U.S. Fish and Wildlife Service

Recovery Plan
for
Rusty Patched Bumble Bee (*Bombus affinis*)

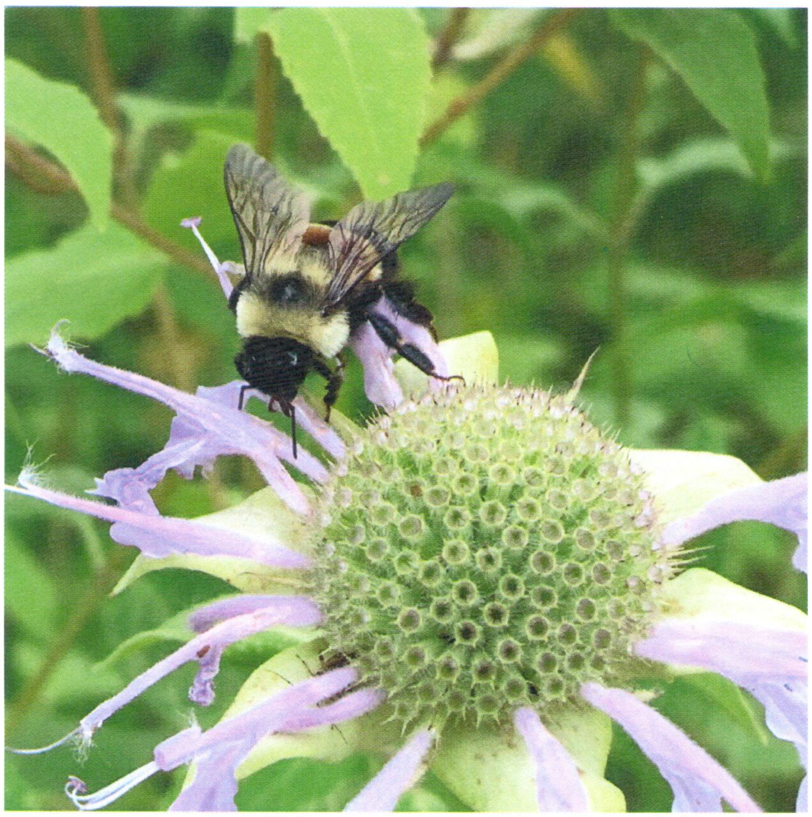

Photo: Tamara Smith, USFWS

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Approved: ______________________________

Regional Director, Region 3
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DISCLAIMER

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Recovery Plan for Rusty Patched Bumble Bee (*Bombus affinis*)

This recovery plan describes the recovery vision and strategy, criteria for determining when the rusty patched bumble bee should be considered for delisting, as well as the broad actions necessary to meet those criteria and time and cost estimates for implementing recovery actions. An introduction provides a brief description of the species' habitat requirements, biology, and limiting factors. The Rusty Patched Bumble Bee Species Status Assessment report (https://www.fws.gov/midwest/Endangered/insects/rpbb/) provides a more detailed accounting of the species biology, threats, and status. A recovery implementation strategy, which serves as an operational plan for stepping down the higher-level recovery actions into specific tasks or activities, is being developed in cooperation with recovery partners. The recovery implementation strategy and species status assessment are developed separately from the recovery plan and can be updated and modified as needed, thereby maximizing flexibility of recovery implementation. More information on the recovery planning process can be found online (https://www.fws.gov/endangered/esa-library/pdf/RPI.pdf).
[Note: Underlined words in this document can be found in the glossary.]

Introduction

Historically, the rusty patched bumble bee was broadly distributed across the eastern United States and upper Midwest, from Maine in the United States and southern Quebec and Ontario in Canada, south to the northeast corner of Georgia, reaching west to the eastern edges of North and South Dakota (Figure 1; USFWS 2016a, p. 49). The rusty patched bumble bee is a social species with an annual cycle that starts in early spring when colonies are initiated by solitary queens emerging from overwintering sites, progresses with the production of workers throughout the summer, and ends with the production of males and new queens in late summer and early fall. Survival and successful recruitment require food from floral resources from early spring through fall, undisturbed nesting habitat in proximity to foraging resources, and overwintering habitat for the next year's queens. Populations consist of tens to hundreds of colonies, and the health (long-term productivity) of populations is affected by the quantity and quality (a diversity of floral resources) of nectar and pollen available and the proximity of these resources to nesting habitat. In addition, bumble bee populations may be limited by landscape features that restrict dispersal, especially of reproductive males and females (USFWS 2016a, pp. 3, 15-17).

