 2022 pp. 4-9). North American bumble bees are imperiled by a multitude of interacting threats that include habitat loss, pesticide use, climate change, and pathogen transmission (Cameron and Sadd 2020 p. 10.1).

The Southern Plains bumble bee is an important generalist pollen and nectar forager of the Great Plains, midwestern, and the southeastern United States but is now declining at an alarming rate. The IUCN has assessed the Southern Plains bumble bee to be endangered (Hatfield et al. 2014 p. 1) and recent analysis shows a continued pattern of decline. Likewise, in a recent study, the Southern Plains bumble bee has experienced a 42% decline in modeled occupancy when compared to its historic condition (Guzman et al. 2021 p. 8). The Southern Plains bumble bee is in serious decline and faces numerous threats, thus we call on the U.S. Fish and Wildlife Service (Service) to act expeditiously to protect it under the Endangered Species Act (ESA).

3. Natural History

3.1. Taxonomy

Bumble bees are members of the genus *Bombus* within the insect order Hymenoptera and family Apidae (Table 1). *Bombus fraternus* was first described by Frederick Smith in 1854 (Smith 1854 p. 385), is classified under the subgenus Cullumanobombus (Williams et al. 2008 p. 52), and is recognized as a valid species under the Integrated Taxonomic Information System (ITIS) (ITIS 2021 p. 1).

Table 1. Taxonomy of *Bombus fraternus*.

Kingdom	*Animalia*
Phylum	*Arthropoda*
Subphylum	*Hexapoda*

Class	*Insecta*
Subclass	*Pterygota*
Order	*Hymenoptera*
Family	*Apidae*
Genus	*Bombus*
Subgenus	*Cullumanobombus*
Species	*fraternus*

3.2. Description

The Southern Plains bumble bee is a member of the subgenus Cullumanobombus and is most similar in appearance to *B. affinis, B. griseocollis,* and *B. rufocinctus*. The Southern Plains bumble bee is a short-tongued bumble bee and is considered early-emerging (Grixti et al. 2009 p. 80). This species can be distinguished from other bumble bees based on physical characteristics and color patterns (Williams et al. 2014 p. 128). Queens are large compared to most other bumble bee species, ranging in size from 25-27 mm (0.97 to 1.07 in); workers range in size from 15-19 mm (0.56 to 0.75 in); both queens and workers are covered in short yellow and black hairs with distinctive flattened, black hairs on the third tergal segment (contrast with *B. affinis, B. griseocollis,* and *B. rufocinctus*) (Williams et al. 2014 p. 128). Hairs on the face and sides of the thorax are usually black, with the metasoma (upper side of abdomen) rectangular in appearance and slightly flattened with yellow hairs on the first and second tergal segments, but the third through sixth tergal segments are entirely black (Williams et al. 2014 p. 128). Males are also large, ranging in size from 22-25 mm (0.85-1.00 in) with bulbous eyes much larger than females and with relatively long antennae. Coloration pattern for males is very similar to females with the area between the wings sometimes extensively yellow (Williams et al. 2014 p. 128).

3.3. Life Cycle

The Southern Plains bumble bee lives in colonies and has an annual life cycle (see Williams et al. 2014 p. 12-15 for greater detail of the bumble bee life cycle). A founding queen (foundress) produces one colony during her lifetime that consists of herself, her worker-caste female offspring, her male offspring, and her female offspring that will mate, hibernate, and form their own colonies the following year. The foundress emerges from hibernation in spring as early as March or April (Figure 1). At the beginning of the colony cycle, the foundress selects an appropriate nesting site while foraging for nectar and pollen for herself and her offspring. Once she has gathered sufficient nectar and pollen she will form individual provisions on which she will lay one or more eggs. The foundress can control the sex of her offspring. Her eggs that are fertilized with sperm stored from mating the previous fall will develop into females, while unfertilized eggs will produce males. The first eggs will be workers who take over foraging, colony defense, and tending to the young. Once the first group of workers has eclosed, the foundress remains in the nest and continues to lay eggs for the production of new workers with free-flying worker numbers peaking in August (Figure 1). A bumble bee colony at its largest can contain several hundred workers (Goulson 2010, p. 8). By midsummer, successful colonies will start producing males (Figure 1). Once developed, males leave the colony in search of a mate. Reproductive females are also produced during the later development of the colony. These new queens do not forage for the colony and eventually leave the colony to mate and find a place to hibernate for the winter. At the end of the season, the foundress and any remaining workers die. New, mated queens (gynes) overwinter and emerge the next spring to start the cycle again.

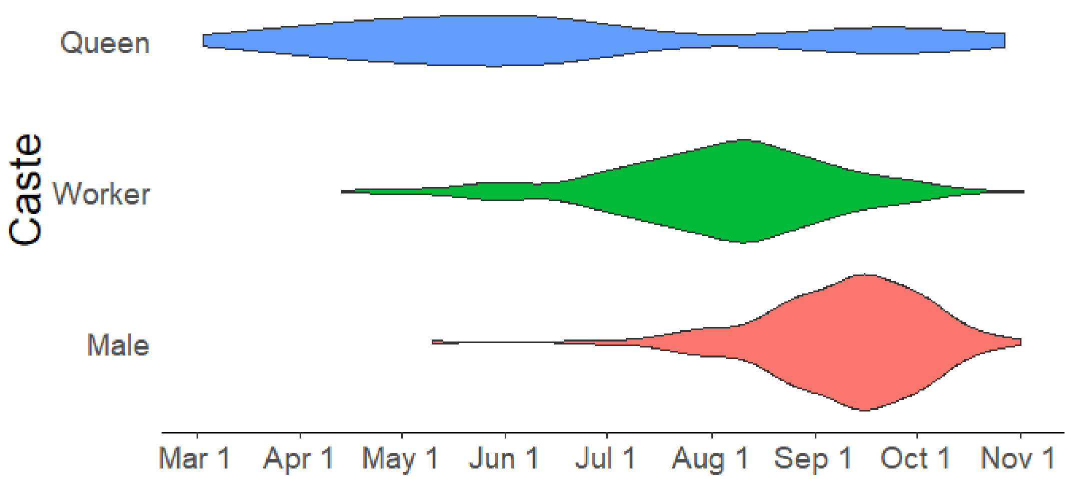


Figure 1. Phenology of the Southern Plains bumble bee. Width of the plot for each caste (male, queen, worker) is proportional to the number of observations at that time of the year. The wider the plot the greater the number of that caste. Emergence time data is derived from the date of observation for all Southern Plains bumble bees in Richardson's 2021 bumble bee dataset.

3.4. Habitat

The Southern Plains bumble bee inhabits open prairies, meadows, and grasslands of the Midwest, throughout the Great Plains from Texas to North Dakota, and in the grasslands and pine savannas of the southeastern coastal plain (Williams et al. 2014 p. 129). Historically, the bee occurred at low densities in open natural and human modified habitats, and recent records show that the Southern Plains bumble bee inhabits intact prairie remnants, sites within the agricultural matrix, and in urbanized habitat. Most records for the Southern Plains bumble bee in published literature come from surveys of remnant grasslands (see Appendix 2). It is unclear how prevalent the Southern Plains bumble bee is within agricultural matrix habitat, however the prevalence of this species is likely low in this habitat type. Evidence from urbanized areas in the species range such as one survey from St. Louis indicates that the bee is not found in residential backyard gardens but has been found in a restored prairie and on an urban farm (Camilo 2017 p. 179).

The specific habitat characteristics for the Southern Plains bumble bee have not yet been studied in detail, but like other bumble bees, the Southern Plains bumble bee requires diverse nectar and pollen resources during the colony period (spring, summer, and fall) and suitable nesting and overwintering sites for mated females and emerging queens (Goulson 2010 pp. 5–12). Recorded floral associations indicate that this species feeds on flowering plants from at least 20 plant families, but prefers plants in the aster (*Asteraceae*), pea (*Fabaceae*), and mint (*Lamiaceae*) families (Appendix 1, Mitchell 1962 p. 527). The relatively uncommon distribution of the Southern Plains bumble bee across open grassland/prairie habitat could be explained by a combination of nesting and overwintering requirements, tongue length, worker body size, colony size, habitat quality, thermoregulation, emergence time, and other factors that influence the distribution of bumble bees generally (Goulson 2010 pp. 151–159).

Nesting and Overwintering Sites

Like all bumble bees, the Southern Plains bumble bee requires suitable nesting sites during the colony formation and rearing period (spring, summer, and fall) and suitable overwintering sites for mated females (Goulson 2010 pp. 5-12). The Southern Plains bumble bee nests both underground and on the surface of the ground (Williams et al. 2014 p. 129). In general, bumble bees are opportunistic nesters that do not dig their own underground nests, but take advantage of pre-existing holes and depressions below the surface formed by rodents or other animals or cavities above the surface created by old logs, stumps, old ground-nesting bird nests, or clumps of grass (Schweitzer et al. 2012 p. 10).

The Southern Plains bumble bee gynes also require sites where they can hibernate during the winter after mating. The specific requirements of overwintering sites of this species require further study, but overwintering sites are distinct from colony nesting sites and may or may not be near foraging areas. Bumble bees are generally known to hibernate close to the ground surface or down an inch or two in loose soil, or under leaf litter or other debris, in sites that are undisturbed and have adequate organic material to provide shelter (Williams et al. 2014 p. 15).

Bumble Bee Ecology

Bumble bees have evolved to rely exclusively on a diet of nectar and pollen, and actively move pollen through the landscape in pursuit of nutritional resources to bring back to the nest. This, along with their large size and specialized hairs, makes them very efficient pollinating animals essential for the reproduction of many plant species (Williams et al. 2014 p. 15). Suitable open meadows with sufficient nectar, pollen, and nesting sites often exist within patchy distributions and bumble bees can exploit scattered resources because they are highly mobile compared to other insects; notably nesting and overwintering sites are often separate from foraging habitat (Goulson 2010 pp. 101-102). The percentage of grasslands, especially native prairie remnants, within 500 m (0.3 mi) of a nest is an important predictor of bumble bee diversity in tall-grass prairie remnants in Iowa (Hines & Hendrix 2005 p. 1481). The temporal distribution of flowering plants is also important, as the amount of nectar and pollen during the early spring and late summer impact colony growth and reproduction (Westphal et al. 2009 p. 192; Goulson 2010 pp. 208–210). Quality of bumble bee habitat varies at the local scale and bumble bees must efficiently forage to sustain their colonies. The foraging range of the Southern Plains bumble bee is not yet known, but as a general rule relatively larger bumble bees like the Southern Plains bumble bee forage over larger areas than smaller bumble bee species (Goulson 2010 p. 96). For example, *B. terrestris* has relatively larger workers and may forage within a few hundred meters of the nest to potentially more than 1,500m (Osborne et al 2008 p. 413). Based on foraging distance, dispersal and other factors of a similar bee (*B. terrestris*), a viable population of Southern Plains bumble bees may require a minimum of 1,000 hectares (10 km x 10 km) of suitable habitat (Kraus et al. 2009 p. 249; Lepais et al. 2010 pp. 826-827). This minimum value may depend on many factors that influence the density of individual colonies within a populated area. Bumble bee populations exist within metapopulations (Goulson 2010 p. 191-198) that ensure resiliency, representation, and redundancy to environmental change (USFWS 2016 p. 10). A single occupied 10 km x 10 km grid cell may likely not be enough to sustain the metapopulation dynamics of the species. Research on other species have shown that the surrounding landscape is an important component that shapes healthy bumble bee communities (Hatfield & LeBuhn 2007 p. 155).

4. Distribution and Status

4.1. Distribution

The Southern Plains bumble bee's historic representation was across the Great Plains, Midwest, along the southeastern coastal plain, and at low levels in the Great Lakes region (Figure 2). The Southern Plains bumble bee has been detected in 28 states[1] (26 states historically) and 500 counties (Richardson 2021). The bee was rarely observed in the northernmost part of its range in North Dakota (2 records) and Michigan (2 records), but these states are included in the historic range. This species was not considered ever present in Wisconsin (Wolf & Ascher 2008 p. 133). There are two new records in Wyoming (Bell 2020 pers. comm.; GBIF.org 2022) and based on the proximity of this observation to other historic observations in Nebraska, we consider Wyoming to be within the range of this species.

[1] The Discoverlife database contains records from three additional states Delaware (undated), Massachusetts 1982, and Minnesota 1939. The undated Delaware and 1939 Minnesota records were not verified as correctly identified Southern Plains bumble bees at the time of petition writing. We consider the Massachusetts record to be erroneous.

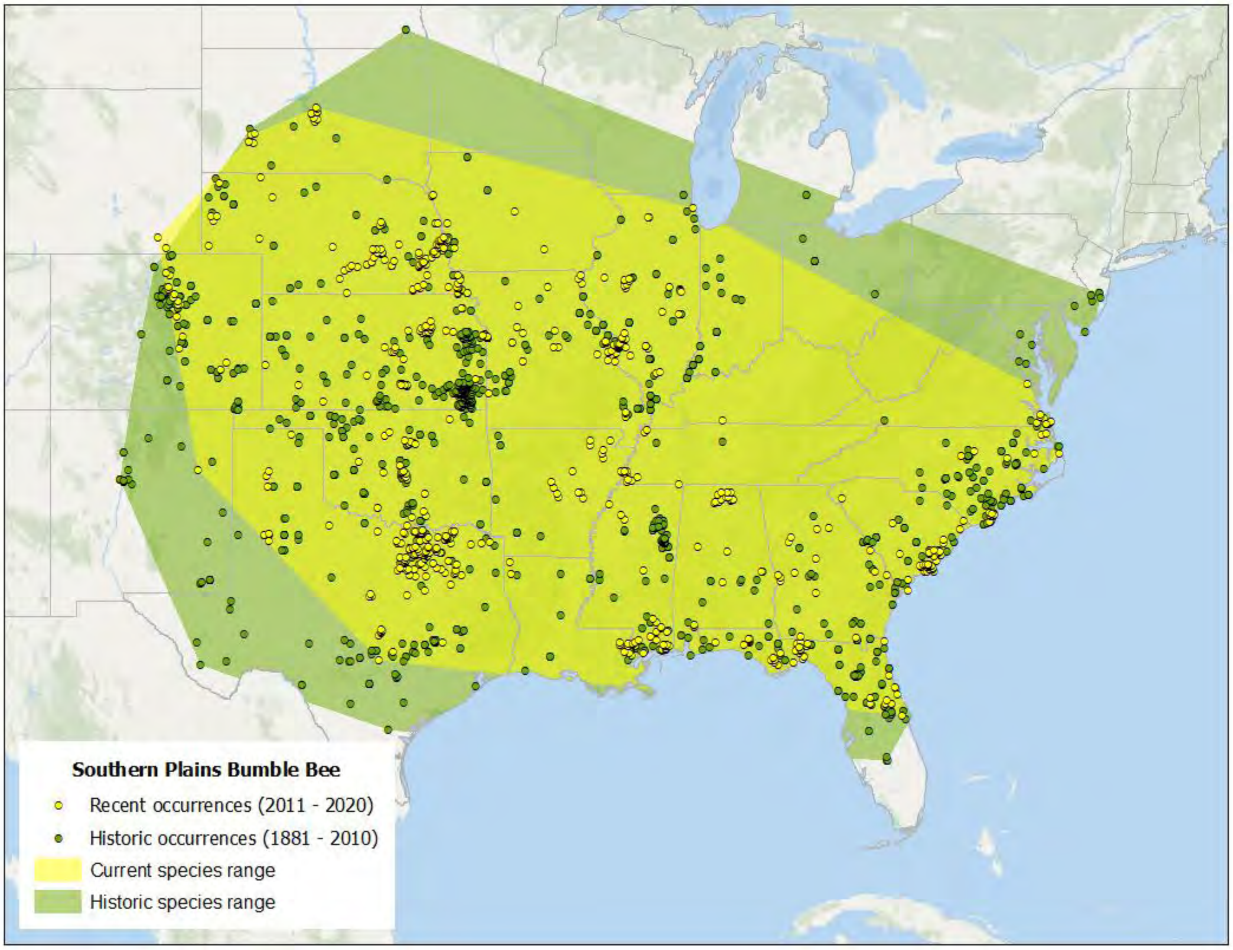


Figure 2. Historic (1881-2010) and recent (2011-2020) observations and range map for the Southern Plains bumble bee. Yellow area indicates current occupied range. Green area indicates historically occupied range. Extent of Occurrence (EOO) polygons were drawn to be the minimum convex polygons required to capture all observations. The Great Lakes, Atlantic Ocean, and Gulf of Mexico were removed from the range area. Data from Richardson 2021.

We calculated a range estimate using Extent of Occurrence (EOO) which represents the minimum area of a convex polygon drawn around the set of observations.[2] Figure 2 represents the EOO of all historic (1881-2010) observations depicted in dark green and the EOO of all the recent (2011-2020) observations depicted in yellow. Overall, the EOO of the Southern Plains bumble bee has declined 24% comparing the decade 2011-2020 to the period 1881-2010 (Figure 2 and Table 2). To compare recent and historic EOO, we divided observations into the historic period containing observations from 1881-2010 and the recent period containing observations from 2011-2020. Since the EOO is dependent on the sampling effort across the species range and increases with sampling effort, we rarified the historic data and calculated historic and recent EOO from equal-sized samples. We controlled for the effects of random sampling bias by

[2] Extent of occurrence and area of occupancy were calculated using the ConR package (version 1.3) for R (version 4.1.0) (Dauby et al. 2017).

drawing 1000 random, equal-sized subsamples of the historic and recent observations. We then averaged across many observation subsamples to compute an average historic and recent EOO. Detailed methods for EOO analysis are provided in Appendix 3. Using equal-sized random resampling the 2011-2020 average EOO is 24% smaller than the 1881-2010 average EOO (Table 2).

Table 2. Southern Plains bumble bee distribution. Mean extent of occurrence (EOO; 95% confidence interval in parentheses) is the average area of a minimum convex polygon fitted around observation locality datasets randomly sampled from observations made in two time periods. Data is from Richardson 2021.

Era	**Extent of Occurrence (km^2)**
Historic (1881-2010)	4,291,732 (3,960,874-4,622,591)
Recent (2011-2020)	3,249,614 (3,004,498-3,249,614)
Recent EOO relative to Historic EOO	75.7% (24.3% decline)

Based on the available bumble bee records, the Southern Plains bumble bee has disappeared from several states along the northern edge of its range. The bee is likely extirpated from Indiana, Maryland, Michigan, New Jersey, North Dakota, and Ohio (Table 3). The Southern Plains bumble bee was never common in these five states, yet this species has not been observed in these states in the past twenty years. Recent systematic surveys of semi-natural meadows in New Jersey (Winfree lab, Rutgers University) failed to find the Southern Plains bumble bee (n = 9,377 total bumble bee observations, Richardson 2021) and large surveys in Maryland and Delaware also failed to record the Southern Plains bumble bee (Kammerer et al. 2020 supplemental). In New Mexico, the Southern Plains bumble bee has only recently been relocated in San Miguel county, one of the eight previously occupied counties. The species has apparently disappeared from western and southern Texas (Figure 2). While new records of the Southern Plains bumble bee have been added for the states of Kentucky and Wyoming, it is likely that the Southern Plains bumble bee was present historically in these states.

4.2. Relative Abundance

In our range wide analysis, the Southern Plains bumble bee's average relative abundance[3] from 2011-2020 (1.7%) was less than half of the average relative abundance of records from 1881-2010 (3.9%) (Table 3). The relative abundance of the Southern Plains bumble bee has decreased decade by decade and our analysis indicates it is now rarer relative to all other bumble bees in its range (Figure 3A).

[3] Relative abundance is the fraction of Southern Plains bumble bee observations compared to all bumble bee observations within the range of the species.

Relative abundance is an indirect way of measuring population stability since consistent, systematic sampling across its range is not available for many species, particularly invertebrates like the Southern Plains bumble bee. While relative abundance for uncommon bumble bees is subject to sources of bias such as sampling technique and sampling effort, we corrected for sampling bias in the following ways (see Appendix 3 for more detailed methods). We used only unique bumble bee observations to remove the effect of the repeated observation of common species at a single site. Removing repeated observations diminished the role of survey technique that may have over or underrepresented an uncommon species like the Southern Plains bumble bee. Unique observations collapsed repeated observations down to a single point, so each observation in the final data set represented an observation with a unique species, date, state, county, latitude, and longitude. We compared only equal sized historic and recent sample sizes and by resampling we can determine the amount of variability in the data and reduce the effect of relying only on one set of observations. Additionally, as data collection methods have changed through time, removing the most common species from the data may reduce the amount of over/under representation of these common species.[4] Figure 3A shows the relative abundance of the Southern Plains bumble bee when compared to the entire dataset of unique bumble bee observations while Figure 3B show the relative abundance of the Southern Plains bumble bee compared to all unique bumble bee observations except for the three most common species (*B. impatiens, B. pensylvanicus, and B. griseocollis*). Both show a pattern of decline in the Southern Plains bumble bee.

[4] Most historic bumble bee collecting events likely did not involve a census of the entire fauna – including abundance – observed in a location, while many newer methodologies do follow this standardized method, thus making common species much more common in current collections than they likely were in historic data; also, the advent of incidental community science records from platforms like iNaturalist also increase the abundance of common species

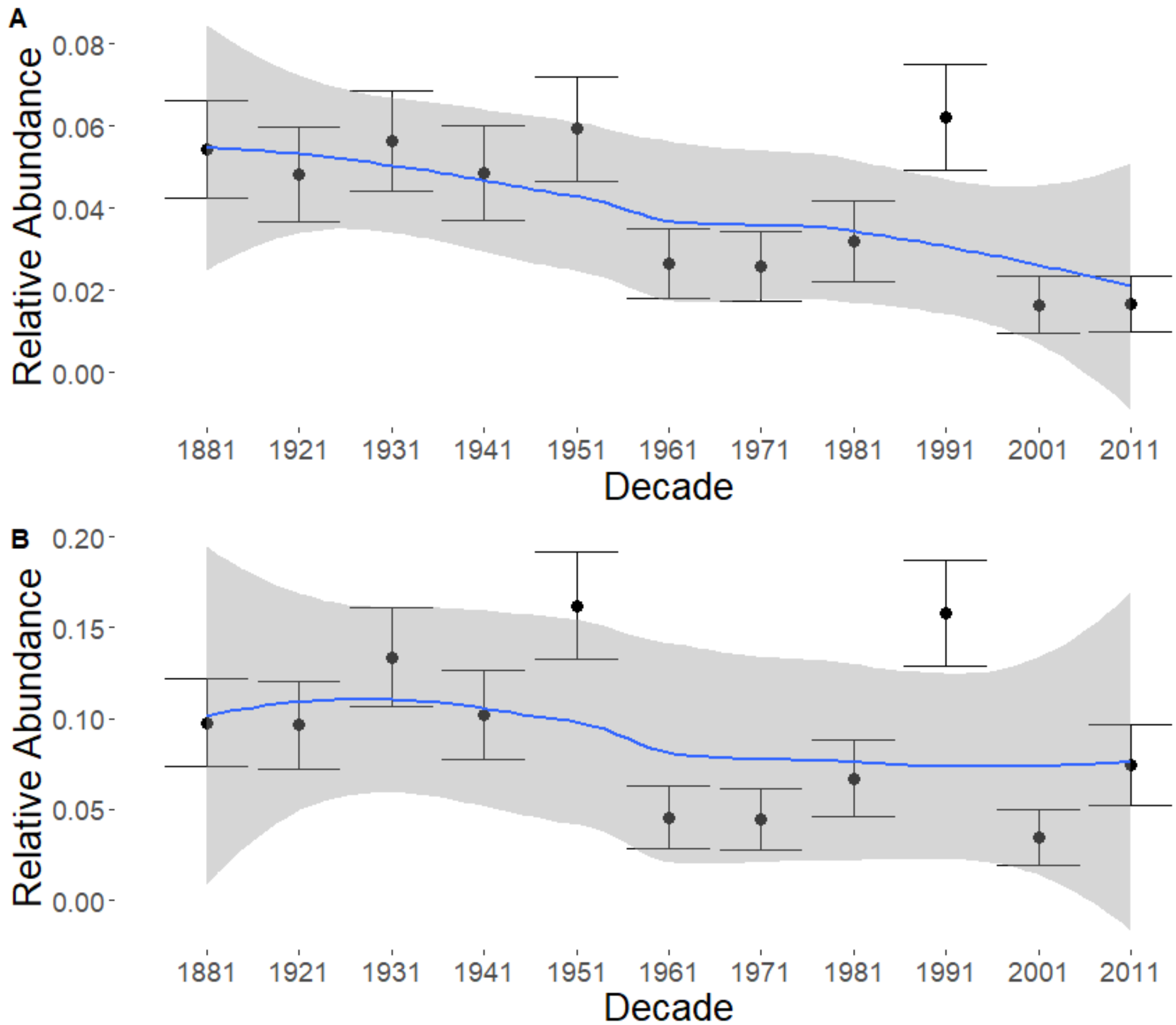


Figure 3. Average relative abundance of the Southern Plains bumble bee. Average relative abundance was calculated using mean values generated from resampling from each decade. Error bars represent 95% confidence intervals for each relative abundance mean. The blue trendline was generated with 'loess' smoothing. (A) Average relative abundance calculated with all species included. (B) Average relative abundance calculated with the three most common species removed (*B. impatiens, B. pensylvanicus,* and *B. griseocollis*). Data is from Richardson (2021).

