Species Status Assessment

Class: Lepidoptera
Family: Lycaenidae
Scientific Name: *Callophrys irus*
Common Name: Frosted elfin

Species synopsis:

The frosted elfin *(Callophrys irus* Godart) is a small and inconspicuous brown lycaenid butterfly. It is univoltine and non-migratory and although it has a broad geographic distribution, occurs in small, localized populations, many of which are declining (NatureServe 2012, Schweitzer et al. 2011). It is one of a suite of specialist disturbance-dependent lepidopteran species threatened by degradation of disclimax and early-successional habitat in the northeastern United States (Wagner et al. 2003). Where their distributions overlap, it has similar habitat requirements to the federally endangered *Lycaeides melissa samuelis* Nabokov (Karner Blue Butterfly), and the phenologically similar *Erynnis persius persius* (Scudder) (Schweitzer et al. 2011, Shapiro 1974, Wagner et al. 2003). Compared to these two species, the Frosted Elfin has a much broader geographic range spanning nearly 15 degrees of latitude (Bried et al. 2012).

Much of the early literature failed to recognize the frosted elfin as a species distinct from *Callophrys henrici* (Grote and Robinson 1867) (Albanese et al. 2007a). However, three named subspecies exist (Swengel 1996). *Incisalia i. irus* ranges from northern New England and New York through Ohio and Michigan to Wisconsin, with scattered populations also further southeast including eastern Maryland and northern Florida. It uses wild lupine (*Lupinus perennis*) as the larval host. *Incisalia i. arsace* (Boisduval and Le Conte) occurs in Atlantic coastal states farther south than the main range of *I. i. irus*, from southern New England to South Carolina and possibly farther south. The larval host of *Incisalia i. arsace* is wild indigo (*Baptisia tinctoria*). *Incisalia i. hadra* occurs in Arkansas, Louisiana, and Texas and also feeds on wild indigo in the larval stage (Swengel 1996).

The genus has since been changed from Incisalia, assigned by Scudder in 1871, to Callophrys, assigned by Godart in 1984. Callophrys is the current name (Xerces Society 2012). *Callophrys i. irus* and *Calliphrys i. arsace* (both found in NY) may be sibling species. These ecotypes differ in feeding habits, food plant, phenology, and possibly larval maculation. Lupine-feeders can usually be distinguished from *Baptisia*-feeder butterflies by wing characteristics alone (Schweitzer, pers. comm. added to Schweitzer 1993b). In addition to physical differences, the *Baptisia* ecotype flies approximately 10 days later than the lupine one at a given latitude, which is in correlation with host plant appearance (Schweitzer 1993b).

Even in areas where both host plants grow together, populations only feed on one species of plant (McCabe, pers. comm.), and the mode of larval feeding between the two ecotypes is different as well. The lupine variety feeds on the flowers and pods in May and June, while the mid-latitude *Baptisia* variety feeds on the developing leaves because flowers will not appear until later. *Baptisia* shoots appear 3 to 6 weeks later than *Lupinis* in the northeast and frosted elfins fly later at comparable latitudes where they use *Baptisia* (Schweitzer 1992). The existence of any association between [potential] larval subspecies is undocumented and unknown. There are other examples of a single species of Lepidoptera displaying Hopkins Host Selection Principal, or having two known larval hosts, but only using one of them when both are present (McCabe, pers. comm.).

Frosted elfins have a broad geographic distribution which, when shown on a typical range map, overstates the species' occurrence significantly. Historically, frosted elfins were distributed from southern Canada and the northeastern United States, south to Florida, and west to Texas and Wisconsin. They are now probably extinct from Canada, Maine, and Illinois and are listed as special concern, threatened, or endangered in 11 states in the eastern United States (NatureServe 2012). Frosted elfins may have been most widespread in the Great Lakes region from southern New England down the coast and Piedmont and into the Carolinas, and from there extended very spottily westward without ever reaching the Mississippi Valley. A disjunct subspecies occurs in Texas and adjacent areas (NatureServe 2012). Although they have a larger global range than the Karner blue butterfly (*Lycaeides melissa samuelis*), the two species are sympatric in the northern part of their range and where they co-occur, frosted elfins are usually less abundant (NatureServe 2012).

Within New York State, two populations are largely mutually exclusive, although they are occasionally found occupying the same area (Albanese et al. 2007). The lupine (*Lupinus perennis*) feeding variety is found widely scattered on sandplains in the upper Hudson Valley, particularly with concentrations in the Albany Pine Bush and the Saratoga Sandplains. However, small populations also persist in Oneida and Genesee Counties and on Long Island. Indigo (*Baptisia* spp.) feeders are found primarily on Long Island, but also occur in the lower Hudson Valley (New York Natural Heritage Program 2009).

