Species Status Assessment Report
for the
Frosted Elfin (*Callophrys irus*)
Version 1.1

Frosted elfin butterfly (photo credit: Pondhawk via Flickr's Creative Commons).

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U.S. Fish and Wildlife Service
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Version 1.0 (November 2017) of this report was available for public review and comment. This version incorporates those comments.

Suggested reference: U.S. Fish and Wildlife Service. 2018. Species status assessment report for the frosted elfin (Callophrys irus), Version 1.2. April 2018. Cortland, NY.

EXECUTIVE SUMMARY

This report summarizes the results of a species status assessment (SSA) conducted for the frosted elfin (*Callophrys irus*). The U.S. Fish and Wildlife Service (Service) is proactively assessing the conservation status of the frosted elfin to determine whether or not the species may warrant federal protection under the Endangered Species Act (Act). The Service has prioritized the frosted elfin's status review, using the July 2016 Methodology for Prioritizing Status Reviews, as a Bin 4 species (species for which proactive conservation efforts by states, landowners, and stakeholders are underway or being developed). As a result of this binning assignment, the Service is working with the state agencies and other partners across the species' range to develop and implement conservation efforts. A determination on the frosted elfin's listing status is scheduled for no later than September 30, 2023, in our National Listing Workplan[1]. The SSA report (and its underlying analyses) does not represent a decision by the Service whether or not to list a species under the Act. Instead, this SSA report provides a review of the best available information strictly related to the biological needs and current status of the frosted elfin.

Using the SSA framework, we consider what a species needs to maintain viability by characterizing the biological status of the species in terms of its resiliency, redundancy, and representation (collectively the "3Rs") (Shaffer *et al.* 2002, pp. 139–140; Wolf *et al.* 2015, entire; Smith *et al.* 2018, entire). Resiliency is the ability to sustain populations in the face of environmental variation and transient perturbations (stochastic events). Redundancy means having a sufficient number of populations for the species to withstand catastrophic events (such as a rare destructive natural event or episode involving many populations). Representation is the ability of a species to adapt to near- and long-term changes in the environment; it is the evolutionary capacity or flexibility of a species. Representation is the range of variation found in a species and this variation—called adaptive diversity—is the source of species' adaptive capabilities.

Our approach for assessing frosted elfin viability involved two of the three stages of an SSA. In Stage 1, we described the species' ecology in terms of the 3Rs; specifically, we identified the ecological requirements for survival and reproduction at the individual, population, and species levels. In Stage 2, we assessed the species' historical and current condition in relation to the 3Rs and identified past and ongoing factors (beneficial and risk factors) that led to the species' current condition. We intend to use this information to identify additional conservation partners and stakeholders so that we can organize a larger conservation effort to identify and implement actions for ensuring the species' viability. Stage 3, assessing the species' future condition and

[1] National Listing Workplan can be viewed at https://www.fws.gov/endangered/what-we-do/listing-workplan.html, accessed December 12, 2017.

viability, will be completed at a later time, prior to making a listing determination, and take into account those conservation efforts planned and implemented on the frosted elfin's behalf.

See Chapter 1 for more information.

Background

The frosted elfin is a small non-migratory butterfly dependent on specific host plants [wild blue lupine (*Lupinus* spp.) and wild indigo (*Baptisia* spp.)] to complete its annual life cycle. Adults fly in early spring, mate, and lay eggs on host plants. Larvae go through four instars and pupate for most of the year on or near host plants in the leaf litter or beneath the soil surface.

There are three described subspecies of the frosted elfin: (*Callophrys irus irus, C. i. hadros,* and *C. i. arsace*). We recognize that there is some uncertainty about the taxonomic validity and/or range of *C. i. arsace* expressed by experts. However, until that uncertainty is resolved with additional genetic data, we will continue to use the published taxonomy as the best available data. Thus, we conducted our analyses for the entire species and each subspecies.

The current range of the frosted elfin includes 25 states (Figure E-1). The species is now likely extirpated in Ontario, Canada, and the District of Columbia, Georgia, Illinois, and Vermont after sites were lost for a variety of reasons including incompatible vegetation management, catastrophic fire, and residential development.

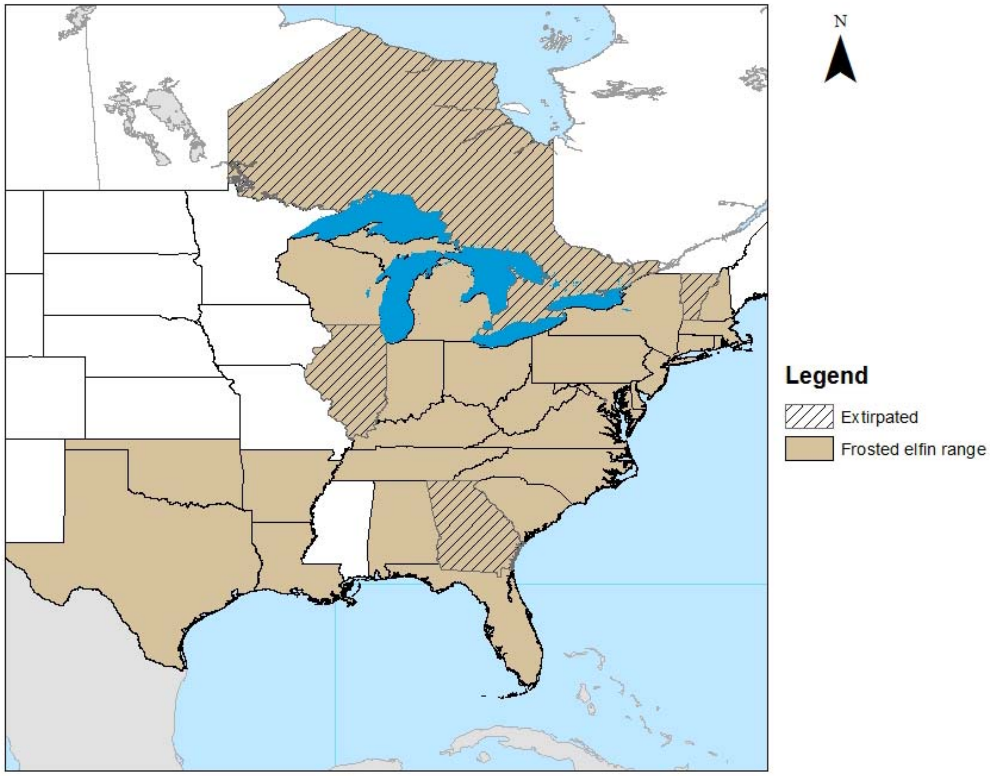

Figure E-1. Current frosted elfin range by State/Province.

A portion of the range overlaps with the federally listed endangered Karner blue butterfly (*Lycaeides melissa samuelis*) (Figure E-2) and positive correlations have been found between abundances of the two species in Wisconsin (Swengel and Swengel 1997, p. 135). Where the species co-occur, both use wild blue lupine as host plants and face similar threats or potential benefits from management.

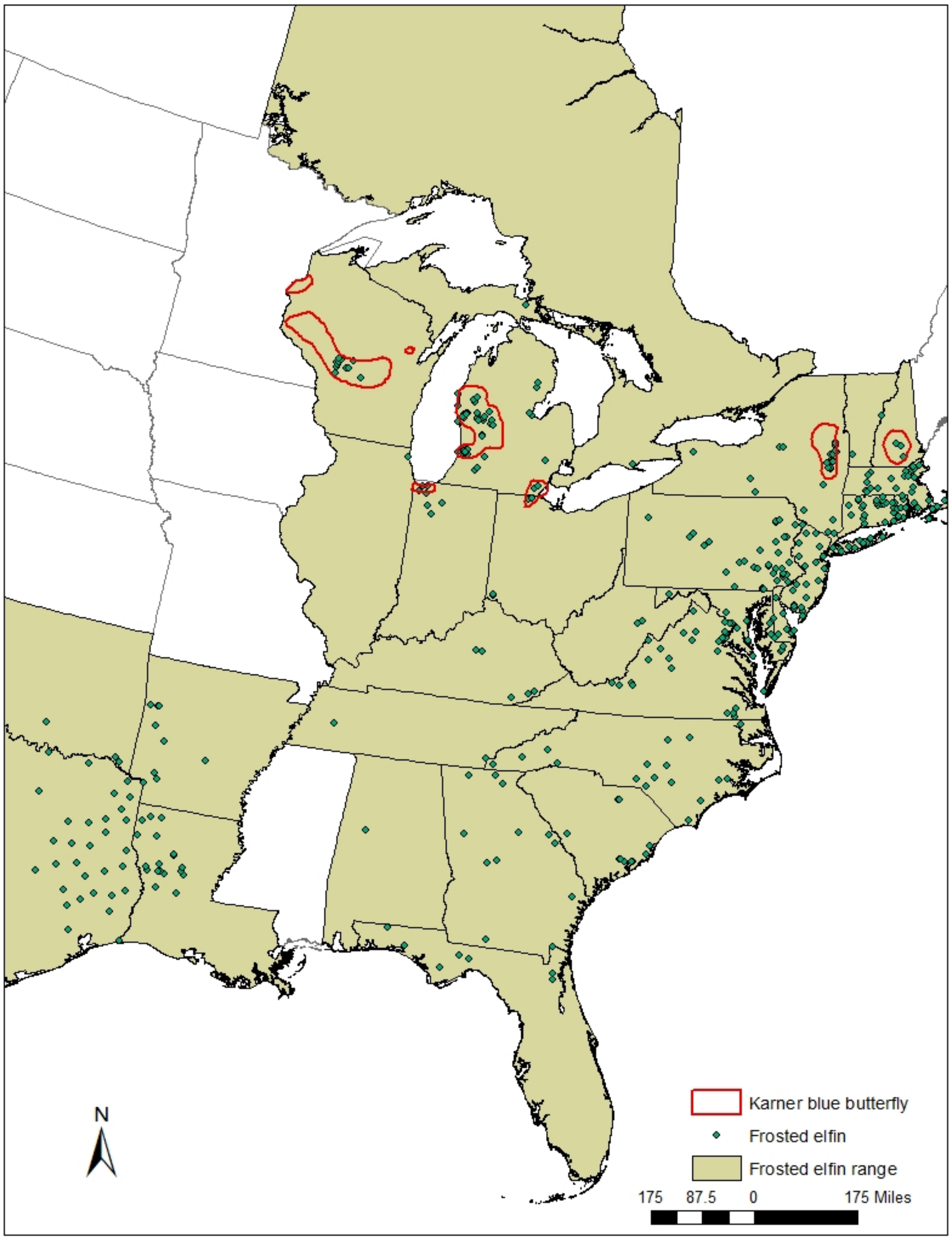

Figure E.2. Current range of the Karner blue butterfly and all known (including presumed extirpated) frosted elfin locations.

See Chapter 2 for additional information.

Methodology

To assess the biological status of the frosted elfin across its range, we used the best available information, including peer-reviewed scientific literature and academic reports, survey data provided by state and federal agencies across the range, and discussions with several frosted elfin experts who provided important information and comments on how to define frosted elfin populations. Fundamental to our analysis of the frosted elfin was the determination of scientifically sound analytical units at a scale useful for assessing the species. In this report, we defined frosted elfin analytical units as populations, which are based primarily on known occurrence locations and proximity to the next closest known occurrence location.

At the species level, the frosted elfin needs a sufficient number and distribution of healthy populations to withstand environmental stochasticity (resiliency), catastrophes (redundancy), and biological and physical changes in its environment (representation) over time.

After consulting with the species' experts, we identified the factors (*i.e.*, stressors and conservation measures to address stressors) most likely affecting the frosted elfin. These include the effects of small population size, habitat loss or degradation from development, invasive plant species, succession, and incompatible management resulting in habitat fragmentation (isolated habitat patches). Ongoing conservation efforts include habitat management or restoration (primarily in areas with overlap with the Karner blue butterfly). As you will note below, for this version of the SSA, we did not explicitly include conservation efforts as a separate metric in our scoring of population health as we felt that conservation effort success can be observed through the size of the butterfly population and habitat condition. See Chapter 4 for more information on the factors influencing frosted elfins.

Most populations had not been visited within the last 10 years or if they were visited, no information about the number of frosted elfin seen or habitat condition was available. In some cases surveys were conducted, habitat appeared suitable, and no frosted elfin were observed, but surveys were not sufficient to suggest "presumed extirpated." Any of these resulted in the population being classified as having an "unknown" condition; therefore, no scoring of the individual metrics was needed (Table E-1). Multiple populations are considered extirpated or presumed extirpated if the habitat is completely gone or is no longer considered suitable for frosted elfins or the habitat appears suitable, but no frosted elfins were observed during multiple subsequent surveys. For the remaining populations, we evaluated their potential resiliency (i.e., population health or condition) using four metrics:

- last number of butterflies observed;
- acreage of host plants;
- current overall habitat condition; and

- number of ongoing stressors to the habitat/population.

These metrics were initially selected in hopes that the supporting data would be consistent across the range of the species and at a resolution suitable for assessing the species at the population level. However, we have concluded that the majority of frosted elfin populations lack sufficient information to assess many of these metrics. We allowed for scoring of metrics even when its status was unknown and summed the individual metric scores to provide an overall condition score of "low," "moderate," or "high" for each population that was then used to assess the current condition across its range (Table E-1).

Table E-1. Current condition category table.

	Condition Class				
Metric	**Unknown**	**Presumed Extirpated**	**Low**	**Moderate**	**High**
FE last count	unknown	0	<15	15 to 30	>30
Acreage of host plant patches	unknown	Not present but restorable	≤0.99 ac (0.4 ha)	1 to 5.9 ac (0.41 to 2.4 ha)	>5.9 ac (>2.4 ha)
Documented stressors	unknown	NA	3+	1 to 2	0
Habitat condition	unknown	NA	Unsuitable	NA	suitable

See Chapter 3 and Appendix A for more details on how we evaluated the overall current condition for each population.

Conclusions

We identified 411 populations across the species' range. These populations were analyzed by subspecies and host plant.

Resiliency (Table E-2): Of the 411 potential populations identified across the range, 30 (7 percent) appear to have been extirpated with the extirpations representing a complete loss of resiliency in those populations. Of the remaining 381 populations, 329 (86 percent) have "unknown" resiliency, 1 (0.3 percent) has a current score of "high" resiliency, 37 (10 percent) have a current score of "moderate" resiliency, and 14 (4 percent) have a current score of "low" resiliency.

Redundancy: The frosted elfin retains some level of redundancy with 381 populations distributed across much of the range; however, over time, populations have been lost from areas of the range. The loss of individual frosted elfin populations and the areas they occupied within the species' historical range has reduced the ability of the frosted elfin to avoid species-level effects from a catastrophic event. In addition, the distance remaining between most extant populations is too great to allow for meaningful genetic exchange or repatriating extirpated sites.

Representation: Frosted elfin populations continue to occur in scattered populations across the geographic range of the species, with losses in the northern extremes (Vermont and Ontario), some eastern areas of the range (Georgia and District of Columbia), and the Midwest (Illinois). We do not have rangewide genetic information to understand the potential impact of those losses. There are similar numbers of frosted elfin populations using either lupine or indigo currently have an "unknown," "presumed extirpated," "low," or "moderate" condition. In terms of subspecies representation, historical vs. current condition is similar for *Callophrys irus irus* and *C. irus hadros.* The majority (83 percent) of all populations (including "presumed extirpated") are considered *C. irus irus* with 15 percent considered *C. irus hadros*. Similar to historical range, only 7 populations (2 percent) are considered *C. irus arsace*. However, the status of all *C. irus arsace* populations is considered "presumed extirpated" (pers. communication, B. Scholtens) resulting in the potential loss of this subspecies. Given the large percentage of populations with "unknown" resiliency, it is difficult to assess the overall status of the species. If many of the "unknown" status sites are actually extirpated, this leaves significant gaps in any of our measures of representation.

Overall assessment: The primary factors currently influencing the status of populations include inherent factors such as effects from small population size and external factors such as loss or degradation of habitat due to succession, invasive species, and incompatible vegetation management. However, given the substantial number of populations (86 percent) in "unknown" condition, there are significant data gaps that make assessing the current condition of the species challenging at this time. Due to the lack of targeted management occurring at most populations outside of the Karner blue butterfly range, and the primary stressors of habitat loss and degradation requiring some form of management, we believe that it is unlikely that many of the "unknown" populations would be in "moderate" or "high" condition, but instead would be in "low" condition. While we could have explicitly made assumptions about the status of each "unknown" population, we have a few years to address this uncertainty with on-the-ground information. To address this uncertainty, additional surveys are needed across much of the range for *Callophyrus irus hadros* and *C. i. irus*. Given some uncertainty expressed about the taxonomic validity of and the suggested extirpation of most sites, surveys and genetic analyses of *C. i. arsace* range are needed. At the same time, sites that are considered to be in "low" or "moderate" condition would benefit from improving and expanding suitable habitat.

Table E-2. Summary of the 3Rs for the Frosted Elfin.

3Rs	Needs	Current Condition
Resiliency (healthy population to withstand stochastic events)	A resilient population needs: Patches of host plants and associated nectar of at least 5.9 acres (ac) (2.4 hectares (ha)) within 2 kilometers (km) (1.24 miles (mi)) of each other Annual frosted elfin peak counts of at least 30 individuals (timeframe to be determined in SSA Phase 3 given that counts are known to fluctuate among years) Minimal stressors or management underway to address stressors	411 populations across range 329 with unknown condition 1 assessed to have high resiliency 37 assessed to have moderate resiliency 14 assessed to have low resiliency 30 likely extirpated
Redundancy (number and distribution of populations to withstand catastrophic events) and Representation (genetic and ecological diversity to maintain adaptive potential)	Multiple populations within representative units (each subspecies and that use each host plant) Sufficient connectivity for periodic genetic exchange.	*Wild lupine* 97 populations across range 66 with unknown condition 1 assessed to have high resiliency 17 assessed to have moderate resiliency 9 assessed to have low resiliency 4 likely extirpated *Wild indigo* 77 populations across range 55 with unknown condition 0 assessed to have high resiliency 15 assessed to have moderate resiliency 4 assessed to have low resiliency 3 likely extirpated

3Rs	Needs	Current Condition
		Unknown host[2] *(or both plants at the site)* 237 populations across range 208 with unknown condition 0 assessed to have high resiliency 5 assessed to have moderate resiliency 1 assessed to have low resiliency 23 likely extirpated ********************* *Callophyrs irus irus* 342 populations across range 269 with unknown condition 1 assessed to have high resiliency 37 assessed to have moderate resiliency 13 assessed to have low resiliency 22 likely extirpated *C. irus hadros* 62 populations across range 60 with unknown condition 0 assessed to have high resiliency 1 assessed to have moderate resiliency 1 assessed to have low resiliency 1 likely extirpated *C. irus arsace* 7 populations across range 0 with unknown condition 0 assessed to have high resiliency 0 assessed to have moderate resiliency 0 assessed to have low resiliency 7 likely extirpated

[2] Host is either wild lupine or wild indigo but no information was provided.