Community science (a.k.a. citizen science) observations of bumble bees contributed a large amount of additional survey effort to the bumble bee database over the past decade (Figure 4A), including many new observations of the Southern Plains bumble bee. Community science data includes Southern Plains bumble bee observations (sample sizes in parentheses) from iNaturalist (n=389), Bumble Bee Watch (n=149), Bug Guide (n=29), and BeeSpotter (n=9). This data represents a significant change in the quantity and methodology of the bumble bee observational data compared to data in previous decades. Some community science data is incidental and opportunistic while other data is robust, reliable, collected using a standardized protocol, and each observation is verified by an expert (e.g. the Nebraska Bumble Bee Atlas). Community science data represents a potential source of bias in the bumble bee database. The available data indicates that the Southern Plains bumble bee is more abundant and widespread in the community science data than other data from 2011-2020 (Figure 4B and 4C). However, the pattern of decline of the Southern Plains bumble bee is present in the data as a whole, whether or not community science data is included in the relative abundance and occupancy estimates.

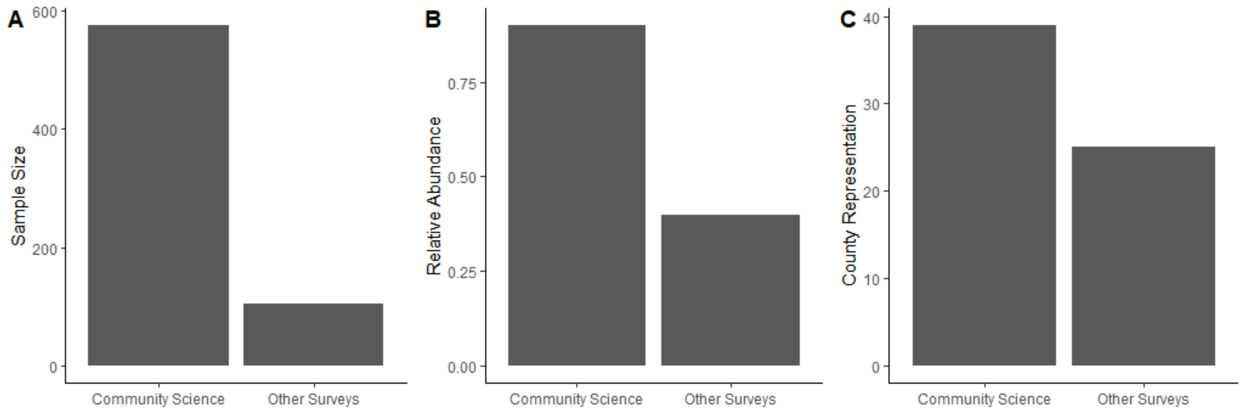


Figure 4. Species trends based on community science data compared to all other observations in the dataset. (A) The total number of observations of the Southern Plains bumble bee from 2011-2020. (B) The relative abundance of the Southern Plains bumble bee expressed as a percentage of all bumble bee observations. (C) The number of counties recorded per 100 observations for the Southern Plains bumble bee. Data is from Richardson (2021).

Regional and statewide bumble bee surveys published in the last decade add to the evidence for decline of the Southern Plains bumble bee (Appendix 2). Likewise, based on Richardson (2021), the relative abundance from 2011-2020 indicate a decline from historic condition (1881-2010) in all but four states in the range of the Southern Plains bumble bee (Table 3). Besides states with no recent observations, the states with the largest declines are Alabama, Georgia, Mississippi, New Mexico, North Carolina, Oklahoma, and Texas. These declines are alarming since the Southern Plains bumble bee was more common in states like Oklahoma, Mississippi, and Texas than in states like New Jersey, Michigan, and North Dakota. The states of Illinois, Oklahoma, Nebraska, and Missouri have published state-level studies on bumble bee populations and/or have recent survey effort and are detailed below.

In Illinois, Grixti et al. (2009) compared observations across more than 100 years of records and found that the Southern Plains bumble bee had declined from 1.2% of records to 0.2% or records with only 4 observations made in the most recent survey in 2007 (Grixti et al. 2009 p. 80). Other more recent data, including from community science surveys for this state show a relative abundance of 0.4% (30 additional records out of 8317 total bumble bee observations) (Richardson 2021). The increased survey effort in the state provides many new records in previously unsurveyed areas, but still confirms that this bee has greatly declined from historic levels. Another study in northern Illinois did not detect the Southern Plains bumble bee in potential habitat at the Midewin National Tallgrass Prairie (Hughes 2018 p. 6).

Oklahoma has historically supported a high relative abundance of the Southern Plains bumble bee where the species represented 15.0% of bumble bees (1900-1949) (Figueroa & Bergey 2015 p. 422). One study of the bumble bee community in Oklahoma found that the Southern Plains bumble bee has declined ~80% to only 3.3% of records (Figueroa & Bergey 2015 p. 422). Records present in Richardson (2021) show a similar magnitude of relative abundance decline in Oklahoma from 12.0% (1881-2010) to 3.0% (2011-2020) for the Southern Plains bumble bee.

Nebraska has some of the best recent bumble bee records because of community science efforts for the Nebraska Bumble Bee Atlas, as well as historic survey efforts (Swenk 1907 pp. 294-297; LaBerge and Webb 1962 pp. 18-20; Golick & Ellis 2006 entire). The available data in Richardson (2021) indicates that the Southern Plains bumble bee may have increased in relative abundance in Nebraska from 2.5% (1881-2010) to 5.9% (2011-2020) (Table 3). However, data from systematic sampling in Nebraska in 2019-2021 show the Southern Plains bumble bee accounted for 3.2% of bumble bees in the state (Xerces Society et al. 2022). This differs from the data from the Nebraska Bumble Boosters Project, a community science inventory conducted 1999-2000, which documented a relative abundance of 0.64% (Richardson 2021).

Historic records (1881-2010) from Missouri indicate that the Southern Plains bumble bee represented 3.8% of observations, while 2011-2020 records show an average relative abundance of 1.3% (Richardson 2021) (Table 3). Like Nebraska, Missouri also has recent systematic sampling for bumble bees conducted by community scientists for the Missouri Bumble Bee Atlas. The results of this survey to date confirm that the Southern Plains bumble bee is rarer than it was historically and show a 1.75% relative abundance (Xerces Society et al. 2022).

Nationwide surveys for bumble bees completed in 2010 and 2019 detected the Southern Plains bumble bee at low levels across its range. The largest nationwide survey for bumble bees was completed by Koch et al. (2015). This survey of 397 locations across the United States surveyed 152 locations within the range of the Southern Plains bumble bee. These surveys found only 16 Southern Plains bumble bees among more than 7,000 specimens (0.2%) (Koch et al. 2015 supplemental data). Another recent, systematic survey for bumble bees was conducted in 2019 by the USGS Native Bee Inventory and Monitoring Lab (BIML) at sites across the country. This nationwide survey of 31 sites including 14 sites within the range of the Southern Plains bumble bee failed to detect any Southern Plains bumble bees despite surveys in seven states within the species range (Strange et al. 2019 supplemental).

Table 3. Average relative abundance of the Southern Plains bumble bee by state. Relative abundance was calculated using the number of unique Southern Plains bumble bee observations divided by the total number of all unique bumble bee observations (including the three most common species). Values represent the average of multiple resampling of state data. Values in parentheses represent 95% confidence intervals of the average relative abundance. Data is from Richardson 2021).

State	1881-2010 Relative Abundance	2011-2020 Relative Abundance
Alabama	9.7% (5.1%-14.3%)	3.6% (0.7%-7.3%)
Arkansas	2.9% (0.4%-5.3%)	3.9% (1.0%-6.8%)
Colorado	1.7% (1.1%-2.3%)	0.9% (0.4%-1.3%)
Florida	6.3% (4.9%-7.8%)	3.3% (2.3%-4.4%)
Georgia	7.4% (5.0%-9.9%)	2.0% (0.6%-3.3%)
Illinois	1.2% (0.9%-1.6%)	0.3% (0.2%-0.5%)
Indiana	2.1% (1.1%-3.1%)	0% (0%-0%)
Iowa	1.9% (0.4%-3.4%)	1.7% (0.2%-3.1%)
Kansas	4.8% (2.9%-6.7%)	6.7% (4.5%-8.9%)
Kentucky	DD	DD
Louisiana	DD	DD
Maryland	0.4% (-0.1%-0.8%)	0% (0%-0%)
Michigan	0.2% (-0.2%-0.5%)	0% (0%-0%)
Mississippi	18.4% (14.6%-22.1%)	6.7% (4.2%-9.1%)
Missouri	3.8% (2.7%-4.9%)	1.3% (0.7%-1.9%)
Nebraska	2.5% (1.7%-3.4%)	5.9% (4.6%-7.1%)
New Jersey	0.1% (0.2%-1.2%)	0% (0%-0%)
New Mexico	4.8% (2.5%-7.2%)	0.3% (-0.3%-0.1%)
North Carolina	11.5% (9.2%-13.7%)	0.9% (0.2%-1.6%)
North Dakota	DD	DD
Ohio	0.5% (-0.2%-1.1%)	0% (0%-0%)

Oklahoma	12.0% (9.9%-14.1%)	3.0% (1.9%-4.2%)
South Carolina	11.1% (6.9%-15.4%)	9.0% (5.1%-12.8%)
South Dakota	2.9% (0.1%-5.1%)	3.4% (0.1%-5.6%)
Tennessee	DD	DD
Texas	11.1% (9.1%-13.2%)	2.4% (1.4%-3.3%)
Virginia	1.4% (-0.2%-3.1%)	0.6% (-0.4%-1.7%)
Wyoming	DD	DD
Entire Range	3.9% (3.6%-4.1%)	1.7% (1.5%-1.8%)

DD=Data Deficient

4.3. Occupancy and Persistence

The Southern Plains bumble bee shows a downward trend in grid cell occupancy over time. Occupancy refers to the proportion of all potential habitat for a species that is currently inhabited. Modeled estimates of occupancy change for Southern Plains bumble bees show that the Southern Plains bumble bee has among the most severe decreases in occupancy among North American bumble bees with an estimate of -42% (Guzman et al. 2021 p. 8). Using Richardson (2021), we measured occupancy for the Southern Plains bumble bee by comparing the number of grid cells with at least one observation of the Southern Plains bumble bee with the total number of grid cells with at least one bumble bee observation of any species. We used 10 km x 10 km grid cells for this analysis,[5] following Szymanski et al. (2016 p. 59). Our analysis showed that the Southern Plains bumble bee has decreased in occupancy over time (Table 4). From 2011 to 2020, the Southern Plains bumble bee occupied about 5.3% of all grid cells with any bumble bee observation, half as much as the occupancy at the beginning of the 20th century and the level in 1991-2000. In the decade 2011-2020, community science has greatly expanded the scope and breadth of bumble bee sampling. Despite this increased search effort, occupancy of the Southern Plains bumble bee remains low.

Table 4. Occupancy of the Southern Plains bumble bee. Data from Richardson (2021).

Period	Total Bumble Bee Occupied Cells	% SPBB Occupancy
1868-1920	710	12.0%
1921-1930	648	9.4%
1931-1940	785	6.6%
1941-1950	627	8.8%

[5] Grid cell analysis was performed using the ConR package (Version 1.3) for R (version 4.1.0) (Dauby et al. 2017).

1951-1960	1033	7.3%
1961-1970	1342	4.7%
1971-1980	1057	5.0%
1981-1990	650	5.8%
1991-2000	710	12.8%
2001-2010	1354	4.9%
2011-2020	8510	5.3%

County occupancy provides another measure of occupancy for the species (Table 5). County representation allows for the inclusion of data points that do not have coordinates, but do have more general state and county information, as is the case with a lot of historic data. We divided the data into historic (1881-2010) and recent (2011-2020) eras. County occupancy is shown as the ratio of the number of counties within a state with Southern Plains bumble bee observations to the number of counties in a state with any bumble bee observation. Historically, the number of counties with at least one bumble bee record (N=1,835) is greater than the number of counties with bumble bee records in the recent era (N=1,765), but overall survey effort is similar in the two time periods. In some states, more counties were sampled from 2011-2020 than were sampled from 1881-2010. Overall, county occupancy has declined by about one-third from 19.1% (1881-2010) to 13.5% (2011-2020). At the state level, declines in county occupancy (Table 5) generally mirror declines in relative abundance (Table 3).

Table 5. Number of counties with Southern Plains bumble bee records by state. Data from Richardson 2021.

State	Historic (1881-2010) Observed / Surveyed Counties	Recent (2011-2020) Observed / Surveyed Counties
Alabama	9/35 (25.7%)	8/53 (15.1%)
Arkansas	5/45 (11.1%)	10/48 (20.8%)
Colorado	20/89 (22.5%)	8/60 (13.3%)
Florida	25/68 (36.8%)	17/63 (27.0%)
Georgia	17/78 (21.8%)	14/89 (15.7%)
Illinois	20/90 (22.2%)	14/89 (15.7%)
Indiana	13/92 (14.1%)	0/68 (0%)
Iowa	4/49 (8.2%)	5/64 (7.8%)
Kansas	27/75 (36.0%)	17/48 (37.5%)
Kentucky	0/28 (0%)*	1/76 (1.3%)
Louisiana	7/28 (25.0%)	2/6 (33.3%)

Maryland	3/30 (10.0%)	0/27 (0%)
Michigan	1/91 (1.1%)	0/83 (0%)
Mississippi	17/39 (43.6%)	12/53 (22.6%)
Missouri	19/89 (21.8%)	18/74 (24.3%)
Nebraska	19/70 (27.1%)	31/55 (56.4%)
New Jersey	4/25 (16.0%)	0/21 (0%)
New Mexico	8/44 (18.2%)	1/28 (3.6%)
North Carolina	28/79 (35.4%)	8/89 (9.0%)
North Dakota	1/40 (2.5%)	0/32 (0%)
Ohio	3/70 (4.3%)	0/87 (0%)
Oklahoma	27/70 (38.6%)	13/62 (21.0%)
South Carolina	12/35 (34.3%)	8/36 (22.2%)
South Dakota	6/57 (10.5%)	4/33 (12.1%)
Tennessee	2/56 (3.6%)	5/76 (6.6%)
Texas	50/234 (21.4%)	37/209 (17.7%)
Virginia	3/106 (2.8%)	4/118 (3.4%)
Wyoming	0/24 (0%)*	1/18 (5.5%)
Overall County Occupancy Rate	350/1835 (19.1%)	239/1765 (13.5%)
Total Occupied States	26	22

*Southern Plains bumble bee was likely present in Wyoming and Kentucky historically, but no preserved specimen records exist from before 2011.

The true proportion of recently occupied counties to historically occupied counties is likely an higher as other county records exist in primary literature that are not included here, as they have no verifiable specimen or photograph. The total number of historically occupied counties is based on data from Richardson (2021), which includes data from physical specimen and photographic records. A systematic literature review for all historic observations was not feasible for this petition.

The persistence of the Southern Plains bumble bee also shows a clear pattern of decline over time (Figure 5). Persistence is a measure of whether a species is recorded in the same area in two time periods. We used random sampling to calculate the average number of counties that had records in an individual decade as well as in the preceding decade. We selected a random sample of Southern Plains bumble bee observations (n=46) based on decade with the smallest number of observations. Within each sample we recorded the number of counties that had an observation each decade that also had an observation in the previous decade. We ran 1,000 bootstrap samples for each decade and calculated a mean number of persistent counties and 95% confidence intervals. Figure 5 shows the average number of counties with repeated Southern Plains bumble bee observations based on random samples. The number of counties with repeated observations decline over time except in the decade 2011-2020, but this is likely due to the large increase in the breadth of sampling that came primarily from community science efforts. Increased survey effort increases the chance of a repeated observation from the preceding decade.

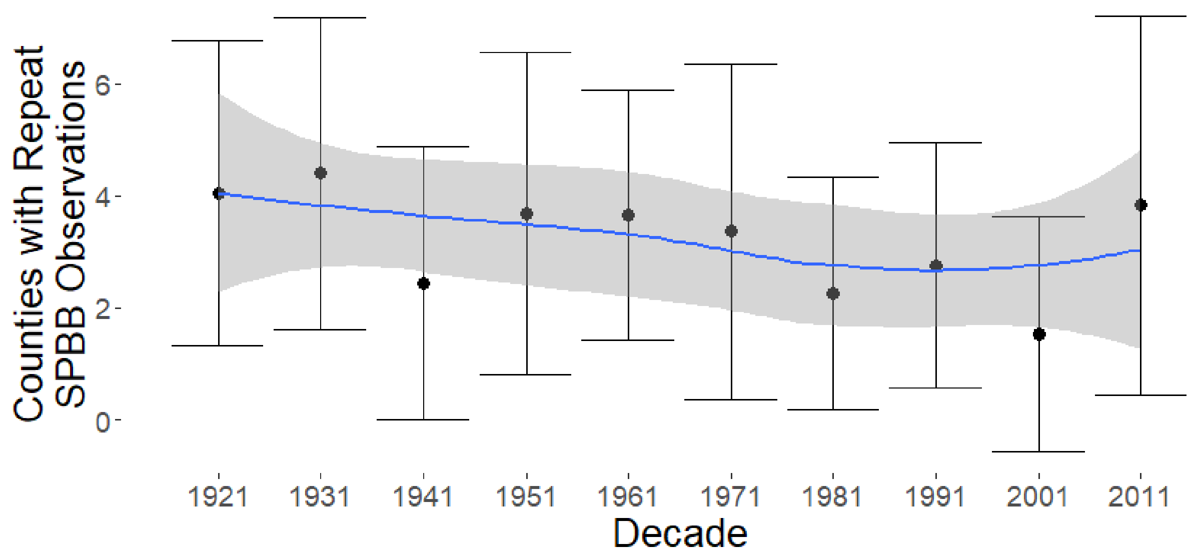


Figure 5. The mean number of counties with repeated Southern Plains bumble bee observations based on equal random samples from each decade. Blue trendline created with 'loess' smoothing. Data is from Richardson 2021.

Additionally, we compared persistence at the county level from the historic period (1881-2010) to the recent period (2011-2020). From 1881-2010, 350 counties had a Southern Plains bumble bee observation and 290 of these counties were resurveyed, meaning that they had at least one observation of any bumble bee between 2011-2020. Of the 290 resurveyed counties, 86 counties had a Southern Plains bumble bee observation from 2011-2020, therefore only 29.7% of resurveyed counties had a repeated Southern Plains bumble bee observation. This percentage of counties with repeated observations may be low because many counties had few total bumble bee observations overall which translates to a low likelihood of observing the Southern Plains bumble bee. Looking instead at the 150 well sampled counties within the species range from 2011-2020 with >100 total bumble bee observations, 39 of these well sampled counties had a historic Southern Plains bumble bee observation, and of these 21 counties had an observation from 1881-2010 and an observation from 2011-2020. Therefore, the county persistence rate of the Southern Plains bumble bee in well sampled counties is 53.8%. For comparison, 74.6% of the best sampled counties from 2011-2020 had a repeated observation of the relatively less common black and gold bee (*Bombus auricomus*) that inhabits a similar range but is not known to have declined.

A county persistence rate between 30 and 50% is similar to previous work. Several researchers have previously calculated persistence using observed occupancy and found it to generally be low. The IUCN assessment compared the historic and recent persistence of the Southern Plains bumble bee and found that the bee persisted across only 43.3% of 50 km x 50 km grid cells (Hatfield et al. 2014 p. 4). Colla et al. (2012) measured this species persistence at 27.3% also using 50km x 50km grid cells (Colla et al. 2012 p. 3590).

4.4. Summary

All methods of analysis, including our independent analysis and published literature, investigating distribution, relative abundance (a proxy for population stability), and occupancy/ persistence show consistent patterns of decline for the Southern Plains bumble bee. These data confirm that the Southern Plains bumble bee is in decline, and at risk from extinction without further protection as warranted by the ESA. Below we present a summary table of the range wide analyses for this species (Table 6).

Table 6. Status summary of for the Southern Plains bumble bee.

Distribution (EOO)	24% decline
Relative Abundance (Range wide)	56% decline
Persistence (Percent of nonpersisting counties)	46%
Occupancy (Guzman et al. 2021 p. 8)	42% decline
Average Decline	**42%**

5. Warranted ESA Protection

The ESA is a "comprehensive scheme with the 'broad purpose' of protecting endangered and threatened species." Ctr. for Biological Diversity v. U.S. Bureau of Land Mgmt., 698 F.3d 1101, 1106 (9th Cir. 2012) (quoting Babbitt v. Sweet Home, 515 U.S. 687, 698 (1995)). Congress' plain intent in enacting the ESA was "to halt and reverse the trend toward species extinction." Tenn. Valley Auth. v. Hill, 437 U.S. 153, 184 (1978). In pursuit of this purpose, the ESA requires that "all Federal departments and agencies shall seek to conserve endangered species and threatened species and shall utilize their authorities in furtherance of [these] purposes." 16 U.S.C. § 1531(c)(1) (emphasis added). Endangered and threatened species are "afforded the highest of priorities" Tenn. Valley Auth., 437 U.S. at 174. "Endangered species" are species that are "in danger of extinction throughout all or a significant portion of its range," and "threatened species" are species that are "likely to become endangered species within the foreseeable future" throughout all or a significant portion of range. 16 U.S.C. § 1532(6), (20). The ESA states that a species shall be determined to be endangered or threatened based on any one of five factors: 1) the present or threatened destruction, modification, or curtailment of its habitat or range; 2) overutilization for commercial, recreational, scientific, or educational purposes; 3) disease or predation; 4) the inadequacy of existing regulatory mechanisms; and 5) other natural or manmade factors affecting its continued existence. Id. § 1533(a)(1).

The Southern Plains bumble bee warrants protection under the ESA. The Southern Plains bumble bee declines documented here are driven by listing factors one, three, four and five. No one threat can be identified as a sole direct causal factor in this decline; rather, the best available science indicates that it is driven by a combination of multiple, concurrent, and interacting threats, including intensive agriculture, pesticide contamination, pathogen spillover, small population dynamics, and climate change. Land conversion to intensive agriculture and other uses that deplete and degrade wild flowering plants has reduced the quantity and quality of habitat throughout the historic range of this species. Likewise, pesticide use on agricultural land harms bumble bees directly by exposure to these poisons and indirectly by removing floral resources (weeds), degrading habitat and weakening bumble bee immune systems (Goulson et al. 2015 p. 6). Insecticides like neonicotinoids are highly toxic to bumble bees but are sparsely regulated, particularly in their extensive use as seed treatments where they are deployed across millions of acres of land that once supported the Southern Plains bumble bee. These factors and others have reduced the populations of an already uncommon species. The Southern Plains bumble bee, as a member of the family Hymenoptera, has a unique method of sex determination that makes declining and fragmented populations vulnerable to rapidly spiraling into an extinction vortex (See Section 6.5.1). The Southern Plains bumble bee needs ESA protection now to coordinate effective conservation efforts to mitigate the interacting factors threatening the survival of this species.

6. Current and Potential Threats

Under the ESA, a species must be listed if it is threatened or endangered because of any of the following 5 factors:

1. present or threatened destruction, modification, or curtailment of its habitat or range;
2. over-utilization of the species for commercial, recreational, scientific, or educational purposes;
3. disease or predation;
4. inadequacy of existing regulatory mechanisms; and
5. other natural or manmade factors affecting its continued existence.

6.1. Habitat Loss and Degradation

Landscape changes that destroy or adversely modify the presence of diverse flora, nesting, and overwintering sites are detrimental to the survival of the Southern Plains bumble bee. Habitat loss is the number one driver of insect declines worldwide (Sánchez-Bayo & Wyckhuys 2019 p. 19). The Southern Plains bumble bee has lost habitat through the destruction, fragmentation, and modification of habitat by intensive agriculture, widespread pesticide use, and disturbance regimes that limit access to floral resources, lower floral richness, and limit nesting sites across its range (Darvill et al. 2006 pp. 608–609; Grixti et al. 2009 p. 81; Goulson 2010 pp. 181–186).

The bee's habitat faces multiple, ongoing threats. The Southern Plains bumble bee inhabits perennial grassland[6] and open woodland that consists of a diversity of native flowering species. Bumble bees require habitat that contains a diverse floral community with nectar and pollen available during the entire growing season (see Section 3.4), as well as suitable nesting and overwintering habitat in reasonable proximity to the foraging habitat. However, perennial grasslands face multiple threats and are among the least protected and most impacted of all biomes where habitat conversion exceeds habitat protection by a factor of 10 to 1 (Hoekstra et al. 2005 p. 25). Native prairie ecosystems have declined by up to 99.9% (Samson & Knopf 1994 p. 418; Noss et al. 1996 Appendix A and B). Native, biodiversity-rich grasslands that are not destroyed completely often have altered plant composition due to introduced grasses, grazing by non-native ungulates, and invasive plants that lower habitat quality for bumble bees (Goulson 2010 pp. 181-183). Urban land expansion is also expected to more than double in area by 2050 (Nowak & Walton 2005 p. 385; Huang et al. 2019 p. 3) and is a threat to grassland and prairie when farmland or semi-natural areas are replaced with roads or other uses that diminish remaining floral and nesting resources. Along with the loss of native plant life, the >98% decline of the black-tailed prairie dog (Cassola 2016 p. 4) across the Great Plains has potentially resulted in the loss of nesting habitat for the Southern Plains bumble bee that relies on preexisting rodent burrows (Williams et al. 2014 p. 129).