Optimal frosted elfin habitat cannot be defined by a single condition. Rather, it is a mosaic of open sandplain, nutrient-poor, xeric habitats that includes grasslands with isolated trees, heathland, thickets of closed pitch-pine scrub oak barrens, and areas with high host plant (blue lupine or wild indigo) densities (Albanese et al. 2007b). The minimum size area needed to support a population seems to be smaller than that for Karner blue in light of their persisting longer in overgrown sites where Karners have died out (Kathy O'Brien, pers. comm.).

Status

a. Current and Legal Protected Status

i. Federal **Not listed** **Candidate?** **No**

ii. New York **Threatened**

b. Natural Heritage Program Rank

i. Global **G3**

ii. New York **S1S2** **Tracked by NYNHP?** **Yes**

Other Rank:

None

Status Discussion:

Historically, frosted elfins ranged from southern Canada, southern Maine, across New York west to Michigan and central Wisconsin, south to Georgia, Illinois, Arkansas, northern portions of the Gulf States, and eastern Texas (State of New York Endangered Species Working group 1994). Although widely distributed, it has historically been considered uncommon and rare (Opler and Malikul 1992).

New York State's position within the global range is central (State of New York Endangered Species Working Group 1994) and records from the New York State Museum show many historic occurrences of the *Lupinis* feeder in Albany County in 1876, 1877, 1895, 1904, and 1934 (State of New York Endangered Species Working Group 1994). A few specimens of the *Baptisia* feeder from Long Island exist at Yale University (Schweitzer 1993a) and populations were also found in Westchester and Richmond counties (Shapiro 1974, State of New York Endangered Species Working Group 1994). According to Shapiro (1974), regional distribution in New York included the Coastal Plain, Hudson Valley, Catskills, Allegheny Plateau, and Erie-Ontario Plain.

Frosted elfin populations occur in Albany, Saratoga, Suffolk, and Genesee counties (Shapiro 1974, Schweitzer 1992), as well as Warren county based on sightings during Karner blue butterfly surveys. The last in Schenectady County was at the Fort Hunter site in Rotterdam (Kathy O'Brien, pers. comm.). Both ecotypes occur on Long Island, the *Baptisia* feeder occurs in Westchester county, and the *Lupinis* feeder occurs in upstate and southwestern New York (Schweitzer 1993a). Populations in the Rome Sandplains (Pfitsch and Williams 2009) and Albany Pine Bush (Bried et al. 2012) are large for this species.

I. Abundance and Distribution Trends

a. North America

i. Abundance

_____ declining ____increasing _____stable __X___unknown

ii. Distribution:

__X___ declining ____increasing _____stable _____unknown

Time frame considered: ____

Moderate decline

b. Regional

i. Abundance

_____ declining ____increasing ____stable __X__unknown

ii. Distribution:

__X__ declining ____increasing ____stable _____unknown

Regional Unit Considered:_______Northeast________________________________
Time Frame Considered: ____

Moderate decline

c. Adjacent States and Provinces

CONNECTICUT Not Present _______ No data _______

i. Abundance

__X__ declining ____increasing ____stable ____unknown

ii. Distribution:

__X__ declining ____increasing ____stable ____unknown

Time frame considered: ____
Listing Status: ______Threatened (S2)________________ SGCN? ____Yes_____

Moderate decline

MASSACHUSETTS Not Present _______ No data ___X____

i. Abundance

____ declining ____increasing ____stable __X___unknown

ii. Distribution:

____ declining ____increasing ____stable ___X_unknown

Time frame considered: ____
Listing Status: _______Special Concern (S2)_______________ SGCN? __Yes___

NEW JERSEY **Not Present** _______ **No data** __X____ **(S2)**

i. **Abundance**

__X__ **declining** ____**increasing** ____**stable** _____**unknown**

ii. **Distribution:**

__X___ **declining** ____**increasing** ____**stable** _____**unknown**

Time frame considered: ____
Listing Status: _____Threatened (S2)_____________ SGCN? ___Yes_____

Moderate decline

ONTARIO **Not Present** __X___ **No data** _______

i. **Abundance**

____ **declining** ____**increasing** ______**stable** ____**unknown**

ii. **Distribution:**

____ **declining** ____**increasing** ______**stable** ____**unknown**

Time frame considered: Has not been seen since 1988- likely Extirpated ____
Listing Status: ______Endangered under provincial legislation______________