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GLOSSARY of KEY DEFINITIONS

Frosted Elfin Population - Our working definition of a frosted elfin population includes these core concepts:

1. Frosted elfin populations consist of a group of many male and female butterflies.

2. Frosted elfins generally (but not always) function as metapopulations made up of multiple subpopulations (or individual populations) that interact with each other.

3. Frosted elfins rely on one of two larval host plant types (wild lupine or wild indigo) and do not occur when one of two host plants is not present.

4. Frosted elfins are sedentary (non-migratory); therefore, they are present within suitable habitat (see suitable habitat definition below) year-round.

5. Populations can be distinguished from one another by greater than 2 kilometers (km) (1.24 miles [mi]) of unsuitable habitat between wild lupine or wild indigo patches or by 10 km (6.21 mi) segments of suitable habitat (i.e., rights-of-way) (see NatureServe 2015, p. 9 for additional thoughts).

Frosted Elfin Suitable Habitat - Habitat is considered suitable for frosted elfin when:

- The overall site condition is considered semi-open canopy (6 to 50 percent cover)
- There is a mosaic of canopy cover and vegetation types (*e.g.*, thickets, open glades, forest patches, herbaceous openings)
- There is presence of relatively abundant nectar species for frosted elfin adults
- There is presence of relatively abundant host plants (wild blue lupine/wild indigo)

Redundancy - means having a sufficient number of populations for the species to withstand catastrophic events (such as a rare destructive natural event or episode involving many populations). Redundancy is about spreading the risk and can be measured through the duplication and distribution of resilient populations across the range of the species. Having multiple populations reduces the likelihood that all populations are affected simultaneously, while having widely distributed populations reduces the likelihood of populations possessing similar vulnerabilities to a catastrophic event. Given sufficient redundancy, single or multiple catastrophic events are unlikely to cause the extinction of a species. Thus, the greater redundancy a species has, the more viable it will be. Furthermore, the more populations and the more diverse or widespread that these populations are, the more likely it is that the adaptive diversity of the species will be preserved. Having multiple resilient populations distributed across the range of the species will help preserve the breadth of adaptive diversity, and hence, the evolutionary flexibility of the species.

Representation - is the ability of a species to adapt to near- and long-term changes in the environment; it is the evolutionary capacity or flexibility of a species. Representation is the range of variation found in a species, and this variation—called adaptive diversity—is the source of species' adaptive capabilities. Representation can, therefore, be measured through the breadth of adaptive diversity of the species. The greater the adaptive diversity, the more responsive and adaptable the species will be over time, and thus, the species is more viable. Maintaining adaptive diversity includes conserving both the ecological diversity and genetic diversity of a species. By maintaining these two sources of adaptive diversity across a species' range, the responsiveness and adaptability of a species over time is preserved. Ecological diversity is the physiological, ecological, and behavioral variation exhibited by a species across its range. Genetic diversity is the number and frequency of unique alleles within and among populations. Phenotypic diversity (the physiological, ecological, and behavioral variation expressed by frosted elfins) is also important for adapting to changes in environmental conditions. Phenotypic variation determines how organisms interact with their environment and how they respond to selection pressures (Hendry *et al.* 2011, p. 161). The degree of phenotypic variation is determined by the diversity of physical and biological pressures to which organisms are exposed, which vary across spatial and temporal scales. Species that span environmental gradients are expected to harbor the most phenotypic and genetic variation (Lankau *et al.* 2011, p. 320).

In addition to preserving the breadth of adaptive diversity, maintaining evolutionary capacity requires maintaining the evolutionary processes that drive evolution, namely, gene flow, genetic drift, and natural selection. Gene flow is expressed through the physical transfer of genes or alleles from one population to another through immigration and breeding. The presence or absence of gene flow can directly affect the size of the gene pool available. Gene flow will generally increase genetic variation within populations by bringing in new alleles from elsewhere, but decrease genetic variation among populations by mixing their gene pools (Hendry *et al.* 2011, p. 173). Genetic drift is the change in the frequency of alleles in a population due to random, stochastic events. Genetic drift always occurs, but is more likely to negatively affect populations that have a smaller effective population size (Ne) and populations that are geographically spread and isolated from one another. Natural selection is the process by which heritable traits can become more (selected for) or less (not selected for) common in a population based on the reproductive success of an individual with those traits. Natural selection influences the gene pool by determining which alleles are perpetuated in particular environments. This selection process generates the unique alleles and allelic frequencies which reflect specific ecological, physiological, and behavioral adaptations that are optimized for survival in different environments.

Resiliency - is the ability to sustain populations in the face of environmental variation and transient perturbations. Environmental variation includes normal year-to-year variation in rainfall and temperatures, as well as unseasonal weather events. Perturbations are stochastic events such as fire, flooding, and storms. Simply stated, resiliency is having the means to recover from "bad years" and disturbances. To be resilient, a species must have healthy populations; that is, populations that are able to sustain themselves through good and bad years. The healthier the populations and the greater number of healthy populations, the more resiliency a species possesses. For many species, resiliency is also affected by the degree of connectivity among populations and the diversity of ecological niches occupied. Connectivity among populations increases the genetic health of individuals (heterozygosity) within a population and bolsters a population's ability to recover from disturbances via rescue effect (immigration). Diversity of climate niches improves a species' resiliency by guarding against disturbances and perturbations affecting all populations similarly (*i.e.*, decreases the chance of all populations experiencing bad years simultaneously or to the same extent).

CHAPTER 1 - INTRODUCTION

Background

The U.S. Fish and Wildlife Service (Service) is proactively assessing the conservation status of the frosted elfin (*Callophrys irus*) to determine whether or not the species may warrant federal protection under the Endangered Species Act (Act). The Service has prioritized the frosted elfin's status review, using the July 2016 Methodology for Prioritizing Status Reviews[3], as a Bin 4 species (species for which proactive conservation efforts by states, landowners, and stakeholders are underway or being developed). As a result of this bin assignment, the Service is working with the state agencies and other partners across the species' range to develop and implement conservation efforts. A determination on the frosted elfin's listing status is scheduled for no later than September 30, 2023, in our National Listing Workplan[4].

Analytical Framework

In support of developing a conservation strategy(ies), we used the first two stages of the Species Status Assessment (SSA) framework to compile the best available data regarding the species' biology and factors that currently influence the species' viability. For the purpose of this SSA, we define viability as the ability of the species to sustain populations in the wild over time[5]. Using the SSA framework, we consider what a species needs to maintain viability by characterizing the biological status of the species in terms of its resiliency, redundancy, and representation (collectively the "3Rs") (Shaffer *et al.* 2002, pp. 139–140; Wolf *et al.* 2015, entire; Smith *et al.* 2018, entire). These principles are generally described below and, more specifically, for the frosted elfin in subsequent chapters.

Resiliency, redundancy, and representation are more thoroughly defined in the Glossary and summarized as follows:

Resiliency is the ability to sustain populations in the face of environmental variation and transient perturbations (stochastic events).

[3] The "Methodology for Prioritizing Status Reviews and Accompanying 12-Month Findings on Petitions for Listing Under the Endangered Species Act" can be viewed at https://www.fws.gov/policy/library/2016/2016-17818.pdf, accessed October 17, 2017.
[4] National Listing Workplan can be viewed at https://www.fws.gov/endangered/what-we-do/listing-workplan.html, accessed December 12, 2017.
[5] For the purpose of this version of the SSA, we have not yet defined a timeframe, but we will define this for Phase 3 of the SSA.

Redundancy means having a sufficient number of populations for the species to withstand catastrophic events (such as a rare destructive natural event or episode involving many populations).

Representation is the ability of a species to adapt to near- and long-term changes in the environment; it is the evolutionary capacity or flexibility of a species. Representation is the range of variation found in a species and this variation—called adaptive diversity—is the source of species' adaptive capabilities.

Our approach for assessing frosted elfin viability involved two of the three stages of an SSA (Figure 1). In Stage 1, we described the species' ecology in terms of the 3Rs; specifically, we identified the ecological requirements for survival and reproduction at the individual, population, and species levels. In Stage 2, we assessed the species' historical and current condition in relation to the 3Rs and identified past and ongoing factors (beneficial and risk factors) that led to the species' current condition. We intend to use this information to identify additional conservation partners and stakeholders so that we can organize a larger conservation effort to identify and implement actions with the goal of ensuring the species' viability. Stage 3, assessing the species' future condition and viability, will be completed at a later time, prior to making a listing determination, and take into account the appropriate conservation efforts planned and implemented on the frosted elfin's behalf (see below).

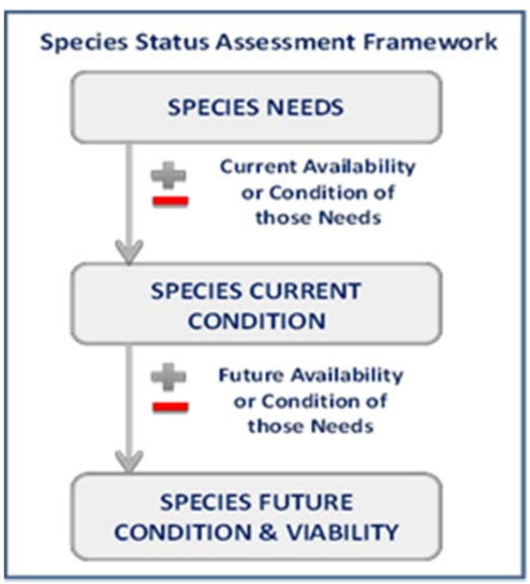

Figure 1. Species Status Assessment Framework.

The SSA report, the product of conducting a SSA, is intended to be a concise review of the species' biology and factors influencing the species, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA report to be easily updated as new information becomes available, and to support all functions of the Endangered Species Program. As such, the SSA report will be a living document upon which other documents, such as conservation strategies, listing rules, recovery plans, and 5-year reviews, would be based if the species warrants listing under the Act.

This SSA report for the frosted elfin is intended to provide the biological support for the decision on whether the species warrants listing as a threatened or endangered species and, if so, whether or not to propose designating critical habitat. The SSA report (and its underlying analyses) does not represent a decision by the Service whether or not to list a species under the Act. Instead, this SSA report provides a review of the best available information strictly related to the biological needs and current status of the frosted elfin.

Prior to making a decision on its listing status under the Act in fiscal year (FY) 2023, we will revise and update the SSA to incorporate any new information about Stages 1 and 2, as well as complete the final component (Stage 3), projecting the likely future condition of the frosted elfin. The draft final report will undergo peer and partner review. The listing decision will be made by the Service after reviewing the updated SSA Report and all relevant laws, regulations, and policies; and the listing decision will be announced in the Federal Register.

CHAPTER 2 – SPECIES INFORMATION

In this chapter we provide basic biological information about the frosted elfin, including its taxonomy, morphological description, and known life history traits. We then outline the resource needs of individuals and populations of the frosted elfin.

Taxonomy and Genetics

The frosted elfin was originally described as *Polyommatus irus* by Jean-Baptiste Godart in 1824, (Johnson 1991, p. 153). The current name is *Callophrys irus*, and it was previously assigned to the genus *Incisalia* (Scudder). The similar looking Henry's elfin (*C. henrici*) was not described until 1867 (Grote and Robinson 1867, p. 174-176) and was often confused with *C. irus* in earlier literature (Cook 1907, p. 181-187; Calhoun 2004, p. 144). Three frosted elfin subspecies have been described (and generally accepted) and these have regional distributions: *C. i. hadros* (originally described as *I. hadros* in Cook and Watson 1909, p. 181) is confined to the southwestern states of Texas, Louisiana, west Arkansas, and Oklahoma; *C. i. arsace* (originally described in Boisduval and Le Conte 1829-[1837], p. 103-104) occurs along the Atlantic Coast with some scientific disagreement about whether it occurs just in South Carolina (Gatrelle 1991, p. 57) or also north into southern New England (Shepherd 2005, p. 3); and *C. i. irus* that occupies the remainder of the inland areas from Florida north to New England and New York (and historically, southern Ontario), through Ohio and Michigan to Wisconsin with scattered populations also farther southeast, including eastern Maryland (Committee of the Status of Endangered Wildlife in Canada [COSEWIC] 2000, p. 3; Shepherd 2005, p. 2; Schweitzer *et al.* 2011, p. 161).

We recognize that there is some uncertainty about the taxonomic validity and/or range of *C. i. arsace* expressed by experts. However, until that uncertainty is resolved with genetic additional data, we will continue to use the published taxonomy[6] as the best available data, with *C. i. arsace* as being limited to coastal South Carolina, pending substantive new information regarding the range for each of the subspecies (Figure 2). Thus, we conducted our analyses for the entire species and each subspecies.

[6] Information from the Integrated Taxonomic Information System and NatureServe can be viewed at https://www.itis.gov, accessed January 30, 2018, and http://explorer.natureserve.org, accessed February 28, 2017.

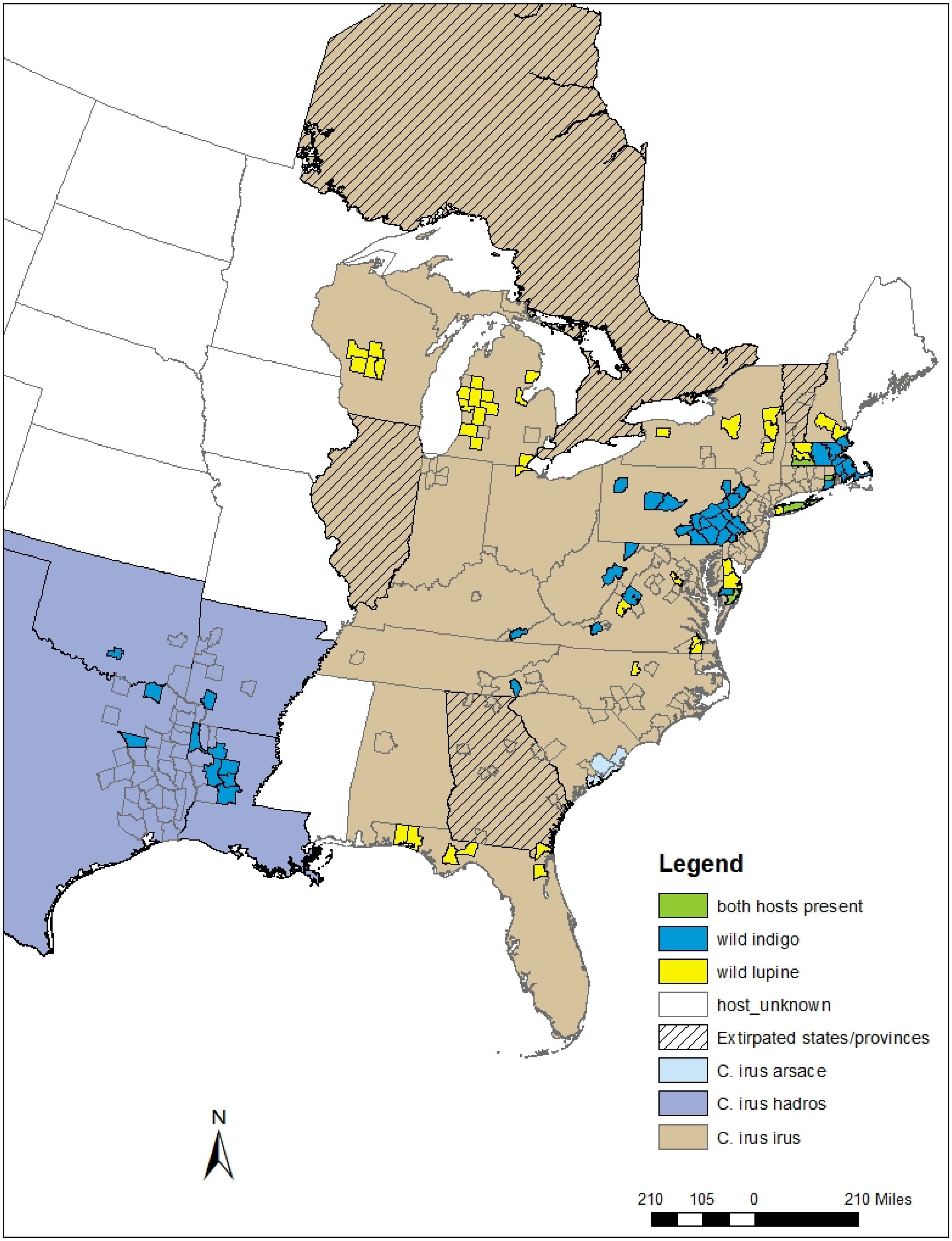

Figure 2. Frosted elfin range by subspecies and counties with information available about host plant use.

The currently accepted classification is:
Class: Insecta
Order: Lepidoptera
Family: Lycaenidae
Subfamily: Theclinae (Hairstreaks)
Genus: *Callophrys*
Species: *irus*
Subspecies: *irus, hadros, arsace*

The frosted elfin is one of approximately 150 known species in North America that are members of the family Lycaenidae (gossamer-wing) (Layberry *et al.* 1998, p. 119). Butterflies in this family are small and have delicate and shimmery wings covered in pigmented scales.

There is limited genetic information available for the frosted elfin. The species is known to be range differentiated, and to some extent morphometrically differentiated, by its host plant. However, no genetic differentiation (Mitochondrial DNA [CO1 gene]) was found between wild lupine (*Lupinus* spp.) and wild indigo (*Baptisia* spp.) feeders from one study site (study site 1) where both host plants occur in Maryland (Frye and Robbins 2015, p. 613). Additionally, no genetic differentiation was found between two Maryland populations separated by 345 kilometers (km) (214 miles [mi]) (Frye and Robbins 2015, p. 613); one of these sites had both host plants and the other just lupine.

Species Description

While all elfins are small butterflies, the frosted elfin is larger than most with a 22 to 36 millimeters (mm) (0.87 to 1.42 inches (in)) wingspan and short tails projecting from the hindwings (Schweitzer *et al.* 2011, p. 160). The upperside of the wings are uniform dark gray brown in color. The underside of the wings is also largely gray brown, but variegated, with a dusting of pale scales on the outer margin of the hindwing, with a dark spot and an irregular dark line (Allen 1997, p. 93) (Figure 3).

Figure 3. Frosted elfin photograph from *https://wisconsinbutterflies.org/butterfly/species/41-frosted-elfin*.