Human-caused disturbance can decrease native floral diversity and likely decrease nesting habitat throughout the Southern Plains bumble bee's range. The Southern Plains bumble bee requires forage and adequate nesting and overwintering habitat during its entire lifecycle to survive and successfully reproduce. New bumble bee queens that are pollen or nectar limited after emerging from the natal colony gain less weight and are less likely to survive hibernation and for the first two weeks after hibernation (Woodard et al. 2019 p. 6-7). Food limitation also reduces the number of males produced (Rotheray et al. 2017 p. 18).

Fragmentation of nesting and floral resources by human-caused disturbances impacts bumble bee abundance and species richness across a landscape (Hines and Hendrix 2005 p. 1481). Habitat fragmentation creates isolated patches of suitable habitat surrounded by large areas of unsuitable habitat that constrain bumble bee colonies (Darvill et al. 2006 pp. 608-609).

---

[6] Perennial grassland refers to all open land (non-forested pastureland and rangeland) that is not used for row crops regardless of its species composition. Data cited here refers to the NRCS Natural Resource Inventory which quantifies "pastureland" and "rangeland". "Pastureland" refers to land managed primarily for the production of introduced forage plants for livestock grazing (USDA 2018 p. 4-1). "Rangeland" refers to land on which the climax or potential plant cover is composed principally of native grasses, grass-like plants, forbs or shrubs suitable for grazing and browsing, and introduced forage species that are managed like rangeland (USDA 2018a p. 3-2).

Thus, in fragmented landscapes bumble bees could struggle to utilize isolated feeding and nesting areas which would negatively impact their population dynamics.

Current land use trends threaten remaining perennial grasslands that are vital for supporting the Southern Plains bumble bee. Perennial grassland is being lost for a variety of factors including forest encroachment, urbanization, conversion to row crops, and unsustainable livestock grazing. The USDA's 2018 Natural Resource Inventory shows that from 1982-2015 pastureland and rangeland acres across the entire country decreased while forestland and developed land increased (USDA 2018a pp. 3–3). Over this same period, Southern Great Plains states like Kansas, New Mexico, Oklahoma, and Texas have lost a total of 4.7 million acres of potential rangeland habitat for the Southern Plains bumble bee (USDA 2018a Table 2). The Midwest lost as much as 30% of its perennial grasslands and states in the Southeast like Florida, Louisiana, and Mississippi have lost 12-42% of their perennial grasslands (USDA 2018a Table 2). Southern Great Plains states have also increased their pastureland over the past few decades (USDA 2018a Table 2). Pastureland is less valuable to bumble bees because it is often seeded with a limited number of non-native grasses, experiences degradation from non-native ungulates including trampling of potential nest sites, and is less florally rich than other grasslands, especially compared to unplowed prairie (Goulson 2010 pp. 181-183).

In addition to losing grassland acreage, the quality of millions of acres of grassland have declined. According to a 2015 NRCS report of rangeland conditions on non-federal land, from 2011-2015 the amount of land with at least a moderate level of departure from reference conditions increased to 25.8% of non-federal rangeland which is an accelerated increase from 2004-2010 (USDA 2018b pp. 4-5). The Southern Great Plains has the greatest concentration of rangeland with at least moderate departure from reference conditions (Figure 6). Rangelands in New Mexico and Texas are also some of the most degraded with 63.7% of rangeland in New Mexico and 41.7% of rangelands in Texas showing at least moderate departure from reference conditions under any metric (USDA 2018b Table 2). These departures from the reference condition are associated with various factors, including invasive species, management, and climate change. Chronic, high-intensity grazing is also a major cause of rangeland degradation in Texas and other states, which may account for the recent departures from reference conditions (Ansley and Hart 2012 p. 1, Murray et al. 2021 p. 1).

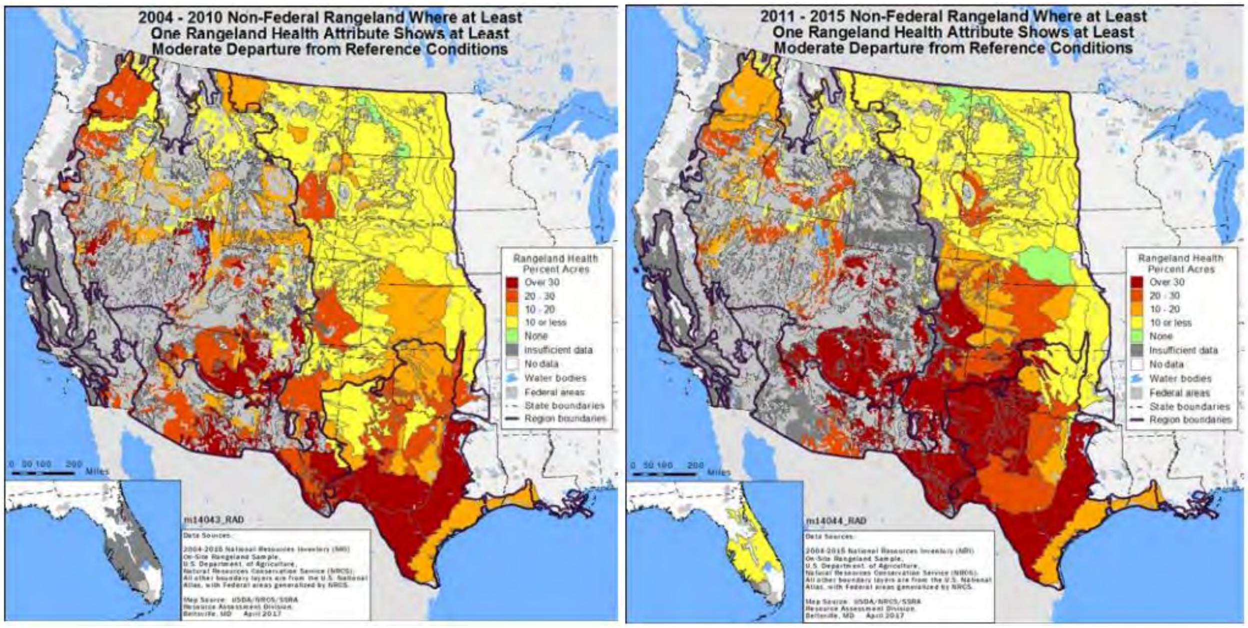


Figure 6. Non-federal rangeland where at least one rangeland health attribute shows at least moderate departure from reference conditions. Figure taken from USDA Non-Federal Rangeland Report (USDA 2018b p. 5).

6.1.1. Agricultural Intensification

Modern, intensive agriculture has accelerated the fragmentation and degradation of habitat for bumble bees (Schweitzer et al. 2012 pp. 7–8). Agriculture continues to expand and intensify as many farmers in the Great Plains continue to plow prairie and grassland at a rate of four football fields per minute to expand the production of industrial operations for corn, soy, wheat (World Wildlife Fund 2020 p. 1; Lark et al. 2020 p. 3). The transition to modern, intensive agriculture has led to vast monoculture crop systems in larger fields that rely on much higher inputs of fertilizer and pesticides (Goulson 2020 p. 1) which destroy and degrade field margin habitat that bumble bees rely on for food and nesting (Hines & Hendrix 2005 p. 1483).

Agricultural land-use that destroys or degrades florally-diverse native perennial grassland has likely contributed to the decline of the Southern Plains bumble bee. In Illinois, changes in agricultural practices and continued expansion that occurred from the 1950s and onward have contributed to broad declines in bumble bee richness and a decline of the Southern Plains bumble bee (Grixti et al. 2009 p. 81). The Southern Great Plains and Southeast have large agricultural areas, the expansion and intensification of which could similarly destroy and degrade habitat for the Southern Plains bumble bee.

Intensively managed agricultural areas that produce monocultures of a small number of crop species may be unattractive to bumble bees (Wheelock et al. 2016 p. 1102). Bumble bees do better in agricultural regions that have greater crop diversity with less corn and soy cropland (Quinlan et al. 2021 p. 6; Hemberger et al. 2021 p. 4). Common bumble bees rely on the grassy strips at field boundaries, forest edges, and along roadsides (Hines and Hendrix 2005 p. 1483).

Many agricultural landscapes have become simplified over time as a result of larger fields, decreased edge, and fewer crop types which reduces the available floral resources and has been shown to reduce the size of foraging bumble bees which possibly decreases colony productivity (Persson & Smith 2011 p. 699) because smaller bees fly shorter distances and for less time per foraging trip (Kenna et al. 2021 p. 7). Simplified cropland ecosystems also tend to show increases in the amount of pesticides used (Meehan et al. 2011 p. 2). The subsequent loss of edge habitat near crop fields and roads has removed valuable habitat for bumble bees because we know that recreating habitat lost to development and industrial agriculture with hedgerows, roadside plantings, and wildflower strips provides beneficial habitat for bumble bees (Kleijn et al. 2015 p. 4).

6.1.2. Pesticides

Pesticide use is a significant threat to the Southern Plains bumble bee. Legal insecticide use can kill individuals outright as well as lead to sublethal effects that could have populations level harms. New studies continue to emerge about the how fungicides harm invertebrates. Herbicide use also causes indirect effects such as habitat degradation. Pesticides in general affect bumble bees that forage, nest, or overwinter in and around agricultural lands, landscaped areas like homes and parks, treated forests and rangelands, along roadsides and other rights of way, and a wide array of other areas. Pesticide is a major contributor to the decline of bumble bee populations across North America and Europe (Goulson et al. 2008 pp. 194–195; Cameron & Sadd 2020 p. 2).

Bumble bee exposure to pesticides occurs in a variety of ways including: direct contact with spray drift, orally when residues are present in nectar or pollen, and through contact with contaminated soil (Fischer & Moriarty 2014 pp. 53–54). Nectar uptake is likely the main source of exposure and poses the largest threat because bumble bees consume large quantities of nectar and pesticides can accumulate in high concentrations in nectar (Goulson et al. 2008 p. 194). Bumble bees are also exposed to pesticides via the soil from treated seeds and over-the-top applications that contaminate bumble bee underground nests and overwintering sites (Hopwood et al. 2016 pp. 14–15). Pesticide exposure can also occur through water sources on and around plants that bees rely on during foraging (Lu et al. 2020 p. 4). Pesticide exposure during spring planting can be especially harmful because foundress queens are the only bumble bees active at this time, and pesticide exposure to queens has a disproportionate impact on whole-colony reproduction and population persistence (Goulson et al. 2008 p. 194; Stoner 2016 pp. 4-5).

The use of pesticides in agricultural and urban settings exposes bumble bees to a pesticide "cocktail" including fungicides, herbicides, and insecticides. The EPA does not study, consider or analyze the impacts of pesticide mixtures and potential synergistic effects in its pesticide regulatory process, but independent studies have shown that pesticide mixtures can create more potent toxic effects (Goulson et al. 2015 p. 1). These chemical cocktails of up to 39 pesticides were found to contaminate pollen, wax, brood, and adult honey bees (Mullin et al. 2010 p. 3) and as many as 60% of bumble bees have detectable levels of at least one pesticide

(Botías et al. 2017 p. 7). There is still much to be learned about pesticide synergistic effects, but we know that the combination of pesticides can have a range of effects at low realistic doses (Almasri et al. 2020 p. 6). As an example, we know that when commonly used ergosterol biosynthesis inhibitor fungicides are mixed with other commonly used neonicotinoids and pyrethroids, the toxicity of the mix is increased 1,000-fold (Goulson et al. 2015 p. 6). These mixtures are ubiquitous throughout managed landscapes in the U.S.

Unlike in Europe, where governments are aiming for aggressive pesticide reduction targets, there is no concerted effort to decrease pesticide use in the U.S., and, as pests develop resistance to specific chemicals, increasing numbers of pesticides are incorporated. Disturbingly, newer pesticides such as the neonicotinoids are also often more persistent in the environment than previous organophosphates and carbamates, resulting in an increasing toxic load on the environment (Dibartolomeis et al. 2019 pp. 3,11). Modern agriculture relies heavily on synthetic pesticides and will likely continue doing so into the future. Although there has been an overall drop in the pounds of pesticide applied over the past several decades (Fernandez-Cornejo et al. 2014 p. 11), the toxicity of pesticide residues to plants and invertebrates has increased (Schulz et al. 2021 p. 2). A recent county-level analysis showed that decreases in application rate of pesticides was outmatched by a larger increase in the toxicity to honey bees (Douglas et al. 2020 p. 3). Agricultural areas of the Southern Great Plains now have much as four times the toxic load to honey bees as they did in the year 2000 (Douglas et al. 2020 p. 6). Increasing potency of toxic insecticides in the environment poses a significant threat to Southern Plains bumble bees.

Herbicides

The extensive use of herbicides to remove unwanted grass and broadleaf plants has removed floral resources from the landscape that are vital for the Southern Plains bumble bee. Herbicides are routinely used across millions of acres of cropland, rangeland, and pastureland throughout the range of the species (DiTomaso 2000 p. 10). Cropland use likely represents the largest amount of herbicide application within the species range, and the use of herbicides on rangelands, hay fields, and pasturelands is also substantial. Overall, herbicide use can degrade the habitat quality of treated lands for the Southern Plains bumble bee and new evidence suggests that some mixtures of herbicides can be directly toxic to bumble bees (Straw et al. 2021 p. 6).

Changes in farming techniques over the past 80 years for the cultivation of large monoculture cropping systems has dramatically increased reliance on herbicides and contributed to the loss of florally diverse field margins and weedy annual plants (Goulson 2019 p. 3) that the Southern Plains bumble bee relies upon for energy and nutrients. The extensive and intensive use of herbicides became common practice in row-crop agriculture over the decades from the 1950's to the 1980's, when greater than 90% of corn and soybean fields were treated with herbicides (Fernandez-Cornejo et al. 2014 p. 13). Since the 1980's, the adoption of corn and soy varieties genetically engineered to withstand the application of one or even multiple common herbicides such as glyphosate and dicamba has brought another wave of increased herbicide use. Between

1995 and 2019, total glyphosate use on just corn and soybeans rose from 10 million to greater than 200 million pounds per year—a 20-fold increase (Figure 7). By 2020, genetically-engineered, herbicide-resistant varieties comprised 94 percent of soybeans,79 percent of corn, and 83 percent cotton grown in the United States (USDA 2020 entire). The increased use of herbicides, in combination with increased field size, destroyed valuable plant diversity along field margins that is absolutely necessary to sustain animal populations that need nectar and pollen throughout the year (Kleijn et al. 2015 p. 4).

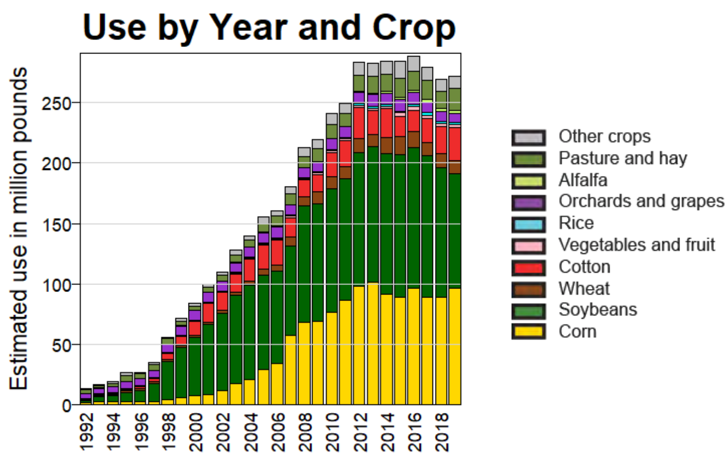


Figure 7. Estimated glyphosate use across the United States. Data and figure from USGS National Pesticide Synthesis Project.

The previous two decades have seen record and near-record lows for Southern Plains bumble bee relative abundance (Figure 3) while also seeing a massive increase in the amount of herbicide applied across the country (Figure 7) (USGS 2017 p. 3). The increase in herbicide use has been driven by the widespread planting of varieties of corn, soybean, and other crops with genetically engineered resistance to multiple herbicides, including glyphosate, 2,4-D, and dicamba (Malcolm 2018 p. 282). Two decades of increasing herbicide usage and the nearly ubiquitous adoption of herbicide-resistant corn and soybeans, there has been a precipitous decline of common milkweed (Pleasants & Oberhauser 2013 p. 136) and many other flowering weeds. Milkweeds are particularly important to the Southern Plains bumble bee. Analysis of the floral associations across all Southern Plains bumble bee records revealed that milkweed is tied with *Helianthus sp.* as the Southern Plains bumble bee's most visited plant, accounting for 14% of all visits (Richardson 2022 unpublished data). Removing this plant from the landscape depletes a vital foraging resource for the Southern Plains bumble bee.

Newer herbicide-resistant crops that are genetically engineered to be resistant to multiple herbicides including such as 2,4-D, dicamba, or glufosinate continue the large-scale use of herbicides in agricultural lands. Dicamba is notoriously drift-prone, moving far beyond the boundaries of crop fields to affect wild plants growing nearby (Knuffman et al. 2020 p. 8-9). The scale of off-target movement of dicamba has the potential to degrade habitat on a level that has not been seen since glyphosate use began to explode nearly 30 years ago. In the year 2021, the

EPA recorded nearly 3,500 incidents of the off-target movement of dicamba that harmed crops and ornamental plants as well as drifted into state parks and wildlife refuges (USEPA 2021d p. 5). This staggering number of incidents included 290 incidents that could have resulted in harm to endangered species and critical habitat (USEPA 2021d p. 5). Reports continue to roll in about widespread dicamba drift damage incidents for summer 2022, but the reports are not yet compiled. Drift-level rates of dicamba were found to reduce flowering of multiple plants, a reduction that coincides with reduced visitation by pollinators (Bohnenblust et al. 2016 p. 147) and dicamba levels far below those estimated to be contained in particle and vapor drift are known to reduce plant diversity (Egan et al. 2014 p. 80). Plants that exist in the margins between agricultural fields are some of the only sources of biodiversity in the sea of crop monocultures that extend across much of the Great Plains. The Southern Plains bumble bee is threatened by its environment being sterilized of plants that are vital to its survival.

Fungicides

Many commonly used fungicides cause serious sublethal harm to the Southern Plains bumble bee. Fungicides are commonly used in agricultural settings and have been found in the great majority (88%) of bumble bees in a farmland survey (Botias et al. 2017 p. 7). Colonies exposed to fungicides like chlorothalonil produce smaller reproductive females (Bernauer et al. 2015 p. 481). Fungicides also interfere with a bee's microbiome and cellular processes which impact their overall health and immune system and increase the disease risk from the microsporidian *Nosema spp*. (Pettis et al. 2013 p. 4). Chlorothalonil usage was the strongest predictor of *Nosema* infection among declining bumble bees in the United States (McArt et al. 2017 p. 6). Chlorothalonil and triazole fungicides inhibit compounds and enzymes in honey bees that detoxify compounds within the cell and downregulate genes involved in producing energy in the mitochondria (Mao et al. 2017 p. 5). These fungicides reduce a bee's ability to extract energy from pollen and nectar and reduce the ability to detoxify its body resulting in a build-up of toxic compounds that weaken the bee (Mao et al. 2017 p. 5) making them more susceptible to infection.

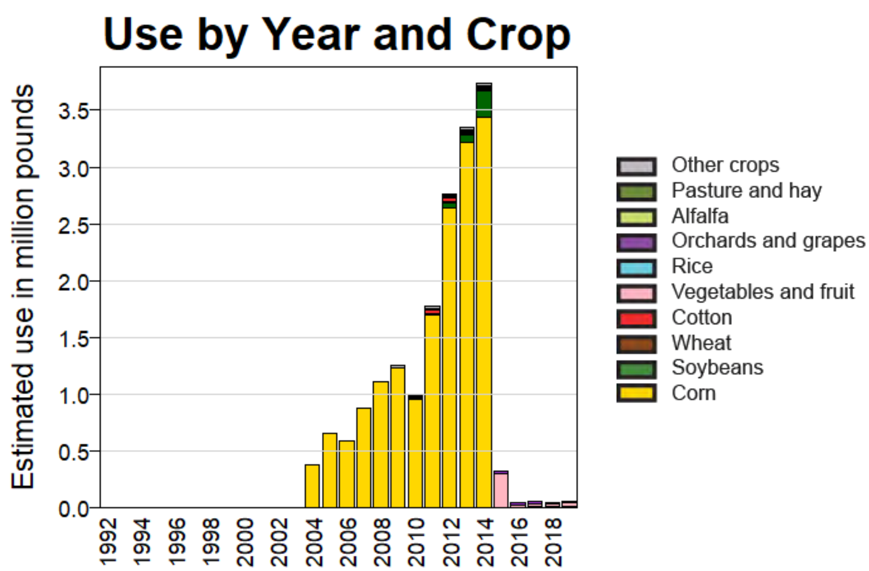
While fungicides are not generally acutely toxic to bumble bees, mixtures of fungicides and certain pyrethroids and neonicotinoids are known to have acute synergistic effects (Pilling & Jepson 1993 p. 296; Raimets et al. 2018 p. 543) by greatly increasing the toxicity of the insecticide. Colonies of the common eastern bumble bee exposed to fungicides like chlorothalonil produce smaller reproductive females (Bernauer et al. 2015 p. 481) and we expect similar impacts to the survival of the next generation for the Southern Plains bumble bee. Even when fungicides are sprayed prior to bloom, the nectar and pollen of flowering crops like almonds have reduced fungal richness which can have consequences for the natural fermentation of pollen provisions—"bee bread"—including increasing fungal infections like chalk brood in honey bees (Yoder et al. 2013 p. 596).

Insecticides

Insecticides threaten the Southern Plains bumble bee because they are acutely toxic to invertebrates and many persist in the environment for years, resulting in chronic exposure. A toxic legacy of numerous insecticidal compounds likely contributed to the decline of the Southern Plains bumble bee over the past 50 years. Organochlorines, carbamates, pyrethroids, organophosphates, neonicotinoids, and other insecticide groups became commonly used on farmland over this time-period which directly and indirectly poisoned insects (Goulson et al. 2015 p. 1). While the total number of pounds of insecticide has declined over the past several decades (Fernandez-Cornejo et al. 2014 p. 11), the toxicity of the insecticides to invertebrates including pollinators has consistently increased (Schulz et al. 2021 p. 2). Therefore, the total toxic load on the environment and on the Southern Plains bumble bee has continued to increase over its multiple decade decline (DiBartolomeis et al. 2019 pp. 10–12) (Figure 8).

The most commonly used class of insecticides in America today, the neonicotinoids (Simon-Delso et al. 2015 pp. 8–11), are a group of synthetically produced, systemic pesticides that are strongly implicated in bumble bee declines (Goulson et al. 2015 p. 5). Neonicotinoids are highly toxic to bumble bees. One neonicotinoid, sulfoxaflor, is eight times more toxic to the common eastern bumble bee than to the honey bee and the neonicotinoid thiamethoxam is three times more toxic to bumble bees (Mundy-Heisz 2022 p. 9). EPA's recent Biological Evaluation of three neonicotinoids found them "likely to adversely affect" the rusty patched bumble bee, nearly all ESA listed insects, and overall about 80% of ESA protected species for imidacloprid, 77% for thiamethoxam, and 67% for clothianidin (USEPA 2021a pp. 3–4, 2021b pp. 3–4, 2021c pp. 3–4). Neonicotinoids are strongly implicated in the decline of the rusty-patched bumble bee which also declined severely in the mid-to-late 1990s as the use of these chemicals rapidly increased (Szymanski et al. 2016 p. 47) (Figure 8). Just like the rusty-patched bumble bee, the exponential increase in neonicotinoid usage also coincides with two decades of low relative abundance for the Southern Plains bumble bee.

A



B

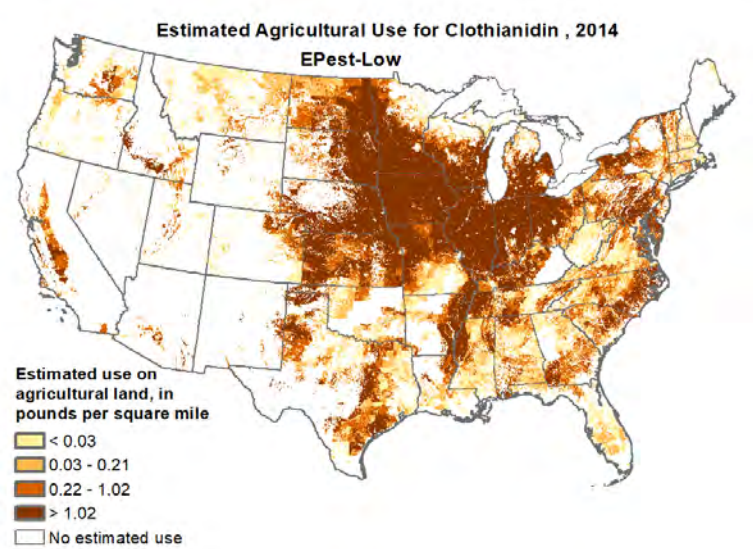


Figure 8. Estimated clothianidin use across the United States. (A) Pounds of clothianidin by crop per year. (B) Estimated agricultural use of clothianidin across the US. Data from USGS National Pesticide Synthesis Project. Note: data for years after 2014 do not include seed treatment use, which accounts for nearly all clothianidin application.

Neonicotinoids present a toxic problem now and for the future of the Southern Plains bumble bee. Since 2009, more than 90% of neonicotinoid literature has shown lethal and sublethal toxicity to bees associated with exposure to neonicotinoids (Lu et al. 2020 p. 12).