PENNSYLVANIA **Not Present** _________ **No data** __X_____

i. **Abundance**

___X__ **declining** ____**increasing** ____**stable** ____**unknown**

ii. **Distribution:**

___X__ **declining** ____**increasing** ____**stable** ____**unknown**

Time frame considered: ____
Listing Status: __________Not listed (S2)__________________ SGCN? ___No___

Moderate decline

QUEBEC **Not Present** ___X___ **No data** _______

VERMONT **Not Present** ___X_____ **No data** __X_____

i. **Abundance**

____ **declining** ____**increasing** ____**stable** __X__**unknown**

ii. **Distribution:**

____ **declining** ____**increasing** ____**stable** __X__**unknown**

Time frame considered: ____

Listing Status: _________Not listed (SNR/SU)___________ SGCN? ___No________

d. NEW YORK **No data** _____

i. **Abundance**

____ **declining** ____**increasing** ____**stable** ___X___**unknown**

ii. **Distribution:**

____ **declining** ____**increasing** __X___**stable** ______**unknown**

Time frame considered: ____

Monitoring in New York.

There is scant published information on lupine-feeding frosted elfin (Swengel 1996), and the only substantial studies in the northeast focused on the indigo feeder (Albanese et al. 2007, 2008). Research is needed on New York populations to support the development of a state recovery plan and monitoring program for the species (NY Natural Heritage 2009, State of New York Frosted Elfin Recovery Team 2011). There is a lack of fundamental information, including which factors may be influencing local population dynamics. In response to this lack of information for recovery planning, Bried et al. (2012) conducted surveys in the Albany Pine Bush in 2001 in which data was used to assess the relationship between adult occupancy (patch use) in an urban pine barrens preserve and a suite of potential controlling factors. The results can be used in a simulation framework to quantitatively inform how many sites and surveys are needed for frosted elfin occupancy monitoring.

Twelve-minute Pollard-Yates surveys have been conducted in the Rome Sand Plains, though more individuals were observed during extended periods. During these walks, the maximum frosted elfin count was near 30 (Pfitsch and Williams 2009). From 18 surveys within New York State between 2003 and 2005, only 2 surveys ever reached a high of 30 individuals (Fiore and Wallstrom 2003-2005 *in* Pfitsch and Williams 2009).

In 2000, a frosted elfin survey was conducted at Karner blue butterfly occupied sites. Of 104 sites surveyed, 46 were found to have at least 1 frosted elfin. At 40 sites, <10 frosted elfins were seen and 6 sites had 10 or more. The highest number of frosted elfins counted at a site was approximately 20. Voucher specimens were collected at 33 of the 46 occupied sites, and the species was present at 13 sites where voucher specimens were not caught. Most sites that still supported Karners (74) were confirmed to also have frosted elfins (45). Two sites from the 2000 survey as well as several from a previous survey in 1998 still held frosted elfins although the Karner had been lost (Somogie and O'Brien, unpublished report).

Trends Discussion:

The short-term trends indicate a decline of 10% to 30%. Long-term trends indicate a large decline in the population of 75% to 90%, which is similar to or lower than nearby states (New York Natural Heritage Program 2009).