Prior to its listing as endangered in 2017, the species experienced a widespread and steep decline. The exact cause of the decline is unknown, but evidence suggests a synergistic interaction between an introduced pathogen and exposure to pesticides (specifically, insecticides and fungicides; USFWS 2016a, p. 53). The remaining populations are exposed to a number of interacting stressors, including pathogens, pesticides, habitat loss and degradation, non-native and managed bees, the effects of climate change, and small population biology (USFWS 2016a, p. 40). These stressors likely operate independently and synergistically. For example, dietary stress due to insufficient floral resources may reduce an individual's resiliency to pathogens and pesticides, exposure to insecticides can reduce resistance to disease, and exposure to fungicides can increase insecticide toxicity (USFWS 2016a, p. 53 and papers cited within). Although the limiting factors are multi-faceted, solutions may be simpler, as actions to reduce or remove any of these stressors are likely to have great benefits (Goulson *et al.* 2015, pp. 6-7).

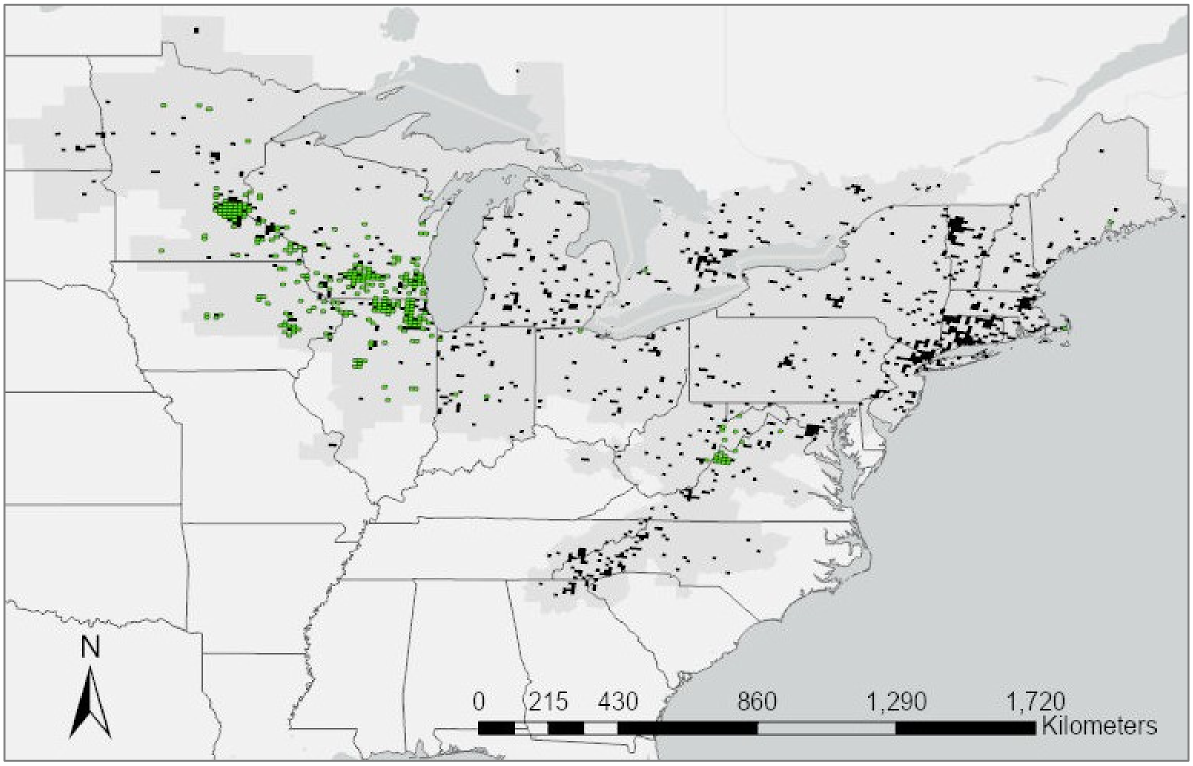

Figure 1: Historical distribution of the rusty patched bumble bee. The historical county range is shaded in gray; historical documented populations (verified record between 1900 and 2006) are shaded in black and extant populations (verified record between 2007 and 2019) are shaded in green. Current maps can be found at https://www.fws.gov/midwest/endangered/insects/rpbb.