Male and female butterflies look very similar; however, they can be identified in flight as females tend to have an orange hue to their wings, appear to be larger, and do not exhibit territorial behaviors (T. Hupf, pers. comm.). Males also have a dark stigma[7] on the forewing (Opler and Krizek 1984, p. 100). While all populations of frosted elfins have adults that exhibit variations in appearance, some consistent tendencies have been observed. There is some evidence of phenotypical differences between lupine versus indigo feeders, with darker and larger individuals typically found feeding on indigo (Opler and Krizek 1984, p. 100; Schweitzer 1992, pp. 69–70; Gatrelle 1991, p. 57). We do not know if this is an important life history characteristic.

In most locations, the larvae (caterpillars) are pale greenish white, with a pale lateral line and oblique dashes along the sides, and covered in short whitish hairs (Allen 1997, p. 94) (Figure 4). However, in Oklahoma, larvae are yellow (Figure 5).

[7] A section of scent scales located on the forewing of a male butterfly.

Figure 4. *Callophrys irus hadros* caterpillar, 3rd instar USA: TEXAS: San Augustine Co., Angelina National Forest, Turkey Hill Wilderness Area, 23-III 2011 (*http://butterfliesofamerica.com/callophrys_irus_hadros_immatures2.htm*)

Figure 5. *Callophyrs irus hadros* caterpillar photo taken on 28 Apr 2011 in Sulphur, Oklahoma © Bryan E. Reynolds.

Two similar looking species overlap in range with the frosted elfin. Henry's elfin and hoary elfin (*Callophrys polios*) also have dusting of pale scales on the hindwing margin. Henry's elfin usually does not have the distinctive dark spot near the tail and has more contrast between outer and inner halves of the hindwing (Schweitzer *et al.* 2011, p. 160) (Figure 6a). The hoary elfin lacks a tail, is smaller (Schweitzer *et al.* 2011, p. 160), and has pale scales on the forewing margin (Allen 1997, p. 93) (Figure 6b).

Figure 6. Henry's Elfin photo (a) by Greg Dysart, Massachusetts Butterfly Club *http://www.naba.org/chapters/nabambc/construct-species-page.asp?sp=Callophrys-henrici.* and Hoary Elfin photo (b) by Bruce de Graaf, Massachusetts Butterfly Club *http://www.naba.org/chapters/nabambc/construct-species-page.asp?sp=hoary-elfin.*

Life History – Individual Needs

Life cycle and longevity - The entire lifecycle of a frosted elfin is completed within one year (Figure 7, Tables 1 and 2). Adults emerge in spring and lay eggs, eggs hatch into larvae that rely on specific host plants of wild lupine or wild indigo, larvae pupate by late July on or near host plants, and remain in this state until the following spring. Details follow.

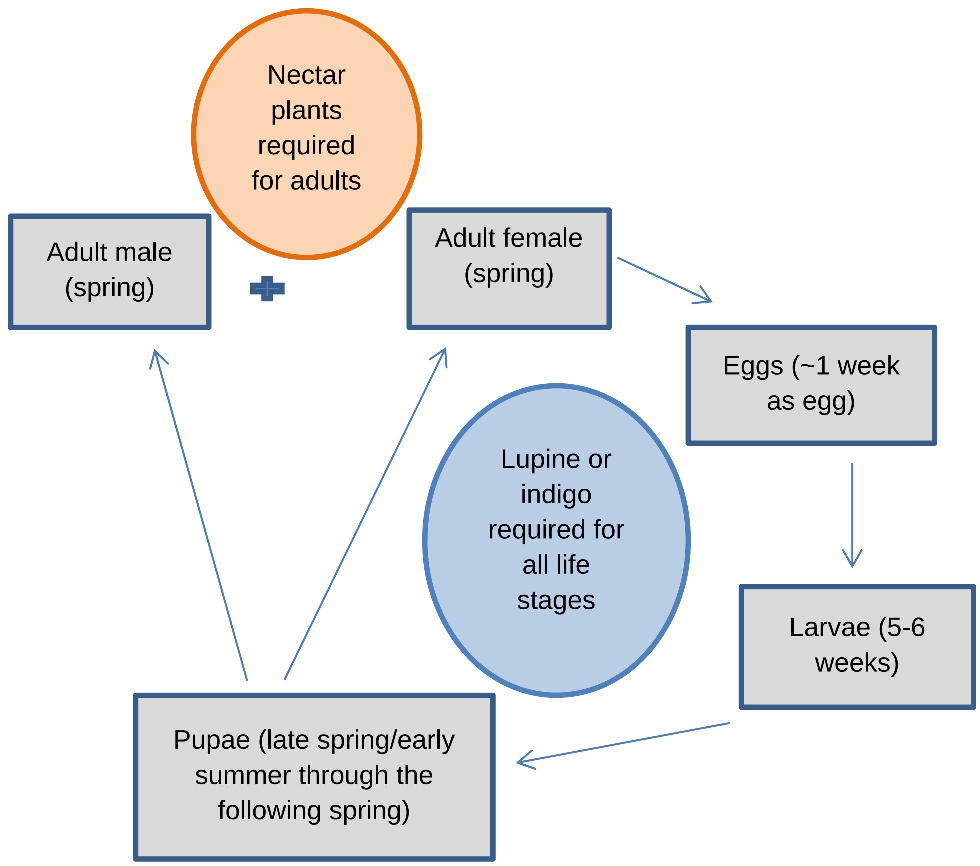

Figure 7. Frosted elfin life cycle.

This species is univoltine (single adult flight period) and adults are diurnal (NatureServe 2015, p. 8). The single flight period lasts approximately 4 to 8 weeks, generally from late April through mid-June in the northern parts of the range, with the peak flight usually occurring in mid-May (Allen 1997, p. 93; Swengel and Swengel 2000, p. 57; Albanese *et al.* 2007b, p. 54; Pfitsch and Williams 2009, p. 228). In Florida, adults may begin emerging in mid-to-late February, but cold spells may delay emergence to late March to mid-April (Thom 2013, p. 30). In Wisconsin, frosted elfin sightings occurred between 14 to 31.5 degrees Celsius (°C) (52.7 to 88.7 degrees Fahrenheit (°F)) and elfin density (detectability) was strongly associated with increasing temperature and no other weather variables (Swengel 1996, p. 55). In New Jersey, frosted elfins have been observed to emerge when wild indigo sprouts are greater than or equal to 6 inches (15.2 cm) in height (T. Hupf, pers. comm.). Over the past 24 to 27 years, with warming spring temperatures, elfin flights have shifted earlier by 4 to 14 days in Massachusetts (Polgar *et al.* 2013, p. 28; Williams *et al.* 2014, pp. 171–173) with a similar earlier trend in Wisconsin (Swengel and Swengel 2014, pp. 336–339). While the flight period for multiple individuals within a population or state can last up to 2 months, individual adults may live 2 to 3 weeks (Environment and Climate Change Canada (ECCC) 2017, p. 7). Adult males actively defend wild lupine patches against other males to gain exclusive access to females for breeding (Packer 1990, p. 263; Swengel 1996, p. 56).

In addition to host plants, adult frosted elfins require nectar sources that are available during their short flight window. The frosted elfin is a generalist when it comes to flower selection for nectaring. They have been observed feeding on a variety of flowers including wild lupine (Swengel 1996, p. 55), bird-foot violet (*Viola pedata*) (Swengel 1996, p. 55), blueberry (*Vaccinium* spp.), huckleberry (*Gaylussacia* spp.) (Thom 2013, p. 22), pin cherry (*Prunus pensylvanica*), sweetbells (*Leucothoe racemosa*), staggerbush (*Lyonia mariana*) (Schweitzer *et al.* 2011, p. 164), and *Rubus* spp. (Allen 1997, p. 94). Adult frosted elfins were also reported to feed on moist sand (Swengel 1996, p. 55).

After mating, adult females visit multiple host plants where they deposit a single egg, usually nestled in the apical shoot[8] of a wild indigo plant (Albanese *et al.* 2008, p. 605) or among the young flower stalks and buds of lupine (Shapiro 1974, p. 245; Swengel 1996, p. 55). The duration of the egg and larval stages varies with temperature, but eggs generally hatch into larvae within 2 weeks of spring adult emergence (Schweitzer *et al.* 2011, p. 163). Albanese *et al.* (2008, p. 605) reported eggs to hatch within one week of oviposition.

During a period of approximately 5 to 6 weeks, larvae feed on one of two specific host plants, either wild lupine or wild indigo, but individuals have not been observed to use both (Schweitzer 1992, p. 69). During this time, they grow in size and pass through four instars [9] (Albanese *et al.* 2008, p. 605). Frosted elfin larvae typically consume flowers and seedpods of wild lupine (Schweitzer 1992, p. 2; Swengel 1996, p. 56) and entire leaves and flower shoots of indigo (Schweitzer 1992, p. 2; Albanese *et al.* 2007a, p. 63). Indigo plants flower later in the summer than wild lupine and flowers are not available during the time that caterpillars are feeding (Schweitzer 1992, p. 70). Late instar larvae are known to girdle stems of the indigo, presumably to increase leaf nutrient concentrations or reduce stem toxicity (Albanese *et al.* 2007a, pp. 64–66). Caterpillars of wild lupine-feeding frosted elfins are reported to be cannibalistic and will also consume caterpillars of other butterfly species (Shapiro 1974, p. 247).

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[8] Tip where new leaf growth occurs.
[9] Period of time between molting events.

Approximately 75 percent of butterfly species in the family Lycaenidae are known to associate with ants (Formicidae) (Fiedler 2006, p. 77; Albanese *et al.* 2007a, p. 62). These associations can be mutualistic or parasitic and range from loose facultative interactions in which larvae are only occasionally tended by several species of ants (about 45 percent of associations), to complex obligate associations in which larvae are always tended by ants, often by only a single species (30 percent) (Pierce *et al.* 2002, p. 734–735). Lycaenids have several organs that produce substances high in sugars and amino acids that may pacify ants from attacking larvae, attract and alert ants if caterpillars are harmed, or provide nutrition (Pierce *et al.* 2002, p. 738, 740). A study of a wild indigo-feeding population of frosted elfins in southeastern Massachusetts documented interactions of five species of ants and late-instar caterpillars and found all but one association to be classified as loose facultative and mutualistic (Albanese *et al.* 2007a, p. 64). However, Schweitzer *et al.* (2011, p. 163) reported that frosted elfin larvae are not usually tended by ants.

Larvae pupate in mid to late spring in Florida (Thom *et al.* 2015, p. 18) and by late July in Massachusetts (Albanese *et al.* 2008, p. 605), and remain in pupal diapause[10] until the following spring. Larvae pupate at the base of the plant, at the soil surface, in the duff, and below the leaf litter (Opler and Krizek 1984, p. 100; COSEWIC 2000, p. 16). Thom *et al.* (2015, p. 17) examined frosted elfin pupation depths in Florida and found 8 out of 12 at the soil surface, in the duff, or just below the leaf litter. The remaining pupae were found at 0.5 centimeter (cm) (0.2 in) (1), 2.0 cm (0.8 in) (2), and 3.0 cm (1.2 in) (1) deep.

Table 1. Northern Frosted Elfin Populations Timeline.

Life stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult				X	X	X						
Egg				X	X	X						
Larvae (caterpillar)					X	X	X	X	X			
Pupae (chrysalis)	X	X	X	X			X	X	X	X	X	X

[10] Period of suspended development.

Table 2. Southern Frosted Elfin Populations Timeline.

Adult		X	X	X								
Egg			X	X								
Larvae (caterpillar)				X	X	X	X					
Pupae (chrysalis)	X	X				X	X	X	X	X	X	X

Habitat Needs **-** Frosted elfins typically occur in small, localized populations (typically metapopulations, see Population Needs section for definition) that are reliant on managed or disturbance-dependent habitats. These habitats are composed of a mosaic of habitat types ranging from herbaceous openings with abundant host plants to forested areas with relatively closed canopies (Wagner *et al.* 2003, p. 96).

Frosted elfins are closely associated with their host plants (see *Movements and Dispersal* section below). Adults, especially indigo feeders, are virtually never seen more than 20 meters (65.6 feet) from stands of the food plant (NatureServe 2015, p. 7). Frosted elfins are found within oak-pine barrens, oak savannas, prairie and dry oak woodlands, and similar anthropogenic habitats such as powerline cuts, railways, old sand/gravel pits, and airports (Wagner *et al.* 2003, p. 96; Schweitzer *et al.* 2011, pp. 163–164; Thom 2013, pp. 21–22). Wild lupine and wild indigo plants both rely on disturbance (natural or anthropogenic) and open to semi-open habitats with partial to full sunlight (Figure 8). In areas with advanced regeneration, such as closed canopy forests and dense shrubby areas, these host plants are usually absent.

Figure 8. Frosted elfin habitat examples of A) Pitch pine scrub oak barrens, Albany Pine Bush Preserve (Photo N. Gifford) and B) wild lupine in Wisconsin (Photo courtesy of WDNR).

Additional studies on microhabitat selection across the range of the species are needed to determine how to best manage for the species. However, based on existing sites, optimal conditions for frosted elfin populations appear to include a range of canopy (tree or shrub) closure. For example, in a Massachusetts population, higher adult frosted elfin densities were observed with increased wild indigo densities and reduced tree cover (Albanese *et al.* 2007b, pp. 58–59) and unshaded (less cover) areas appear to be important for adult oviposition (egg-laying) behavior on wild lupine and associated flights (Swengel 1996, p. 56). However, Albanese *et al.* (2008, p. 612) found that females laid eggs indiscriminately without respect to vegetative or environmental features, but late instar larvae were most abundant in microhabitats with shade, suggesting some overhead cover may be important for larval success. Shade provided by canopy cover moderates daytime temperature extremes, as well as water stress for plants and larvae, resulting in higher larval survival rates (Albanese *et al.* 2008, p. 612). Shade can also delay the terminal phase of plant growth (senescence), leaving flowers available for longer periods for frosted elfins. Providing host plants with a diverse range of microhabitat conditions may be vital to the long-term persistence of colonies (Albanese *et al.* 2008, p. 613). Similar investigations of a northern Florida population yielded similar findings, with frosted elfin larvae showing an affinity for microhabitats with large lupine plants, low amounts of ground cover vegetation, and some shade (Thom and Daniels 2017, pp. 46–51).

In addition to considering varying canopy cover conditions, size of host plant or other microhabitat features may impact frosted elfin occupancy. For example, in Massachusetts, larvae were more likely to be found on large (greater than 0.6 square meter (m^2)) (6.5 square feet (ft^2)) indigo plants (Albanese *et al.* 2008, p. 609) and in Florida, more eggs and larvae were found on larger lupine plants with more leaves per stem, in areas with heavy litter and duff, with some open space around the host plant, and a lack of competing lupine herbivores (Thom and Daniels 2017, p. 46).

***Movements and Dispersal* -** Frosted elfins are sedentary (non-migratory) and are, therefore, present within suitable habitat patches year-round. Dispersal distances vary depending on presence of suitable habitat. Periodic dispersal events of individual adult frosted elfin may occur as far as 10 km (6.21 mi) from natal patches of indigo/lupine if suitable habitat is present along the way; however, shorter routine distances are anticipated and movements greater than 2 km (1.24 mi) are considered unlikely across areas of unsuitable habitat (no host plants) (NatureServe 2015, p. 9).

Summary of Individual Needs

Frosted elfin needs are summarized in Table 3. In general, individual frosted elfin butterflies are habitat specialists and require nectar plants and one of two specific host plants (wild lupine or wild indigo) within a mosaic of canopy cover. Adults have localized movements with some capability of dispersal up to 10 km (6.21 mi).

Table 3. Summary of frosted elfin life history information by life stage.

Life Stage	Life history information
Adults	• Require warm spring temperatures for pupae to eclose (complete metamorphosis and emerge) into adults • Flight period for 1 to 2 months with individual adults living 1 to 2 weeks • Presence of males and females for breeding • Males are territorial, so multiple patches of host plants are needed to accommodate several territories • Require wild blue lupine or wild indigo in sunny, open areas for oviposition and associated flights • Require diverse array of nectar plants with flowers available during flight period
Eggs	• Require lupine or indigo plants for shelter
Larvae	• Require lupine or indigo plants in partial shade for shelter • Feed primarily on flowers and seedpods of wild lupine (and perhaps leaves during the last instar) OR feed on shoots and leaves of wild indigo • Potential mutualistic relationship with ants?
Pupae	• May use lupine or indigo plants for shelter • Larvae may also move into leaf litter or soil before pupating
All	• Habitat specialists • Residents (non-migratory)

Population Needs

For the purpose of this assessment, we define viability as the ability of the species to sustain populations in the wild over time[11]. Using the SSA framework, we describe the current species' viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (the 3Rs). See Chapter 1 for detailed information.

[11] For the purpose of this version of the SSA, we have not yet defined a timeframe, but we will define this for Phase 3 of the SSA.

Population viability requires healthy demographics and sufficient habitat to support a healthy demography (Table 4, Appendix A). In all but one instance (one New Hampshire location), we lack population estimates of population size (N) or population growth rate (lambda, λ) for this species. Therefore, we have used surrogate information to assess population health. We evaluated potential resiliency of frosted elfin populations using four metrics for assessing population health (total last number of butterflies observed) and the condition of the supporting habitat (acreage of host plants, current overall habitat condition, and ongoing stressors to the habitat). We also considered using information on the trend of frosted elfin counts and the number of host plant patches (SSA version 1.0). However, most sites have little information on either of these metrics. In the future, we may reconsider incorporating these metrics or others into the overall assessment of frosted elfin population condition.

***Population Structure* -** Frosted elfin butterflies occur within populations (see GLOSSARY) containing multiple males and females. These populations occupy a single large patch of suitable habitat or (more frequently) occur as a metapopulation made up of subpopulations utilizing multiple smaller patches (Swengel 1996, p. 56) of larval host plants and associated nectar plants (NatureServe 2015, p. 7; ECCC 2017, p. 12).

***Population Size* -** Frosted elfins were never considered abundant in Canada (ECCC 2017, p. vi) and are currently not considered abundant anywhere in the range (NatureServe 2015, p. 2 "G3" Rank and all S ranks at or below S3; also see, Appendix B). Pfitsch and Williams (2009, p. 231) found that the number of frosted elfins within populations are never highly abundant and considered their transect counts of approximately 30 individuals to be large for the species.

Similar to other small, resident butterfly species, frosted elfins have been documented to undergo considerable population fluctuations (Swengel 1996, p. 59; Swengel and Swengel 2014, pp. 342–343) between generations, which has been attributed to a number of factors, including variations in habitat, climatic conditions, and parasitoid abundance (Swengel and Swengel 2014, p. 332). To withstand these natural fluctuations, populations should be large enough to tolerate the demographic and genetic consequences of these stochastic events (Shaffer *et al.* 2002, p. 140).

Albanese *et al.* (2007b, pp. 54, 58) suggested that small subpopulations are probably more short-lived than larger subpopulations, finding two subpopulations with less than four observed individual adults to disappear (at least for 1 year) while another subpopulation was found. As some small subpopulations disappear, adequate numbers of frosted elfin are necessary nearby to repopulate those sites.