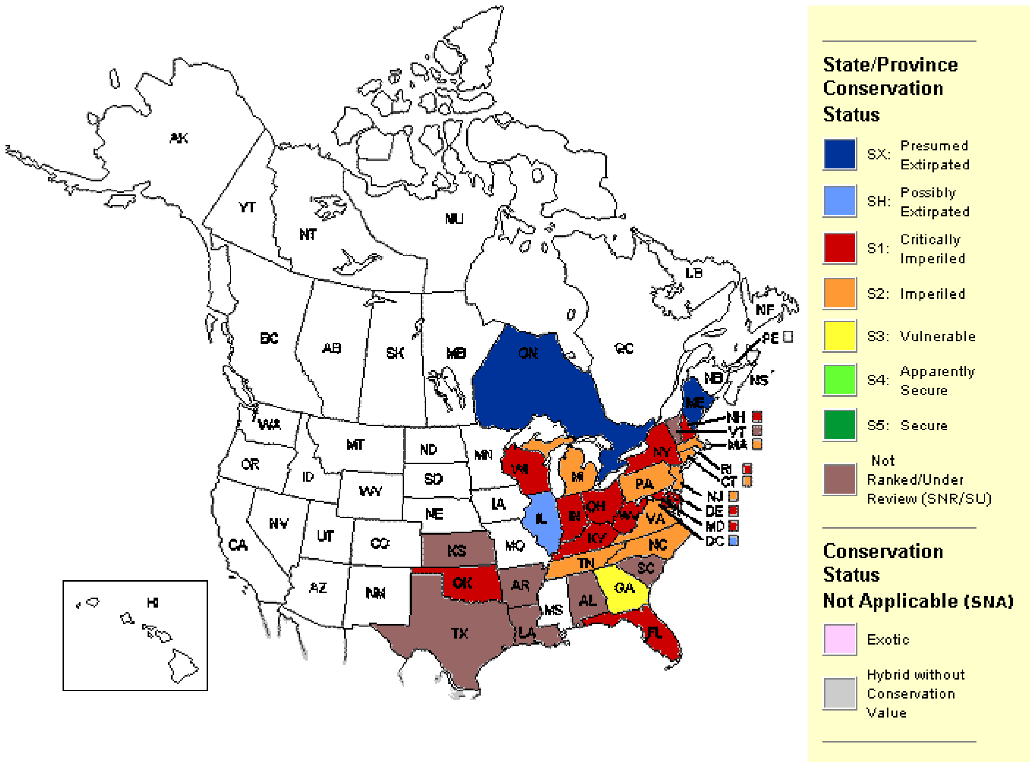

Figure 1. Conservation status of the frosted elfin in North America (NatureServe 2012).

Figure 2. Distribution of the frosted elfin in New York (New York Nature Explorer 2009).

II. New York Rarity, if known:

Historic	# of Animals	# of Occurrences	% of State
prior to 1970	________	________	________
prior to 1980	________	1 county	________
prior to 1990	________	________	________

Details of historic occurrence:

Historically confirmed occurrence in Genesse county in 1970 (New York Nature Explorer 2009).

Current	# of Animals	# of Occurrences	% of State
	________	__6 counties__	________

Details of current occurrence:

Saratoga (2005), Warren (2005), Nassau (2005), Suffolk (2006), Oneida (2006), Albany Counties (New York Nature Explorer 2009).

New York's Contribution to Species North American Range:

Distribution (percent of NY where species occurs)

__X__ 0-5%

____ 6-10%

____ 11-25%

____ 26-50%

____ >50%

Abundance (within NY distribution)

___ abundant

___ common

___ fairly common

_X_ uncommon

___ rare

NY's Contribution to North American range

_X__ 0-5%

____ 6-10%

____ 11-25%

____ 26-50%

____ >50%

Classification of New York Range

__X___ Core

_ __ Peripheral

____ Disjunct

Distance to core population:

____

IV. Primary Habitat or Community Type:

1. Native barrens and savannah

2. Old field managed grasslands

3. Powerline

Habitat or Community Type Trend in New York:

___X__ Declining ____Stable ____ Increasing _ __Unknown

Time frame of decline/increase: ______________________________

Habitat Specialist? __X___ Yes ______ No

Indicator Species? _____ Yes ___X __ No

Habitat Discussion:

Optimal adult frosted elfin habitat includes areas with high host plant densities and moderate tree canopy cover. Areas of high adult frosted elfin density and activity are open areas with interspersed tree cover rather than the middle of large open expanses (Albanese et al. 2007a). In contrast, late instar larvae are found in more shaded areas, on host plants close to trees and under partial canopy cover (Albanese 2006). Although the adult population is associated with open habitat, partial canopy cover over the host plant appears to be vital for the development of frosted elfin larvae. Typical places where frosted elfins can be found include pine-oak and oak-heath scrub, roadsides, and open, brushy fields along the edges of open woods (Shapiro 1974, Opler and Malikul 1992, State of New York Endangered Species Working Group 1994).

Because of the inconsistency in habitat preference between adults and larvae, the species cannot be categorized as either shade tolerant or intolerant. Instead, frosted elfins require canopy heterogeneity. Requirements are similar to that of the Karner blue butterfly (Grundel et al. 1998a, US Fish and Wildlife Service 2003). The habitat for both species is best characterized as open savannah, where scattered trees and shrubs provide partial or filtered shade to an herbaceous/graminoid dominated groundcover.

Even in areas where host plant densities decreased, studies have shown that adult frosted elfin densities can remain relatively stable if shrub cover is dominated by native species and is <16%. Frosted elfin populations are highly sensitive to the invasion and establishment of non-native plant species in the habitat, and even low amounts of non-native shrub cover (<2.1%) have been shown to reduce frosted elfin densities, especially when the problem is compounded with low native herbaceous cover of <36% (Albanese et al. 2007b). Perisistence in the Albany Pine Bush appears very high on even small groups of host plant that are relatively isolated from other occupied areas (N. Gifford pers comm.).