Recovery Vision and Strategy

The recovery vision for the rusty patched bumble bee is to conserve a sufficient number and distribution of populations to ensure the species' long-term viability such that it may be removed from the List of Endangered and Threatened Wildlife. To achieve long-term viability, the species must endure the pressures of: 1) environmental and demographic stochasticity, 2) stressors, 3) catastrophes, and 4) novel changes in its environment, which requires multiple, healthy populations widely distributed across the breadth of adaptive diversity (USFWS 2016a, pp. 20-21). Incorporating the conservation principles of representation, resiliency, and redundancy ensures a sufficient number and distribution of populations such that the species can withstand these pressures.

Achieving the recovery vision requires a multi-pronged recovery strategy with spatial and temporal components. Spatially, the path to achieving recovery is structured by delineating units that ensure adaptive capacity is sufficient to allow for both near and long-term adaptation to novel changes in the species' environment. The strategy also includes restoring redundancy and resiliency within these units to ensure the species can withstand natural annual variation, stressors, and catastrophes.

Temporally, the recovery strategy focuses on a sequence of first halting declines, then reversing declines, and ultimately securing the long-term viability of the species across a specified range. This phased approach involves emphasizing different objectives as recovery proceeds, thereby focusing initially on preventing extinction before moving toward broader, more proactive conservation objectives. The specific objectives include:

1. Preventing further loss of populations by (a) identifying and ameliorating the threats driving the declines, (b) increasing the health of individuals and the number of colonies comprising populations, and (c) ensuring appropriate connectivity between populations.
2. Ameliorating pervasive threats, including those from pathogens, pesticides, habitat loss, managed bees, and effects of climate change.
3. Buffering against catastrophes and environmental stochasticity (may require reintroduction into unoccupied areas within the historical range) by increasing the number of genetically and demographically healthy populations and the spatial distribution of those populations.
4. Buffering against novel changes in its physical and biological environment by restoring populations across the breadth of its natural adaptive diversity.
5. Protecting populations and their habitats and abating threats into the foreseeable future.

This recovery plan identifies the principal uncertainties and assumptions underlying the initial stage of the rusty patched bumble bee recovery effort. Resolution of these key uncertainties is needed to provide confidence that the criteria ensure the rusty patched bumble bee is resilient to annual stochasticity and stressors, is able to withstand catastrophic events, and has sufficient ability to adapt to novel changes in its environment. Adaptive management, using the recovery implementation strategy, is key to resolving these uncertainties and verifying the assumptions and hypotheses. The key uncertainties include:

1. What is needed to maintain a healthy population? Specifically:
    a. The number of colonies needed to support a healthy population
    b. The physical and habitat requirements for nesting success and overwinter survival
    c. The foraging requirements of colonies
    d. The dispersal ecology of males and queens
    e. The minimum effective population size (Ne) and connectivity (gene flow) needed between populations to ensure population health
2. What distribution of populations within each conservation unit is needed to meet the recovery criteria?
3. What are the geographic-specific stressors affecting population health and to what extent are they preventing the full recovery of the rusty patched bumble bee?
4. What are the effects of climate change and how to alleviate those effects into the future?

Lastly, involvement and support from partners and the public is integral to rusty patched bumble bee conservation. The cornerstone of this strategy is sustaining and expanding conservation partnerships and general public participation by implementing recovery through close collaboration and public outreach. This will help shape and coordinate short-term recovery efforts within the context of a cohesive, long-term approach.

Recovery Criteria

Recovery criteria provide objective, measurable benchmarks to indicate when recovery may have been achieved. These criteria are founded on the best scientific information available for the species and may require modification as the aforementioned uncertainties are resolved.

A. Downlisting Criteria

Criterion A1: Maintain healthy populations of the rusty patched bumble bee in each of the 5 Conservation Units (Figure 2), as demonstrated by each unit having the following:

1) **a minimum number of healthy populations as specified in Table 1 and**
2) **a stable or increasing trend in percent occupancy over a minimum of 5-10 years.**

Criterion A2: Ensure population clusters are distributed across a diversity of habitat, ecological, and climate types within each Conservation Unit. A population cluster is three or more healthy populations that are adjacent to each other.