Neonicotinoids are used on at least 140 different crops (Simon-Delso et al. 2015 p. 8) on over half of the cropland in the United States (DiBartolomeis et al. 2019 p. 7) including throughout the species' range. By far the largest use of neonicotinoids is as seed treatments which are known to persist in soil and contaminate crop blooms and field margin plants (Lu et al. 2020 p. 12-13). The contamination of field margin soils and plants with neonicotinoids correlates with lower bee species richness overall (Main et al. 2020 p. 7). Neonicotinoids are often applied to seeds and sold to farmers at a premium for prophylactic protection despite studies showing a lack of clear economic benefit (Meyers & Hill 2014 pp. 1–2; Krupke et al. 2017 p. 145).

Neonicotinoid insecticides adversely affect all members of a bumble bee colony, especially reproductive members. At sublethal levels, neonicotinoids impair reproduction. For example, thiamethoxam impairs ovary development in bumble bees (Baron et al. 2017 p. 4) and impairs sperm viability in bumble bees (Minnameyer et al. 2021 pp. 20–21). Imidacloprid causes reductions in both reproductive success and production/survival of reproductive females (Whitehorn et al. 2012 pp. 1–2; Wu-Smart & Spivak 2018 pp. 4–5; Raine 2018 p. 1). In addition to reproductive consequences, neonicotinoids impair normal functioning of colonies making them less able to learn and remember (Siviter et al. 2018 p. 5), disrupt circadian rhythm and sleep (Kiah et al. 2021 pp. 7–9), can reduce their foraging motivation (Lämsä et al. 2018 p. 4), and reduce foraging efficiency (Feltham et al. 2014 p. 9; Siviter et al. 2021 p. 3). Impacts to workers reduce the foraging potential of the colony so that it cannot produce as many reproductive females which can result in significant reductions in their populations.

The Southern Plains bumble bee inhabits open farmland and fields (Williams et al. 2014 p. 129) across the Great Plains and the Southeast that are increasingly contaminated with pesticides. Two of the decades with fewest observations of the Southern Plains bumble bee over the past 100+ years occurred in the past twenty years, coinciding with the rise of neonicotinoids and herbicide resistant crops. The combination of decreased plant diversity and the hazards of fungicides and insecticides make agricultural areas increasingly inhospitable to the Southern Plains bumble bee. Without strong mitigations and restrictions on their use, neonicotinoids and other highly problematic pesticides are likely to continue to harm this species well into the future.

6.1.3. Invasive Plant Species Encroachment

Invasive plants threaten Southern Plains bumble bee throughout its range. Invasive woody vegetation and introduced weeds, often have adverse effects on native plant communities (DiTomaso 2000 p. 2, Gaskin et al. 2021 pp. 1-2) which can reduce forage quality for bumble bees (see below).

Tree and shrub encroachment in the Great Plains

Due to fire suppression and overgrazing (which reduces fine fuels needed for fire), millions of acres of grasslands in the Southern Great Plains have become woodlands and forests dominated by one or more *Juniperus sp.* and honey mesquite (*Prosopsis glandulosa*) (Gaskin et al. 2021 pp. 2-3). In the Central Great Plains, *Juniperus virginiana* (eastern redcedar) is the primary invasive tree, and as in the Southern Great Plains, its proliferation is resulting in the conversion of large areas of grassland into woodland and forest (Gaskin et al. 2021 p. 2). Similarly, the spread of *Lespedeza cuneata*, an exotic, leguminous subshrub/forb growing only 1-1.5 meters tall, can become a monoculture or near monoculture. These dominant invasive species reduce the diversity and abundance of native forbs that are essential forage for Southern Plains bumble bee.

Invasive grass encroachment

Encroachment of invasive cool-season grasses, primarily Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*) in the Northern and Central Great Plains is a significant issue that leads to loss of plant (graminoid and forb) diversity on rangeland (DeKeyser et al. 2015 p. 257, Grant et al. 2020 p. 4) and, ultimately, habitat degradation for rangeland wildlife (Kral-O'Brien et al. 2019 p. 307). Kentucky bluegrass invasion can lead to reduced forb species richness and butterfly community simplification, showing that this problematic invasive grass has impacts on pollinator communities (Kral-O'Brien et al. 2019 p. 307). Both grasses can also increase on rangelands that are repeatedly grazed at high to moderate levels (Toledo et al. 2014 p. 545). Because Kentucky bluegrass and smooth brome grow earlier in the spring than native cool-season grasses and can rapidly spread through vegetative reproduction, they can thrive under a variety of management techniques (Cully et al. 2003 p. 996, Prosser et al. 2003 p. 669, Kral-O'Brien et al. 2019 p. 302).

In the Southern Great Plains and Southeast, invasive warm-season grasses appear likely to be more of a threat to Southern Plains bumble bee than are invasive cool-season grasses. Two of the most problematic species are King Ranch bluestem (*Bothriochloa ischaemum*) and cogongrass (*Imperata cylindrica*). King Ranch bluestem has become very common in the Southern Great Plains, particularly in Texas, and can outcompete most native plant species. This reduces flowering plant diversity (Gabbard and Fowler 2007 p. 7), which in turn is likely to reduce nectar and pollen availability for the Southern Plains bumble bee. In the southeast, cogongrass has become highly problematic where it too can outcompete native plant species (Dozier et al 1998 p. 740), and in doing so, likely reduces nectar and pollen availability.

6.1.4. Exploitative Livestock Management Practices

Ruminant Grazing

Livestock graze large areas within the range of the Southern Plains bumble bee, which can reduce the habitat quality for pollinators (Kearns and Inouye 1997 p. 305; Black et al. 2011 p. 10), lead to soil erosion, loss of biologic integrity, promote invasive species, and generally degrade grasslands (Fleischner 1994 p. 631; Belsky et al. 1999 entire). Although the severity of the impacts of grazing on the Southern Plains bumble bee is unclear, there is ample evidence that chronic, high-intensity grazing reduces abundance and diversity of many pollinating insects (e.g. Vavra et al. 2007 pp. 67-68; Hanula et al. 2016 p. 432; Lazaro et al. 2016 p. 408).

The impacts of grazing vary significantly across ecosystems and across years. Habitat in the arid parts of the species range in west Texas and New Mexico is likely more sensitive to grazing pressure (Belsky et al. 1999 p. 2, Schieltz and Rubenstein 2016 p. 12). In general, domestic grazing animals can harm bumble bees by trampling soil, removing floral resources, and altering plant community composition which can lead to a linear decline in bee abundance and species richness (Yoshihara et al. 2008 p. 2384; Tadey 2015 p. 455; Lázaro et al. 2016 p. 408).

Chronic, high-intensity grazing, especially during the spring and summer, reduces the amount of floral resources and degrades grassland habitat for bumble bees (Goulson 2010 pp. 210–211). In addition, grazing animals cause soil compaction which negatively affects a bumble bee's ability to find shelter in abandoned rodent holes or develop new nest sites that are not at risk of being trampled (Black et al. 2011 p. 10; Kimoto et al. 2012 p. p.7-8; Bueno et al. 2012 pp. 5–6).

Haying

Farmers and land managers across the species range often hay their grasslands and pastures which can pose risks to bumble bees by abruptly removing flowers at a site (Black et al. 2011 pp. 10-11). Haying when plant nutrient levels are at their peak—which is typically in mid-summer—risks the loss of all nectar and pollen sources, potentially interrupting colony growth. Many farmers cut multiple hay crops per year, which compounds the harm to floral resources and surface nests (Williams & Osborne 2009 p. 372), and multiple cuttings year after year can cause nutrient depletion, reducing grassland health over the long term.

Non-native honey bees

The honey bee (*Apis mellifera*) can harm bumble bees through direct competition for floral resources (Mallinger et al. 2017 pp. 24–25). Honey bee colonies are classified as managed livestock and can outcompete wild bees because they support more individual bees than any other social bee and are able to outcompete native bees for nectar and pollen resources on the landscape because they can recruit nest mates to floral resources (Cane & Tepedino 2016 p. 206). Honey bees are known to exploit the most abundant floral patches which may drive wild bees to less abundant areas to decrease competition (Hung et al. 2019 p. 4). A single honey bee colony can consume 44lbs (20kg) of pollen and nectar over the course of a foraging season (Cane & Tepedino 2016 p. 206). A small 40-hive commercial apiary removes enough nectar and pollen in three months equivalent to that needed to rear 4,000,000 solitary bee larvae (Cane & Tepedino 2016 p. 207). We estimate the same pollen could support as many as 20,000 bumble bee colonies.

Honey bee competition leads to many knock-on effects affects to native bees by depleting pollen and nectar (Torné-Noguera et al. 2016 p. 14), reducing fecundity (Paini & Roberts 2005 pp. 107–108), enhancing parasitism (Goodell 2003 p. 13), floral host preemption (Roubik & Villanueva-Gutiérrez 2009 p. 156), reducing foraging success (Henry & Rodet 2018 p. 2), and pathogen spillover (Fürst et al. 2014 pp. 3–4; Burnham et al. 2021 pp. 5-6; Colla et al. 2006 p. 461). There is ample evidence that honey bees transmit multiple diseases to wild bumble bees (see section 6.3).

The Southern Plains bumble bee inhabits many natural, semi-natural, and developed lands where honey bees are present. Farmers often bring in honey bees to provide supplemental pollination service to their crops, and commercial and hobby beekeepers use hives to produce honey. Many beekeepers have permits to place their hives on natural areas like National Forests and National Grasslands which introduces honey bees into valuable natural and semi-natural habitat, without adequate environmental review (Grand Canyon Trust et al. 2020 pp. 2-3). In natural areas, honey bees reduce the diversity of wild bees and disrupt the hierarchical structure of plant-pollinator networks (Valido et al. 2019 pp. 2-3). Apiaries on public and private land have been shown to have contributed to the decline of at least one bumble bee species. The western bumble bee, which has declined by >90% (Graves et al. 2020 p. 7), has been shown to have lower foraging success and reduced reproductive success when near honey bee hives (Thomson 2004 pp. 463–464). Honey bees also changes bumble bee foraging behavior (Elbgami et al. 2014 p. 508), lowers average bumble bee body size (Goulson & Sparrow 2009 pp. 7–8), and causes pathogen spillover (Fürst et al. 2014 pp. 3–4).

In response to pollinator declines, efforts to increase pollinator habitat such as planting wildflower strips, hedgerows, and roadsides can provide little to no benefit if there are nearby honey bee hives. A recent study showed that wild bee richness and abundance was lower on farms that had honey bee hives regardless of whether there were wildflower strips intended to support wild bees (Angelella et al. 2021 p. 3). Another study showed that for bumble bees, the benefit of providing flower strips to bumble bee queen and male abundance was lower if there were also honey bee hives (Bommarco et al. 2021 p. 5).

Domesticated bumble bees

Commercial bumble bees, particularly the common eastern bumble bee (*Bombus impatiens*), expose wild bumble bees to diseases (Colla et al 2006 p. 465). In the United States *B. impatiens* is the commonly domesticated bumble bee currently used in greenhouses and in open field settings to provide crop pollination services (Velthius & Van Doorn 2006 p. 432). Bumble bees used for pollinating greenhouse crops are likely responsible for substantial pathogen spillover from domesticated to wild bees via shared flowers (see threats section 6.3 for details about pathogen spillover) (Colla et al. 2006 p. 465). Pathogen spillover is implicated in the decline of several species including the rusty-patched bumble bee (Colla and Packer 2008 p. 1388). The decline of both the American bumble bee and the yellow-banded bumble bee have been correlated with vegetable greenhouse density (Szabo et al. 2012 p. 235) which potentially facilitate escaped domesticated bumble bees that spillover disease to wild populations. While the impact of pathogen spillover from domesticated bumble bees to the Southern Plains bumble bee has not been studied, pathogen spillover remains a considerable, potential risk.

6.1.5 Changes to Fire Regimes

Private and publicly held land across the range of the Southern Plains bumble bee often lack appropriate fire management strategies. Fire has played a vital role in the evolution of grasslands in the United States, but is often suppressed. The reintroduction of fire in a controlled way is regarded as beneficial for pollinators in the long-term (Black et al. 2011 p. 11). Suppression of natural fires or a lack of prescribed fire can result in a net loss of habitat for the bee (Hatfield et al. 2014 p. 6). Lack of fire has been and continues to be a problem that has led to the encroachment and invasion of woody plants in the Southern Great Plains (Coppedge et al. 2001 pp. 682–683; Gaskin et al. 2021 p. 2). Invasive species that flourish without fire reduce available habitat for the Southern Plains bumble bee (Hatfield et al. 2014 p. 11).

Prescribed fires that are well executed can control invasive species and increase flowering plant abundance and diversity (Brockway et al. 2002 pp. 136, 145) thereby increasing the habitat value for bumble bees. However, prescribed fire can directly harm bees in the short term and if mismanaged can risk serious harm to bumble bees. Inappropriate timing, duration, intensity, and patchiness of prescribed fire can result in destruction of overwintering queens, nest sites and removal to key foraging resources (Hatfield et al. 2014 p. 5). Sites with few individuals remaining are the most vulnerable if fire is poorly implemented.

6.2 Overutilization

At present, the Southern Plains bumble bee is not known to be used for any commercial recreational, scientific, or educational purposes. However, this species is more vulnerable to overutilization compared to more common bumble bees given its relative rarity.

6.3 Disease

Bumble bees spread disease between wild and introduced populations via pathogen spillover which occurs when pathogens (viruses, bacteria, parasites, etc.) are passed from one heavily infected ‘reservoir’ population to a suitable species or population that has low levels of infection (Colla et al. 2006 p. 461). Many pathogens infect bumble bees and these pathogens transmit from colony to colony primarily through shared flowers (Figueroa et al. 2019 p. 1). When bumble bees forage on flowers, they leave behind pathogen particles especially through their propensity to defecate on the flowers they visit (Figueroa et al. 2019 pp. 5–7). Pathogen spillover from domesticated honey and bumble bees has been heavily implicated as a contributing factor to the decline of several species of North American bumble bees (Cameron & Sadd 2020 p. 3). The evidence for the widespread, population-level effect of pathogen spillover to the Southern Plains bumble bee is limited (Cordes et al. 2012 p. 212), but it should still be considered a potential contributing factor. Domesticated bumble bees have only been widely used for crop pollination since the late 1990s and early 2000s (Velthius and Vandoorn 2006 p. 429), but their use is expected to continue to increase (see e.g. Velthius and Vandoorn 2006 p. 433). The demand for greenhouse pollination service is increasing, with the greenhouse area under production for tomatoes increasing by almost 50% from 2007-2017 and the area under production for other vegetables increasing 75% from 2002-2017 (USDA AgStats 2020b). Commercially raised bumble bees often have high levels of infection and have been shown to spread parasites to wild bumble bees outside greenhouses (Colla et al. 2006 pp. 463-465; Graystock et al. 2013 p. 1210).

Nosema bombi and *N. ceranae*

The microsporidians *Nosema bombi* and *N. ceranae* are parasites related to fungi that spread through the release of highly resistant, long-lived spores in feces (Otti & Schmid-Hempel 2007 p. 119). *Nosema* spp. replicate within the midgut of the bee by infecting and damaging cells and then is excreted in the hive or onto flowers (Otti & Schmid-Hempel 2007 p. 119). Both *N. bombi* and *N. carinae* infect bumble bees and spillover from honey bees and domesticated bumble bees, negatively impacting wild colony growth, immune function, and reproduction (Graystock et al. 2013b p. 1212; Fürst et al. 2014 pp. 3–4; Graystock et al. 2016 p. 68). *N. bombi* is known to have infected some species of North American bumble bees prior to the introduction of domesticated colonies and causes lowers colony-level fitness in lab and field experiments by reducing the number of reproductive members and the number of workers (Otti & Schmid-Hempel 2008 p. 579). *N. ceranae* is a parasite of the Asian honey bee (*Apis ceranae*) that infects the European honey bee (*Apis mellifera*) and is known to spillover from honey bees to wild bumble bees (Graystock et al. 2016 p. 68) reducing bumblebee survival with additional sub-lethal effects on behavior (Graystock et al. 2013a pp. 116–117).

Contaminated feces from commercially reared bumble bees and infected wild bees are spread onto flowers that are visited by non-infected wild bumble bee populations (Colla et al. 2006 p. 465). It is likely that *N. bombi* spilled over into domesticated colonies which then facilitated the spread of *N. bombi* to other wild bumble bees because of their transportation and propagation (Graystock et al. 2016 p. 69). The spillover of both parasites is made worse because of the movement of domesticated bumble bee colonies around the country and their potential to contaminate flowers that are shared with wild bumble bees.

Crithidia

Crithidia bombi is a trypanosome protozoan and gut parasite that is highly prevalent among North American bumble bees (Cordes et al. 2012 p. 212), but can have deleterious effects at the individual and colony level. Compared to uninfected bees, this pathogen reduces colony-founding success, male production, colony size, and overall colony fitness (Brown et al. 2003 p. 997-998) as well as interferes with learning among bumble bee foragers (Otterstater et al. 2005 p. 386-387).

In UK bumble bees, a recent study found that commercial *B. terrestris* often pick up *Crithidia* infections where they can reach levels that could increase the spread of this infection back to wild bees (Martin et al. 2021 p. 537). A declining species like the Southern Plains bumble bee with potentially lower populations and lower genetic diversity may be more affected than stable species, as has been demonstrated with UK bumble bees (Whitehorn et al. 2011 p. 1200).

RNA Viruses

RNA viruses have been best studied in honey bees, but have recently been found in North American wild bumble bees (Singh et al. 2010 p. 2). Many RNA viruses have been identified and some are known to directly spillover to wild bumble bees including the deformed wing virus (DWV) (Singh et al. 2010 p. 4-6; Alger et al. 2019 p. 5). Surveys of bumble bees within one km (0.6 mi) of apiaries showed higher levels of DWV and black queen cell virus while the virus was absent from wild bumble bees with no apiary nearby (Alger et al. 2019 p. 5). Honey bee viruses infect wild bumble bees through shared flowers with a larger effect when floral abundance is low (Burnham et al. 2021 pp. 5-6). Infection with DWV causes wing deformities in bumble bees similar to honey bees (Genersch et al. 2006 p. 3). Spillover of RNA viruses from nearby honey bees presents a potential risk to the Southern Plains bumble bees.

6.4 Inadequacy of Existing Regulatory Mechanisms

Existing federal, state, and local regulatory mechanisms are inadequate to protect against the threats to the Southern Plains bumble bee, which include habitat destruction and modification, disease, climate change and the use of pesticides.

Any voluntary measures taken to protect the Southern Plains bumble bee or promote pollinator habitat generally throughout the species' range are inadequate to address the threats across its range. To the extent that any voluntary, i.e., non-regulatory, mechanisms exist to protect the Southern Plains bumble bee, FWS cannot rely on voluntary measures to deny listing of species. Voluntary and unenforceable conservation efforts are simply *per se* insufficient as "regulatory mechanisms" under 16 U.S.C. 1533(a)(1)(d):

> [T]he Secretary may not rely on plans for future actions to reduce threats and protect a species as a basis for deciding that listing is not currently warranted . . . . For the same reason that the Secretary may not rely on future actions, he should not be able to rely on unenforceable efforts. Absent some method of enforcing compliance, protection of a species can never be assured. Voluntary actions, like those planned in the future, are necessarily speculative . . . . Therefore, voluntary or future conservation efforts by a state should be given no weight in the listing decision (*Oregon Natural Resources Council v. Daley,* 6 F. Supp.2d 1139, 1154-155 (D. Or. 1998).

This species is recognized as imperiled or needing protection by some international and state entities, but these recognitions do not provide adequate legal protections. Internationally, NatureServe ranks the Southern Plains bumble bee as G3 or vulnerable from 2018 (NatureServe 2018 p. 1), and the International Union for the Conservation of Nature (IUCN) assessed the species as endangered (Hatfield et al. 2014 p. 2). NatureServe and the IUCN designations are non-regulatory and are for informational purposes only. At the state level, the Southern Plains bumble bee is not formally protected under any state endangered species acts. The Southern Plains bumble bee is a “Species of Greatest Conservation Need” (SGCN) in Colorado, Florida, Illinois, Missouri, Nebraska, New Jersey, North Carolina, Oklahoma, and Virginia.

The most comprehensive database of bumble bee observations available indicates that the Southern Plains bumble bee survives mostly on privately held lands that offer no regulatory conservation mechanisms for this bee. Of the 681 recent Southern Plains bumble bee observations (2011-2020) 204 (30%) were found on public land. For comparison, 37% of all bumble bee records[7] from the same time period were found on public land, which indicates a smaller percentage of Southern Plains bumble bees are found in these aeras. Of course, public land does not guarantee any level of protection and only 56 out of 681 (8%) of Southern Plains bumble bee observations from 2011-2020 have been found on public land managed for biodiversity (i.e. wildlife refuges, national parks, and wilderness areas). This small percentage of records on public lands is inadequate to protect this species from extinction. The broad range of the Southern Plains bumble bee requires the protections that are provided by the ESA.

The Endangered Species Act is the only adequate regulatory mechanism available to protect the Southern Plains bumble bee.

6.4.5 Federal Mechanisms

Several federal regulations have the stated purpose of properly managing and protecting habitat for wildlife, but there are currently none that provide adequate regulatory mechanisms to protect it in the absence of ESA listing.

National Forest Management Act

The National Forest Management Act (NFMA) of 1976 establishes that the nation’s national forests are to be managed for multiple uses including to “provide for diversity of plant and animal communities…” (g)(3)(B). Additional requirements for forest management based on NFMA state that to comply with ecosystem integrity and diversity requirements the plan must “…maintain the diversity of plant and animal communities and support the persistence of most native species in the plan area.” (219.9) The 2018 revised planning rule states that the regional forester has the authority to write or review management plans to include species of conservation concern (219.9(c)). While the regional forester may have the authority to designate the Southern Plains bumble bee as a species of conservation concern, the burden falls on individual forest service regions to make the assessments for each species. Even if the species was to be protected on some forests as a species of conservation concern, this protection is limited in scope and geography and thus is an inadequate regulatory mechanism.

[7] Bumble bee records were narrowed to include only those observations within 50 km of a Southern Plains bumble bee observation.

Federal Land Policy and Management Act

The Federal Land Policy and Management Act (FLPMA) of 1976 regulates the "management, protection, development, and enhancement of public lands" with the intention to "…preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife…" (FLPMA). Under this act, mining, grazing, logging and other activities on Bureau of Land Management lands are regulated by the creation of management plans. While these plans typically do set aside some lands for wildlife protection, they do not consider the specific needs of bumble bees, or the southern great , but there are no explicit provisions that require management to maintain habitat suitable for the bee

National Environmental Policy Act

The National Environmental Policy Act (NEPA) is America's foundational environmental law for protecting the environment. NEPA is a national charter for establishing policy, setting goals, and carrying out policies that relate to the environment. This act requires Federal agencies to consider the effects of their actions on the environment through the utilization of environmental assessments and environmental impact statements. These reports must disclose any adverse impacts to the environment including to sensitive species such as the Southern Plains bumble bee. However, the law only requires agencies to disclose the impacts of their actions; it does not prohibit agencies from choosing alternatives that will negatively affect individuals or populations.

The Wilderness Act

The Wilderness Act of 1964 (U.S. Congress 1964 p. 1) allows for the designation of protected wilderness areas on public land to "…retain its primeval character and influence, without permanent improvements or human habitation…" (U.S. Congress 1964 p. 1). Wilderness areas protect many species from human impacts; however, very few Southern Plains bumble bees have been found in areas designated as Wilderness, which is not unexpected as many such areas are in high elevation zones which do not support this species. Even considering all possibly occupied wilderness areas, the amount of wilderness areas within the species range represent a tiny portion of its current range. The protection offered by the *Wilderness Act* is not adequate to protect this species.

Related Species Protections under the Endangered Species Act

There are no other species protected under the Endangered Species Act that would coincidentally provide sufficient protection for the Southern Plains bumble bee. The ESA offers protection to one other bee in a portion of the Southern Plains bumble bee's range—the rusty patched bumble bee. The rusty patched bumble bee is a wide ranging, generalist bumble bee, but its protected status provides inadequate protection across the range of the Southern Plains bumble bee. The rusty-patched bumble bee's historic range does overlap with areas where the Southern Plains bumble bee is declining in the upper Midwest and the northeastern United

States. However, the rusty-patched bumble bee has been denied designated critical habitat and has declined to relatively very few populations that are spread sporadically across 41 counties which represent only 11% of historically occupied counties (Szymanski et al. 2016 p. 35). Therefore, the rusty-patched bumble bee's currently limited, sporadic distribution does not provide significant overlap with the more southern range of the Southern Plains bumble bee. FWS has described areas of high and low habitat potential for the rusty-patched bumble bee (USFWS n.d. p. 1) and only five individual observations (5 low potential and 0 high potential) of the 681 recent Southern Plains bumble bee observations (2011-2020) are located within any rusty-patched bumble bee potential habitat. The protections for the rusty-patched bumble bee offer limited habitat protections without critical habitat designation, but they also fail to address other threats, such as pesticides.

Other grassland insect species are protected under the ESA within the range of the Southern Plains bumble bee, but they protect only a fraction of the bee's range. Wide-ranging grassland species of butterflies within the range of the bee include: the Dakota skipper (*Hesperia dakotae*), the Poweshiek skipperling (*Oarisma poweshiek*), and the Karner blue (*Lycaeides melissa samuelis*). The Dakota skipper and Poweshiek skipperling exist only in native prairie remnants which cover very small areas throughout their former range (USFWS 2014 p. 63717), so the protections offered by these species protects very little habitat overall for the Southern Plains bumble bee which can survive in agricultural and urban areas in the Midwest. The Karner blue butterfly has a large historic range across the upper Midwest and into the northeastern states, however the remnant oak savannah and pine barren habitat with its host lupine is highly fragmented and degraded (USFWS 2003 p. 1) and represents a very narrow portion of the possible habitat that would be suitable for the Southern Plains bumble bee. These butterfly listings together would not provide protection across the wide range of the Southern Plains bumble bee.