As discussed in the Individual Needs section above, microhabitat conditions of host plants may influence frosted elfin survival and, therefore, abundance. In addition, increased abundance of frosted elfin larvae has been associated with larger lupine (Thom and Daniels 2017, p. 46) and indigo plants (Albanese *et al.* 2008, p. 612). In indigo-feeding populations, early instar larvae feed on the young leaves in apical shoots. Many small Lepidoptera (like frosted elfin) are predominantly early-season feeders, as young leaves are a high quality food with higher protein and water levels (Mattson 1980, p. 139). Butterflies that appear later in the season often feed selectively on the richest plant tissues (seeds, buds, shoots) as plants increase in fiber and decrease in nitrogen and water (Mattson 1980, p. 139). Large wild indigo plants have a greater number of apical shoots and more abundant young foliage for developing larvae (Albanese *et al.* 2008, p. 612). Large host plants may provide enough high quality food for frosted elfins to survive until pupation, which may allow them to avoid the risks of predation and exposure to adverse weather conditions associated with moving to another host plant (Albanese *et al.* 2008, p. 612).

Habitat Size and Connectivity - Small, remnant fragments of oak-pine barrens habitat do not support many of the more specialized shrubland Lepidoptera (*e.g.*, Karner blue butterfly [*Lycaeides melissa samuelis*]) (Wagner *et al.* 2003, p. 106). However, frosted elfins do not appear to require as extensive an amount of habitat as the Karner blue butterfly, that is assumed to require at least 640 ac (259 ha) of suitable habitat within a 6,400-ac (2,590-ha) complex for "large viable populations" of 6,000 adults (and at least 320 ac (129 ha) of suitable habitat assumed for "viable populations" with half the of population target) (Service 2003, Appendix F). For example, in central Wisconsin, frosted elfin units[12] typically contained a large patch or multiple smaller patches of high-density lupine (Swengel 1996, p. 56) with 50 percent of observed individuals occurring within patches greater than or equal to 5.93 ac (2.4 ha). Only 3 percent (5 of 149) were observed in lupine patches less than or equal to 0.99 ac (0.4 ha) with the remaining 97 percent observed in patches ranging from 1.98 to 79.07 ac (0.8 to 32 ha) in size. Similar to lupine, frosted elfin density has also been correlated with higher density of indigo plants (Albanese *et al.* 2007b, p. 58)

In addition to overall extent of host plant and associated nectar plants, frosted elfin populations may benefit from having multiple patches of suitable habitat available. As discussed above, variable microhabitats appear important for the various life stages of frosted elfins. Multiple patches of habitat for a given population may be important to provide varying canopy cover and a range of microhabitat characteristics that will support suitable habitat conditions despite annual variation in weather. With multiple patches, populations are also distributed such that impacts to one patch would have a lessor impact on the entire population. Finally, because males are territorial (Packer 1990, p. 263; Swengel 1996, p. 56; COSEWIC 2000, p. 15) more patches should result in more territories and increased reproduction with a greater likelihood of gene exchange.

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[12] Survey unit that varied by management, vegetation type, vegetation quality, or canopy (Swengel 1996, p. 48).

As mentioned above, frosted elfins are considered sedentary (non-migratory) and are closely associated with their host plants. If enough food resources are available, larvae may stay on one individual host plant for their entire development. Mature larvae can wander several meters to their pupation sites (Schweitzer *et al.* 2011, p. 163). While most daily movements would be expected in close proximity to host plants, Schweitzer *et al.* (2011, p. 164) described adult females as very good colonizers (able to find and exploit) of habitat patches up to 2 km (1.24 mi) away. If substantial (undefined) colonies are nearby, a patch of as small as five host plants may host a few larvae and produce a few adults (Schweitzer *et al.* 2011, p. 164).

Summary of Population Needs

Frosted elfin population needs are summarized in Table 4 and more details are provided in Appendix A. In general, frosted elfin populations would be considered healthy if they have greater than 30 individuals observed during a single count, have at least 5.93 ac (2.4 ha) of available host plants, and occur within an area with ample suitable nectar plants and a complex of canopy cover types.

Table 4. Population needs for frosted elfin.

Requirement for Population Resiliency	Metric
Healthy population	Sufficient number of frosted elfins. ≥30 frosted elfin adults observed. This is the number of frosted elfins last counted across all transects (or other method) for a given population. The count could be based on one day or multiple days within the same season (if different locations within the population were sampled across multiple days).
Habitat to support healthy populations	Sufficient habitat size. >5.93 ac (2.4 ha) of host plants.
	Overall habitat is considered suitable. The overall site condition is considered semi-open canopy (6 to 50 percent) with a mosaic of canopy cover and vegetation types (*e.g.*, thickets, open glades, forest patches, herbaceous openings). There is presence of relatively abundant nectar species for frosted elfin adults.
	Minimal stressors impacting patches within a population.

Historical Range and Distribution

The distribution of the frosted elfin once extended from southern Ontario and the northeastern United States, south to Florida, and west to Texas and Wisconsin (Allen 1997, p. 93; Opler and Krizek 1984, p. 100) (Figure 9). Maine was previously considered part of the range, but this appears to have been in error due to confusion with *Callophrys henrici* (Calhoun 2017).

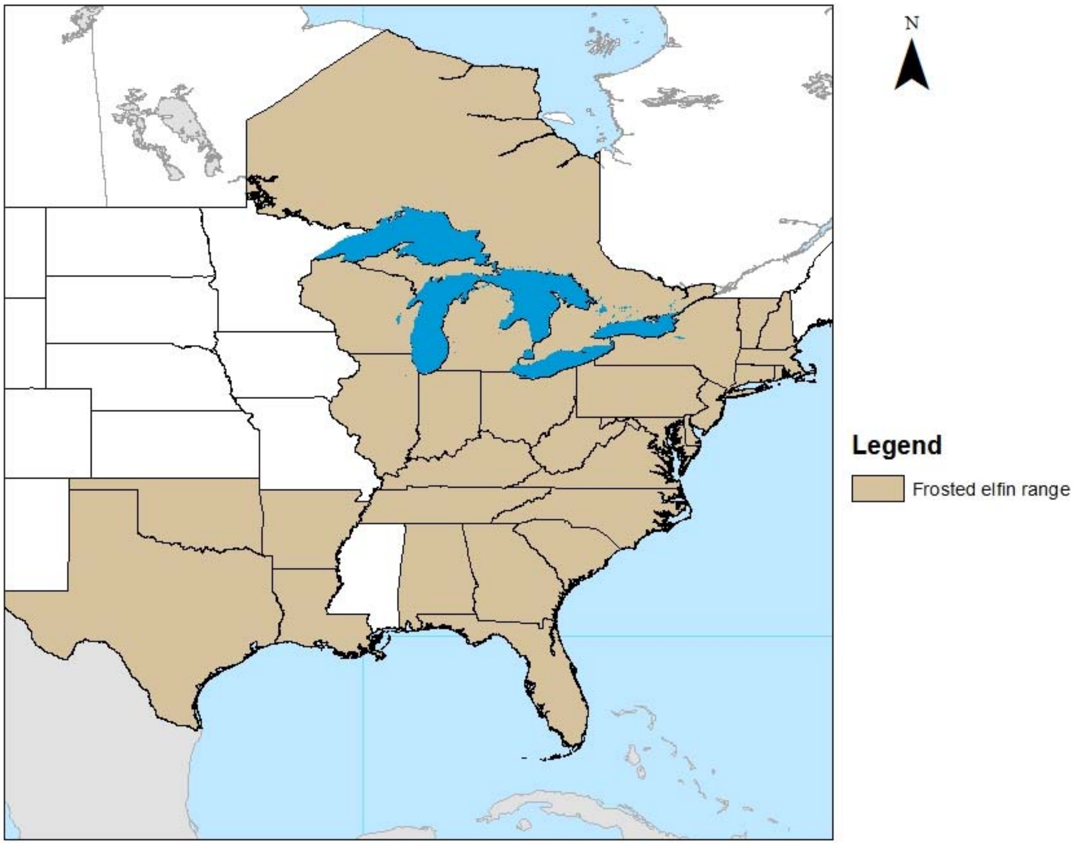

Figure 9. Historical frosted elfin range by State/Province.

Current Range and Distribution

The frosted elfin continues to have a wide range (25 states) in North America (Figure 10). However, the species is likely extirpated from Ontario, Canada, and the District of Columbia, Georgia, Illinois, and Vermont due to loss of host plants as a result of incompatible vegetation management, loss of frosted elfin populations and habitat from catastrophic fire, and residential development. Most frosted elfin populations are essentially isolated from one another, and repopulation of extirpated locations from extant sites is unlikely to occur without active management. There are no known records from Mississippi.

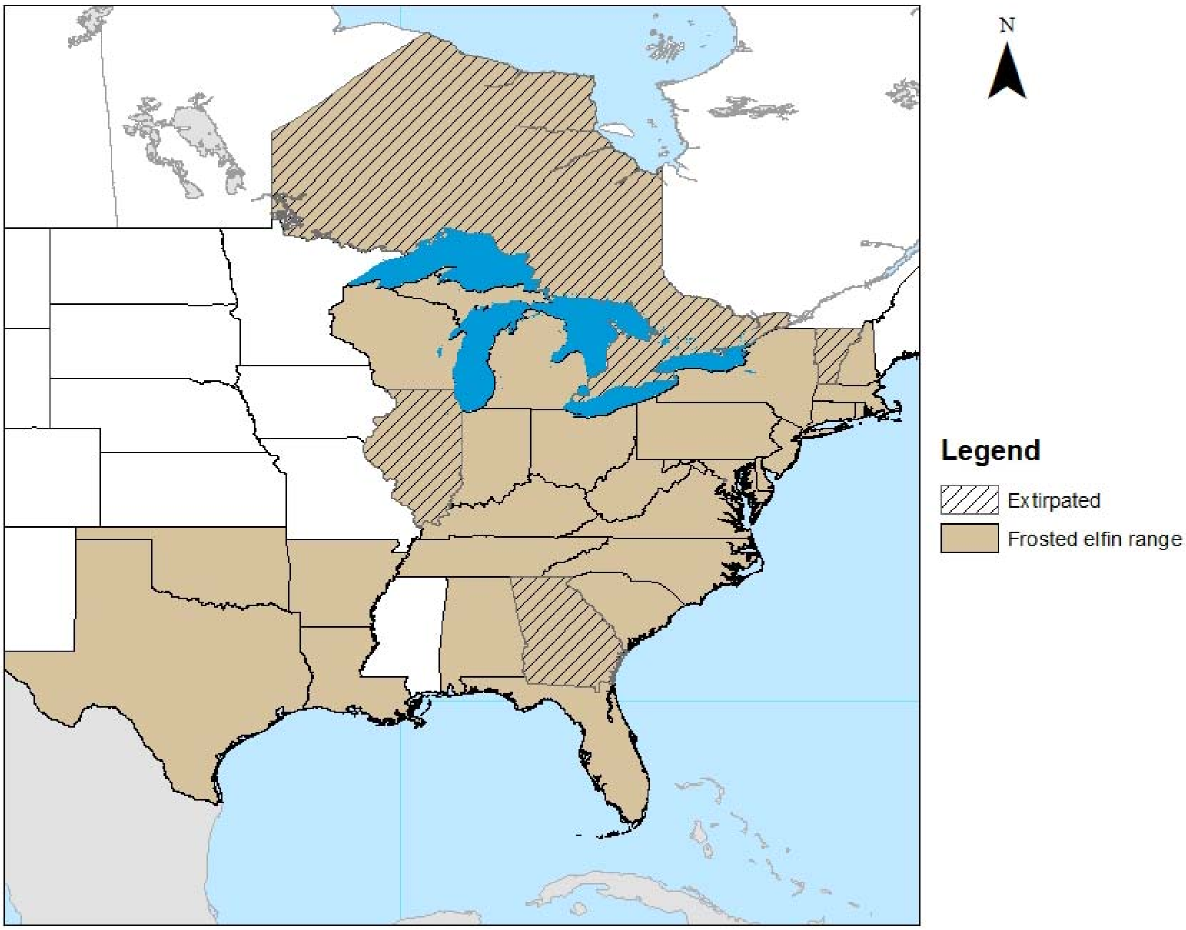

Figure 10. Current frosted elfin range by State/Province.

A portion of the range overlaps with the federally listed endangered Karner blue butterfly (Figure 11) and positive correlations have been found between abundances of the two species in Wisconsin (Swengel and Swengel 1997, p. 135). Where the species co-occur, both use wild lupine and face similar threats or potential benefits from management.

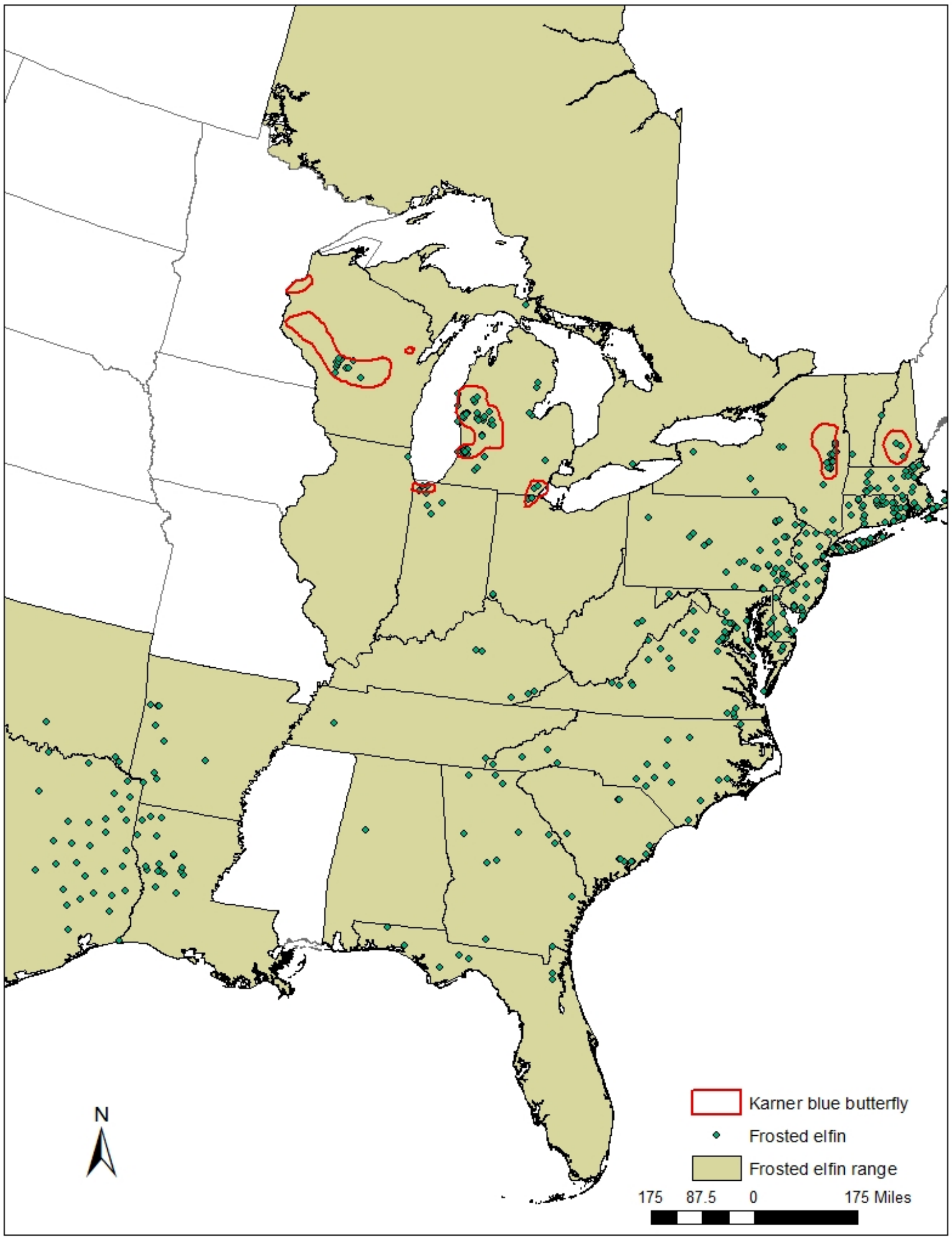

Figure 11. Current range of the Karner blue butterfly and all known (including presumed extirpated) frosted elfin locations.

CHAPTER 3 – SPECIES NEEDS

The frosted elfin needs multiple resilient (i.e., healthy) populations (Table 4) distributed throughout its representative units to provide for redundancy and representation (see the Glossary for definitions). The more populations, and the wider the distribution of those populations, the more redundancy the species will have. Redundancy (see details below) reduces the risk that a species as a whole will be negatively impacted if an area of the species' range is negatively affected by a catastrophic natural or anthropogenic event at a given point in time and increases the probability of maintaining natural gene flow and ecological processes (Wolf *et al.* 2015, pp. 205–206). Species that are well distributed across their historical range are less susceptible to the risk of extinction as a result of a catastrophic event than species confined to smaller areas of their range.

Representation

In considering what may be important representative units for the frosted elfin, we identified three primary means of defining frosted elfin diversity: assumed genetic differences (subspecies); variation in behavior/habitat use (host plants); and potential adaptation to variation in climatic conditions across latitudinal gradients.

As discussed in Chapter 2, the frosted elfin has three described subspecies. Subspecies are distinguished by genetic and/or phenotypic diversity and occupy geographically distinct areas. *Callophrys irus irus* is the most widespread subspecies, with *C. i. arsace* and *C. i. hadros* occupying limited distributions in the southeast and southwest, respectively. In addition to differences in geographic location, *C. i. arsace* and *C. i. hadros* tend to be larger in size with darker coloration than *C. i. irus*. While we are unaware of any specific studies measuring the amount of genetic diversity among the subspecies, geographic isolation and variation in size and coloration alludes to some amount of genetic diversity within this species.

Gene flow is influenced by the degree of connectivity and landscape permeability (Lankau *et al.* 2011, p. 320). Gene flow may be somewhat limited among frosted elfin populations due to their rare and patchy distributions and sedentary (non-migratory) behavior. There may be additional finer scale genetic diversity among subspecies at a population scale, but as discussed above, this was not observed from two isolated populations in Maryland (Frye and Robbins 2015, p. 613).