Table 1. Minimum number of healthy populations

Conservation Unit	Number of healthy populations
Unit 1	42
Unit 2	21
Unit 3	52
Unit 4	52
Unit 5	52

B. Delisting Criteria

Criterion B1: Downlisting criteria A1 and A2 have been met.

Criterion B2: Mechanisms are in place that provide a high level of certainty that downlisting criteria will continue to be met into the foreseeable future.

Specifically, Conservation Unit-specific mechanisms will ensure that into the foreseeable future:

1) The number and distribution of healthy populations will be maintained at the levels needed to meet downlisting criteria,
2) A sufficient quality and quantity of habitat will be maintained to support those healthy populations, and

3) The negative effects from threats (including but not limited to pathogens, pesticides, climate change, and non-native bees and managed bumble bees) have been reduced such that the population-level effects are negligible.

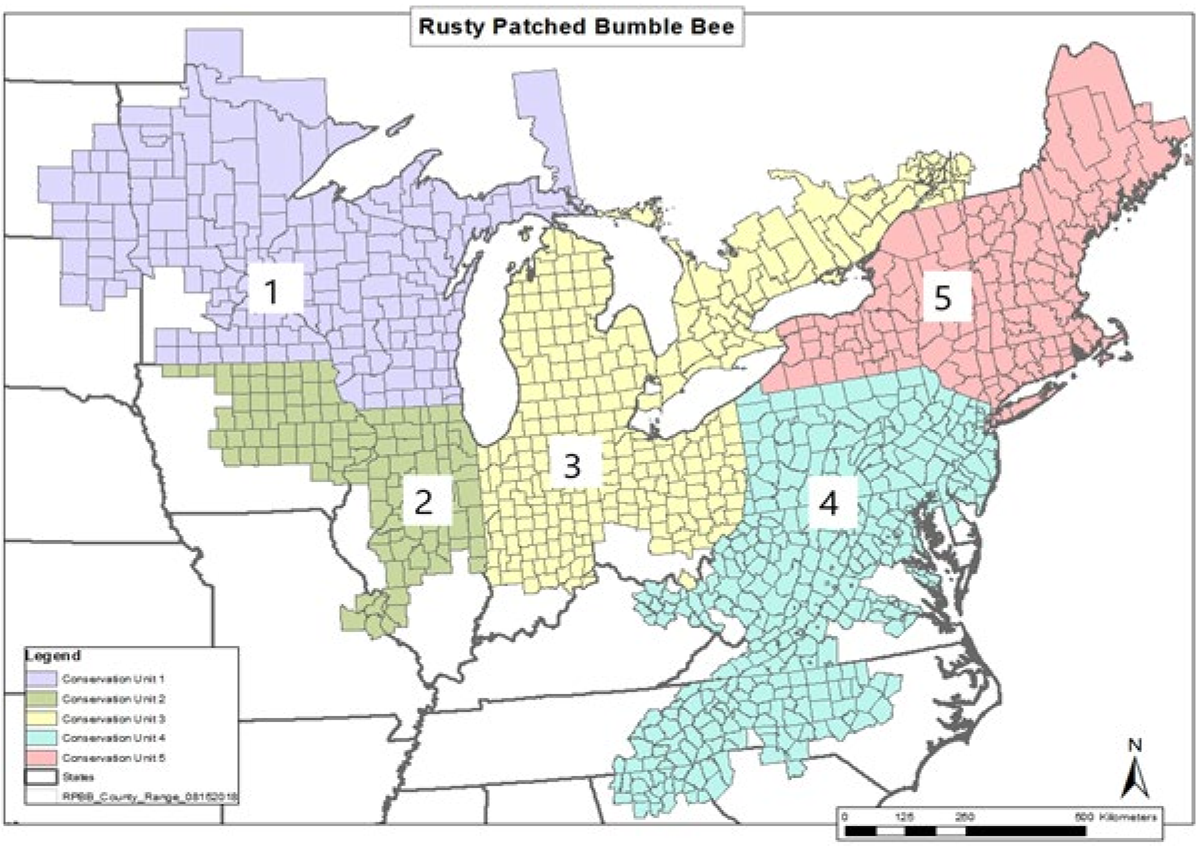

Figure 2: Rusty patched bumble bee Conservation Units (CUs) from west to east: CU1 (Upper West), CU2 (Lower West), CU3 (Midwest), CU4 (Southeast), and CU5 (Northeast). In the event of a previously unknown county record, the county would be assigned a CU according to its U.S. state or Canadian province.