Due to their larval dependence on legumes (*Fabaceae*) with inflated pods, frosted elfins only occur in areas where the soil is acidic enough to support the growth of their host plants—blue lupine (*Lupinus pernnis*) in Albany, Genesee, Oneida, Warren, and Saratoga counties, and wild indigo (*Baptisia tinctoria*) in Richmond county (Shapiro 1974, State of New York Endangered Species Working Group 1994). Blue false indigo (*B. australis*) in Westchester county and rattlebox (*Crotalaria sagittalus*) are also sometimes selected (Shapiro 1974, State of New York Endangered Species Working Group 1994). Both types are usually associated with pine barrens in NY, although many lupine-feeder sites including those in Saratoga and Genesee counties, are oak savanna (Schweitzer 1993a, State of New York Endangered Species Working Group 1994).

North of New Jersey, natural habitat for the *Baptisia* ecotype rarely exists due to fire suppression. Frosted elfins now commonly use railroad or powerline right-of-ways, old fields, and rarely, roadsides. Powerlines provide good quality, stable habitat with dispersal corridors that lead to other sites (Schweitzer 1993b). Similar sites are often used by the *Lupinus*-feeder as well (Schweitzer 1993a, State of New York Endangered Species Working Group 1994).

The density of the larval plant appears to be the most important variable in frosted elfin densities. Optimal habitat contains high host plant densities and moderate tree canopy cover. In a study by Albanese et al. (2007b), adult frosted elfin densities were greatest when host plant density was >2.6m^2 and tree cover was <29%. Densities decreased when tree canopy cover increased even when host plant density was high. Greater tree canopy cover may decrease temperature and affect other microclimate variables. Cooler microclimate temperatures discourage shade intolerant butterflies that require minimum temperatures for flight (Albanese et al. 2007b).

More specifically, butterfly abundance is related to the number of host plants growing under specific microhabitat conditions rather than host plant abundance and therefore, conservation depends not only on identification of adult-habitat associations but also the microhabitat conditions suitable for larvae (Albanese et al. 2008), to which several factors contribute including microenvironmental features (Singer 1972), climatic conditions and their interactions (Singer 1972), quality and quantity of host plant (Grundel et al. 1998b), predators and parasitoids (Sato and Ohsacki 1987, Ohsacki and Sato 1994), and the presence of ants (Albanese et al. 2007a). Host plant abundance at both microsite and landscape scales is more important than the size of a particular lupine patch (Swengel 1996).

V. New York Species Demographics and Life History

__X____ Breeder in New York

__X___ Summer Resident

__X___ Winter Resident

_____ Anadromous

_____ Non-breeder in New York

_____ Summer Resident

_____ Winter Resident

_____ Catadromous

_____ Migratory only

_____Unknown

Species Demographics and Life History Discussion:

The frosted elfin is a univoltine species that over-winters as pupa. Pupation occurs in the litter at the base of the host plant (Opler and Krizek 1984, State of New York Endangered Species Working Group 1994) or below the soil surface when referring to the lupine feeder (Schweitzer 1993a, State of New York Endangered Species Working Group 1994). Frosted elfins are fire-resistant in their pupae stage (Schweitzer 1993b).

Flight in New York has been documented from mid-May to early June (State of New York Endangered Species Working Group 1994), although monitoring efforts in Central New York have suggested a flight period from late April into early June, where abundance peaks around 10 May (Pfitsch and Williams 2009). These results are consistent with timing in Massachusetts, where adults emerge from late April to early June and peak around mid-May (Albanese et all. 2007b).

Detailed research in Wisconsin showed that peak flight occurred just before or at the beginning of peak flowering of blue lupine and the emergence of the first Karner blue adults of the year. The flight period spanned 27-31 days, and peak dates shifted in correspondence with phenological development (Swengel 1996). Adult emergence is staggered and fresh individuals can be seen for approximately one month (New York Natural Heritage Program 2009). A marked annual fluctuation exists (Glassberg 1993, Swengel and Swengel 2000), which could make the timing of monitoring efforts difficult.

Females lay single eggs on host plants, where larvae remain and develop for a six-week period (Nelson 2002). Following a brief egg stage, the larval stage lasts for approximately one month dependent on weather. By the end of June, most of the larvae have pupated (New York Natural Heritage Program 2009).