Pesticide Regulations

The US Environmental Protection Agency (EPA) evaluates the risk of pesticides to bees by using honey bees as a surrogate for all native bees. Bumble bee physiology, behavior, and life cycle characteristics differ from honey bees in many ways that are not considered when tests are applied only to honey bees. For example, bumble bee larvae are fed raw pollen and nectar whereas honey bees process nectar and pollen within nurse bees digestive systems before feeding larvae (Fischer & Moriarty 2014 p. 53). Bumble bee larvae are also in direct contact with raw nectar and pollen provisions rather than in individual cells like honey bees and therefore have a different exposure profile (Fischer & Moriarty 2014 p. 53). Further, the persistent residues of pesticides in soil can contaminate bumble bee nests and overwintering sites but this not considered by the EPA when assessing risk to a species that spends its entire life above ground.

Pesticide risk assessments are conducted on only single active ingredients yet pesticides can have additive or synergistic effects whereby two or more active ingredients may have a more toxic effect than either chemical on its own (Andersch et al. 2010 p. 1). Further, inert ingredients are not tested for risk to bees. It is common practice for pesticide applicators to mix multiple pesticides together, and non-honey bees can be exposed to multiple chemicals (Hladik et al. 2016 p. 473). There is no current EPA testing protocol to determine the synergistic risk from pesticides or their inert ingredients despite evidence for these effects.

Additionally, EPA's response to bumble bee kills has been inadequate in the face of persistent and systemic neonicotinoid pesticides. In 2013, the application of a neonicotinoid insecticides at a legal rate to *Tilia* trees in Oregon killed as many as 100,000 bumble bees that contacted poisoned flowers (Hatfield et al. 2021 p. 6). In response, the EPA now prevents foliar applications of nitroguanidine neonicotinoids on non-agricultural plants while plants are flowering (Bradbury 2013 pp. 2–5). However, these systemic neonicotinoids can remain in plant tissue for weeks to years after application (Mach et al. 2018 p. 867), therefore this change in regulation was inadequate to protect bumble bees that will continue to feed on the poisoned nectar of these trees.

Honey Bee and Bumble Bee Regulations

No government at any level has taken meaningful action to address the threat of honey bees to wild bees. However, we know that the transport of non-native species can quickly introduce new diseases and parasites wild populations (Daszak et al. 2000 p. 446) that could negatively affect wild bumble bees. Federal regulations regarding honey bees are insufficient to protect bumble bees from transmitted diseases. Honey bees are regulated by the United States Department of Agriculture (USDA) and the Animal and Plant Health Inspection Service (APHIS) as agricultural commodities. USDA has the power to slow the spread of honey bee diseases to native species through the Honey Bee Act of 1922 which is intended to restrict the importation and movement of honey bees into and around the country (Honeybee Act 1922). Apiculturists move their honey bees great distances around the country and weak laws at the federal and state level could lead to the transmission and spread of diseases to wild bumble bees.

The Honey Bee Act is specific to honey bees and does not regulate diseases in managed bumble bees; nor is there an equivalent act or law that would regulate bumble bees. The USDA allows the international movement of managed Canadian bumble bees into the United States which include: the eastern bumble bee (*Bombus impatiens*) and the western bumble bee (*Bombus occidentalis*) (7 CFR § 322.5). The current regulations do not require any imported bumble bees to be inspected or tested for diseases (7 CFR § 322.5). Managed bumble bees can easily escape greenhouses unless they are properly maintained and native bees can acquire pathogens after visiting the same flower as an infected bee (Cameron & Sadd 2020 p. 10.9). This inadequate regulation presents a continued threat of disease transmission and direct competition for floral resources to the Southern Plains bumble bee and other native bumble bees.

6.4.6 State Mechanisms

For this petition, we reviewed state wildlife action plans (SWAPs) and have reviewed their analysis of the status of the Southern Plains bumble bee. Across its 26-state historic range, the Southern Plains bumble bee is recognized by only nine states as a Species of Greatest Conservation Need (SGCN), and no state has legal protection for this species. Indeed, several states do not include insects under their state endangered species act. The Southern Plains bumble bee is considered a SGCN by the SWAPs of nine states including: Colorado, Florida, Illinois, Nebraska, New Jersey, North Carolina, Oklahoma, and Virginia. The status of "species of greatest conservation need" (SGCN) does not have regulatory status like "threatened" or "endangered" status under any state endangered species act.

SWAPs are non-regulatory documents that provide information on species status and outline the conservation goals of the state and are required for states to complete in order to obtain state wildlife grants.[8][9] States are not required by law to carry out what is outlined in their SWAPS. SWAPS are highly variable across states and reflect different conservation priorities and different levels of species-specific information. Several states address neither bees nor bumblebees in their SWAPs. Additionally, some SWAPs do not list terrestrial invertebrates as SGCN and highlight the fact that more data on the species is needed to evaluate their conservation needs. Several states also have "Pollinator Plans" but they focus almost entirely on commercial managed bees, rather than native bees. Overall, designations in SWAPs and Pollinator Plans do not constitute adequate regulatory mechanisms and are therefore insufficient to protect the Southern Plains bumble bee.

Alabama

Alabama's SWAP does not mention the Southern Plains bumble bee and the species is not categorized as a SGCN. While the SWAP is effective until 2025, it states that "[a]dditional emphasis may be placed on adding invertebrate groups to SWAPs in the future" because of the decline of pollinators recognized by a 2014 Presidential Memorandum (Alabama DCNR 2015 p. 31). Additionally, the Southern Plains bumble bee did not appear in a search of other state documents.

Arkansas

Arkansas's SWAP does not mention the Southern Plains bumble bee and the species is not categorized as a SGCN. In fact, only one species of Hymenoptera is included in the Arkansas SWAP. Additionally, the Southern Plains bumble bee did not appear in a search of other state documents.

[8] The Department of the Interior and Related Agencies Appropriations Act, 2002 (PL 107-63)
[9] State Wildlife Grant funding is only available for states that complete a SWAP every ten years.

Colorado

Colorado's SWAP recognizes the Southern Plains bumble bee as a SGCN and as a tier 2 species, meaning that it is "apparently secure, but with cause for long-term concern" (Colorado Parks and Wildlife 2015 p. 691). However, Colorado Parks and Wildlife does not have statutory authority over invertebrate species, with the exception of mollusks (Colorado Parks and Wildlife 2015 p. B-1).

Delaware

The Southern Plains bumble bee is not protected under the state's endangered species act. Delaware's SWAP identifies the species as a Tier 1 SGCN (Delaware Department of Natural Resources and Environmental Control. 2015 Appendix 1).

Florida

Florida's SWAP discusses the importance of bees and other pollinator species in pollination and how human activities like pesticide use and planting native species, especially by individual Florida residents, can harm and benefit them (Florida Fish and Wildlife Conservation Commission 2019 p. 123). The SWAP recognizes the Southern Plains bumble bee as a SGCN (Florida Fish and Wildlife Conservation Commission 2019 p. 167), however does not afford the species any formal protections at the state level.

Georgia

The Georgia SWAP fails to provide any information on the Southern Plains bumble bee and does not recognize it as a SGCN. A limited number of terrestrial arthropods are designated as "high priority" under the Georgia SWAP, including the rusty-patched bumble bee (Georgia Department of Natural Resources Wildlife Resources Division 2015 p. 119). The only pollinating insect protected under Georgia's state endangered species act is the rusty-patched bumble bee (GDNR n.d. p. 1) which only occupied a small number of counties in northern Georgia (Szymanski et al. 2016 p. 36).

Illinois

Illinois' Wildlife Action Plan Implementation Guide categorizes the Southern Plains bumble bee as a SGCN because of its rarity and declining status (Illinois DNR 2015 p. 265). The IWAP provides significant information about this species including the number of counties occupied and notes on habitat stressors (Illinois DNR 2015 p. 49). The IWAP's Implementation Guide provides a list of specific actions the state will take to protect pollinator species: conserving existing pollinator habitat areas, restoring/creating habitat areas in urban landscapes and incorporating plant species with varied bloom times, using integrated pest management, surveying and inventorying pollinator taxa, including pollinator data in databases, development of S-ranks and G-ranks for pollinator species, developing community outreach programs, and establishing pollinator corridors (Illinois DNR 2015 pp. 84–85). However, SGNC status does not offer legally enforceable protections under the state endangered species act and are therefore inadequate to ensure its survival and recovery.

Indiana

In the state of Indiana, neither insects nor invertebrates (with the exception of mollusks) are protected under state law (IDNR 2015 p. 46). No bees of any species are identified as SGCN.

Iowa

The Southern Plains bumble bee is not categorized as a SGCN in Iowa’s Wildlife Action Plan, but other insect taxonomic groups including butterflies and dragonflies are included as SGCN (Iowa DNR 2015 pp. 49–52). The IWAP notes that "[b]asic information is needed for several taxonomic groups of conservation concern” such as bees to potentially add the taxonomic group to the plan (Iowa DNR 2015 p. 126). Additionally, the Southern Plains bumble bee could not be found in a search of other state documents.

Kansas

Kansas’s Wildlife Action Plan does not mention the Southern Plains bumble bee and the species is not categorized as a SGCN. The SWAP includes a brief summary on pollinators (Kansas DWPT 2015 p. 18) which provides some information on pollinator declines, but it does not establish specific steps for the state to address this decline. Additionally, a search of other state documents for the Southern Plains bumble bee did not yield any results.

Louisiana

The Louisiana Wildlife Action Plan includes the American bumble bee as a SGCN but not the Southern Plains bumble bee (Louisiana FWS 2015 p. xxxvi). The SWAP includes measures to help conserve pollinator species, such as avoiding application of insecticides and retaining habitat features that benefit pollinators (Louisiana FWS 2015 pp. 53–54). However, these measures are voluntary and are unlikely to help recover a species without directed effort from formal protections.

Michigan

Although the Southern Plains bumble bee is not included in the SGCN, both the rusty-patched bumble bee and the yellow banded bumble bee are included in the Michigan SWAP (Michigan DNR 2015 p. 18). Only the rusty-patched and yellow-banded bumble bees are formally protected under the state endangered species act (Michigan Natural Features Inventory n.d. p. 1).

Mississippi

Mississippi’s SWAP does not list any pollinators as SGCN or having state protected status because the distribution and abundance of pollinators are poorly known (MDWFP 2016 p. 46). The Southern Plains bumble bee is not specifically discussed, and the SWAP specifically prioritizes researching *Bombus* species and other key pollinators, stating "[s]ince the current status of pollinator species in Mississippi is largely unknown…Current distribution of bumblebees (*Bombus spp*.) and other key pollinator species or groups should be a priority" (MDWFP 2016 p. 46).

Missouri

Missouri includes the Southern Plains bumble bee as a SGCN in their Comprehensive Conservation Strategy from 2020 (Missouri Department of Conservation 2020 p. 198). However, the Southern Plains bumble bee species is not protected under the state endangered species statute. The Missouri SWAP recognizes the threat of pesticides to pollinators (Missouri Department of Conservation 2015 p. 38). The SWAP states that Missouri is reducing threats to bumble bees by "working to reduce the application of insecticides on conservation areas and is conducting several studies that will examine the impacts of such chemicals on terrestrial and aquatic invertebrates" (Missouri Department of Conservation 2015 p. 14). This very limited conservation action provides minimal habitat improvement because it only applies to conservation areas and not the broader agricultural landscape.

Nebraska

Nebraska includes the Southern Plains bumble bee as a SGCN (Schneider et al. 2018 p. 42). The SWAP describes *B. fraternus* as declining and the current population status is unknown (Schneider et al. 2018 p. 42). This species is not formally protected under Nebraska state endangered species statutes.

New Jersey

New Jersey's SWAP includes *Bombus fraternus* as a SGCN (NJDEPDFW 2018 p. 26). The SWAP also includes a map of the species' range in New Jersey, while also stating that its abundance is uncommon, and the population is declining. The Southern Plains bumble bee is not formally protected under the New Jersey state endangered species statute (NJDEPDFW 2018 p. B-11).

New Mexico

New Mexico's SWAP does not include the Southern Plains bumble bee or any mention of "bee" or "pollinator." Additionally, the species is not found in a search of other state documents.

North Carolina

The Southern Plains bumble bee is a SGCN in North Carolina's SWAP (North Carolina Wildlife Resources Commission 2015 p. 49). This state recognizes the decline of this species stating that, "…if the long-term declining trend for relative abundance of the Southern Plains bumble bee continues, this species could potentially go extinct by the end of the century" (North

Carolina Wildlife Resources Commission 2015 pp. 180–181), but the state has not formally protected the species under the state endangered species statue.

North Dakota

North Dakota's SWAP names multiple butterflies as SGCN (Dyke et al. 2015 Appendix F) but does not address the Southern Plains bumble bee.

Ohio

The Southern Plains bumble bee is not mentioned in Ohio's SWAP and is not categorized as a SGCN. Additionally, *Bombus fraternus* did not appear in a search of other state documents. Ohio Department of Natural Resources Division of Wildlife's protection to terrestrial invertebrates "…is limited to species classified as endangered only"(Ohio Division of Wildlife 2015 p. 109). The Department mentions only the rusty-patched bumble bee and no other bees as threatened, species of concern, or special interest.

Oklahoma

The Southern Plains bumble bee is categorized as a SGCN Priority Tier III in Oklahoma's SWAP (Oklahoma Department of Wildlife Conservation 2016 p. 409). However, this does not provide adequate regulatory mechanisms to protect the species.

South Carolina

South Carolina's SWAP does not categorize the Southern Plains bumble bee as a SGCN. Additionally, the SWAP states that most priority insect species cannot be ranked at this time due to lack of data.

South Dakota

The Southern Plains bumble bee is not mentioned in South Dakota's SWAP and is not categorized as a SGCN. The state of South Dakota's Department of Agriculture does have a Managed Pollinator Plan, but it is only be applicable to managed pollinators and beekeepers in the state.

Tennessee

Tennessee's SWAP does not recognize the Southern Plains bumble bee as a SGCN. The only bee mentioned in Tennessee's SWAP is the Eastern Carpenter Bee. Tennessee's Department of Transportation has worked to establish a Pollinator Habitat Program, however, there is no mention or protections specifically for the Southern Plains bumble bee.

Texas

The Southern Plains bumble bee is not mentioned in Texas's Wildlife Action Plan and is not categorized as a SGCN. The SWAP references other bee species, such as the Southern Plains bumble bee. Texas Parks & Wildlife's website includes only general information about the

Southern Plains bumble bee (Texas Parks and Wildlife Department n.d. p. 1). Texas's Monarch and Native Pollinator Conservation Plan (2016) does not mention or protect the Southern Plains bumble bee.

Virginia

Virginia's SWAP includes the Southern Plains bumble bee as a SGCN (VDGIF 2015 pp. 26–144) and is also on the state list of rare animals (Roble 2020 p. 47). The Virginia Department of Agriculture and Consumer Services also published a Pollinator Protection Plan in 2017.[10] However,Virginia's Pollinator Protection Plan is aimed at conserving honey bees with little mention or protection for native pollinators.

State Honey Bee Regulation

Regulations on the transportation and inspection of honey bee hives for disease and other threats are inconsistent across states (Mailander 2019 p. 16). For instance, honey bee hive registration is voluntary in Colorado and New York (Mailander 2019 p. 36,40) and even in states with mandatory registration, hobby apiculture is often exempted if a beekeeper has fewer than five hives (Mailander 2019 p. 16). There are no clear regulations that determine how often hives should be screened or for which pathogens as many states provide inspections only at the request of the beekeeper.

6.5 Other Natural or Manmade Threats

6.5.5 Loss of Genetic Diversity, Small Populations, and Production of Diploid Males

The decline in persistence and range occupancy of the Southern Plains bumble bee may indicate increased isolation and risk of inbreeding depression among remaining populations like in other uncommon and declining bumble bees (Darvill et al. 2006 p. 602). This species was historically uncommon which likely makes it more vulnerable to threats that decrease effective population size. Bumble bees can disperse up to 10 km (6.2 miles) from their natal nests, but typical dispersal is most likely three km (1.86 miles) (USFWS 2018 p. 21). Bumble bee populations exist in a metapopulation structure, with isolated populations experiencing occasional gene flow from others, lessening the potential for inbreeding depression and protecting population viability (Goulson 2010 p. 191-198; Hanski & Gyllenberg 1993 pp. 36–38). Bumble bee populations that are in decline exhibit a loss of genetic diversity and gene flow over time, while stable populations are less likely to show such changes (Lozier et al. 2011 p. 4883). The risk of inbreeding depression highlights the need for connectivity between colonies and habitat patches, and thus the need for protection of designated critical habitat that provides

[10] Pollinator Protection Plan, Virginia Department of Agriculture and Consumer Services (Last visited Apr. 16, 2021), https://www.vdacs.virginia.gov/plant-industry-services-pollinator-protection-plan.shtml#:~:text=VDACS'%20Plan%20is%20a%20voluntary,means%20to%20further%20protect%20pollinators.

sufficient floral resources and nesting sites as well as facilitates dispersal to mitigate the threats of small populations.

Declining genetic diversity can have the effect of accelerating population decline via the “diploid male extinction vortex” (Grozinger & Zayed 2020 p. 278). Bees are particularly vulnerable to the loss of genetic diversity because of their haplodiploid genetic structure for sex determination (Zayed 2009 p. 239). In haplodiploid animals, sex is determined at a single locus, where homozygous individuals express a male phenotype and heterozygous are female. In such animals, unfertilized haploid eggs result in normal males, while fertilized (and thus diploid) eggs normally are heterozygous at this locus, producing normal females. In populations with low allelic richness at this locus, diploid individuals may instead be homozygous, and thus express male rather than female phenotype. In such cases, the animal develops normally, but is sterile (Zayed & Packer 2009 p. 239). This sex determination system in small populations with limited gene flow makes populations more susceptible to inbreeding depression which is a major threat to bee population viability (Zayed 2009 p. 244). Females that fertilize eggs to produce females waste reproductive effort when males are inadvertently produced, leading to increased male-biased sex ratio and further reduced population sizes, creating a positive feedback loop that ultimately leads to extinction (Zayed & Packer 2005 pp. 10744–10745; Zayed 2009 pp. 239, 241). The production of diploid males in haplodiploid bees can increase extinction risk by 50%-63%, an order of magnitude higher than extinction risk caused by inbreeding alone (Zayed & Packer 2005 pp. 10744–10745). Due to declining occupancy and persistence, Southern Plains bumble bee populations may be increasingly isolated over time, thereby reducing gene flow among populations and increasing the risk of inbreeding depression and the production of diploid males.

6.5.6 Climate Change

Global climate change poses a major indirect threat to the Southern Plains bumble bee (Cameron & Sadd 2020 pp. 8–9). Global climate change’s impact on temperature and precipitation is threatening stability of the plant resources that the Southern Plains bumble bee relies on for food and habitat (Cameron & Sadd 2020 p. 9). Due to climate change-related temporal shifts in flowering or phenological patterns of these plants, the Southern Plains bumble bee phenology may become mismatched with certain plants and lead to gaps in the availability of food resources (Schweiger et al. 2010 p. 779). Climate change can also reduce the quality of nectar resources for bumble bees which can reduce bumble bee worker longevity (Hoover et al. 2012 p. 14).

Human activities have increased global average temperatures 0.8-1.2°C above pre-industrial levels with a trend of about 0.2°C per decade due to past and current emissions (Intergovernmental Panel on Climate Change 2018 p. 4). At current emissions rates, global temperatures will increase by 1.5°C between 2030-2052, resulting in sea level rise, increased incidence of severe weather events, and loss of ecosystems (Intergovernmental Panel on Climate Change 2018 p. 4). Average temperatures have already risen across the large range of the

Southern Plains bumble bee with increases in the Southern Great Plains, the midwestern, and southeastern parts of the country; of 0.42°C (0.76°F), 0.7°C (1.26°F), and 0.26°C (0.46°F) respectively (USGCRP 2017 p. 187).

Bumble bees have evolved to fly and forage at lower temperatures than other bees and are found at higher latitudes and altitudes (Heinrich 1972 p. 185). Bumble bees fly longest and most efficiently at a preferred temperature which likely varies by species and by size of the bee with flight time generally increasing up to about 24°C (75°F). Above 24°C, bumble bees cannot fly as far or for as long (Kenna et al. 2021 p. 6), and they cannot fly if a bumble bee's thorax temperature exceeds 42-44°C (108°F-111°F) (Goulson 2010 p. 17). In locations where hotter temperatures result in a reduction in the length of time bumble bees can fly, then each colony will have fewer foraging trips and thus fewer resources to rear large colonies. Bumble bees are known to have been extirpated from areas with extreme temperatures, independent of land use in some cases (Kerr et al. 2015 p. 179).

Disruptive range shifts are also possible because of climate change at the northern and southern extents of the Southern Plains bumble bee's range (Cameron & Sadd 2020 p. 8). For example, the southern portion of North American bumble bee's ranges are shrinking due to rising temperatures (Kerr et al. 2015 p. 178) but could expand range in the northern portion because of higher temperatures and a longer growing season (Kenna et al. 2021 pp. 6–7). However, a proportional shift northward to remain within the preferred temperature range is not occurring and is leading to a "range compression" of North American's bumble bees (Kerr et al. 2015 p. 178). The Southern Plains bumble bee is showing a pattern of range compression because of losses in the northern and southern parts of its range (Figure 2). If present trends continue, the Southern Plains bumble bee will lose population representation and be unable to adapt to a warming climate.

6.5.7 Combined Threats

The best available science shows that a combination of threats from small populations, pesticides, habitat loss, and disease enhance the extinction risk from any single threat for bumble bees (Brown et al. 2000 p. 425; Cameron and Sadd 2020 p. 14-15; Fauser-Misslin et al. 2014 pp. 453–455; Goulson et al. 2015 p. 6). No one threat has solely precipitated the decline of the Southern Plains bumble bee across its range, rather a combination of factors creates conditions that amplify impacts of all threats.

The Southern Plains bumble bee risks potential extinction vortex effects to populations that are stressed by a reduced or monotonous floral diet, pesticide exposure, small population size, disease spread, the impacts of climate change, and perhaps other stressors. Any colony or population may experience some or all these stressors simultaneously. Stressors often co-occur and can be mutually reinforcing, increasing the impact of any single threat (Cameron and Sadd 2020 p. 14). Multiple stressors act on common bumble bees in complex ways, but can reduce colony growth (Dance et al. 2017 pp. 7-8; Botías et al. 2021 pp. 425–426), impair immune systems (Brown et al. 2000 p. 425; Brunner et al. 2014 p. 3), and reduce reproductive output (Malfi et al. 2018 pp. 25-26). As an uncommon bee, any stressor that harms colony growth or reduces genetic diversity pushes their populations closer to a threshold where the effective population size is too low to maintain (Grozinger & Zayed 2020 p. 278).

Degraded habitat is an underlying stressor that interacts with disease pressure from domesticated bees and pesticide exposure. Poor quality habitat can restrict the distribution of floral patches and increase competition and visitation frequency, thereby enhancing the spread of pathogens such as RNA viruses through shared flowers (Burnham et al. 2021 pp. 5-6). Certain infectious disease such as the commonly occurring gut parasite *Critidia bombi* can also become more virulent under starvation stress (Brown et al. 2000 p. 425) because of reduced immune response (Brunner et al. 2014 p. 3). Bumble bee immune response is also impacted by pesticide exposure (see section 6.1.2), and malnutrition, as a result of a monotonous diet, coupled with neonicotinoid insecticide exposure has been shown to reduce *B. terrestris* colony growth, reproduction rates, and male size (Dance et al. 2017 pp. 7-8; Botías et al. 2021 pp. 425–426).

To combat the threats of habitat loss, pesticides, and pathogens, the Southern Plains bumble bee needs more—not less—quality habitat to gain the energy and nutrition they need to overcome threats and recover. While the specific impact of multiple stressors on bumble bees has not been studied on rare and/or declining species, addressing any threat singularly will be inadequate to conserve and protect this bee. Addressing these multiple threats to the Southern Plains bumble bee requires the power of protection under the Endangered Species Act and the concurrent designation of critical habitat.

7 Request for Critical Habitat Designation

We urge the Service to designate critical habitat for the Southern Plains bumble bee concurrent with listing it as endangered under the ESA. Critical habitat as defined by Section 3 of the ESA is: (i) the specific areas within the geographical area occupied by a species, at the time it is listed in accordance with the provisions of section 1533 of this title, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) the specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 1533 of this title, upon a determination by the Secretary that such areas are essential for the conservation of the species (16 U.S.C. § 1532(5)).

Congress recognized that the protection of habitat is essential to the recovery and/or survival of listed species, stating that: "classifying a species as endangered or threatened is only the first step in ensuring its survival. Of equal or more importance is the determination of the habitat necessary for that species' continued existence… If the protection of endangered and threatened species depends in large measure on the preservation of the species' habitat, then the ultimate effectiveness of the Endangered Species Act will depend on the designation of critical habitat." H. Rep. No. 94-887 at 3 (1976).

Critical habitat is an extremely effective and important component of the ESA, without which the Southern Plains bumble bee's chance for survival significantly diminishes. Petitioners request that the Service propose critical habitat for the bee concurrently with its listing.