Rationale:

Downlisting Criteria: The life-history strategy of the rusty patched bumble bee is being highly abundant and broadly distributed across a diversity of ecological communities and climates (thousands of populations documented across 29 states and 2 Canadian provinces; USFWS 2016a, p. 29). While restoring all its historical occurrences is unnecessary for recovery, restoring the rusty patched bumble bee's natural high abundance and broad distribution are needed for the species to withstand environmental stochasticity, stressors, and catastrophes, and adapt to changes over time.

Maintaining healthy populations in each of the five Conservation Units (criterion A1) captures the variation in adaptive diversity across the rusty patched bumble bee's range, thereby preserving a wide breadth of genetic and ecological diversity and maintaining the species' ability to adapt to a changing environment (USFWS 2016a, pp. 20-21). The likelihood of populations persisting in the Conservation Units is a function of the trend in and the number of healthy populations (O'Grady *et al.* 2004, p. 518). The minimum number of healthy populations provides evidence of successful recruitment within each Conservation Unit, while ensuring a stable or increasing trend in occupancy provides evidence that the species is no longer in decline. See the Appendix for a description of the methodologies used to determine the target number of healthy populations and to assess whether this criterion has been met.

Population clusters (criterion A2) foster gene flow between populations, thereby facilitating demographic rescue, ensuring genetic health, and maintaining adaptability of populations. Maintaining gene flow between populations is especially important in species like the rusty patched bumble bee because of genetic characteristics that can produce inviable or sterile males (that is, single locus complementary sex determination), which may lead to rapid extirpation, especially after populations become small and isolated (Zayed and Packer 2005, p. 10744; Zayed 2009, entire).

Population clusters distributed across a diversity of climatological regions and habitats (criterion A2) guards against regional-scale environmental stochasticity, broad-scale catastrophic events (for example, regional heat waves and droughts), disease epidemics, and climate change. The ideal number and location of clusters will vary with Conservation Unit characteristics (for example, likelihood and degree of regional-scale environmental stochasticity, diversity of climates, potential for gene swamping and outbreeding depression). Achieving criterion A2, in combination with criterion A1, provides confidence of the rusty patched bumble bee's long-term viability in each of the Conservation Units.

Delisting Criteria: Having healthy populations and population clusters with stable or increasing occupancy trends in each of the five Conservation Units (criterion B1) provides assurance that the rusty patched bumble bee is not in danger of extinction throughout all or a significant portion of its range.

Mechanisms (criterion B2) such as agreements, regulations, plans, conservation easements, and land acquisition are needed to ensure the downlisting criteria will continue to be met into the foreseeable future. For example, developing and implementing species-specific management plans and best management practices can be used to maintain sufficient quality and quantity of habitat into the foreseeable future. Similarly, implementing species-specific integrated pest management programs (to manage adverse effects of pesticides), implementing disease epidemic prevention plans (to reduce disease introduction and spread), and participating in clean stock programs (to manage adverse effects from commercially-managed bees) may be used to manage threats into the foreseeable future.

Recovery Actions

This section describes the broad categories of actions necessary to achieve the recovery vision for the rusty patched bumble bee. These actions apply to each of the Conservation Units, but specific implementation may differ geographically (population-specific). These broad categories of actions will be used to develop step-down, recovery implementation strategies and prioritized tasks specific to each Conservation Unit's needs. Additionally, some actions will be developed and coordinated across Conservation Units as they apply range wide (for example, research needs, outreach, and education). The recovery implementation strategies will be developed in coordination with our conservation partners and updated on an as-needed basis.

The broad categories of actions include:

1. **Minimize risks due to disease, pests, pathogens, and parasites**. Successful measures to minimize risk of disease, pests, pathogens, and parasites spread from non-native bees, managed bumble bees, and other sources may include the following:
    a. Conduct population-specific disease, pest, pathogen, and parasite assessments and risk analyses.
    b. Implement and enforce clean stock programs.
    c. Implement good practices for production and use of non-native and managed bees (for example, monitoring pathogens in bee stocks and preventing escapes from greenhouses).
    d. Conduct research on sources, exposure, and impacts of disease, pests, pathogens, and parasites.
    e. Provide outreach and education to the public, honeybee hobbyists, and commercial beekeepers.