The frosted elfin shows phenotypic variation in its use of host plant species, with different populations feeding on either lupine or wild indigo, but not both. Genetic studies on caterpillars from both lupine-feeding and indigo-feeding populations have shown that these populations are not genetically distinct despite their phenotypic variation (Frye and Robbins 2015, p. 607). Although this does not speak to adaptive capacity of frosted elfin if their chosen host plant is no longer available, the breadth of host plant use will allow at least a subset of frosted elfin populations to persist on the landscape if one host plant species is impacted or lost. Because lupine and wild indigo have offset life cycles, frosted elfin caterpillars have adapted to use different parts of the plants. Lupine is available earlier in the growing season and, as a result, caterpillars feed on lupine flowers, while indigo feeding caterpillars are limited to apical shoots and leaves of indigo plants as flowers are not available. Wild lupine-feeding populations are found in the Carolina Fall Line Sand Hills south to northern Florida, and in the Great Lakes region from Wisconsin to northern Ohio into New York and interior New England. Populations that feed on wild indigo occur closer to the Atlantic coast from Massachusetts south to North Carolina, as well as scattered locations in West Virginia, southern Ohio, Kentucky, and Arkansas to Texas (Schweitzer *et al.* 2011, p. 162).

The frosted elfin has a broad distribution and, as a result, is exposed to a wide variety of climatic conditions across latitudinal gradients. Frosted elfins in southern populations have been observed to adapt to warmer climates by emerging earlier in the spring, shifting the entire lifecycle by approximately 10 days (Schweitzer 1992, p. 2). Frosted elfins in northern states are adapted to contend with colder conditions and snowpack; however, as stated in Chapter 2, over the past two decades, with warming spring temperatures, elfin flights have shifted earlier in Massachusetts and Wisconsin (Polgar *et al*. 2013, p. 28; Swengel and Swengel 2014, pp. 336–339; Williams *et al*. 2014, pp. 171–173). Maintaining populations across historical latitudinal, longitudinal, elevational, and climatic gradients increases the likelihood that the species will retain the potential for adaptation over time. Local adaptation to temperature, precipitation, host plants and nectar sources, and community interactions have all been identified for butterflies (Aardema *et al.* 2011, pp. 295–297).

Redundancy

Redundancy for the frosted elfin is best achieved by having multiple resilient populations widely distributed across the species' range, which reduces the likelihood that all populations are affected simultaneously. Also, having widely distributed populations reduces the likelihood of populations possessing similar vulnerabilities to a catastrophic event, thereby retaining adaptive diversity. Furthermore, diverse and widespread populations of frosted elfins may contribute to the adaptive diversity (representation) of the species if redundant populations are adapting to different conditions.

As discussed in Chapter 2, frosted elfins are typically found in low numbers in a given population (Pfitsch and Williams 2009, p. 231) and have often been documented to undergo considerable population fluctuations (ECCC 2017, p. 12). Therefore, frequent stochastic events or more localized stressors can be catastrophic events affecting one or multiple populations resulting in a lower level of redundancy for the species. Taking this into consideration, the types of events that we considered potentially catastrophic to frosted elfins include wild fire and extreme weather events (*e.g.*, drought, late frost, late snow, lack of snowpack with freezing temperatures). Herbivory, incompatible habitat management, and pesticide spraying (*e.g.*, gypsy moth spraying) may also affect multiple populations and may act as a catastrophic event on the species depending on scale of effect (see Chapter 4 for more information on these stressors and potential impact to the frosted elfin).

Given the species' life history traits, we expect that certain extreme weather events such as drought, late frost, and late snow to adversely impact the frosted elfin, with the severity of the impact to the species based on the scale of the effect. In general, droughts often have a negative impact on butterfly populations in general, in part due to host plant early senescence or death (Aardema *et al.* 2011, p. 296). This would especially be true for highly localized species. Therefore, we expect that frosted elfin populations would be severely impacted by drought, especially by more wide-spread droughts affecting the species on a more regional scale. This provides additional rationale for managing sites to provide areas with both sun and shade to help buffer effects to plants from drier years. We would expect that frosted elfin abundance would also be negatively impacted by late frost and snow (decreasing butterfly flights and potentially freezing individuals) as Swengel and Swengel (2014, p. 345) found that species' abundance in Wisconsin increased with warmer springs and lower season-long snowfalls.

Large-scale wild fire would be expected to have an adverse effect on frosted elfins as well. Frosted elfins pupate in the soil or leaf litter, but the chrysalis is often not buried deeply enough to avoid injury or death from fires. However, lupine and indigo are both disturbance dependent species and fire (either natural or prescribed) can increase the size and health of host plant patches. Overall, impacts to frosted elfins may be dependent on the size and intensity of a fire, and the ability of butterflies to recolonize from other habitat patches.

Summary

In summary, the frosted elfin requires multiple resilient populations spread across the geographic range of the three subspecies, both host plants, and across the geographical extent (Table 5).

Table 5. Ecological requirements for species-level viability.

3Rs	Requisites	Metric
Resiliency (able to withstand stochastic events)	Healthy populations	Populations with: 1) Sufficient number of frosted elfins (≥ to 30 frosted elfin adults observed during the last count); 2) Stable to increasing trend in frosted elfin counts; 3) Sufficient habitat size (> 5.93 ac (2.4 ha) of host plants); 4) Multiple host plant patches (> 5 patches); 5) Overall habitat is considered suitable. The overall site condition is considered semi-open canopy (6 to 50 percent) with a mosaic of canopy cover and vegetation types (*e.g.*, thickets, open glades, forest patches, herbaceous openings). There is presence of relatively abundant nectar species for frosted elfin adults; and 6) Minimal stressors impacting patches within a population.
Representation (to maintain evolutionary capacity)	Maintain adaptive diversity	Healthy populations distributed across areas of unique adaptive diversity (*e.g.*, within each subspecies, using both host plant types, and across latitudinal gradients) with sufficient connectivity for periodic genetic exchange.
Redundancy (to withstand catastrophic events)	Sufficient distribution of healthy populations	Sufficient distribution to guard against catastrophic events significantly compromising species adaptive diversity.
	Sufficient number of healthy populations	Adequate number of healthy populations to buffer against catastrophic losses of adaptive diversity.

CHAPTER 4 – FACTORS INFLUENCING VIABILITY

The primary factors influencing frosted elfin population viability (*i.e.*, influencing population demography and habitat) include: inherent factors (*e.g.*, effects of small population size) and one external driver (loss or alteration of habitat) (Table 6). Other contributing factors may include pesticides, competition, predation, and parasitism.

Table 6. Factors influencing frosted elfin viability at the individual, population, and species levels.

Stressor	Individual	Population	Species (multiple populations)
Inherent factors	X	X	X
Habitat Loss and Degradation	X	X	X
Insecticides	X	X	
Disease	unknown		
Competition with other caterpillars	X		
Predation	X		
Parasitism	X		

Stressors

Inherent Factors

Frosted elfins exhibit several inherent traits that influence population viability, including: specialized habitat requirements, limited dispersal ability, small population size, area of occupancy, or extent of occurrence (ECCC 2017, p. 25). As discussed in Chapter 2, frosted elfins are generally not abundant within a given population (Pfitsch and Williams 2009, p. 231) and have often been documented to undergo considerable population fluctuations (ECCC 2017, p. 12). Small population size puts sites at greater risk of extirpation from stochastic events (spring storms, spring and summer drought) or management activities. In addition, smaller populations may have reduced genetic diversity. Genetic drift[13] occurs in all species, but is more likely to negatively affect populations that have a smaller effective population size[14] and populations that are geographically spread and isolated from one another.

[13] The variation in the relative frequency of different genotypes in a small population, owing to the chance disappearance of particular genes as individuals die or do not reproduce.
[14] The number of individuals in a population who contribute offspring to the next generation.

Habitat Loss and Degradation

The primary external factor impacting frosted elfins is habitat availability (COSEWIC 2000, p. 16). The frosted elfin faces habitat loss from a variety of sources, including conversion of habitat as a result of human mediated causes such as development, invasive plant species, recreational activity, dumping in rights-of-way (ROWs), and fire exclusion or management, as well as natural causes such as succession. The frosted elfin overlaps with the Karner blue butterfly within the northern states and that species is influenced by similar factors (Service 2003, pp. 1, 38–39).

Conversion **-** Since European settlement, greater than 99 percent of tallgrass prairie and oak savanna have been lost, primarily because of conversion to agriculture (Swengel 1998, p. 77). Disking of soils during the spring is attributed to the loss of habitat and possible extirpation at a frosted elfin site in New Jersey (Golden and Pettigrew 2005, p. 2). In addition, dry, sandy soils, which are required for host plants, are also optimal for development (COSEWIC 2000, p. 16). In Connecticut, sites often occur in utility ROWs and gravel access roads and timber mats have buried plants in several locations (L. Saucier, pers. comm.). In response to our request for information from states and other frosted elfin experts, at least 30 frosted elfin populations were identified as having development as a potential stressor and two sites were identified as extirpated due to development (Service unpublished data). Co-occurring Karner blue butterfly sites have also been identified as having potential for being converted for agriculture, forestry, industrial, residential and commercial development (Service 2003, p. 38). Conversion impacts entire populations (rather than individual butterflies) and is a factor for multiple populations.

Succession **-** Wagner *et al.* (2003, pp. 106–107) surmised the greatest threat to shrubland Lepidoptera, such as the frosted elfin, in southern New England and southeastern New York is loss and fragmentation of native shrublands from habitat destruction and fire suppression. Without fire in shrublands, white pine and shade-tolerant hardwoods will replace barrens vegetation (Pfitsch and Williams 2009, p. 227; Motzkin *et al*. 1999, p. 269). Since European settlement, fire suppression and changes in land use have also significantly reduced the amount of oak savanna (Yarrish 2011, p. 1), resulting in pitch-pine scrub oak being considered globally rare (G2) (New York Natural Heritage Program [NYNHP] 2017, p. 1). In response to our request for information from states and other frosted elfin experts, succession was identified as a potential stressor to at least 46 populations across the range (Service unpublished data). Succession can impact entire populations (rather than individual butterflies) and is a factor for multiple populations.

Invasive Species **-** Frosted elfin populations may be highly sensitive to the invasion and establishment of non-native plant species (Albanese *et al.* 2007b, p. 61). A variety of common invasive species such as orange hawkweed (*Hieracium aurantiacum*), leafy spurge (*Euphorbia esula*), crown vetch (*Coronilla varia*), white sweet clover (*Melilotus alba*), and Pennsylvania sedge (*Carex pennsylvanicus*) can quickly dominate early successional habitats, resulting in reduced wild lupine and nectar source availability (Service 2003, p. 43). In response to our request for information from states and other frosted elfin experts, invasive species were identified as a potential stressor to at least seven populations across the range (Service unpublished data). Invasive species can affect entire populations (rather than individual butterflies) and are a factor for multiple populations.

Vegetation Management **-** Because frosted elfins depend on early successional savanna/barrens habitats that support wild lupine/indigo, maintenance and restoration of these habitats are key to the species' conservation. Management techniques, such as prescribed burning or mechanical cutting, can be effective tools for maintaining and restoring shrublands and barrens (Wagner *et al.* 2003, p. 107). However, mortality to individual frosted elfins is unavoidable in known occupied sites when conducting land management activities such as burning, mowing, and herbicide application because frosted elfins are present year-round within host plant patches. The degree of mortality on the life stages involved (egg, larvae, pupae, and adult) will depend on the type, timing, and scope of the activities being conducted.

Optimal management for a given site is anticipated to vary across the range. Because fire is a natural disturbance in pitch-pine scrub oak barrens (Parshall and Foster 2002, p. 1309), it is often a preferred method of habitat management in the northeast (Wagner *et al.* 2003, p. 107). However, Wisconsin's best and most consistently occupied frosted elfin site was not managed with fire, but with late-season mowing no more than once/year, with only a partial cutting in many years (Swengel 1996, p. 57). Further, fire may be damaging to frosted elfin populations (especially small populations). No frosted elfins have been seen in any fire management unit in Wisconsin post-fire (no matter how many years afterwards) (Swengel and Swengel 2007, p. 268-269). At a site in Florida, frosted elfin larvae observations decreased from 53-54% of lupine plants to 3.3% of lupine plants 14 months after the site was burned (Thom and Daniels 2017, p. 46).

Selective tree removal may also be an effective tool for maintaining habitat for frosted elfins. In a New York-based study, experimental removal of white pine resulted in improved wild lupine flowering and an expansion of habitat for the frosted elfin (Pfitsch and Williams 2009, p. 231). The removal of trees also increased sunlight, decreased soil acidity, resulted in more wild lupine inflorescences (which translated to more oviposition sites), and created open spaces for additional territories for frosted elfin males (which may increase reproductive success through decreased competition) (Pfitsch and Williams 2009, p. 231).

In order to avoid the risk of impacting entire populations during management, Wagner *et al.* (2003, p. 107) recommended segmenting and rotating management units and allowing for refugia until sites are expanded and populations are bolstered. Swengel and Swengel (2007, p. 139) found this type of management to have generally positive results, with a higher or similar abundance of butterflies (including frosted elfins) in the refugium than in comparison sites that were fire-managed without refugium. An appropriate amount of time should be permitted between burns within the same area, as this will allow time for populations to recolonize from refugia within or adjacent to the burned unit. Thom *et al.* (2015, pp. 19–20) came to similar conclusions.

In addition to impacts from compatible management, given the frequent small population sizes (see above), incompatible management activities may result in extirpation of a population. Examples of incompatible management practices that have impacted frosted elfins include too frequent mowing, burning, or herbicide application on host plants and nectar plants.

Herbicide application to frosted elfin habitat along a right-of-way in New Jersey removed most woody vegetation, grasses, and nectar plants (Golden and Pettigrew 2005, p. 8). Deer browse was intense on wild indigo the following season as it was one of the only remaining herbaceous plants and frosted elfins were absent the following year (Golden and Pettigrew 2005, p. 8). Herbicide application may also reduce the viability and survivability of Lepidopterans by reducing food plant quality (Stark *et al.* 2012, p. 27). Herbicide drift has been identified as having the potential to impact wild blue lupine and nectar plants in Canada (ECCC 2017, p. 32).

Targeted herbicide application can be important for vegetation control, which preserves habitat conditions required by various species of Lepidoptera. However, even if applied in a targeted manner, certain herbicides have also been shown to have lethal and sub-lethal effects on butterflies and moths through contact via dermal and digestive routes (Russell and Schultz 2010, p. 53).

We are unaware of any research specifically studying the effects of herbicides on the frosted elfin. There are studies on the habitat associate Karner blue butterfly. The Service (2003, p. G-83) stated that herbicides, Accord® (glyphosate) and Accord® + Oust® (sulfometuron methyl) (with Entry II surfactant), can be used with minimal direct impact on the Karner blue butterfly. Operational concentrations of Accord® or Accord® + Oust®, all with Entry II, did not affect egg development, pupation of larvae, emergence of adults, size of pupae, or rate of pupal formation (Sucoff *et al.* 2001, p. 17). Karner blue eggs treated with Accord® + Garlon® 4 (triclopyr ester) resulted in 22 percent fewer adults hatch than in controls; translated to field conditions, the Service anticipated that this would result in a 3.5 percent reduction of adults (Sucoff *et al*. 2001, p. 18). The Service concluded that herbicides should be used with care (applying outside of the flight season) to minimize impacts to the Karner blue butterfly (Service 2003, p. G-83).

Russell and Schultz (2010, pp. 57–58) found that two grass herbicides (fluazifop-*p*-butyl and sethoxydim) and a surfactant (Preference®) affected two butterfly species (*Icaricia icarioides blackmorei* and *Pieris rapae*) differently, in terms of sub-lethal and lethal effects. Survival of *I. i. blackmorei* was not impacted, but *P. rapae* larvae experienced 32 percent and 21 percent decrease in survival with sethoxydim and fluazifop-*p*-butyl, respectively. *I. i. blackmorei* reached pupation and eclosed earlier which could impact reproduction for a species dependent on seasonal host plants. Those authors also noted that, based on standard toxicity testing with honeybees, the USEPA considers both herbicides to have low toxicity to invertebrates, but tests using honeybees may not be transferable to Lepidopterans. Restricting the timing of herbicide applications until diapause, in many cases protects sensitive life stages of species of concern (Russell and Schultz 2010, pp. 60–61).

In summary, management is a key component of restoring and maintaining suitable frosted elfin habitat. However, small populations can be impacted by management intended to benefit the species and incompatible vegetation management can result in the loss of populations. In response to our request for information from state natural resource agencies and other frosted elfin experts, vegetation management was identified as a potential stressor to at least 17 populations across the range (Service unpublished data). Compatible management generally affects individual butterflies with overall benefits to populations. Incompatible management can affect entire populations (rather than individual butterflies) and is a factor for multiple populations.

***ORVs and Human Disturbance* -** Several states identified off-road vehicle (ORV) use as currently impacting frosted elfin populations. Off-road vehicles can crush frosted elfin eggs, larvae, and pupae and damage or destroy host and nectar plants. Off-road vehicles can also cause significant soil erosion. In response to our request for information from states and other frosted elfin experts, ORVs were identified as a potential stressor to at least 11 populations across the range (Service unpublished data). Off-road vehicle damage can affect entire populations (rather than individual butterflies) and is a factor for multiple populations.

Frosted elfins may also be impacted by other forms of human disturbance, based on observations of other species. For example, Bennett *et al.* (2013, p. 1791) found that adult Karner blue butterflies flushed in response to people walking down a trail at the Indiana Dunes National Lakeshore. This disruption incurs a cost in reduced time and energy available for reproduction and they estimated the potential for reduction in oviposition rate by 50 percent (Bennett *et al.* 2013, p. 1794). However, Swengel 1996 (p. 57) found increased numbers of frosted elfin at sites that had some low intensity recreational use. While there is the potential that recreation may have effects on individual adult frosted elfins, there is no indication of population level effects.

Herbivory **-** Herbivory is a natural process that many plants are exposed to throughout their lifecycle. Lupine is known to be browsed by white-tailed deer (*Odocoileus virginianus*), woodchuck (*Marmota monax*), and insects such as painted lady larvae (*Vanessa cardui*) (Service 2003, p. 19, 43). Frosted elfin females lay eggs on new unopened lupine flowers (Pfitsch and Williams 2009, p. 226; Swengel 1996, p. 47; Frye 2012, p. 427). When those flowers are grazed by deer, direct mortality of frosted elfin eggs (and possibly larvae) may occur. Overgrazing of lupine by white-tailed deer may have contributed to a decline of Karner blue butterfly in the Albany Pine Bush area of New York in the 1970s to 1980s and an extirpation of frosted elfins at two sites in Pennsylvania (Wagner *et al.* 2003, p. 108). In addition, reduction of indigo due to browsing by deer may have contributed to extirpation at frosted elfin sites in New Jersey (Golden and Pettigrew 2005, unnumbered). Excessive deer browsing of wild lupine is managed in some areas in Ontario (ECCC 2017, p. 31), but likely remains a stressor at multiple U.S. locations. In response to our request for information from states and other frosted elfin experts, herbivory was identified as a potential stressor to at least 20 populations across the range (Service unpublished data). Herbivory can affect entire populations (rather than individual butterflies) and is a factor for multiple populations.