8 Conclusion

This petition reviews the best scientific and commercial information available regarding the historic, present, and future threats facing the Southern Plains bumble bee and has determined that the species has declined in EOO, relative abundance, occupancy, and persistence compared to historic levels. The Southern Plains bumble bee is warranted for protection under the ESA as it is imperiled by threats factors 1) the present or threatened destruction, modification, or curtailment of its habitat or range; 3) disease or predation; 4) the inadequacy of existing regulatory mechanisms; and 5) other natural or manmade factors. This species is threatened by lack of genetic diversity and small population sizes that are exacerbated by degraded habitat, pesticide exposure, and disease transmission from domesticated bees. The Southern Plains bumble bee has experienced alarming declines throughout its range and is expected to continue to decline in the future as threats are not managed and are expected to continue. Additionally, there are no existing regulatory mechanisms which are adequate to protect the Southern Plains bumble bee. Federal ESA protection is the best, most effective option for conserving this species across its range. The ESA requires that the Services promptly issue an initial finding as to whether this petition "presents substantial scientific or commercial information indicating that the petitioned action may be warranted." 16 U.S.C. § 1533(b)(3)(A). We thank you for your prompt attention to this petition.

9 References

Alabama Department of Conservation and Natural Resources. 2015. Alabama's wildlife action plan. Available from https://www.outdooralabama.com/sites/default/files/Research/SWCS/AL_SWAP_FINAL June2017.pdf.

Alger SA, Burnham PA, Boncristiani HF, Brody AK. 2019. RNA virus spillover from managed honeybees (*Apis mellifera*) to wild bumblebees (*Bombus spp*.). PLOS ONE **14**:e0217822. Public Library of Science. https://doi.org/10.1371/journal.pone.0217822.

Almasri H, Tavares DA, Pioz M, Sené D, Tchamitchian S, Cousin M, Brunet JL, Belzunces LP. 2020. Mixtures of an insecticide, a fungicide and a herbicide induce high toxicities and systemic physiological disturbances in winter *Apis mellifera* honey bees. Ecotoxicology and Environmental Safety **203**:111013.

Andersch W, Jeschke P, Thielert W. 2010. Synergistic Insecticide Mixtures. US20100216637A1. Available from https://patents.google.com/patent/US20100216637/en (accessed November 18, 2019).

Angelella, GM, McCullough CT, O'Rourke ME. 2021. Honey bee hives decrease wild bee abundance, species richness, and fruit count on farms regardless of wildflower strips. Sci. Rep. **11**:3202.

Ansley J. Hart C. 2012. Drivers of vegetation change on Texas rangelands. AgriLife Extension, Texas A&M System. College Station, TX.

Arduser M. 2015. Report on bees collected at selected Midwestern US Fish and Wildlife Refuges 2012 to 2013. U.S. Fish and Wildlife Service.

Baron GL, Raine NE, Brown MJF. 2017. General and species-specific impacts of a neonicotinoid insecticide on the ovary development and feeding of wild bumblebee queens. Proceedings of the Royal Society B: Biological Sciences **284**:20170123.

Bartomeus I, Ascher JS, Gibbs J, Danforth BN, Wagner DL, Hedtke SM, Winfree R. 2013. Historical changes in northeastern US bee pollinators related to shared ecological traits. Proceedings of the National Academy of Sciences **110**:4656–4660.

Beckham JL, Atkinson S. 2017. An updated understanding of Texas bumble bee (Hymenoptera: Apidae) species presence and potential distributions in Texas, USA. PeerJ **5**:e3612. PeerJ Inc.

Beckham JL, Warriner MD, Atkinson SF, Kennedy JH. 2016. The Persistence of Bumble Bees (Hymenoptera: Apidae) in Northeastern Texas. Proceedings of the Entomological Society of Washington **118**:481–497. Entomological Society of Washington.

Belsky AJ, Matzke A, Uselman S. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. J. Soil Water Conserv. **54**:419–431.

Bernauer OM, Gaines-Day HR, Steffan SA. 2015. Colonies of bumble bees (*Bombus impatiens*) produce fewer workers, less bee biomass, and have smaller mother queens following fungicide exposure. Insects **6**:478–488.

Black SH, Shepherd M, Vaughan M. 2011. Rangeland management for pollinators. Rangelands **33**:9–13.

Bohnenblust EW, Vaudo AD, Egan JF, Mortensen DA, Tooker JF. 2016. Effects of the herbicide dicamba on nontarget plants and pollinator visitation. Environmental Toxicology and Chemistry **35**:144–151.

Bommarco R, Lindström SAM, Raderschall CA, Gagic V, Lundin O. 2021. Flower strips enhance abundance of bumble bee queens and males in landscapes with few honey bee hives. Biological Conservation **263**:109363.

Botías C, David A, Hill EM, Goulson D. 2017. Quantifying exposure of wild bumblebees to mixtures of agrochemicals in agricultural and urban landscapes. Environmental Pollution **222**:73–82.
Botías C, Jones JC, Pamminger T, Bartomeus I, Hughes WOH, Goulson D. 2021. Multiple stressors interact to impair the performance of bumblebee (*Bombus terrestris*) colonies. Journal of Animal Ecology **90**:415–431.
Bradbury S. 2013. Pollinator pesticide labeling for nitroguanidine neonicotinoid products. Available from https://www.epa.gov/sites/production/files/2013-11/documents/bee-label-info-ltr.pdf.
Brockway DG, Gatewood RG, Paris RB. 2002. Restoring fire as an ecological process in shortgrass prairie ecosystems: initial effects of prescribed burning during the dormant and growing seasons. Journal of Environmental Management **65**:135–152.
Brown MJF, Loosli R, Schmid-Hempel P. 2000. Condition-dependent expression of virulence in a trypanosome infecting bumblebees. Oikos **91**:421–427.
Brown MJF, Schmid-Hempel R, Schmid-Hempel P. 2003. Strong context-dependent virulence in a host–parasite system: reconciling genetic evidence with theory. Journal of Animal Ecology **72**:994–1002.
Brunner FS, Schmid-Hempel P, Barribeau SM. 2014. Protein-poor diet reduces host-specific immune gene expression in *Bombus terrestris*. Proceedings of the Royal Society B: Biological Sciences **281**:20140128. Royal Society.
Bueno C, Ruckstuhl KE, Arrigo N, Aivaz AN, Neuhaus P. 2012. Impacts of cattle grazing on small-rodent communities: an experimental case study. Can. J. Zool. **90**:22–30.
Burnham PA, Alger SA, Case B, Boncristiani H, Hébert-Dufresne L, Brody AK. 2021. Flowers as dirty doorknobs: Deformed wing virus transmitted between *Apis mellifera* and *Bombus impatiens* through shared flowers. Journal of Applied Ecology **58**:2065–2074.
Cameron SA, Lozier JD, Strange JP, Koch JB, Cordes N, Solter LF, Griswold TL. 2011. Patterns of widespread decline in North American bumble bees. Proceedings of the National Academy of Sciences **108**:662–667.
Cameron SA, Sadd BM. 2020. Global trends in bumble bee health. Annual Review of Entomology **65**. https://www.annualreviews.org/doi/10.1146/annurev-ento-011118-111847.
Camilo GR, Muñiz PA, Arduser MS, Spevak EM. 2017. A Checklist of the bees (Hymenoptera: Apoidea) of St. Louis, Missouri, USA. Journal of the Kansas Entomological Society **90**:175–188.
Cane JH, Tepedino VJ. 2016. Gauging the effect of honey bee pollen collection on native bee communities. Conservation Letters **10**:205–210.
Cassola F. 2016. *Cynomys ludovicianus*, Arizona black-tailed prairie dog. The IUCN Red List of Threatened Species. Available from http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T6091A22261137.en.
Colla SR, Otterstatter MC, Gegear RJ, Thomson JD. 2006. Plight of the bumble bee: Pathogen spillover from commercial to wild populations. Biological Conservation **129**:461–467.
Colla SR, Packer L. 2008. Evidence for decline in eastern North American bumblebees (Hymenoptera: Apidae), with special focus on *Bombus affinis* Cresson. Biodiversity and Conservation **17**:1379.
Colorado Parks and Wildlife (CPW). 2015. State wildlife action plan. Colorado Parks and Wildlife.
Coppedge BR, Engle DM, Fuhlendorf SD, Masters RE, Gregory MS. 2001. Landscape cover

type and pattern dynamics in fragmented Southern Great Plains grasslands, USA. Landscape Ecology **16**:677–690.
Cordes N, Huang WF, Strange JP, Cameron SA, Griswold TL, Lozier JD, Solter LF. 2012. Interspecific geographic distribution and variation of the pathogens *Nosema bombi* and *Crithidia* species in United States bumble bee populations. Journal of Invertebrate Pathology **109**:209–216.
Cully AE, Cully Jr. JF, Hiebert RD. 2003. Invasion of exotic plant species in tallgrass prairie fragments. Conservation Biology **17**:990–998.
Dance C, Botías C, Goulson D. 2017. The combined effects of a monotonous diet and exposure to thiamethoxam on the performance of bumblebee micro-colonies. Ecotoxicology and Environmental Safety **139**:194–201.
Darvill B, Ellis JS, Lye GC, Goulson D. 2006. Population structure and inbreeding in a rare and declining bumblebee, *Bombus muscorum* (Hymenoptera: Apidae). Molecular Ecology **15**:601–611.
Daszak P, Cunningham AA, Hyatt AD. 2000. Emerging infectious diseases of wildlife-- threats to biodiversity and human health. Science **287**:443–449. American Association for the Advancement of Science.
Dauby G et al. 2017. ConR: An R package to assist large-scale multispecies preliminary conservation assessments using distribution data. Ecology and Evolution **7**:11292–11303. John Wiley & Sons, Ltd.
Delaware Department of Natural Resources and Environmental Control (DDNREC). 2015. 2015-2025 Delaware wildlife action plan. Delaware Department of Natural Resources and Environmental Control, Dover, Delaware.
DeKeyser ES, Dennhardt LA, Hendrickson J. 2015. Kentucky bluegrass (*Poa pratensis*) Invasion in the Northern Great Plains: A Story of Rapid Dominance in an Endangered Ecosystem. Invasive Plant Science and Management **8**:255–261.
De Luca PA, Vallejo-Marín M. 2013. What's the 'buzz' about? The ecology and evolutionary significance of buzz-pollination. Current Opinion in Plant Biology **16**:429–435.
DiBartolomeis M, Kegley S, Mineau P, Radford R, Klein K. 2019. An assessment of acute insecticide toxicity loading (AITL) of chemical pesticides used on agricultural land in the United States. PLOS ONE **14**:e0220029.
DiTomaso JM. 2000. Invasive weeds in rangelands: Species, impacts, and management. Weed Science **48**:255–265. Cambridge University Press.
Douglas MR, Sponsler DB, Lonsdorf EV, Grozinger CM. 2020. County-level analysis reveals a rapidly shifting landscape of insecticide hazard to honey bees (*Apis mellifera*) on US farmland. Scientific Reports **10**:1–11.
Dozier H, Gaffney JF, McDonald SK, Johnson ERRL, Shilling DG. 1998. Cogongrass in the United States: History, ecology, impacts, and management. Weed Technology **12**: 737-743.
Drons DJ. 2012. An Inventory of Native Bees (Hymenoptera: Apiformes) in the Black Hills of South Dakota and Wyoming. Master of Science. South Dakota State University.
Dyke SR, Johnson SK, Isakson PT. 2015. North Dakota state wildlife action plan. North Dakota Game and Fish Department, Bismark, North Dakota. Available from https://gf.nd.gov/publications/599.
Egan JF, Barlow KM, Mortensen DA. 2014. A meta-analysis on the effects of 2, 4-D and dicamba drift on soybean and cotton. Weed Science **62**:193–206.
Elbgami T, Kunin WE, Hughes WOH, Biesmeijer JC. 2014. The effect of proximity to a

honeybee apiary on bumblebee colony fitness, development, and performance. Apidologie **45**:504–513.
Fauser-Misslin A, Sadd BM, Neumann P, Sandrock C. 2014. Influence of combined pesticide and parasite exposure on bumblebee colony traits in the laboratory. Journal of Applied Ecology **51**:450–459.
Feltham H, Park K, Goulson D. 2014. Field realistic doses of pesticide imidacloprid reduce bumblebee pollen foraging efficiency. Ecotoxicology **23**:317–323.
Fernandez-Cornejo J, Nehring R, Osteen C, Wechsler S, Martin A, Vialou A. 2014. Pesticide use in U.S. agriculture: 21 selected crops, 1960-2008. Economic Information Bulletin 124. USDA Economic Research Service. Available from https://www.ers.usda.gov/webdocs/publications/43854/46734_eib124.pdf.
Figueroa LL et al. 2019. Bee pathogen transmission dynamics: deposition, persistence, and acquisition on flowers. Proceedings of the Royal Society B: Biological Sciences **286**:20190603. Royal Society.
Figueroa LL, Bergey EA. 2015. Bumble bees (Hymenoptera: Apidae) of Oklahoma: Past and present biodiversity. Journal of the Kansas Entomological Society **88**:418–429. Kansas Entomological Society.
Fischer D, Moriarty T, editors. 2014. Pesticide Risk Assessment for Pollinators, 1st edition. John Wiley & Sons, Ltd. Available from http://onlinelibrary.wiley.com/doi/10.1002/9781118852408.
Fleischner TL. 1994. Ecological Costs of Livestock Grazing in Western North America. Conservation Biology **8**:629–644.
Florida Fish and Wildlife Conservation Commission (FFWCC). 2019. Florida's state wildlife action plan. Available from https://myfwc.com/media/22767/2019-action-plan.pdf.
Fürst MA, McMahon DP, Osborne JL, Paxton RJ, Brown MJF. 2014. Disease associations between honeybees and bumblebees as a threat to wild pollinators. Nature **506**:364–366. Nature Publishing Group.
Gabbard B L, Fowler NL. 2007. Wide ecological amplitude of a diversity-reducing invasive grass. Biological Invasions **9**:149-160.
Gaskin JF et al. 2021. Managing invasive plants on Great Plains grasslands: A discussion of current challenges. Rangeland Ecology & Management **78**:235–249.
GBIF.org. 2022. GBIF Occurrence Download. https://doi.org/10.15468/dl.frejh3.
Genersch E, Yue C, Fries I, de Miranda JR. 2006. Detection of deformed wing virus, a honey bee viral pathogen, in bumble bees (*Bombus terrestris* and *Bombus pascuorum*) with wing deformities. Journal of Invertebrate Pathology **91**:61–63.
Georgia Department of Natural Resources (GDNR). 2015. State wildlife action plan. Available from https://georgiawildlife.com/sites/default/files/wrd/pdf/swap/SWAP2015MainReport_92015.pdf.
Georgia Department of Natural Resources (GDNR). (n.d.). Georgia rare natural elements. Available from https://www.georgiabiodiversity.org/natels/element_lists?group=arthropod.
Geroff RK, Gibbs J, McCravy KW. 2014. Assessing bee (Hymenoptera: Apoidea) diversity of an Illinois restored tallgrass prairie: Methodology and conservation considerations. Journal of Insect Conservation **18**:951–964.
Golick DA, Ellis MD. 2006. An update on the distribution and diversity of *Bombus* in Nebraska (Hymenoptera: Apidae). J. Kans. Entomol. Soc. **79**: 341–347.
Goodell K. 2003. Food availability affects *Osmia pumila* (Hymenoptera: Megachilidae)

foraging, reproduction, and brood parasitism. Oecologia **134**:518–527.
Goulson D. 2010. Bumblebees: Behaviour, Ecology, and Conservation Second edition. Oxford University, Oxford, United Kingdom.
Goulson D. 2019. The insect apocalypse, and why it matters. Current Biology **29**:R967–R971.
Goulson D. 2020. Pesticides, corporate irresponsibility, and the fate of our planet. One Earth **2**:302–305.
Goulson D, Lye GC, Darvill B. 2008. Decline and conservation of bumble bees. Annual Review of Entomology **53**:191–208.
Goulson D, Nicholls E, Botias C, Rotheray EL. 2015. Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. Science **347**:1255957–1255957.
Goulson D, Sparrow KR. 2009. Evidence for competition between honeybees and bumblebees; effects on bumblebee worker size. Journal of Insect Conservation **13**:177–181.
Grab H, Brokaw J, Anderson E, Gedlinske L, Gibbs J, Wilson J, Loeb G, Isaacs R, Poveda K. 2019. Habitat enhancements rescue bee body size from the negative effects of landscape simplification. Journal of Applied Ecology **56**:2144–2154.
Grand Canyon Trust et al., Petition to Sonny Perdue, Secretary of Agriculture and Vicki Christiansen, Chief U.S. Forest Service, Sent July, 29th 2020.
Grant TA, Shaffer TL, Flanders B. 2020. Resiliency of Native Prairies to Invasion by Kentucky Bluegrass, Smooth Brome, and Woody Vegetation. Rangeland Ecology & Management **73**:321-328.
Graves TA et al. 2020. Western bumble bee: declines in the continental United States and range-wide information gaps. Ecosphere **11**:e03141.
Graystock P, Blane EJ, McFrederick QS, Goulson D, Hughes WOH. 2016. Do managed bees drive parasite spread and emergence in wild bees? International Journal for Parasitology: Parasites and Wildlife **5**:64–75.
Graystock P, Yates K, Darvill B, Goulson D, Hughes WOH. 2013a. Emerging dangers: Deadly effects of an emergent parasite in a new pollinator host. Journal of Invertebrate Pathology **114**:114–119.
Graystock P, Yates K, Evison SEF, Darvill B, Goulson D, Hughes WOH. 2013b. The Trojan hives: pollinator pathogens, imported and distributed in bumblebee colonies. Journal of Applied Ecology **50**:1207–1215.
Grixti JC, Wong LT, Cameron SA, Favret C. 2009. Decline of bumble bees (*Bombus*) in the North American Midwest. Biological Conservation **142**:75–84.
Grozinger CM, Zayed A. 2020. Improving bee health through genomics. Nature Reviews Genetics **21**:277–291. Nature Publishing Group.
Guzman LM, Johnson SA, Mooers AO, M'Gonigle LK. 2021. Using historical data to estimate bumble bee occurrence: Variable trends across species provide little support for community-level declines. Biological Conservation **257**:109141.
Hall HG, Ascher JS. 2011. Surveys of wild bees (Hymenoptera: Apoidea: Anthophila) in organic farms of Alachua County in north-central Florida. The Florida Entomologist **94**:539–552. Florida Entomological Society.
Hanski I, Gyllenberg M. 1993. Two general metapopulation models and the core-satellite species hypothesis. The American Naturalist **142**:17–41.
Hanula JL, Ulyshen MD, Horn S. 2016. Conserving Pollinators in North American Forests: A Review. Natural Areas Journal **36**:427–439.

Hatfield R, LeBuhn G. 2007. Patch and landscape factors shape community assemblage of bumble bees, *Bombus spp*. (Hymenoptera: Apidae), in montane meadows. Biological Conservation **139**:150–158.

Hatfield R, Jepsen S, Thorp R, Richardson L, Colla S. 2014. Bombus fraternus. The IUCN Red List of Threatened Species. Available from http://dx.doi.org/10.2305/IUCN.UK.2014-3.RLTS.T44937623A69001851.en.

Hatfield RG, Strange JP, Koch JB, Jepsen S, Stapleton I. 2021. Neonicotinoid pesticides cause mass fatalities of native bumble bees: A case study from Wilsonville, Oregon, United States. Environmental Entomology **50**:1095–1104.

Hemberger J, Crossley MS, Gratton C. 2021. Historical decrease in agricultural landscape diversity is associated with shifts in bumble bee species occurrence. Ecology Letters **24**:1800–1813.

Henry M, Rodet G. 2018. Controlling the impact of the managed honeybee on wild bees in protected areas. Scientific Reports **8**:9308. Nature Publishing Group.

Hines HM, Hendrix SD. 2005. Bumble bee (Hymenoptera: Apidae) diversity and abundance in tallgrass prairie patches: Effects of local and landscape floral resources. Environmental Entomology **34**:1477–1484.

Hladik ML, Vandever M, Smalling KL. 2016. Exposure of native bees foraging in an agricultural landscape to current-use pesticides. Science of The Total Environment **542**:469–477.

Hoekstra JM, Boucher TM, Ricketts TH, Roberts C. 2005. Confronting a biome crisis: global disparities of habitat loss and protection. Ecology Letters **8**:23–29.

Hoover SER, Ladley JJ, Shchepetkina AA, Tisch M, Gieseg SP, Tylianakis JM. 2012. Warming, CO2, and nitrogen deposition interactively affect a plant-pollinator mutualism. Ecology Letters **15**:227–234.

Hopwood J, Code A, Vaughan M, Biddinger D, Shepherd M, Black SH, Lee-Mäder E, Mazzacano C. 2016. How neonicotinoids can kill bees: The science behind the role these insecticides play in harming bees. Xerces Society for Invertebrate Conservation, Portland, Oregon. Available from https://xerces.org/sites/default/files/2018-05/16-022_01_XercesSoc_How-Neonicotinoids-Can-Kill-Bees_web.pdf.

Huang K, Li X, Liu X, Seto KC. 2019. Projecting global urban land expansion and heat island intensification through 2050. Environmental Research Letters **14**:114037. IOP Publishing.

Hughes A. 2018. Survey of the critically endangered rusty patched bumble bee (*Bombus affinis*) at Midewin National Tallgrass Prairie, (USDA-FS) Ill. Pence-Boyce STEM Student Scholarship. Available from https://digitalcommons.olivet.edu/pence_boyce/2.

Hung K-LJ, Kingston JM, Lee A, Holway DA, Kohn JR. 2019. Non-native honey bees disproportionately dominate the most abundant floral resources in a biodiversity hotspot. Proceedings of the Royal Society B: Biological Sciences **286**:20182901. Royal Society.

Illinois Department of Natural Resources (ILDNR). 2015. 2015 Implementation guide to the Illinois wildlife action plan. Available from https://www2.illinois.gov/dnr/conservation/IWAP/Documents/ IWAPImplementationGuide2015.pdf.

Iowa Department of Natural Resources (IDNR). 2015. Iowa’s wildlife action plan: Securing a future for fish and wildlife. Des Moines, Iowa, USA. Available from https://www.iowadnr.gov/Portals/idnr/uploads/Wildlife Stewardship/iwap/iwap_chapters.pdf.

Indiana Department of Natural Resources (IDNR). 2015. Indiana state wildlife action plan.

Available from https://www.in.gov/dnr/fish-and-wildlife/files/swap/fw-SWAP_2015.pdf.
IPBES. 2016. The assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. S.G. Potts, V. L. Imperatriz-Fonseca, and H. T. Ngo (eds). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. https://doi.org/10.5281/zenodo.3402856
ITIS. 2021. ITIS standard report page: *Bombus fraternus*. Available from https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=714805#null.
IUCN. 2000. IUCN Red List categories and criteria. Version 3.1. Available from https://www.iucn.org/sites/dev/files/import/downloads/redlistcatsenglish.pdf.
IUCN. 2022. The IUCN Red List of threatened species. Available from https://www.iucnredlist.org/en (accessed July 27, 2022).
Kammerer M, Tooker JF, Grozinger CM. 2020. A long-term dataset on wild bee abundance in Mid-Atlantic United States. Scientific Data **7**:1–8. Nature Publishing Group.
Kansas Department of Wildlife Parks and Tourism (KDWPT). 2015. Kansas wildlife action plan. Available from https://ksoutdoors.com/content/download/47442/484423/file/Complete Plan.pdf.
Kearns CA, Inouye DW. 1997. Pollinators, Flowering Plants, and Conservation Biology. BioScience **47**:297–307.
Kenna D, Pawar S, Gill RJ. 2021. Thermal flight performance reveals impact of warming on bumblebee foraging potential. Functional Ecology **35**:2508–2522.
Kiah T, Hidalgo S, Bangfu Z, Rands SA, Hodge JJL. 2021. Neonicotinoids disrupt memory, circadian behaviour and sleep. Scientific Reports **11**:2061–2075. Nature Publishing Group.
Kimoto C, DeBano SJ, Thorp RW, Taylor RV, Schmalz H, DelCurto T, Johnson T, Kennedy PL, Rao S. 2012. Short-term responses of native bees to livestock and implications for managing ecosystem services in grasslands. Ecosphere **3**:art88.
Kleijn D et al. 2015. Delivery of crop pollination services is an insufficient argument for wild pollinator conservation. Nature Communications **6**:1–9. Nature Publishing Group.
Knuffman L, Erndt-Pitcher K, May E. 2020. Drifting toward disaster: How dicamba herbicides are harming cultivated and wild landscapes. Washington, D.C.: National Wildlife Federation; Champaign, Il: Prairie Rivers Network; Portland, OR: Xerces Society for Invertebrate Conservation.
Koch JB, Lozier J, Strange JP, Ikerd H, Griswold T, Cordes N, Solter L, Stewart I, Cameron SA. 2015. USBombus, a database of contemporary survey data for North American Bumble Bees (Hymenoptera, Apidae, Bombus) distributed in the United States. Biodiversity Data Journal. Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4698456/.
Kral-O'Brien KC, Limb RF, Hovick, TJ, Harmon, JP. 2019. Compositional Shifts in Forb and Butterfly Communities Associated with Kentucky Bluegrass Invasions. Rangeland Ecology and Management **72**:301-309.
Krupke CH, Holland JD, Long EY, Eitzer BD. 2017. Planting of neonicotinoid-treated maize poses risks for honey bees and other non-target organisms over a wide area without consistent crop yield benefit. Journal of Applied Ecology **54**:1449–1458.
LaBerge, W. E., and M. C. Webb. 1962. The Bumblebees of Nebraska. Historical Research Bulletins of the Nebraska Agricultural Experiment Station.
Lamke K. 2019. A descriptive study of wild bees (Hymenoptera: Apoidea: Apiformes) and

angiosperms in a Tallgrass Prairie Corridor of Southeastern Nebraska. M.S. University of Nebraska, Lincoln, Nebraska. Available from https://digitalcommons.unl.edu/entomologydiss/58.