    Estimated cost: $1,200,000.

2. **Minimize exposure to harmful pesticides**. Successful minimization measures may include the following:
    a. Conduct population-specific pesticide assessments and risk analyses.
    b. Conduct research on sources, exposure, and impacts of pesticides.
    c. Implement pesticide minimization measures (for example, create pesticide registry programs, implement pollinator-safe labeling on nursery plants, establish buffers around populations, implement integrated pest management).
    d. Provide outreach and education to the public and agricultural community.

    Estimated cost: $855,000.

3. **Manage and protect populations.** Measures to increase the number and distribution of populations and improve the health of target populations may include the following:
    a. Increase effective population sizes at target populations.
    b. Implement conservation propagation methods (such as augmentation or enhancement, reintroduction, insurance populations, and translocation) after weighing the benefits against the risks (for example, spreading of disease and pathogens in the wild, adversely altering genetic composition and adaptation of wild populations).
    c. Manage populations to improve resiliency to the effects of climate change.
    d. Conduct research to understand biological and life-history requisites to maintain or restore populations (for example, demographics, nesting and overwintering ecology, genetics, dispersal behavior, and effects of climate change).
    e. Engage the public to garner support for rusty patched bumble bee conservation.

    Estimated cost: $3,785,000.

4. **Assess population and habitat status and trends through monitoring and surveys**. This may include, but is not limited to, the following:

   a. Develop and use rigorous standardized protocols and community science to monitor population health, habitat, and threats.
   b. Conduct surveys at potential new sites.
   c. Engage the public in rusty patched bumble bee monitoring and survey efforts through community science.

   Estimated cost: $7,977,000.

5. **Manage, protect, and enhance habitat**. Successful management, protection, and enhancement measures may include the following:
   a. Maintain, improve, and restore overwintering, foraging, and nesting habitat.
   b. Restore habitat connectivity to enable dispersal.
   c. Develop and implement adaptive habitat management plans, considering monitoring results from Action #4 above, and refine management.
   d. Create and implement habitat management incentive programs.
   e. Secure permanent protection of habitat through land acquisition or conservation easements.
   f. Conduct research to determine efficient and effective habitat management techniques.
   g. Manage habitat to improve resiliency to the effects of climate change.
   h. Provide outreach and education to the public and land managers to garner support for habitat conservation at local and regional levels.

   Estimated cost: $2,692,000 (+ undetermined cost for potential land acquisition).

Estimated Date of Recovery: If all actions are fully funded and implemented as outlined, including full cooperation of partners needed to achieve recovery, we anticipate delisting could be achieved as soon as 2061. It is difficult to estimate the time it will take to accomplish recovery actions such that the delisting criteria have been met because the exact causes of population declines remain unclear. Assuming the causes could be identified within the next 10 years, it would likely take at least another 20 years to address the causes, followed by an additional 10 years to monitor the response of populations. Thus, we estimate that recovery could be accomplished in 40 years. We recognize, however, that it may take longer than this estimate to recover and delist the species.

Estimated Cost of Delisting: The estimated costs associated with implementing recovery actions for delisting are $16,509,000. Cost estimates reflect costs for actions needed to achieve rusty patched bumble bee recovery. Some cost for recovery actions are not determinable at this time, therefore, the total cost for recovery may be higher than this estimate.

Glossary

Adaptive diversity – The range of variation within a species, and the source of species' adaptive capabilities. For rusty patched bumble bee, its adaptive diversity is a function of the amount and spatial distribution of genetic and phenotypic diversity (USFWS 2016a, pp. 20-21). By maintaining these two sources of adaptive diversity, rusty patched bumble bee responsiveness and adaptability is preserved.

Allelic richness – The number of alleles present at a locus.

Colony – A genetically related unit consisting of a single foundress queen, female workers, males, and gynes (reproductive females). Colony sizes of rusty patched bumble bee are considered large compared to other bumble bees, and healthy colonies may consist of up to 1000 individual workers in a season (Macfarlane *et al.* 1994, pp. 3-4).