Host Plant Disease **-** Plant diseases affecting lupine or indigo may reduce individual plant's food quality to frosted elfins or render areas unsuitable for frosted elfins to complete their life cycle, both of which could result in larvae mortality or reduced adult fecundity. Wild blue lupine leaves are attacked by both powdery mildew (*Erysiphe polygoni*) and a type of leaf rust (*Puccinia andropogonis*) (Service 2003, p. 42). We are unaware of any studies linking host plant disease to impacts to the frosted elfin; however, healthy host plants are an important need for this species. While there is the potential that host plant disease may have effects on individual adult frosted elfins, there is no indication of population level effects.

Insecticides

Insecticides are a tool to chemically control the spread of invasive insects. Use of insecticides may result in mortality of non-target species, depending upon the type of chemical, the application method, length of exposure, and the insect's tolerance. Little has been published on the effects of insecticides on non-target butterflies, especially sub-lethal effects (Mule *et al.* 2017, p. 4). However, adult and larval butterflies are susceptible to lethal and sub-lethal effects from insecticide application from direct aerial spraying and from residues on plant foods (Hoang *et al.* 2011, p. 998).

Gypsy Moth Spraying - Gypsy moths (*Lymantria dispar dispar*) are an invasive species that can completely defoliate trees. Control of gypsy moths includes aerial spraying. The four approved insecticides used in aerial spraying to eradicate gypsy moth are two biological insecticides *Bacillus thuringiensis* var. *kurstaki* (Btk) and nucleopolyhedrosis virus (Gypchek) and two chemical insecticides diflubenzuron (Dimilin®) and tebufenozide (Mimic®) (U.S. Department of Agriculture [USDA] 2010, p. G2). Of these, only Gypchek is known to be non-toxic to non-target invertebrates, including lepidopterans, because it is a virus that only affects gypsy moths (Stafford 2017, p. 9; USDA 2010, p G6). Consequently, Gypchek is recommended for areas that are known to contain rare and endangered lepidopterans (Stafford 2017, p. 9; USDA 2010, p. G6), but supplies of Gypchek are limited due to an expensive production process (Stafford 2017, p. 9; USDA 2012, p. G6).

Based on a review of the literature, Schweitzer (2004, p. 42) concluded that Btk is toxic to many, if not all, lepidopteran species within the family Lycaenidae, which includes the frosted elfin, experiencing "very high" mortality. Herms *et al.* (1997, pp. 132–134) found that the larvae of the Karner blue butterfly was susceptible to mortality from exposure to Btk at typical field application rates. Because of this evidence, the Service encourages using alternative control methods in Karner blue butterfly areas (Service 2003, p. 40). Although Btk spores have been shown to be lethal to swallowtails (*Papilio* spp.) for at least a month (Schweitzer 2004, p. 38; Johnson *et al.* 1995, p. 288), Schweitzer in NatureServe (2015, p. 3) proposed that "stronger" frosted elfin populations could survive one application of Btk because larval production is staggered, so that those larva that hatch later would be unaffected.

More persistent pesticides, such as the chemical diflubenzuron, are more likely to eradicate a population of Lepidoptera than Btk, which is typically lethal up to one week after application (Schweitzer 2004, p. 38; Johnson *et al.* 1995, p. 288). Diflubenzuron is a chitin inhibitor and is lethal to immatures of most arthropods that ingest it (Schweitzer 2004, p. 12). It is also considered a contact insecticide, but most research suggests that this is not a major source of non-target mortality in applications aimed at gypsy moth and that ingestion is clearly the major source of mortality to most terrestrial organisms and aquatic leaf shredders (Schweitzer 2004, p. 35). Diflubenzuron is known to remain on leaves at lethal doses until after leaf fall and will sometimes remain in leaf litter for a second year (Schweitzer 2004, p. 32).

Insecticide spraying for gypsy moths is thought to have contributed to the decline of the frosted elfin in Ontario (ECCC 2017, p. 27). Currently, gypsy moth populations are considered to be under control and spraying for this species is unlikely to be a significant stressor to frosted elfins in Canada (ECCC 2017, p. 27) because the last Btk spraying by the province of Ontario occurred in 1991, and the program was cancelled in 1992.

Other Pesticides - In a systematic review of studies that investigated the effects of pesticides on butterflies, Mule *et al.* 2017 (p. 3), found that 6 insecticides commonly used for mosquito control and/or crop protection (naled, permethrin, dichlorvos, resmethrin, malathion, and imidacloprid) had lethal and sub-lethal effects on 20 species from 4 families of butterflies, including 5 of the Lycaenidae family. All these insecticides had negative effects (*e.g.*, increased mortality, interrupted feeding, and altered oviposition) for larval and adult life stages of all species, but different species exhibited different sensitivity to different pesticides (Mule *et al*. 2017, p. 4). For example, Hoang *et al.* (2011, p. 1000) investigated effects of mosquito control (permethrin, naled, and dichlorvos) for adult and fifth-instar larvae of common buckeye (*Junonia coenia*), painted lady (*Vanessa cardui*), zebra longwing (*Heliconius charitonius*), atala hairstreak (*Eumaeus atala*), and white peacock (*Anartia jatrophae*) and found that, in general, permethrin was most toxic. Hoang *et al.* (2011, p. 1004) also found that several butterflies appeared more sensitive to the insecticides than honeybees, which are commonly used during U.S. Environmental Protection Agency [EPA] testing; with field application of both permethrin and naled potentially presenting acute hazards to butterflies, but no anticipated acute hazard from dichlorvos.

Mosquito control has been identified as a possible contributor to the decline of butterflies in the Florida Keys (Salvato 2001, p. 8). Salvato (2001, entire) monitored populations of Florida leafwing (*Anaea troglodyta floridalis*) and Bartram's hairstreak (*Strymon acis bartrami*) and conducted toxicity experiments for naled, malathion, and permethrin on non-threatened surrogate species. He found reduced *A. troglodyta floridalis* density in sprayed locations, but the opposite for *S. acis bartrami* (Salvato 2001, p. 11). In the lab, surrogates were sensitive to chemicals with naled, and permethrin was found to be most toxic (Salvato 2001, p. 13). A risk assessment found that for non-target Florida Keys butterflies (Heperidae, Papilionidae, Nymphalidae, Pieridae, and Lycaenidae) exposed to naled, the greatest risk of mortality was for the family Lycaenidae (Bargar 2012, p. 4).

Neonicotinoids are another class of insecticides that are poorly studied in terms of impacts to butterflies. Neonicotinoids were developed in the 1980s and have rapidly become one of the most widely used insecticides in the world (Goulson 2013, p. 978). Neonicotinoids are applied via seed coating, foliar spraying, or in irrigation water. Detectible levels of neonicotinoids have been found in wild flowers (including nectar) adjacent to agricultural fields (Stewart *et al.* 2014, pp. 9764–9765; Wood and Goulson 2017, pp. 17286–89). Non-target areas at a distance from agricultural fields may be exposed to neonicotinoids by transportation through water courses (Gilburn *et al.* 2015, p. 3). Gilburn *et al.* (2015, pp. 5–7) modeled potential impacts on population indices for 17 common butterflies in English agricultural landscapes; while there were some variable species effects, there was a strong negative correlation with neonicotinoid use, meaning that butterfly abundance decreased as number of hectares treated with neonicotinoids in the previous year increased. The well-studied butterfly fauna of lowland

California have exhibited declines in total number of species and occupancy records for individual species within the past 40 years (Forister *et al.* 2016, pp. 3–4). The study authors found a significant negative association between butterfly populations and increasing neonicotinoid application, while controlling for the variables of land use and other factors (Forister *et al.* 2016, pp. 3–4).

Pecenka and Lundgren (2015, p. 4) fed clothianidin (a neonicotinoid pesticide) treated leaves to first instar monarch (*Danaus plexippus*) caterpillars. Sublethal effects on growth (reduced body length and development rate of first instar) were found at dietary concentrations of 0.5 to 1 parts per billion (ppb) clothianidin. These authors found that milkweed (*Asclepias* spp.) plants adjacent to corn fields contained a mean concentration of clothianidin of 1.14 ppb, with a maximum concentration of 4 ppb. The authors concluded that monarch larvae may be exposed to clothianidin in the field at potentially harmful concentrations.

Additional studies are needed to understand the full extent of the toxicity of neonicotinoids to butterflies (Gilburn *et al.* 2015, p. 9).

In summary, insecticide application has the potential to result in population level effects where populations are exposed to drift from intended application locations. Additional information is needed to determine where this may be occurring throughout the range.

Competition with other Caterpillars

We do not know the extent to which frosted elfin may be affected by competition with other butterfly or moth species. Competition with the Karner blue butterfly is a possibility given that they both use wild lupine in parts of the frosted elfin range and frequently co-occur. However, as mentioned above, positive correlations have been found between abundances of the two species (Swengel and Swengel 1997, p. 135).

Conversely, Thom and Daniels (2017, p. 50) found fewer frosted elfin larvae on host plants associated with the presence of some moth species that use lupine and indigo as food sources. Specifically, caterpillars of the crambid moth (*Uresiphita reversalis*) were the most observed species. While individual frosted elfin may be impacted at some sites, there is no indication of population level effects from competition at this time.

Predation/Parasitism

Very little research has been conducted on the natural predators of the frosted elfin. As stated above, herbivores can inadvertently kill frosted elfins present on grazed host plants. There is some information available on impacts to the co-occurring Karner blue butterfly, with some mortality of larvae from predators or parasitoids. For example, Karner blue butterfly larval predators include pentatomid stink bugs (*Podisus maculiventris*), wasps (*Polistes fuscatus* and *P. metricus*), and ants (*Formica schaufussi* and *F. incerta*) (Savignano 1990, pp. 8, 88). Four larval parasitoids have been reared from field collected Karner blue butterfly larvae: a tachinid fly (*Aplomya theclarum*), a braconid wasp (*Apanteles* sp.), and two ichneumonid wasps (*Neotypus nobilitator nobilitator* and *Paranoia geniculate*) (Savignano 1990, p. 44). Several insect predators have been observed attacking adult Karner blue butterflies, including spiders, robber flies, ambush bugs, assassin bugs, and dragonflies (Service 2003, p. 42). While individual frosted elfin may be impacted at some sites, there is no indication of population level effects for any population across the range from predation or parasitism at this time.

Disease

Disease pathogens of the frosted elfin have not been identified.

<u>Ongoing Conservation Efforts</u>

State Considerations

The frosted elfin receives some level of protection in multiple states. It is state listed as endangered in Delaware (Delaware Division of Fish and Wildlife, 2013, p. 4), Indiana (Indiana General Assembly 2015, p. 8), Kentucky (Kentucky State Nature Preserves Commission 2015, p. 34), Maryland (Maryland Natural Heritage Program 2016, p.8), New Hampshire (New Hampshire Fish and Game 2015, Appendix A, p. 34), and Ohio (Ohio Department of Natural Resources 2017, p. 5), and is state listed as threatened in Connecticut (Connecticut Department of Energy and Environmental Protection 2015, p. 4), Michigan (State of Michigan 2017, p. 6), New Jersey (Golden and Pettigrew 2005, p. 2; New Jersey Department of Environmental Protection undated, p. 1), New York (New York State Department of Environmental Conservation 2017, p. 2), and Wisconsin (Wisconsin Department of Natural Resources 2015, p. 3). Protections afforded by state listing varies. For example, in Delaware[15], the importation, transportation, possession, or sale of any endangered species of fish or wildlife, or hides or other parts thereof, or the sale or possession with the intent to sell of any article made in whole or in part from the skin, hide, or other parts of endangered species of fish or wildlife is prohibited, except under license or permit from the Division. In Indiana, there are no take prohibitions. In Maryland[16], Michigan[17], New Hampshire[18], and Wisconsin[19], take of a listed species is

[15] Delaware Section 601 of Title 7 available at: http://delcode.delaware.gov/title7/c006/index.shtml accessed March 6, 2018.
[16] Code of Maryland Regulations 08.03.08 available at: http://mdrules.elaws.us/comar/08.03.08 accessed March 6, 2018.

prohibited without a permit. In Ohio, the Division of Wildlife[20] may restrict the taking or possession of endangered species. There are some limited prohibitions against taking a threatened species in Connecticut[21].

The frosted elfin is on the advisory list as a species of special concern in Massachusetts. Special Concern means documented by biological research and inventory to have suffered a decline that could threaten the species if allowed to continue unchecked, or occurring in such small numbers, or with such a restricted distribution, or specialized habitat requirements, that it could easily become threatened. In Massachusetts, in addition to take provisions, environmental review provisions are established for habitat areas (Priority Habitat) identified as areas where there is the potential that take of any endangered, threatened, or special concern species may occur as a result of any project or activity.

Many states consider the frosted elfin a Species of Greatest Conservation Need (SGCN) (Appendix B). These states are prioritizing the frosted elfin as a species that merits additional attention.

Federal Considerations

There are several Department of Defense installations that benefit the frosted elfin through direct or indirect consideration in Integrated Natural Resource Management Plans (INRMPs[22]):

- Camp Edwards, Massachusetts

The frosted elfin is included in a table of state listed fauna at Camp Edwards (Massachusetts Army National Guard Camp Edwards (MANGCE) 2009, p. 82). No specific management actions are included for this species, but scrub oak shrubland currently covers 2,107 acres of Camp Edwards (MANGCE 2009, p. 57) and is managed in multiple states of succession for the

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[17] Michigan Act 451, Section 324.36505 available at: http://www.legislature.mi.gov/(S(dlu1vfubfomq1opnrrwjxyez))/mileg.aspx?page=getObject&objectName=mcl-324-36505&highlight=pittman accessed March 6, 2018.
[18] New Hampshire Title XVIII, Section 212-A:5 available at: https://www.animallaw.info/statute/nh-endangered-chapter-212-endangered-species-conservation-act#212-A:2 accessed March 6, 2018.
[19]Wisconsin Chapter 20 Subchapter IX Section 29.604 http://docs.legis.wisconsin.gov/statutes/statutes/29/IX/604 Accessed March 6, 2018.
[20] Ohio Code Title 15 Section 1531.25 available at: http://codes.ohio.gov/orc/1531.25 accessed March 6, 2018
[21] Connecticut Code Chapter 495, Section 26-311 available at: https://law.justia.com/codes/connecticut/2013/title-26/chapter-495/section-26-311/ accessed March 6, 2018.
[22] An INRMP is a cooperative agreement among the Department of Defense installation, Service, and respective state fish and wildlife agency. They are planning documents to help ensure military operations and natural resources conservation are integrated and consistent with applicable legal requirements, such as the Sikes Act.

purposes of protection of sensitive species, soil stabilization, wildlife food and cover, and military training (MANGCE 2009, p. 112).

- Fort McCoy, Wisconsin

The frosted elfin is included as a state listed species (Fort McCoy Directorate of Public Works (FMDPW) 2012, Appendix F) and the following language explains their requirements. "In general, there are no restrictions placed on military training activities from Army species at risk, federal species of concern, or state listed species. Fort McCoy is committed to the wise stewardship of the natural resources found on the installation to include rare and sensitive species. Attempts are made to minimize impacts to these species from training activities, construction, and maintenance activities whenever feasible. Impacts to these species from construction projects are considered under the National Environmental Policy Act Review process. If a construction project (*i.e.* building or range construction) will impact state listed species, the Wisconsin Department of Natural Resources requires alternatives be considered that do not impact these species or, if that is not possible, minimize impacts to these species (FMDPW 2012, p. 19)." Karner blue butterflies occur at Fort McCoy and there are multiple actions included for surveys and management (FMDPW 2012, pp. 56–57) which should also benefit the frosted elfin. Fort McCoy plans to conduct surveys in 2018 to document species distribution across the installation. Fort McCoy also plans to conduct small habitat modifications to improve habitat for both the Karner blue butterfly and frosted elfin. Small stands of tree removal and white pine removals are under consideration.

- Westover Air Force Base, Massachusetts

The frosted elfin is included in a table of sensitive species documented in and near Westover Airforce Base (Air Force Reserve Command 2016, p. 19). No specific management actions are included for this species.

- Indiantown Gap, Pennsylvania

The frosted elfin is included in tables of state listed and state watch species and SGCN at Fort Indiantown Gap (Pennsylvania Department of Military and Veterans Affairs (PDMVA) 2016, p. 54, p. 68). No specific management actions are included for this species, but there is a goal to provide for the longevity of species identified at any level (regional, state, or federal) as being at risk or under high responsibility including rare, threatened, and endangered animals and plants through active management, conservation, and propagation (PDMVA 2016, p. 16).

The frosted elfin occurs on several other federal lands where various agencies may have the opportunity to conduct habitat management including: Fort Bragg in North Carolina, Coulter

National Park and Indiana Dunes National Park in Indiana, Huron-Manistee National Forest in Michigan, and Kisatchie National Forest in Louisiana. The frosted elfin also occurs on the Apalachicola National Forest in Florida and the U.S. Forest Service [USFS] has a planned project to determine presence/absence of frosted elfins and optimal burn regimes for their conservation.

Recovery Plans/Strategies

The frosted elfin is considered extirpated in Canada, but it is protected under the Species at Risk Act. Environment and Climate Change Canada has developed a recovery strategy for frosted elfin, Karner blue butterfly, and Eastern Persius duskywing (*Erynnis persius*) to assess the potential for restoration of frosted elfin in Ontario and the habitat management and restoration activities that would benefit the species (ECCC 2017, entire). The recovery strategy includes actions associated with habitat restoration, management, and protection, conducting research, and assessing the potential for reintroduction of frosted elfin in the future, if reintroduction is determined to be necessary and biologically and technically feasible.

The State of New Jersey has developed a state management plan for frosted elfin (Golden and Pettigrew 2005, entire). Conservation efforts include managing existing habitats and improving the suitability of habitat for this species at other sites.

Conservation Efforts that Overlap with the Karner Blue Butterfly

The frosted elfin is expected to benefit from ongoing efforts to restore and manage habitat for the federally endangered Karner blue butterfly. While the majority of the species range does not overlap with Karner blue butterflies, the frosted elfin and Karner blue butterfly have potentially overlapping ranges in Illinois (frosted elfin extirpated), Indiana, Ohio, New York, New Hampshire, and Wisconsin. The Karner Blue Butterfly Recovery Plan (Service 2003, pp. 62–100) lists multiple recovery actions that should benefit both species. Examples include protecting and managing habitat, monitoring populations, evaluating and implementing translocation, developing and implementing information and exchange programs, and conducting important research.