Lämsä J, Kuusela E, Tuomi J, Juntunen S, Watts PC. 2018. Low dose of neonicotinoid insecticide reduces foraging motivation of bumblebees. Proceedings of the Royal Society B: Biological Sciences **285**:20180506.

Lark TJ, Spawn SA, Bougie M, Gibbs HK. 2020. Cropland expansion in the United States produces marginal yields at high costs to wildlife. Nature Communications **11**:4295. Nature Publishing Group.

Lázaro A, Tscheulin T, Devalez J, Nakas G, Petanidou T. 2016. Effects of grazing intensity on pollinator abundance and diversity, and on pollination services. Ecological Entomology **41**:400–412.

Lepais O, Darvill B, O'connor S, Osborne JL, Sanderson RA, Cussans J, Goffe L, Goulson D. 2010. Estimation of bumblebee queen dispersal distances using sibship reconstruction method. Molecular Ecology **19**:819–831.

Louisiana Fish and Wildlife Service (LFWS). 2015. Louisiana wildlife action plan. Available from https://www.wlf.louisiana.gov/assets/Resources/Publications/Wildlife_Action_Plans/Wildlife_Action_Plan_2015.pdf.

Lozier JD, Strange JP, Stewart IJ, Cameron SA. 2011. Patterns of range-wide genetic variation in six North American bumble bee (Apidae: *Bombus*) species. Molecular Ecology **20**:4870–4888.

Lu C, Hung Y-T, Cheng Q. 2020. A Review of sub-lethal neonicotinoid insecticides exposure and effects on pollinators. Current Pollution Reports **6**:137–151.

Mach BM, Bondarenko S, Potter DA. 2018. Uptake and dissipation of neonicotinoid residues in nectar and foliage of systemically treated woody landscape plants. Environmental Toxicology and Chemistry **37**:860–870.

Mailander D. 2019. When honey bees hit the road: The role of federal, state, and local laws in regulating honey bee transportation. University of Oregon School of Law Environmental and Natural Resources Law Center.

Main AR, Webb EB, Goyne KW, Mengel D. 2020. Reduced species richness of native bees in field margins associated with neonicotinoid concentrations in non-target soils. Agriculture, Ecosystems & Environment **287**:106693.

Malcolm SB. 2018. Anthropogenic impacts on mortality and population viability of the monarch butterfly. Annual Review of Entomology **63**:277–302.

Malfi RL, Walter JA, Roulston TH, Stuligross C, McIntosh S, Bauer L. 2018. The influence of conopid flies on bumble bee colony productivity under different food resource conditions. Ecological Monographs **88**:653–671.

Mallinger RE, Gaines-Day HR, Gratton C. 2017. Do managed bees have negative effects on wild bees?: A systematic review of the literature. PLOS ONE **12**:e0189268.

Mao W, Schuler MA, Berenbaum MR. 2017. Disruption of quercetin metabolism by fungicide affects energy production in honey bees (*Apis mellifera*). Proceedings of the National Academy of Sciences **114**:2538–2543. National Academy of Sciences.

Martin CD, Fountain MT, Brown MJF. 2021. The potential for parasite spill-back from commercial bumblebee colonies: a neglected threat to wild bees? Journal of Insect Conservation **25**:531–539.

McArt SH, Urbanowicz C, McCoshum S, Irwin RE, Adler LS. 2017. Landscape predictors of pathogen prevalence and range contractions in US bumblebees. Proceedings of the Royal Society B: Biological Sciences **284**:20172181.
Meehan TD, Werling BP, Landis DA, Gratton C. 2011. Agricultural landscape simplification and insecticide use in the midwestern United States. Proceedings of the National Academy of Sciences **108**:11500–11505.
Meyers C, Hill E. 2014. Benefits of neonicotinoid seed treatments to soybean production. Environmental Protection Agency, Office of Chemical Safety and Pollution Prevention, Washington, D.C. Available from https://www.epa.gov/pollinator-protection/benefits-neonicotinoid-seed-treatments-soybean-production.
Michigan Department of Natural Resources (MDNR). 2015. Michigan's wildlife action plan 2015-2020: Appendix 1 species of greatest conservation need. Available from https://www.michigan.gov/documents/dnr/17_appendix1_sgcn_rationales_500078_7.pdf.
Michigan Natural Features Inventory. (n.d.). Michigan Bumble Bees. Available from https://mnfi.anr.msu.edu/resources/michigan-bumble-bees (accessed August 6, 2021).
Minnameyer A, Strobl V, Bruckner S, Camenzind DW, Van Oystaeyen A, Wäckers F, Williams GR, Yañez O, Neumann P, Straub L. 2021. Eusocial insect declines: Insecticide impairs sperm and feeding glands in bumblebees. Science of The Total Environment **785**:146955.
Mississippi Department of Wildlife Fish and Parks (MDWFP). 2016. Mississippi state wildlife action plan. Available from https://www.mdwfp.com/media/251788/mississippi_swap_revised_16_september_2016__reduced_.pdf.
Missouri Department of Conservation. 2015. Missouri state wildlife action plan. Available from https://mdc.mo.gov/sites/default/files/2020-04/SWAP_0.pdf.
Missouri Department of Conservation. 2020. The Missouri comprehensive conservation strategy. Available from https://mdc.mo.gov/sites/default/files/2021-10/MO%20Comprehensive%20Conservation%20Strategy_12-31-20_0.pdf.
Mitchell TB. 1962. Bees of the Eastern United States. Technical Bulletin 152. North Carolina Agricultural Experiment Station.
Moisset B, Buchmann S. 2011. Bee basics: An introduction to our native bees. USDA Forest Service and Pollinator Partnership.
Mullin CA, Frazier M, Frazier JL, Ashcraft S, Simonds R, vanEngelsdorp D, Pettis JS. 2010. High levels of miticides and agrochemicals in North American apiaries: Implications for honey bee health. PLOS ONE **5**:e9754. Public Library of Science.
Mundy-Heisz KA, Prosser RS, Raine NE. 2022. Acute oral toxicity and risks of four classes of systemic insecticide to the common eastern bumblebee (*Bombus impatiens*). Chemosphere **295**:133771.
Murray DB, James PM, Michael SM, Devin RE, Kevin DM. 2021. Effective Management Practices for Increasing Native Plant Diversity on Mesquite Savanna-Texas Wintergrass-Dominated Rangelands. Rangeland Ecology & Management **75**: 161-169.
NatureServe. 2021. *Bombus fraternus* | NatureServe Explorer. Available from https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.832125/Bombus_fraternus (accessed July 2, 2021).
New Jersey Department of Environmental Protection Division of Fish and Wildlife (NJDEPDF). 2018. New Jersey's wildlife action plan. New Jersey Department of Environmental Protection Division of Fish and Wildlife, Trenton, New Jersey.
North Carolina Wildlife Resources Commission (NCWRC). 2015. 2015 North Carolina wildlife

action plan. Available from https://www.ncwildlife.org/portals/0/Conserving/documents/ActionPlan/WAP_complete.pdf.
Noss RF, LaRoe ET, Scott JM. 1996. Endangered ecosystems of the United States: A preliminary assessment of loss and degradation. Ecological Restoration **14**:95.1-95.
Nowak DJ, Walton JT. 2005. Projected urban growth (2000–2050) and its estimated impact on the US forest resource. Journal of Forestry **103**:383–389.
Obama B. 2014. Presidential memorandum—creating a federal strategy to promote the health of honey bees and other pollinators. https://obamawhitehouse.archives.gov/the-press-office/2014/06/20/presidential-memorandum-creating-federal-strategy-promote-health-honey-b. Accessed 10 June 2020. Ohio Division of Wildlife. 2015. Ohio's state wildlife action plan. Available from https://ohiodnr.gov/static/documents/wildlife/wildlife-management/OH_SWAP_2015.pdf.
Oklahoma Department of Wildlife Conservation. 2016. Oklahoma comprehensive wildlife conservation strategy: A strategic conservation plan for Oklahoma's rare and declining wildlife planning for the future of Oklahoma's wildlife. Available from https://www.wildlifedepartment.com/sites/default/files/Oklahoma%20Comprehensive%20Wildlife%20Conservation%20Strategy_0.pdf.
Osborne JL, Martin AP, Carreck NL, Swain JL, Knight ME, Goulson D, Hale RJ, Sanderson RA. 2008. Bumblebee flight distances in relation to the forage landscape. Journal of Animal Ecology **77**:406–415.
Otti O, Schmid-Hempel P. 2007. *Nosema bombi*: A pollinator parasite with detrimental fitness effects. Journal of Invertebrate Pathology **96**:118–124.
Otti O, Schmid-Hempel P. 2008. A field experiment on the effect of *Nosema bombi* in colonies of the bumblebee *Bombus terrestris*. Ecological Entomology **33**:577–582.
Otto CRV, Smart A, Cornman RS, Simanonok M, Iwanowicz DD. 2020. Forage and habitat for pollinators in the northern Great Plains--Implications for U.S. Department of Agriculture conservation programs. U.S. Geological Survey. Available from https://pubs.usgs.gov/of/2020/1037/ofr20201037.pdf.
Owens BE, Allain L, Gorder ECV, Bossart JL, Carlton CE. 2018. The bees (Hymenoptera: Apoidea) of Louisiana: An updated, annotated checklist. Proceedings of the Entomological Society of Washington **120**:272–307. Entomological Society of Washington.
Paini DR, Roberts JD. 2005. Commercial honey bees (*Apis mellifera*) reduce the fecundity of an Australian native bee (*Hylaeus alcyoneus*). Biological Conservation **123**:103–112.
Park CN, Overall LM, Smith LM, Lagrange T, McMurry S. 2017. Melittofauna and other potential pollinators in wetland and uplands in south central Nebraska (Insecta: Apoidea). Zootaxa **42**:255–280.
Peat J, Tucker J, Goulson D. 2005. Does intraspecific size variation in bumblebees allow colonies to efficiently exploit different flowers? Ecological Entomology **30**:176–181.
Persson AS, Smith HG. 2011. Bumblebee colonies produce larger foragers in complex landscapes. Basic and Applied Ecology **12**:695–702.
Pettis JS, Lichtenberg EM, Andree M, Stitzinger J, Rose R, vanEngelsdorp D. 2013. Crop pollination exposes honey bees to pesticides which alters their susceptibility to the gut pathogen *Nosema ceranae*. PLOS ONE **8**:e70182.
Pilling ED, Jepson PC. 1993. Synergism between EBI fungicides and a pyrethroid insecticide in the honeybee (*Apis mellifera*). Pesticide Science **39**:293–297.
Pleasants JM, Oberhauser KS. 2013. Milkweed loss in agricultural fields because of herbicide

use: effect on the monarch butterfly population. Insect Conservation and Diversity **6**:135–144.
Prosser CW, Sedivec KK, Barker WT. 2003. Tracked vehicle effects on vegetation and soil characteristics. Journal of Range Management **53**:666–670
Quinlan GM, Milbrath MO, Otto CRV, Isaacs R. 2021. Farmland in U.S. Conservation Reserve Program has unique floral composition that promotes bee summer foraging. Basic and Applied Ecology **56**:358-368.
Raimets R, Karise R, Mänd M, Kaart T, Ponting S, Song J, Cresswell JE. 2018. Synergistic interactions between a variety of insecticides and an ergosterol biosynthesis inhibitor fungicide in dietary exposures of bumble bees (*Bombus terrestris* L.). Pest Management Science **74**:541–546.
Raine NE. 2018. Pesticide affects social behavior of bees. Science **362**:643–644.
Roble S. 2020. Natural heritage resources of Virginia: Rare animals. Natural heritage rare species lists (2020-Summer). Virginia Division of Natural Heritage, Richmond, Virginia. Available from https://www.dcr.virginia.gov/natural-heritage/document/anlistjun2020.pdf.
Rotheray EL, Osborne JL, Goulson D. 2017. Quantifying the food requirements and effects of food stress on bumble bee colony development. Journal of Apicultural Research **56**:288–299.
Roubik DW, Villanueva-Gutiérrez R. 2009. Invasive Africanized honey bee impact on native solitary bees: a pollen resource and trap nest analysis. Biological Journal of the Linnean Society **98**:152–160. Oxford Academic.
Samson F, Knopf F. 1994. Prairie conservation in North America. BioScience **44**:418–421. Oxford Academic.
Sánchez-Bayo F, Wyckhuys KAG. 2019. Worldwide decline of the entomofauna: A review of its drivers. Biological Conservation **232**:8–27.
Schieltz JM, Rubenstein DI. 2016. Evidence based review: positive versus negative effects of livestock grazing on wildlife. What do we really know? Environmental Research Letters **11**:113003.
Schneider R, Fritz M, Jorgenson J, Schainost S, Simpson R, Steinaur G, Rothe-Groleau C. 2018. Revision of the tier 1 and 2 lists of species of greatest conservation need: A supplement to the Nebraska Natural Legacy Project state wildlife action plan. The Nebraska Game and Parks Commission, Lincoln, Nebraska. Available from http://outdoornebraska.gov/wp-content/uploads/2018/11/NE-SWAP-SGCN-Revision-Supplemental-Document-2018-Final_edited-1.pdf.
Schulz R, Bub S, Petschick LL, Stehle S, Wolfram J. 2021. Applied pesticide toxicity shifts toward plants and invertebrates, even in GM crops. Science **372**:81–84. American Association for the Advancement of Science.
Schweitzer D, Capuano N, Young B, Colla S. 2012. Conservation and management of North American bumble bees. USDA Forest Service, Washington, D.C.
Scott VL, Ascher JS, Griswold TL, Nufio CR. 2011. The bees of Colorado (Hymenoptera: Apoidea: Anthophila). Natural History Inventory of Colorado. University of Colorado Museum of Natural History, Boulder, Coloado. Available from https://www.colorado.edu/cumuseum/sites/default/files/attached-files/the_bees_of_colorado.pdf.

Selfridge J, Frye C, Gibbs J, Jean R. 2017. The Bee Fauna of Inland Sand Dune and Ridge Woodland Communities in Worcester County, Maryland. Northeastern Naturalist **24**:421–445.

Simon-Delso N et al. 2015. Systemic insecticides (neonicotinoids and fipronil): trends, uses, mode of action and metabolites. Environmental Science and Pollution Research **22**:5–34.

Singh R, Levitt AL, Rajotte EG, Holmes EC, Ostiguy N, vanEngelsdorp D, Lipkin WI, dePamphilis CW, Toth AL, Cox-Foster DL. 2010. RNA viruses in hymenopteran pollinators: Evidence of inter-taxa virus transmission via pollen and potential impact on non-apis hymenopteran species. PLOS ONE 5:e14357. Public Library of Science.

Siviter H, Koricheva J, Brown MJF, Leadbeater E. 2018. Quantifying the impact of pesticides on learning and memory in bees. Journal of Applied Ecology **55**:2812–2821.

Siviter H, Johnson AK, Muth F. 2021. Bumblebees exposed to a neonicotinoid pesticide make suboptimal foraging decisions. Environmental Entomology **50**:1299–1303.

Smith BA, Brown RL, Laberge W, Griswold T. 2012. A faunistic survey of bees (Hymenoptera: Apoidea) in the Black Belt Prairie of Mississippi. Journal of the Kansas Entomological Society **85**:32–47.

Smith F. 1854. Catalogue of the Hymenopterous Insects in the Collection of the British Museum Part II Apidae. London, U.K.

Stephenson P, Griswold T, Arduser M, Dowling A, Krementz D. 2018. Checklist of bees (Hymenoptera: Apoidea) from managed emergent wetlands in the lower Mississippi Alluvial Valley of Arkansas. Biodiversity Data Journal **6**:e24071. Pensoft Publishers.

Stoner KA. 2016. Current pesticide risk assessment protocols do not adequately address differences between honey bees (*Apis mellifera*) and Bumble Bees (*Bombus spp*.). Frontiers in Environmental Science **4**.

Strange JP, Tripodi AD. 2019. Characterizing bumble bee (*Bombus*) communities in the United States and assessing a conservation monitoring method. Ecology and Evolution **9**:1061–1069.

Straw EA, Carpentier EN, Brown MJF. 2021. Roundup causes high levels of mortality following contact exposure in bumble bees. Journal of Applied Ecology **58**:1167–1176.

Swenk, MH, Cockerell TDA. 1907. The bees of Nebraska. Entomological News **18**:293-300.

Szabo ND, Colla SR, Wagner DL, Gall LF, Kerr JT. 2012. Do pathogen spillover, pesticide use, or habitat loss explain recent North American bumblebee declines? Conservation Letters **5**:232–239.

Szymanski J, Smith T, Horton A, Parkin M, Ragan L, Masson G, Olson E, Glifford K, Hill L. 2016. Rusty patched bumble bee (*Bombus affinis*) species status assessment. U.S. Fish and Wildlife Service. Available from https://ecos.fws.gov/ServCat/DownloadFile/120109.

Tadey M. 2015. Indirect effects of grazing intensity on pollinators and floral visitation. Ecological Entomology **40**:451–460.

Texas Parks and Wildlife Department. (n.d.). Native Pollinators & Private Lands: Bumble Bee Conservation in Texas. Available from https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/native-pollinators/bumblebees.phtml.

Thomson D. 2004. Competitive interactions between the invasive European honey bee and native bumble bees. Ecology **85**:458–470.

Toledo D, Sanderson M, Spaeth K, Hendrickson J, Printz J. 2014. Extent of Kentucky bluegrass and its effects on native plant species diversity and ecosystem services in the Northern

Great Plains of the USA. Invasive Plant Science and Management **7**:543–552
Torné-Noguera A, Rodrigo A, Osorio S, Bosch J. 2016. Collateral effects of beekeeping: Impacts on pollen-nectar resources and wild bee communities. Basic and Applied Ecology **17**:199–209.
Tripodi AD, Szalanski AL. 2015. The bumble bees (Hymenoptera: Apidae: *Bombus*) of Arkansas, fifty years later. Journal of Melittology:1–17.
U.S. Congress. 1922. Honeybee Act. 7 U.S. Code § 281. Available from https://www.law.cornell.edu/uscode/text/7/281.
U.S. Congress. 1964. Wilderness Act. 16 U.S. Code § 1131-1136. Available from https://www.law.cornell.edu/uscode/text/16/1131.
USDA. 2018a. Summary report: 2015 National resources inventory. U.S. Department of Agriculture, Natural Resource Conservation Service and the Center for Survey Statistics and Methodology at Iowa State University, Washington, D.C. and Ames, Iowa.
USDA. 2018b. Non-Federal rangeland report: 2015 Natural resource inventory. US. Department of Agriculture, Natural Resource Conservation Service and the Center for Survey Statistics and Methodology at Iowa State University, Washington, D.C. and Ames, Iowa. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri/.
USDA. 2020a. Adoption of genetically engineered crops in the U.S. 2000-2020. U.S. Department of Agriculture. Available from https://www.ers.usda.gov/webdocs/DataFiles/47649/alltables.xls?v=6559.9.
USDA. 2020b. USDA/NASS QuickStats Ad-hoc Query Tool. Available from https://quickstats.nass.usda.gov/ (accessed September 15, 2020).
USEPA. 2021a. Clothianidin executive summary for draft biological evaluation. U.S. Environmental Protection Agency, Washington, D.C. Available from https://www.epa.gov/endangered-species/draft-national-level-listed-species-biological-evaluation-clothianidin#executive-summary.
USEPA. 2021b. Imidacloprid executive summary for draft biological evaluation. U.S. Environmental Protection Agency, Washington, D.C. Available from https://www.epa.gov/endangered-species/draft-national-level-listed-species-biological-evaluation-imidacloprid#executive-summary.
USEPA. 2021c. Thiamethoxam executive summary for draft biological evaluation. U.S. Environmental Protection Agency, Washington, D.C. Available from https://www.epa.gov/endangered-species/draft-national-level-listed-species-biological-evaluation-thiamethoxam#executive-summary.
USEPA. 2021d. Status of over-the-top dicamba: Summary of 2021 usage, incidents and consequences of off-target movement, and impacts of stakeholder-suggested mitigations. U.S. Environmental Protection Agency, Washington, D.C. Available from https://downloads.regulations.gov/EPA-HQ-OPP-2020-0492-0021/content.pdf.
USFWS. 2003. Karner blue butterfly (*Lycaeides melissa samuelis*) recovery plan. U.S. Fish and Wildlife Service, Fort Snelling, MN.
USFWS. 2014. Endangered and threatened wildlife and plants; Threatened species status for Dakota skipper and endangered species status for Poweshiek skipperling. U.S. Fish and Wildlife Service. Federal Register.
USFWS. 2016. USFWS species status assessment framework. U.S. Fish and Wildlife Service. Available from https://www.fws.gov/endangered/improving_ESA/pdf/SSA%20 Framework%20v3.4-8_10_2016.pdf.
USFWS. 2018. Species status assessment for the yellow banded bumble bee (*Bombus terricola*)

Version 1.0. U.S. Fish and Wildlife Service, Hadley, Maryland. Available from https://ecos.fws.gov/ServCat/DownloadFile/164401.
USFWS. (n.d.). Rusty Patched Bumble Bee Map. Available from https://www.fws.gov/midwest/endangered/insects/rpbb/rpbbmap.html (accessed August 11, 2020).
USGCRP. 2017. Climate science special report: Fourth national climate assessment, Volume I. U.S. Global Change Research Program, Washington, D.C. Available from doi.org/10.7930/J0J964J6.
Valido A, Rodríguez-Rodríguez MC, Jordano P. 2019. Honeybees disrupt the structure and functionality of plant-pollinator networks. Scientific Reports **9**:4711. Nature Publishing Group.
Vavra M, Parks CG, Wisdom MJ. 2007. Biodiversity, exotic plant species, and herbivory: The good, the bad, and the ungulate. Forest Ecology and Management **246**:66–72.
Velthuis HH, Van Doorn A. 2006. A century of advances in bumblebee domestication and the economic and environmental aspects of its commercialization for pollination. Apidologie **37**:421–451.
Virginia Department of Game and Inland Fisheries (VDGIF). 2015. Virginia's 2015 wildlife action plan. Virginia Department of Game and Inland Fisheries. Available from http://bewildvirginia.org/wildlife-action-plan/pdf/2015-Virginia-Wildlife-Action-Plan.pdf.
Warriner MD. 2011. Bumblebees (Hymenoptera: Apidae) of remnant grasslands in Arkansas. Journal of the Kansas Entomological Society **84**:43–50.
Westphal C, Steffan-Dewenter I, Tscharntke T. 2009. Mass flowering oilseed rape improves early colony growth but not sexual reproduction of bumblebees. Journal of Applied Ecology **46**:187–193.
Wheelock MJ, Rey KP, O'Neal ME. 2016. Defining the insect pollinator community found in Iowa corn and soybean fields: Implications for pollinator conservation. Environmental Entomology **45**:1099–1106.
Whitehorn PR, Tinsley MC, Brown MJF, Darvill B, Goulson D. 2011. Genetic diversity, parasite prevalence and immunity in wild bumblebees. Proceedings of the Royal Society B: Biological Sciences **278**:1195–1202. Royal Society.
Whitehorn PR, O'Connor S, Wackers FL, Goulson D. 2012. Neonicotinoid pesticide reduces bumble bee colony growth and queen production. Science **336**:351–352.
Williams PH, Cameron SA, Hines HM, Cederberg B, Rasmont P. 2008. A simplified subgeneric classification of the bumblebees (genus *Bombus*). Apidologie **39**:46–74.
Williams PH, Osborne JL. 2009. Bumblebee vulnerability and conservation world-wide. Apidologie **40**:367–387. EDP Sciences.
Williams PH, Thorp RW, Richardson LL, Colla SR. 2014. The Bumble Bees of North America: An Identification Guide. Princeton University Press, Princeton, New Jersey.
Wolf AT, Ascher JS. 2008. Bees of Wisconsin (Hymenoptera: Apoidea: Anthophila) **41**:41.
World Wildlife Fund. 2020. 2020 Plowprint. World Wildlife Fund. Available from https://c402277.ssl.cf1.rackcdn.com/publications/1359/files/original/PlowprintReport_2020_FINAL_08042020.pdf?1596569610.
Wu-Smart J, Spivak M. 2018. Effects of neonicotinoid imidacloprid exposure on bumble bee (Hymenoptera: Apidae) queen survival and nest initiation. Environmental Entomology **47**:55–62.
The Xerces Society, Wildlife Preservation Canada, York University, University of Ottawa, The

Montreal Insectarium, The London Natural History Museum, BeeSpotter. 2022. Data accessed from Bumble Bee Watch, a collaborative website to track and conserve North America's bumble bees. Available from http://www.bumblebeewatch.org/app/#/bees/lists. Accessed 3/10/2022.

Yoder JA, Jajack AJ, Rosselot AE, Smith TJ, Yerke MC, Sammataro D. 2013. Fungicide contamination reduces beneficial fungi in bee bread based on an area-wide field study in honey bee, *Apis mellifera*, colonies. Journal of Toxicology and Environmental Health. Part A **76**:587–600.