Gene swamping – Loss of the genetic variance at a locus under selection because gene flow is too high (Lenormand 2002, Glossary, p. 188).

Healthy population – A population that successfully recruits (produces queens and males) over time. To successfully recruit, a population needs to be demographically and genetically healthy (USFWS 2016a, pp. 18-20).

- *Demographic health* – Tens to hundreds of colonies, population growth rates stable or increasing (lambda, λ >1), individuals in good physical body condition (for example, low pathogen and pesticide loads)
- *Genetic health* – Large effective population size (N_e), high heterozygosity (He) and allelic richness, low or natural levels of diploid male prevalence, and sufficient gene flow between populations to maintain He and allelic richness.

Insurance population – A healthy functioning population managed in captivity to maintain genetic diversity in case of catastrophic loss in the wild.

N_e – Effective population size. The number of mated gynes (females that will become queens).

Nesting habitat – Nests are typically in abandoned rodent nests or other similar cavities in well-drained soil and sheltered from the elements (Plath 1922, pp. 190-191; Frison 1923, pp. 265-267; Macfarlane *et al.* 1994, p. 4; Evans 2020, pers. comm). Bumble bees may nest in a variety of habitats including forest and forest edges, agricultural and urban landscapes, and grassland (Liczner and Colla 2019, p. 794), but may favor transitional zones between wooded and open habitats and other landscapes with dense leaf litter and fallen logs (Lanterman *et al.* 2019, pp. 136-137).

Outbreeding depression – Reduced fitness of offspring from mating between genetically divergent individuals (Whiteley *et al.* 2015, p. 42).

Overwintering habitat – Overwintering likely occurs primarily in woodlands, where they form a chamber in soft soil, a few centimeters deep, sometimes using compost or mole hills (Goulson 2010, p. 11). Overwintering queens are found mostly in shaded areas near trees or in banks without dense vegetation (Liczner and Colla 2019, p. 792).

Population – A population is a collection of tens to hundreds of colonies. We defined population as a single 10 x 10 kilometer (km) grid (for further explanation see USFWS 2016a, p. 11).

Redundancy – An indicator of the ability of a species to withstand catastrophic events by spreading risk among multiple populations or across a large area (Smith *et al.* 2018, p. 304). Catastrophes are stochastic events that are expected to lead a population collapse regardless of population health and for which adaptation is unlikely (USFWS 2016b, p. 13).

Representation – An indicator of the ability of a species to adapt to changing environmental conditions over time as characterized by the breadth of genetic and environmental diversity within and among populations (Smith *et al.* 2018, p. 304). Changes include both near-term and long-term changes in its physical (for example, climate conditions, habitat conditions, habitat structure) and biological (for example, pathogens, competitors, predators) environments.

Reproductive capacity – The average number, size, and composition (number of workers, gynes, and males produced) of the colonies comprising a population.

Resiliency – The ability of a species to withstand stochastic disturbance; resiliency is positively related to population size and growth rate and may be influenced by connectivity among populations (Smith *et al*. 2018, p. 304). Stochastic disturbance includes environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature, rainfall), periodic disturbances within the normal range of variation (fire, floods, storms), and demographic stochasticity (normal variation in demographic rates such as mortality and fecundity). Simply stated, resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions.

Single locus complementary sex determination (sl-CSD) – The underlying genetic system that determines the sex of some insects, in which heterozygotes (two genes inherited for a trait, one from the mother and one from the father) at a single sex gene locus (chromosome where a gene is located) develop as females, while hemizygotes (normal haploid) and homozygous diploids develop as males (for further information see Zayed and Packer 2005, p. 10744).

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Appendix

Methodology for determining downlisting criterion A1

Delineating Conservation Units – The Conservation Units were delineated by overlaying Bailey's Ecoregion Divisions (Bailey 1983, Bailey *et al.* 1994) (to capture differences in ecological communities) with five degree longitudinal and latitudinal lines (to capture temperature variation), and then slightly modified to incorporate physical barriers to dispersal (for example, Lake Michigan) and state boundaries for ease of Recovery Implementation Strategy planning and implementation. Lastly, the Bailey's Ecoregion Divisions in the Appalachian Mountains (Hot Continental Mountains) and Piedmont areas (Subtropical Division) were combined because the species was not historically common and consistently found throughout the Piedmont region (Subtropical Division) in the southeastern United States.