Multiple agencies and partners are currently managing for Karner blue butterflies across its range. Fort McCoy is discussed above. The states of Wisconsin and Michigan have statewide Habitat Conservation Plans (HCP) for activities such as forestry and rights-of-way management. Frosted elfins are not included as a covered species, but are discussed as a Karner blue butterfly-associated species (Wisconsin Department of Natural Resources 2010, Appendix B; Michigan Department of Natural Resources 2009, p. 23, 35)

The frosted elfin is identified in two specific conservation efforts in the New York. The Nature Conservancy developed a 30-year Safe Harbor Agreement (The Nature Conservancy 2010, entire) that is intended to improve conservation of frosted elfin, along with Karner blue butterfly and Persius duskywing in eastern New York, through the restoration, creation, enhancement, and management of their habitat on non-federal land. The agreement focuses on maintenance of existing habitat that may be threatened by natural succession, invasive species, or other loss or fragmentation. Suitable habitat may also be created where it does not currently exist. However, no landowners have been signed up to date.

In addition, National Grid developed a 50-year HCP (National Grid 2012, entire) that established a new 5-ac (2 ha) habitat preserve in Queensbury, New York (National Grid 2012, pp. 69–70). This site has been restored and is currently managed. National Grid also contributes to right-of-way habitat management adjacent to previously established habitat within the Albany Pine Bush Preserve that supports populations of wild lupine, frosted elfin, and Karner blue butterfly (National Grid 2012, p. 70). National Grid also plans to create and promote habitat within strategically-selected right-of-way areas (National Grid 2012, p. 71). As of 2017, the HCP is in its fifth year of implementation.

Habitat Restoration and Management outside the Range of the Karner Blue Butterfly

We are unaware of habitat restoration and management occurring at most populations outside of the range of the Karner blue butterfly. Exceptions include efforts proposed at sites in New Jersey (see Recovery Plans section) and at Camp Edwards and Camp Curtis Guild by the MANGCE. In addition, the U.S. Forest Service considers the frosted elfin during prescribed burning schedules on the Apalachicola National Forest in Florida.

Conservation efforts for pollinators and for the monarch butterfly (*Danaus plexippus*) may benefit frosted elfins. This is particularly true in southern states where monarch conservation efforts are focusing more heavily on habitat conservation (B. Hutchins, pers. comm.).

The Maryland Department of Natural Resources (DNR), the Service, and TNC are planning to plant lupine on the lower shore, expanding frosted elfin habitat. Maryland is also planning to propagate lupine collected from wild plants where seed can be collected on an annual basis for restoration projects. They will also temporarily (April to July) install electric deer fence around the main lupine/frosted elfin plot of Pocomoke State Forest. Similar to work done by Thom *et al.* (2015, entire), Maryland DNR is working with Salisbury University and the Salisbury Zoo to conduct a lab pupation study to observe where the larvae are pupating (litter or soil and how deep).

Planned Surveys

We are aware of a few planned survey efforts for the frosted elfin. New York has developed a protocol for a native pollinator survey that will include frosted elfin (Schlesinger *et al.* 2017, p. 18). This should help determine where additional targeted surveys or future protection or habitat management strategies may be appropriate. Surveys should begin in 2018.

Arkansas partners have received State Wildlife Grant Funding to expand current knowledge on the population distributions and abundance of this species, as well as help inform management decisions supporting its habitat. The study began in February 2018.

Texas Parks and Wildlife is assessing the status of frosted elfin populations in Texas. As an initial phase, Texas Parks and Wildlife is currently contracting with the North American Butterfly Association (NABA) to: 1) assess population viability for five populations that have been documented as extant since 2010; 2) conduct additional surveys for extant populations within the historic range of the species; and 3) evaluate and update the current NatureServe state conservation status rank for the species. The NABA project will utilize citizen scientists to survey for frosted elfins across both its current and historic ranges during the 2018 flight season.

Delaware Division of Fish and Wildlife plans to conduct surveys in 2018 for pollinator species, including the frosted elfin. They will revisit known or historical sites to document presence and abundance and conduct vegetation surveys.

Surveys in Maryland are planned at the current and historic sites on the eastern shore.

New Hampshire Fish and Game (NHFG) will be conducting distance sampling for frosted elfins in 2018. New Hampshire Fish and Game also plans to collect data on eggs laid per female, hatch success, and larval survival in their captive rearing lab.

In Ohio, there is a long-term butterfly transect at The Nature Conservancy’s Kitty Todd Reserve. The Toledo Zoo plans to conduct distance sampling for the Karner blue butterfly, but all species information will be collected.

West Virginia Department of Natural Resources plans to visit the two known sites in West Virginia in 2018, pending landowner permission.

Summary

In summary, there are multiple factors (positive and negative) affecting the current status of individual frosted elfins, as well as frosted elfin populations, primarily those associated with the suitability of habitat. Management is needed at most sites to maintain open to semi-open canopy conditions favorable for host plants. However, given the small butterfly population size at many sites, care is needed to minimize impacts to individual butterflies during restoration and management. Little active management is known to occur for the frosted elfin outside the range of the Karner blue butterfly.

CHAPTER 5 – CURRENT CONDITION

To assess the current condition of frosted elfin populations, we requested information on the number and location of frosted elfin occurrences, counts at last surveys, stressors, and land ownership. We conducted a second request for additional information, expanding this to include the number of host plants, acreage of host plants, frosted elfin trend, and overall habitat condition, and based this request on frosted elfin "population" rather than occurrence. After review of best available data provided, we removed "trend in frosted elfin count" and "number of host plant patches" as metrics. We found that "trend in frosted elfin count" data were rarely available. For the majority of populations, the status of frosted elfin populations was unknown because last counts were conducted more than 10 years ago; therefore, trend was similarly unknown. We plan to work with species experts to collect additional frosted elfin count and trend data during future surveys to consider it in our future analysis. We did not find the "number of host plant patches" to be a meaningful metric at this time because it was rarely provided and likely sufficiently addressed with the acreage of host plant patches and overall habitat condition, but we will revisit this concept in the future as more surveys are conducted. Also, for this version of the SSA, we did not explicitly include conservation efforts as a separate metric in our scoring of population health, as we felt that conservation effort success can be observed through the size of the butterfly population and habitat condition.

Most populations had not been visited within the last 10 years or if they were visited, no information about the number of frosted elfin seen or habitat condition was available. In some cases, surveys were conducted, habitat appeared suitable, and no frosted elfin were observed, but surveys were not sufficient to suggest "presumed extirpated." Any of these resulted in the population being classified as having an "unknown" condition; therefore, no scoring of the individual metrics was needed. Multiple populations are considered "presumed extirpated" as the habitat is no longer suitable or habitat is suitable, but no frosted elfins were observed during multiple subsequent surveys; therefore, no scoring of the individual metrics was needed.

For the remaining populations, we evaluated their potential resiliency (*i.e.,* population health or condition) using four metrics:

- last number of butterflies observed;
- acreage of host plants;
- current overall habitat condition; and
- number of ongoing stressors to the habitat/population.

These metrics were initially selected in hopes that the supporting data would be consistent across the range of the species and at a resolution suitable for assessing the species at the population level. However, we have concluded that the majority of frosted elfin populations lack sufficient information to assess many of these metrics. We allowed for scoring of metrics even when its status was unknown and summed the metric scores to provide an overall condition score of "low," "moderate," or "high" for each population that was then used to assess the current condition across its range (Table 7).

Table 7. Current condition category table.

	Condition Class				
Metric	**Unknown**	**Presumed Extirpated**	**Low**	**Moderate**	**High**
FE last count	unknown or 0 with insufficient survey effort	0	<15	15 to 30	>30
Acreage of host plant patches	unknown	0 or any size, but butterflies no longer present	≤0.99 ac (0.4 ha)	1 to 5.9 ac (0.41 to 2.4 ha)	> 5.9 ac (>2.4 ha)
Documented stressors	unknown	any number	3+	1 to 2	0
Habitat condition	unknown	can be either	unsuitable	can be either	suitable

The results of the frosted elfin population assessment provide the basis for our analyses of the species' current status using the 3Rs. The population condition scores allow us to assess and compare the resiliency of each frosted elfin population; however, given the number of populations across the range, we provide summaries by condition score below (Tables 8 to 10, Figures 12 to 14) which then support our analyses of the species' redundancy (within and among the various populations) and representation (across its environmental settings). We emphasize that this portion of the assessment is a "snapshot in time" of the frosted elfin's current condition and does not consider future trends which will be assessed at a later time.

Table 8. Summary of frosted elfin population condition. Appendix A details our methodology for evaluating the current condition of each population and Table 7 defines the condition categories.

Frosted Elfin Population Condition	Number of Populations	Percentage of Total
Unknown	329	80
Presumed Extirpated	30	7
Low	14	3
Moderate	37	9
High	1	<1
Total	411	100

Table 9. Summary of frosted elfin population condition by host plant.

Frosted Elfin Population Condition	Number of Populations (lupine)	Number of Populations (indigo)	Number of Populations (unknown host[23])	Total
Unknown	66	55	208	329
Presumed Extirpated	4	3	23	30
Low	9	4	1	14
Moderate	17	15	5	37
High	1	0	0	1
Total	97	77	237	411

[23] Host is either wild lupine or wild indigo, but no information was provided.

Table 10. Summary of frosted elfin population condition by subspecies.

Frosted Elfin Population Condition	**Number of Populations (*C. i. irus*)**	**Number of Populations (*C. i. arsace*)**	**Number of Populations (*C. i. hadros*)**	**Total**
Unknown	269	0	60	329
Presumed Extirpated	22	7	1	30
Low	13	0	1	14
Moderate	37	0	0	37
High	1	0	0	1
Total	342	7	62	411

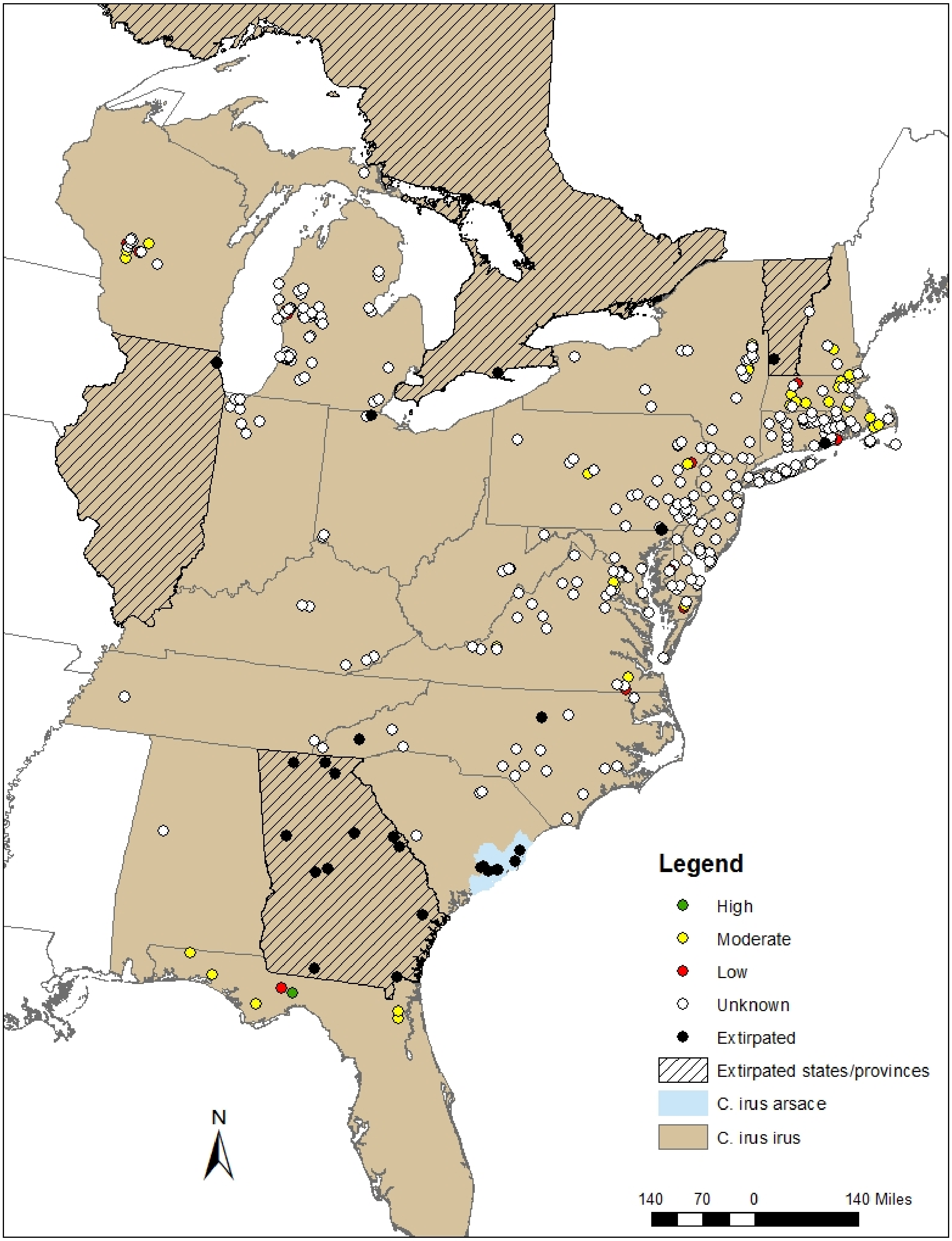

Figure 12. *Callophrys irus irus* population condition.

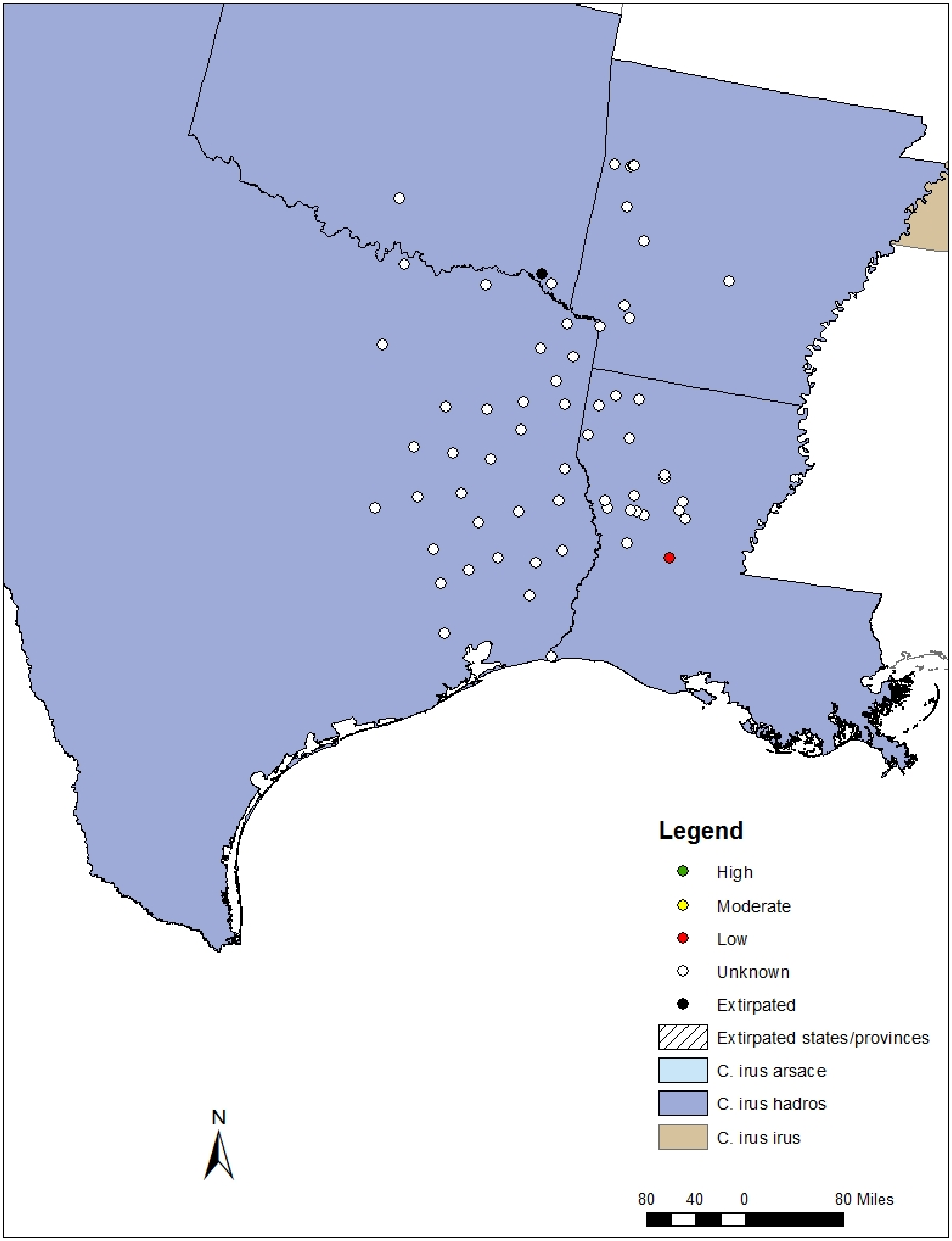

Figure 13. *Callophrys irus hadros* population condition.

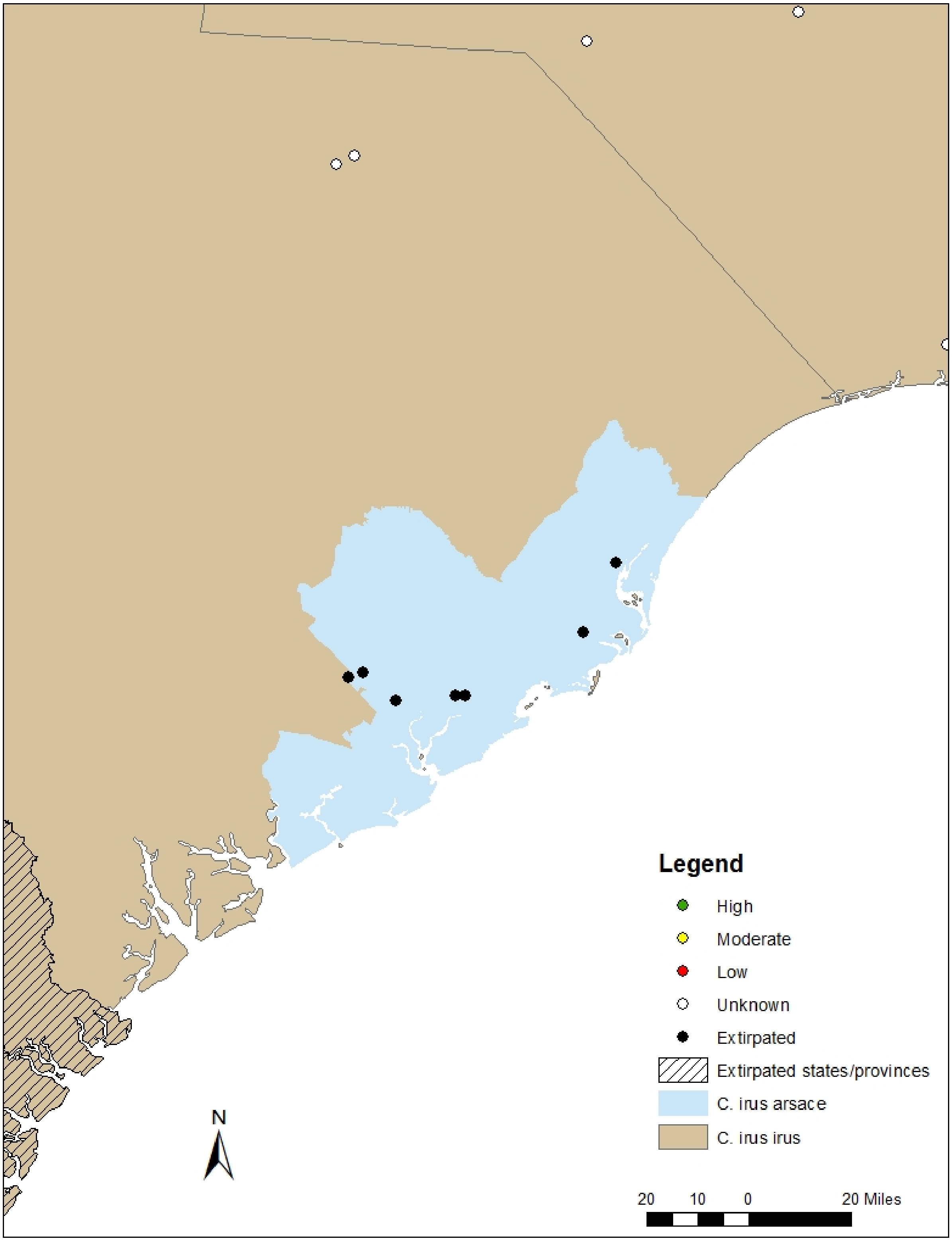

Figure 14. *Callophrys irus arsace* population condition.