Yoshihara Y, Chimeddorj B, Buuveibaatar B, Lhagvasuren B, Takatsuki S. 2008. Effects of livestock grazing on pollination on a steppe in eastern Mongolia. Biological Conservation **141**:2376–2386.

Zayed A. 2009. Bee genetics and conservation. Apidologie **40**:237–262.

Zayed A, Packer L. 2005. Complementary sex determination substantially increases extinction proneness of haplodiploid populations. Proceedings of the National Academy of Sciences **102**:10742–10746.

Personal Communication

Bell C. 2020. Email.

Appendix 1

Recorded floral associations of the Southern Plains bumble bee.

Family	Scientific Name	Number of Records	Record Source
Acanthaceae	*Odontonema cuspidatum*	1	Richardson 2021
Amaryllidaceae	*Allium sp.*	1	Richardson 2021
Anacardiaceae	*Rhus glabra*	1	LACM-ENTB
Anacardiaceae	*Rhus sp.*	--	Mitchell 1962
Apiaceae	*Eryngium leavenworthii*	1	Richardson 2021
Apiaceae	*Eryngium sp.*	2	Mitchell 1962 Richardson 2021
Apiaceae	*Zizia sp.*	--	Robertson 1929
Apocynaceae	*Amsonia sp.*	1	Richardson 2021
Asclepiadaceae	*Asclepias curassavica*	1	Richardson 2021
Asclepiadaceae	*Asclepias hirtella*	1	Richardson 2021
Asclepiadaceae	*Asclepias incarnata*	13	Richardson 2021
Asclepiadaceae	*Asclepias sp.*	16	Robertson 1929 Richardson 2021
Asclepiadaceae	*Asclepias speciosa*	3	Richardson 2021
Asclepiadaceae	*Asclepias syriaca*	2	Richardson 2021
Asclepiadaceae	*Asclepias tomentosa*	1	Richardson 2021
Asclepiadaceae	*Asclepias verticillata*	1	Richardson 2021
Asclepiadaceae	*Asclepias viridiflora*	1	Richardson 2021
Asclepiadaceae	*Asclepias viridis*	7	Richardson 2021
Araliaceae	*Aralia spinosa*	1	Richardson 2021
Asteraceae	*Arnica mollis*	1	Richardson 2021
Asteraceae	*Aster pilosum*	1	Richardson 2021
Asteraceae	*Aster sp.*	5	AMNH-BEE Robertson 1929 Richardson 2021
Asteraceae	*Bidens cernua*	1	Richardson 2021
Asteraceae	*Bidens pilosa*	3	LACM-ENTB
Asteraceae	*Bidens sp.*	1	Mitchell 1962 Richardson 2021

Asteraceae	*Boltiana sp.*	--	Robertson 1929
Asteraceae	*Brauneria (Echinacea)*	--	Robertson 1929
Asteraceae	*Carduus nutans*	3	Richardson 2021
Asteraceae	*Centaurea sp.*	1	Richardson 2021
Asteraceae	*Chrysothamnus sp.*	6	Richardson 2021
Asteraceae	*Circium arvense*	3	Richardson 2021
Asteraceae	*Circium sp.*	13	Robertson 1929 Richardson 2021
Asteraceae	*Cirsium altissimum*	5	Richardson 2021
Asteraceae	*Cirsium discolor*	3	Richardson 2021
Asteraceae	*Cirsium horridulum*	2	Richardson 2021
Asteraceae	*Coreopsis sp.*	2	Richardson 2021
Asteraceae	*Cosmos sp.*	2	Richardson 2021
Asteraceae	*Cosmos sulphureus*	1	Richardson 2021
Asteraceae	*Echinacea pallida*	1	Richardson 2021
Asteraceae	*Echinacea purpurea*	5	Richardson 2021
Asteraceae	*Engelmannia pinnatifida*	1	Richardson 2021
Asteraceae	*Erigeron annuus*	1	Richardson 2021
Asteraceae	*Eupatorium hyssopifolium*	2	BMEC-ENT Richardson 2021
Asteraceae	*Eupatorium perfoliatum*	1	Richardson 2021
Asteraceae	*Eupatorium serotinum*	2	Richardson 2021
Asteraceae	*Eupatorium sp.*	--	Robertson 1929
Asteraceae	*Eutrochium sp.*	1	Richardson 2021
Asteraceae	*Gaillardia pulchella*	1	Richardson 2021
Asteraceae	*Gaillardia sp.*	--	Mitchell 1962
Asteraceae	*Grindelia papposa*	2	Richardson 2021
Asteraceae	*Helenium autumnale*	4	Richardson 2021
Asteraceae	*Helenium sp.*	--	Robertson 1929
Asteraceae	*Helenium tenuifolium*	3	AMNH-BEE Richardson 2021
Asteraceae	*Helianthus annuus*	23	Richardson 2021
Asteraceae	*Helianthus grosseseratus*	2	Richardson 2021
Asteraceae	*Helianthus lenticularis*	2	Richardson 2021

Asteraceae	*Helianthus maximiliani*	6	Richardson 2021
Asteraceae	*Helianthus mollis*	1	Richardson 2021
Asteraceae	*Helianthus rigidus*	3	Richardson 2021
Asteraceae	*Helianthus sp.*	53	EMEC Robertson 1929 Richardson 2021
Asteraceae	*Helianthus tuberosus*	1	Richardson 2021
Asteraceae	*Heliopsis helianthoides*	1	Richardson 2021
Asteraceae	*Krigia sp.*	--	Robertson 1929
Asteraceae	*Liatris aspera*	3	Richardson 2021
Asteraceae	*Liatris mucronate*	1	Richardson 2021
Asteraceae	*Liatris punctata*	5	Richardson 2021
Asteraceae	*Liatris pynchnostatia*	1	Richardson 2021
Asteraceae	*Liatris sp.*	2	Richardson 2021
Asteraceae	*Liatris spicata*	1	Richardson 2021
Asteraceae	*Oligoneuron nitidum*	2	Richardson 2021
Asteraceae	*Oligoneuron rigidum*	1	Richardson 2021
Asteraceae	*Ratibida pinnata*	30	Richardson 2021
Asteraceae	*Ratibida sp.*	2	Richardson 2021
Asteraceae	*Rudbeckia hirta*	1	Richardson 2021
Asteraceae	*Rudbeckia sp.*	--	Robertson 1929
Asteraceae	*Silphium laciniata*	1	Richardson 2021
Asteraceae	*Silphium sp.*	--	Robertson 1929
Asteraceae	*Solidago canadensis*	1	Richardson 2021
Asteraceae	*Solidago gigantea*	2	Richardson 2021
Asteraceae	*Solidago nitida*	1	Richardson 2021
Asteraceae	*Solidago rigida*	1	Richardson 2021
Asteraceae	*Solidago serotina*	2	Richardson 2021
Asteraceae	*Solidago sp.*	9	BMEC-ENT Robertson 1929 AMNH-BEE Richardson 2021
Asteraceae	*Solidago speciosa*	1	Richardson 2021
Asteraceae	*Symphyotrichum ericoides*	1	Richardson 2021

Asteraceae	*Symphyotrichum praealtum*	1	Richardson 2021
Asteraceae	*Taraxacum sp.*	1	Richardson 2021
Asteraceae	*Tithonia diversifolia*	1	Richardson 2021
Asteraceae	*Tithonia rotundifolia*	1	Richardson 2021
Asteraceae	*Verbesina alternifolia*	1	Richardson 2021
Asteraceae	*Verbesina encelioides*	1	Richardson 2021
Asteraceae	*Vernonia baldwinii*	4	Richardson 2021
Asteraceae	*Vernonia sp.*	1	Richardson 2021
Asteraceae	*Zinnia sp.*	1	Richardson 2021
Boraginaceae	*Lithospermum sp.*	--	Robertson 1929
Cleomaceae	*Cleome serrulata*	1	Richardson 2021
Cleomaceae	*Cleome serrulate*	1	UCRC-ENT
Cleomaceae	*Cleome sp.*	7	Richardson 2021
Clusiaceae	*Hypericum sp.*	--	Mitchell 1962
Crassulaceae	*Sedum sp.*	1	Richardson 2021
Crassulaceae	*Sedum spectablie*	1	Richardson 2021
Cucurbitaceae	*Citrullus lanatus*	1	Richardson 2021
Cucurbitaceae	*Cucurbita pepo*	1	BBSL
Cyrillaceae	*Cyrilla racemiflora*	1	Richardson 2021
Ericaceae	*Lyonia mariana*	1	Richardson 2021
Ericaceae	*Vaccinium sp.*	1	Mitchell 1962 Richardson 2021
Euphorbiaceae	*Euphorbia sp.*	2	BMEC-ENT Richardson 2021
Fabaceae	*Astragalus bisulcatus*	1	Richardson 2021
Fabaceae	*Astragalus latiflorus missouriensis*	3	Richardson 2021
Fabaceae	*Astragalus missouriensis*	1	Richardson 2021
Fabaceae	*Baptisia australis*	1	Richardson 2021
Fabaceae	*Baptisia laevicaullis*	1	Richardson 2021
Fabaceae	*Cassia chamaecrista*	9	Richardson 2021
Fabaceae	*Cassia sp.*	--	Robertson 1929
Fabaceae	*Chamaecrista fascicularis*	4	Richardson 2021
Fabaceae	*Dalea candida*	14	Richardson 2021

Fabaceae	*Dalea purpurea*	17	Richardson 2021
Fabaceae	*Kuhnistera sp.*	--	Mitchell 1962
Fabaceae	*Lespedeza sp.*	1	Mitchell 1962 Richardson 2021
Fabaceae	*Lupinus sp.*	3	LACM-ENTB Richardson 2021
Fabaceae	*Medicago sativa*	4	Richardson 2021
Fabaceae	*Medicago sp.*	2	BMEC-ENT
Fabaceae	*Melilotus alba*	15	Richardson 2021
Fabaceae	*Melilotus officinalis*	5	Richardson 2021
Fabaceae	*Melilotus sp.*	3	Robertson 1929 Richardson 2021
Fabaceae	*Mimosa nuttallii*	1	Richardson 2021
Fabaceae	*Neptunia lutea*	3	Richardson 2021
Fabaceae	*Petalostemon sp.*	1	Robertson 1929 Richardson 2021
Fabaceae	*Prosopis glandulosa*	32	Richardson 2021
Fabaceae	*Psoralea floribunda*	1	Richardson 2021
Fabaceae	*Psoralea sp.*	--	Robertson 1929
Fabaceae	*Robinia sp.*	--	Robertson 1929
Fabaceae	*Trifolium pratense*	5	Richardson 2021
Fabaceae	*Trifolium sp.*	1	Robertson 1929 Richardson 2021
Fabaceae	*Vicia sp.*	1	Richardson 2021
Hippocastanaceae	*Aesculus sp.*	--	Robertson 1929
Lamiaceae	*Monarda fistulosa*	1	Richardson 2021
Lamiaceae	*Monarda punctata*	2	Richardson 2021
Lamiaceae	*Monarda sp.*	--	Mitchell 1962
Lamiaceae	*Pycnanthemum muticum*	1	Richardson 2021
Lamiaceae	*Pycnanthemum sp.*	--	Robertson 1929
Lamiaceae	*Salvia azurea*	1	Richardson 2021
Lamiaceae	*Teucrium sp.*	--	Robertson 1929
Loauaceae	*Mentzelia sp.*	1	Richardson 2021
Loleaceae	*Ligustrum sp.*	1	Richardson 2021

Lythraceae	*Lagerstroemia sp.*	1	BMEC-ENT Richardson 2021
Malvaceae	*Convolvulus sp.*	1	Richardson 2021
Malvaceae	*Gossypium sp.*	8	Richardson 2021
Malvaceae	*Hibiscus moscheutos*	1	Richardson 2021
Nelumbonaceae	*Nelumbo sp.*	--	Robertson 1929
Passifloraceae	*Passiflora incarnata*	1	Richardson 2021
Passifloraceae	*Passiflora sp.*	1	Richardson 2021
Plantaginaceae	*Besseya plantaginea*	1	Richardson 2021
Plantaginaceae	*Collinsia sp.*	--	Robertson 1929
Plantaginaceae	*Penstemon degeneri*	3	Richardson 2021
Plantaginaceae	*Penstemon digitalis*	13	Richardson 2021
Plantaginaceae	*Penstemon sp.*	2	Richardson 2021
Polygalaceae	*Polygala sp.*	1	Richardson 2021
Polygonaceae	*Bistorta bistortoides*	1	Richardson 2021
Polygonaceae	*Brunnichia cirrhosa*	2	Richardson 2021
Polygonaceae	*Polygonum sp.*	1	Richardson 2021
Polygonaceae	*Polygonum amphibium*	4	Richardson 2021
Ranunculaceae	*Delphinium virescens*	1	Richardson 2021
Rosaceae	*Padus sp.*	--	Mitchell 1962
Rosaceae	*Prunus sp.*	1	Richardson 2021
Rosaceae	*Prunus virginiana*	1	Richardson 2021
Rosaceae	*Rosa arkansana*	1	Richardson 2021
Rosaceae	*Rosa sp.*	1	Richardson 2021
Rosaceae	*Rubus aboriginum*	1	Richardson 2021
Rosaceae	*Rubus sp.*	2	UCRC-ENT Richardson 2021
Rosaceae	*Spirea sp.*	1	Richardson 2021
Rubiaceae	*Cephalanthus occidentalis*	4	Richardson 2021
Rubiaceae	*Cephalanthus sp.*	--	Robertson 1929
Rubiaceae	*Hedyotis nigricans*	1	Richardson 2021
Salicaceae	*Salix sp.*	4	Richardson 2021
Sapindaceae	*Sapindus drummondii*	1	Richardson 2021

Scrophulariaceae	*Buddleja sp.*	2	Richardson 2021
Solanaceae	*Solanum rostratum*	4	Richardson 2021
Solanaceae	*Solanum sp.*	2	Robertson 1929 Richardson 2021
Verbenaceae	*Caryopteris clandonensis*	1	Richardson 2021
Verbenaceae	*Verbena sp.*	--	Robertson 1929

Appendix 2

Recent bumble bee survey effort (2011-2020).

Author	**State**	**Extent**	**Number of *B. fraternus* Observations**	***B. fraternus* Relative Abundance**
		Nationwide		
Koch et al. 2015 USBombus	Nationwide (41 states)	397 locations	16 records (4 states)	17930 total 7320 in range 0.2%
Strange and Tripodi 2019	Nationwide	Nationwide	0 records	0%
Strange et al. 2019 BIML Survey	Nationwide	45 sites	0 records	0%
		Regional		
Arduser 2015	Iowa, Illinois, Minnesota, Missouri, Wisconsin	Nine National Wildlife Refuges	Present at 2 National Wildlife Refuges 6 records	1.3%
Bee Spotter 2007-2020	Illinois, Iowa, Indiana, Ohio, Missouri, Virginia, Michigan, Wisconsin, Maryland	Statewide	16 records	0.3%
Bumble Bee Watch (Xerces Society)	Regional	States within *B. fraternus* range	151 records	5914 total 151 fraternus 2.6%

Drons 2012	Black Hills of South Dakota and Wyoming	94 sites	Present	Not provided
Kammerer et al. 2020	Maryland, Delaware, District of Columbia, Virginia	Statewide	0 records	0%
Otto et al. 2020	Minnesota, North Dakota, South Dakota	Private CRP and EQIP land	0 record	0%
		State and County		
Tripodi and Szalanski 2015	Arkansas	Statewide	Present in 18 counties	Not provided, but proportion of occupied counties remained stable between historic and contemporary periods.
Warriner 2011	Arkansas	Statewide	Present at five sites	Not provided
Stephenson et al. 2018	Arkansas	Mississippi Alluvial Valley	Present at three sites	Not provided
Kearns et al. 2017	Colorado	Boulder County	14 records	0.7% of total (2.7% at low elevations)
Scott et al. 2011	Colorado	Statewide	21 counties	Not provided
Hall & Ascher 2011	Florida	Alachua County	1 record	25%
Hughes 2018	Illinois	Midewin National Tallgrass Prairie	0 records	0%
Geroff et al. 2014	Illinois	Western Illinois University, Life Science Station	0 record	0%
Owens et al. 2018	Louisiana	Statewide	Present	Not provided
Selfridge et al. 2017	Maryland	Worchester County, 30	0 records	0%

		forested dune study sites		
Smith et al. 2012	Mississippi	Black Belt Prairie	169 records	16.4%
Camilo et al. 2017	Missouri	St. Louis	Two recorded populations	Not provided
Lamke 2019	Nebraska	Southeastern Nebraska	Present	Not provided
Nebraska Bumble Bee Atlas (Xerces Society)	Nebraska	Statewide	79 records	3.0%
Park et al. 2017	Nebraska	Statewide	21 records	Not provided
Figueroa and Bergey 2015	Oklahoma	Statewide	9 records	3.3%
Beckham and Atkinson 2017	Texas	Statewide	86 records	6%
Beckham et al. 2016	Texas	24 counties in NE Texas	73 records	20.2%

Appendix 3

Species status assessment methodology

Distribution

Due to uneven sampling effort across time, the number of Southern Plains bumble bee records varies between decades. EOO is sensitive to the sample size and sampling bias (Figure 9). We checked for the effect of sample size on the EOO estimate. We took random samples of all Southern Plains bumble bee records of varying sizes from 100-1500 observations. For each sample size category, we performed 1,000 resamples and calculated average EOO and 95% confidence intervals. Based on this resampling, the mean EOO value reached 95% of the maximum EOO value between 600-700 observations (Figure 9). Based on this benchmark, decadal comparisons were not considered to accurately estimate EOO given the small (<100) number of Southern Plains bumble bee observations per decade. Calculating EOO for decadal periods showed high variability and EOO was directly related to the number of observations in the decade which underrepresents EOO in decades with lower survey effort.

We therefore compared the historic period (1881-2010) with the recent period (2011-2020) using random resampling to control for sampling effort and bias. Using the observational data for this species, multiple samples were taken from the historic and recent period and their EOO values were averaged together to reduce the chance of a particularly high or low EOO value from the initial sample. Since the most recent decade contained a smaller number of observations (n=662) compared to the historic period, the EOO from the recent decade was compared to the EOO from the historic period with an equal sample size. Random resampling was used to control for sampling bias or a potential gradual range shift, the entire dataset was resampled 1000 times at a sample size of n=662 and the mean EOO was calculated along with 95% confidence intervals for the EOO in the recent and historic periods.

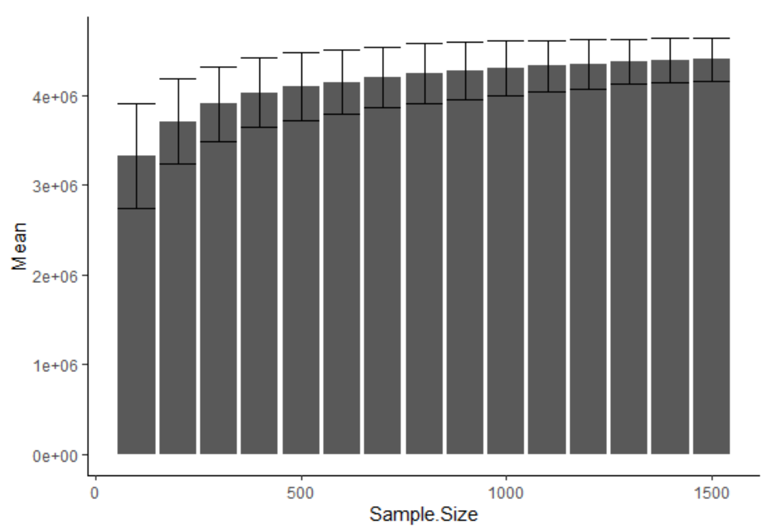


Figure 9. Mean EOO calculated for sample sizes 100-1500. Bars represent 95% confidence intervals. For each sample size, 1000 bootstrap resamplings were conducted to quantify the variability of EOO based on a particular sample size.

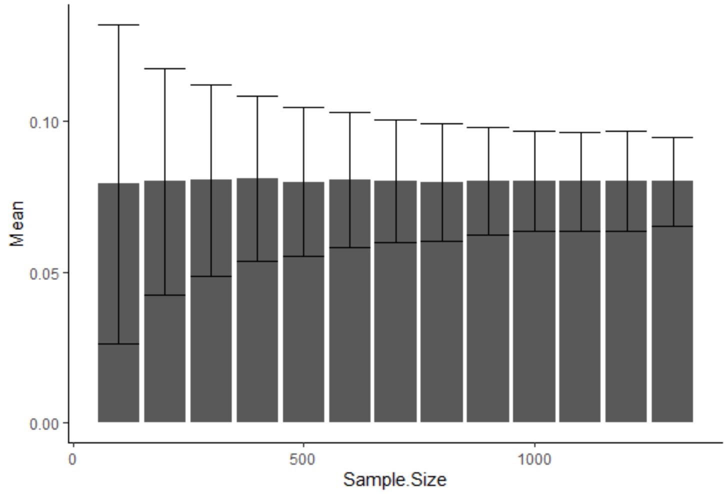
Relative Abundance

While the population size of this species cannot be determined directly with the data available, changes in the frequency of observation relative to other species can be used as a proxy for population stability. We used relative abundance, the number of Southern Plains bumble bee observations relative to the total number of bumble bee observations within its range for this measure. Bumble bee survey methods have changed considerably over the 100+ years of records and are variable between decades and the trends in observation frequency of uncommon species can be obscured by multiple sources of sampling bias. To control for these factors, we used random resampling and data filtering. First, we divided the observations of this species into decadal slices. Second, bumble bee observations in each decade were constrained to reduce geographic and sampling bias. To find the bumble bee records to be used as the reference, we used ArcGIS to include only those observations within 50km of a Southern Plains bumble bee observation. When a record had only county-level information (no lat/long), all bumble bees within that county were included. To further address sampling bias, only distinct bumble bee records were included. Distinct records have a unique day, month, year, state, county, latitude, and longitude. Thus, repeated observations of the same species, on the same day, and at the same latitude/longitude were filtered out to reduce the effect of sampling effort and methods which can under or over represent uncommon species. Due to evolving methods of data collection, including community science, the abundance of common species can depress the relative abundance of uncommon species. Finally, we used bootstrap resampling to address sampling bias and quantify uncertainty in the calculated relative abundance. As survey effort differed between decades, we used the decade with the least number of observations (n=595) to standardize effort. From each other decade we randomly selected 595 distinct bumble bee records, repeated the process 1,000 times, and then reported the average relative abundance with 95% confidence intervals.

Figure 3a shows the relative abundance calculated using distinct and filtered records with bootstrap sampling as described above. Additionally, we checked for the influence of common species by calculating relative abundance after removing the three most common species from the dataset: the common eastern (*Bombus impatiens*), the American (*Bombus pensylvanicus*), and the brown-belted (*Bombus griseocollis*) and this additional relative abundance metric is shown in Figure 3b.

We additionally checked how sample size affected observed relative abundance. Random resampling of the entire dataset revealed that mean relative abundance is robust to sample size when averaged across 1,000 bootstrap samples. Increased sample size decreased the variability in the calculated relative abundance value (Figure 10). Sample sizes above 500 were considered to have acceptable amounts of variability in the calculated relative abundance value.

A



B

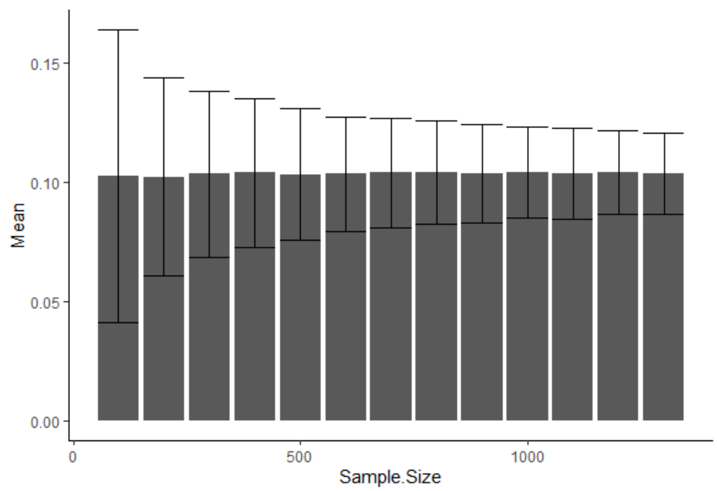


Figure 10. Relative abundance calculated using sample sizes ranging from 100-1500 bumble bees. Each bar represents the average relative abundance calculated from 1000 resamples using data from the decade 2011-2020 (A) and 1881-1920 (B) for each sample size category. The error bars represent 95% confidence intervals for the average relative abundance.

Persistence

We used random sampling to measure county-level persistence over time. Decades with larger numbers of observations have larger numbers of county records, so to control for sampling effort we used random sampling to calculate mean values for persistence. A county was considered persistent if the Southern Plains bumble bee was found in the same county two subsequent decades. All persistence calculations were done using only distinct observations that had unique day, month, year, decade, state, county, latitude, and longitude. This was done to remove repeated observations to control the amount of sampling effort per location.

We used random sampling to calculate the average number of counties that had records in an individual decade as well as in the preceding decade. We selected a random sample of Southern Plains bumble bee observations (n=46) based on the decade with the smallest number of observations. Within each sample we recorded the number of counties that had an observation in each decade that also had an observation in the previous decade. We ran 1000 bootstrap samples for each decade and calculated a mean number of persistent counties and 95% confidence intervals. Results are shown in Figure 5.