Minimum Number of Healthy Populations – We calculated the minimum number of healthy populations for each Conservation Unit by the following steps.

- Step 1 - Calculated rusty patched bumble bee average decadal percent occupancy: As a population is a collection of tens to hundreds of colonies, of which the number and location vary over time, we applied a grid methodology. Briefly, we overlaid 10 x 10 km grids across the range of rusty patched bumble bee and assigned a unique numerical identifier to each 10 x 10 km grid; a grid occupied by rusty patched bumble bee represents a population (USFWS 2016a, p. 11). A *Bombus* grid is a grid that has at least one occurrence of any *Bombus* species during a decade. The percent occupancy is the proportion of *Bombus* grids occupied by rusty patched bumble bee over a decade. We calculated the average decadal percent occupancy as the mean decadal percent occupancy (that is, sum the decadal percent occupancy and divide by the number of decades (6)).
- Step 2 - Calculated the target number of populations: We multiplied the rusty patched bumble bee's average decadal percent occupancy (Step 1) by the total number of *Bombus* grids per Conservation Unit (Table A1).
- Step 3 - Calculated the target minimum number of healthy populations: Used Cochrane's (1977, p. 76) standard statistical sample size equation, $n = n_o \div 1 + (n_o/N)$, where, N is the target number of populations (calculated in Step 2) and $n_o = z^2 * p * (1-p) \div e^2$. z^2 is the standard normal variate based on the confidence coefficient (1.65, 90% confidence), p is the standard deviation (0.5), and e is the error tolerance level (10%). In Step 2, we calculated our target number of healthy populations for recovery. It is unnecessary to document the health of all those populations if we monitor an adequate subset. Cochrane's equation gives us the subset needed to feel confident that our target number of populations (Step 2) are healthy as well.

Table A1. Unit-specific percent occupancy and population targets. Average decadal percent occupancy is the mean proportion of *Bombus* grids occupied by rusty patched bumble bee over six decades. The number of populations (N) is the number of rusty patched bumble bee populations to achieve recovery. The number of healthy populations (n) is the minimum number of populations that require documentation of being healthy.

Conservation Unit	Average Decadal % Occupancy	# Population (N)	# Healthy Populations (n)
Unit 1	16	113	42
Unit 2	11	31	21
Unit 3	21	219	52
Unit 4	25	226	52
Unit 5	27	219	52

Planned methodology and information to consider when assessing whether downlisting recovery criteria have been achieved

Trend in percent occupancy – The percent occupancy can be calculated using the grid methodology described above and computed as the proportion of *Bombus* grids within a Conservation Unit that are occupied. A stable or increasing occupancy trend (growth rate >0.0) should be determined using a statistically valid method with an appropriate level of precision (for example, alpha = 0.05). The specific survey methods and frequency of surveys should be established following a standardized, statistically valid methodology. We plan to develop this protocol as part of the recovery implementation strategy process.

Population health – Population health is measured by its ability to successfully recruit (produces gynes and males) over time. To successfully recruit, a population needs to be demographically and genetically healthy. The significant determinants of demographic health are population abundance (the number of successful nests) and population growth rate. The population abundance required to support a viable population varies spatially but should be sufficiently large to withstand environmental stochasticity and maintain genetic health (for example, avoid diploid male vortex); population growth rates need to be greater than 1.0 given the species' sensitivity to environmental stochasticity. Both of these variables, population abundance and growth rate, are influenced by the amount and quality of floral resources, nesting habitat, and overwintering habitat. Population abundance and growth are also influenced by the physical body condition (for example, low pesticide and pathogen loads) of individuals comprising the populations. The determinants of genetic health for most species include effective (breeding) population size, heterozygosity and allelic richness, and gene flow; for rusty patched bumble bee, prevalence of diploid males may also be an important measure of genetic health.

As the minimum or threshold values for demographic and genetic determinants are not yet known, a standardized methodology to evaluate population health needs to be developed. Specifically, the analysis should be designed to assess population demographic and genetic health along with incorporating environmental stochasticity, catastrophes, and resilience to stressors (including but not limited to pathogens, pesticides, climate change, and non-native bees and managed bumble bees). The analysis should conform to scientific standards and apply the best available data and feasible methodologies.