We lack sufficient information to understand the status of the majority of frosted elfin populations. Most (329 out of 411) populations have not been surveyed within the last 10 years or if they were visited, no information about the number of frosted elfin seen or habitat condition was available. Updated surveys (with peak counts) would improve the accuracy of the population condition assessment. Given the lack of targeted management occurring at populations outside of the Karner blue butterfly range and the primary stressors of habitat loss and degradation requiring some form of management, we do not anticipate that most of the "unknown" populations would be in "moderate" or "high" condition.

Of the populations that had been visited within the last 10 years that are not considered likely extirpated, 61 had additional information available on at least one of the metrics of interest (Table 11). Looking at median results, populations had small last counts (2 butterflies), had host plant patches available totaling ~3.1 ac (1.3 ha) of habitat, faced two stressors, and had overall suitable habitat conditions.

Table 11. Frosted elfin metrics for populations with some level of information.

Metric	Number of Populations	Results
Last frosted elfin count	52	0 to 157 (median = 2)
Acreage of host plant	19	0.005 to 2,348 (median= 3.1)
Stressors	52	0 to 4 (median of 2)
Overall habitat suitability	15	12 yes, 3 no

While we lack detailed information on most populations, we do have some general indication of conservation status by state. The frosted elfin has been state ranked as S1[24] in 13 states (Delaware, Florida, Indiana, Kentucky, Maryland, New Hampshire, New York, Ohio, Oklahoma, Rhode Island, Vermont, West Virginia, and Wisconsin), S2/S3 in 3 states (Connecticut, Michigan, and Tennessee) S2[25] in 4 states (Massachusetts, New Jersey, North Carolina, and Virginia), S1/S2 in Pennsylvania, and S3[26] in Georgia and Louisiana. State ranking does not provide any legal protections.

[24] S1 corresponds to a status of very rare or critically imperiled: at very high risk of extinction or extirpation due to extreme rarity (often 5 or fewer populations or occurrences), very steep declines, or other factors.
[25] S2 corresponds to a status of imperiled due to rarity (6 to 20 known extant populations) or because of some factor(s) making it very vulnerable to extirpation.
[26] S3 corresponds to a status of vulnerable due to restricted range, relatively few populations, recent and widespread declines, or other factors making it vulnerable to extinction.

Summary

Resiliency (Table E-2): Of the 411 potential populations identified across the range, 30 (7 percent) appear to have been extirpated with the extirpations representing a complete loss of resiliency in those populations. Of the remaining 381 populations, 329 (86 percent) have “unknown” resiliency, 1 (0.3 percent) has a current score of “high” resiliency, 37 (10 percent) have a current score of “moderate” resiliency, and 14 (4 percent) have a current score of “low” resiliency.

Redundancy: The frosted elfin retains some level of redundancy with 381 populations distributed across much of the range; however, over time, populations have been lost from areas of the range. The loss of individual frosted elfin populations and the areas they occupied within the species’ historical range has reduced the ability of the frosted elfin to avoid species-level effects from a catastrophic event. In addition, the distance remaining between most extant populations is too great to allow for meaningful genetic exchange or repatriating extirpated sites.

Representation: Frosted elfin populations continue to occur in scattered populations across the geographic range of the species, with losses of representation in the northern extremes (Vermont and Ontario), some eastern areas of the range (Georgia and District of Columbia), and the Midwest (Illinois). There are similar numbers of frosted elfin populations using either lupine or indigo currently have an “unknown,” “presumed extirpated,” “low,” or “moderate” condition. In terms of subspecies representation, historical vs. current condition is similar for *Callophrys irus irus* and *C. irus hadros.* The majority (83 percent) of all populations (including “presumed extirpated”) are considered *C. irus irus* with 15 percent considered *C. irus hadros*. Similar to historical range, only 7 populations (2 percent) are considered *C. irus arsace*. However, the status of all *C. irus arsace* populations is considered “presumed extirpated” (pers. communication, B. Scholtens) resulting in the potential loss of this subspecies. Given the large percentage of populations with “unknown” resiliency, it is difficult to assess the overall status of the species. If many of the “unknown” status sites are actually extirpated, this leaves significant gaps in any of our measures of representation.

Overall assessment: The primary factors currently influencing the status of populations include inherent factors such as effects from small population size and external factors such as loss or degradation of habitat due to succession, invasive species, and incompatible vegetation management. However, given the substantial number of populations (86 percent) in “unknown” condition, there are significant data gaps that make assessing the current condition of the species challenging at this time. Due to the lack of targeted management occurring at most populations outside the Karner blue butterfly range and the primary stressors of habitat loss and degradation requiring some form of management, we believe that it is unlikely that many of the “unknown” populations would be in “moderate” or “high” condition, but instead would be in “low” condition. To address this uncertainty, additional surveys are needed across much of the range for *Callophyrus irus hadros* and *C. i. irus*. Given some uncertainty expressed about the taxonomic validity of and the suggested extirpation of most sites, surveys and genetic analyses of *C. i. arsace* range are needed.

Table 10. Summary of the 3Rs for the Frosted Elfin.

3Rs	Needs	Current Condition
Resiliency (healthy population to withstand stochastic events)	A resilient population needs: Patches of host plants and associated nectar of at least 5.9 acres (ac) (2.4 hectares (ha)) within 2 kilometers (km) (1.24 miles (mi)) of each other Annual frosted elfin peak counts of at least 30 individuals (timeframe to be determined in SSA Phase 3 given that counts are known to fluctuate among years) Minimal stressors or management underway to address stressors	411 populations across range 329 with unknown condition 1 assessed to have high resiliency 37 assessed to have moderate resiliency 14 assessed to have low resiliency 30 likely extirpated
Redundancy (number and distribution of populations to withstand catastrophic events) and Representation (genetic and ecological diversity to maintain adaptive potential)	Multiple populations within representative units (each subspecies and that use each host plant) Sufficient connectivity for periodic genetic exchange.	*Wild lupine* 97 populations across range 66 with unknown condition 1 assessed to have high resiliency 17 assessed to have moderate resiliency 9 assessed to have low resiliency 4 likely extirpated *Wild indigo* 77 populations across range 55 with unknown condition 0 assessed to have high resiliency 15 assessed to have moderate resiliency 4 assessed to have low resiliency 3 likely extirpated

3Rs	Needs	Current Condition
		Unknown host[27] *(or both plants at the site)* 237 populations across range 208 with unknown condition 0 assessed to have high resiliency 5 assessed to have moderate resiliency 1 assessed to have low resiliency 23 likely extirpated ********************** *Callophyrs irus irus* 342 populations across range 269 with unknown condition 1 assessed to have high resiliency 37 assessed to have moderate resiliency 13 assessed to have low resiliency 22 likely extirpated *C. irus hadros* 62 populations across range 60 with unknown condition 0 assessed to have high resiliency 1 assessed to have moderate resiliency 1 assessed to have low resiliency 1 likely extirpated *C. irus arsace* 7 populations across range 0 with unknown condition 0 assessed to have high resiliency 0 assessed to have moderate resiliency 0 assessed to have low resiliency 7 likely extirpated

[27] Host is either wild lupine or wild indigo, but no information was provided.

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APPENDIX A. Methods

1) Data Source

We requested any available information on current and historic frosted elfin populations from State, Federal, and Tribal partners, as well as species experts. We also obtained observation/voucher data from the Butterflies and Moths of North America database (BAMONA). Data records were assembled in excel tables.

For sites without associated spatial data, spatial point locations were taken from center-points of counties or from Google map searches when more exact locational positions than county were provided. Where we could match sites from BAMONA records to those obtained from agencies/experts, we added the dates as notes for those records. We combined all records into one population for those with the same latitude/longitude or for those within 2 km (1.24 mi) of each other. To do this, we used the near tool in ArcGIS version 10.4.

We delineated the range for each subspecies by county.

We delineated the range of host plants by county.

2) Definition of Population

For the purposes of evaluating the condition of frosted elfin populations, we developed a working definition of "population." After reviewing the best available information, including input from frosted elfin experts across the range, our working definition of a frosted elfin population includes these core concepts:

1. Frosted elfin populations consist of a group of many male and female butterflies.

2. Frosted elfins generally (but not always) function as metapopulations made up of multiple subpopulations (or individual populations) that interact with each other.

3. Frosted elfins rely on one of two larval host plant types (wild lupine or wild indigo) and do not occur when one of two host plants is not present.

4. Frosted elfins are sedentary (non-migratory); therefore, they are present within suitable habitat (see suitable habitat definition below) year-round.

5. Populations can be distinguished from one another by greater than 2 kilometers (km) (1.24 miles [mi]) of unsuitable habitat between wild lupine or wild indigo patches or

by 10 km (6.21 mi) segments of suitable habitat (*i.e.,* rights-of-way) (see NatureServe 2015, p. 9 for additional thoughts).

3) Evaluation of Data by Population for Each Metric

Metrics - We proposed six metrics to assess the current condition of each population: last frosted elfin count, trend in frosted elfin counts, number of host plant patches, acreage of host plant patches, documented stressors, and overall habitat condition. After review of best available data provided, we removed "trend in frosted elfin count" and "number of host plant patches" as metrics. We found that "trend in frosted elfin count" data were rarely available. For the majority of populations, the status of frosted elfin populations was unknown because last counts were conducted more than 10 years ago; therefore, trend was similarly unknown. We plan to work with species experts to collect additional frosted elfin count and trend data during future surveys, to consider it in our future analysis. We did not find the "number of host plant patches" to be a meaningful metric at this time because it was rarely provided and likely sufficiently addressed with the acreage of host plant patches and overall habitat condition, but we will revisit this concept in the future as more surveys are conducted.

Frosted elfin last count

Rationale: This is the number of frosted elfins last counted across all transects (or other method) for a given population. The count could be based on one day or multiple days within the same season (if different locations within the population were sampled across multiple days). We assume population counts are correlated with actual population size. For example, Collier *et al.* (2008, p. 21) found a high correlation between Pollard transect counts and population estimates derived from mark-release-recapture for the bitterbush blue (*Theclinesthes albocincta*), another Lycaenid butterfly.

Frosted elfin appear to have a naturally patchy or low level of abundance. Frosted elfins were never considered abundant in Canada (ECCC 2017, p. vi) and are currently not considered abundant anywhere in the range (NatureServe 2015, p. 2 "G3" Rank and all S ranks at or below S3; also see, Appendix B). Pfitsch and Williams (2009, p. 231) found that frosted elfin populations are never highly abundant and considered their transect counts of approximately 30 individuals to be large for the species.

We recognize that counts may not have been conducted during the peak flight period and would, therefore, be a lower count than the possible maximum for a given year. Over time, we anticipate that more populations will be counted during peak flight period to obtain more accurate reflection of population health.

We ranked this metric as follows: last count of less than 15 frosted elfin as low, 15 to 30 frosted elfin as moderate, and greater than 30 frosted elfin as high. Multiple surveys (*e.g.*, 3 surveys within a 5-year period) with zero butterflies would be considered extirpated.

Acreage of host plant patches

Rationale: Larger acreages should provide more habitat for larger populations. In addition, if parts of a patch are impacts by a stressor, if the patch is large enough, there may some suitable habitat remaining.

In central Wisconsin, frosted elfin units typically contained a large patch or multiple smaller patches of high-density lupine (Swengel 1996, p. 56) with 50 percent of observed individuals occurring within patches greater than or equal to 5.93 acre (2.4 ha). Only 3 percent (5/149) were observed in lupine patches less than or equal to 0.99 ac (0.4 ha) with the remaining 97 percent observed in patches ranging from 1.98 to 79.07 ac (0.8 to 32 ha).

Lupine occurs in dense patches in a dune area of less than 2.47 ac (1 ha) in central New York where a "large" population of frosted elfin occurs (Pfitsch and Williams 2009, p. 227, 231).

We ranked lupine acreage of less than 0.99 ac (0.4 ha) as low, 1 to 5.93 ac (0.41 to 2.4 ha) as good, and greater than 5.93 ac (2.4 ha) as high.

Documented stressors

Rationale: We assume that the more stressors affecting a population, the lower the population's resilience.

We are focusing on stressors that are considered likely to influence population viability. These include: human mediated causes of development, invasive plant species, natural causes of succession, and herbivory.

We ranked this metric as follows: 3 or more stressors as low, 1 to 2 stressors as moderate, and 0 stressors as high.

Habitat condition

Rationale: Presence of suitable habitat is the primary driver affecting frosted elfin population status. Individual sites generally lack quantitative measurements for many habitat metrics and so we asked a simple yes/no for managers to assess whether habitat for the population is currently suitable using the description below.

Habitat is considered suitable for frosted elfin when:

- The overall site condition is considered semi-open canopy (6 to 50 percent cover)
- There is a mosaic of canopy cover and vegetation types (*e.g.*, thickets, open glades, forest patches, herbaceous openings)
- There is presence of relatively abundant nectar species for frosted elfin adults
- There is presence of relatively abundant host plants (wild blue lupine/wild indigo)

We ranked populations with unsuitable habitat as low and suitable habitat as high.

***Scoring System* -** We developed a scoring system for each metric using existing available information (Table A-1). We then solicited expert review of the proposed metrics and thresholds. We assigned scores for each population and then normalized those scores.

Table A-1. Scoring system for frosted elfin population metrics.

	Condition Class				
Metric	**Unknown**	**Extirpated**	**Low**	**Moderate**	**High**
FE last count	unknown	NA	<15	15 to 30	>30
Score	*0*		*-1*	*1*	*2*
Normalized score	*0.33*		*0*	*0.67*	*1.0*
Acreage of host plant patches	unknown	NA	≤0.99 ac (0.4 ha)	1 to 5.9 ac (0.41 to 2.4 ha)	> 5.9 ac (>2.4 ha)
Score	*0*		*-1*	*1*	*2*
Normalized score	*0.33*		*0*	*0.67*	*1.0*
Documented stressors	unknown	NA	3+	1 to 2	0
Score	*0*		*-1*	*1*	*2*
Normalized score	*0.33*		*0*	*0.67*	*1.0*
Habitat condition	unknown	NA	Unsuitable	NA	suitable
Score	*0*		*-1*		*1*
Normalized score	*0.5*		*0*		*1.0*

4) Evaluation of Overall Population Condition

The following definitions were used to describe overall population condition.

Presumed Extirpated - Historical records indicate the presence of frosted elfin during at least one survey AND currently:

- Habitat is no longer suitable for frosted elfin; or
- Habitat is suitable for frosted elfin, but no butterflies were observed during multiple subsequent surveys (*e.g.*, 3 surveys within a 5-year period).

Unknown - At least one survey has indicated presence of frosted elfin AND currently:

- Habitat appears suitable for frosted elfin, but no butterfly surveys have been conducted in recent (10) years (*i.e.*, since 2007); or
- Habitat appears suitable, no butterflies have been observed during recent (10) years, but survey effort is considered insufficient to suggest "presumed extirpated"; or
- There is no information to indicate habitat condition or number of frosted elfin butterflies observed during last count.

For the remaining populations, we calculated the overall condition for each population based on the <u>sum</u> of the normalized scores.

Low Condition – 0 – 1.33 (up to 1 moderate metric)

Moderate Condition – 1.34 – 3.01 (up to 1 high metric)

High Condition – Greater than 3.01 (three or more high metrics)

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APPENDIX B. Frosted Elfin Status by State/Province.

State/Province	State Protection	State Conservation Status[28]	SGCN[29]	Notes
Alabama		not ranked	N	Historical records – needs surveying
Arkansas		not ranked	Y	
Connecticut	T	S2S3	Y	
Delaware	E	S1	Y	
District of Columbia		SH	Y, Tier 3	Extirpated or never occurred
Florida		S1	Y	
Georgia		S3	Y	No current records – likely extirpated
Illinois		SH	Y	Likely extirpated
Indiana	E	S1	Y	
Kansas		NR		No records of ever occurring
Kentucky	E	S1	N	
Louisiana		S3	Y, Tier 3	
Maine		SX	N	Unlikely it ever occurred – species error (Calhoun 2017)
Maryland	E	S1	Y	
Massachusetts	SC	S2	Y	
Michigan	T	S2S3	Y	
New Hampshire	E	S1	Y	
New Jersey	T	S2		
New York	T	S1	Y	
North Carolina		S2	N	
Ohio	E	S1	Y	
Oklahoma		S1		

[28] S1 = Critically imperiled, S2 = Imperiled, S3 = Vulnerable, SX = Presumed Extirpated, NR = Not Ranked
[29] SGCN refers to species of greatest conservation need

State/Province	State Protection	State Conservation Status[28]	SGCN[29]	Notes
Ontario, Canada	Protected under SARA	SX		Likely Extirpated
Pennsylvania		S1S2	Y	
Rhode Island		S1	Y	
South Carolina		not ranked	N	
Tennessee		S2S3	Y	
Texas		not ranked	N	
Vermont		S1	N	Likely Extirpated
Virginia		S2	Y, Tier 4	
West Virginia		S1	Y	
Wisconsin	T	S1	Y	