Results of a study in New Hampshire indicate 36 days for the total larval period. The larvae then cease feeding, burrow into the dry leaf litter, and pupate at the surface of the soil. They construct a thin pad of silk to rest on, dorsal side down, with surrounding leaf litter held together with strands of silk and forming a loose envelope around the pupa (Albanese et al. 2007a). Most of the year is spent in the pupal stage, and the entire timeline for *Baptisia* feeders probably occurs a bit later than that of lupine feeders in similar climates (New York Natural Heritage Program 2009).

In a study by Swengel (1996), all ovipositors occurred on young stalks of green or greenish-white lupine flower buds. Oviposition is slow and deliberate and ovipositing females appear to use two types of flight: fluttery (slow and erratic, low over vegetation) and direct (rapid linear movement from host plant to host plant. Oviposition behaviors occur between 1100 and 1630 hour CST in a temperature range of 18-30^{0}C and in mostly sunny conditions, usually, but not always, in unshaded places. While under observation, the female often slowly paced up and down the flower buds while repeatedly bending down her antennae and probing in and out with her abdomen among the small, tightly packed buds (Swengel 1996).

Unlike pine elfins, male frosted elfins are very territorial, with territories proximal to lupine patches where females lay eggs (Pfitsch and Williams 2009). Male core territories in Rome, NY were approximately 1x3 m in sandy soil, although butterflies fly and defend larger patches. When defending their territory against other frosted elfins, males will fly 25 m or higher in spiral flight. When defending against other insects, the flight is low and direct (Williams 2010).

Female frosted elfin butterflies deposit their eggs on the apical shoots of wild indigo and lupine plants, where early instar larvae feed on the leaves in these shoots (Albanese et al. 2007b). According to Mattson (1980) and Scriber and Slansky (1981), young leaves are preferred because protein and water content is highest, making them a high quality food for developing larvae, and defensive compounds and digestibility reducing defenses are in smaller concentrations. However, many experts believe that the pods are the key food on which larvae are dependent.

First-instar larvae prefer to feed on new apical growth, skeletonizing the surface of the leaves. Second instar larva fed on the leaf edges also. In the third and fourth instars, larva consumed entire leaves. By this stage, feeding was concentrated on a particular branch of the host plant, causing defoliation. In the fourth-instar stage, larvae would rest and feed at the base of the main stem and periodically ascend to the top to consume leaves (Albanese et al. 2007a).

Late-instar frosted elfins display a unique feeding behavior on wild indigo. By consuming the epidermis near the base of the main stem of the wild indigo plant, larvae produce rings. Larvae continue to feed around the circumference of the stem until the outer tissue (epidermis and cortex) is completely consumed. This exposes the inner vascular tissue in an unbroken ring, effectively girdling the main stem of the plant. Usually only one complete feeding ring was present on a single stem, but sometimes two or more rings were present. Scar tissue developed in the area of the feeding ring, which caused it to persist throughout most of the year and as such, can be used to determine the presence of the species (Albanese et al. 2007a).

The girdling behavior allows larvae to tap phloem sap and obtain additional water and nutrients, which are especially critical in the warm, dry habitat that frosted elfin larva experience in the latter half of their development. This sap can also be obtained by simply chewing a hole in the stem, however, complete girdling serves an additional purpose by stopping phloemmatic flow back to the roots and resulting in an accumulation of carbohydrates. Growing caterpillars must have adequate amounts of carbohydrates, amino acids, other nutrients, and water obtained from their food (Albanese et al. 2007a).

Stem-girdling of wild indigo increased the concentration of carbohydrates available to larva feeding on the stem and leaf tissue. Larvae obtain their carbohydrates and water by consuming phloem sap at the girdle and by periodically ascending to consume the leaves (Albanese et al. 2007a). Leaves retain their natural concentrations of protein, amino acid, and water content because the girdling does not affect the xylem and water and nitrogen continue to transport through the roots (Noel 1970).

Although the usual limiting nutrient for herbivores is dietary nitrogen, nitrogen-fixing legumes such as wild indigo and its leaves presumably have high concentrations of nitrogen (Mattson 1980). This is especially true of the young, growing leaves preferred by frosted elfin larva and therefore, carbohydrates presumably become the limiting nutrient (Albanese et al. 2007a).

Partly shaded areas are better than those in full sun as canopy cover moderates temperature extremes and water stress for both the plants and larvae (Grundel et al. 1998b). Larger host plants are thought to be more productive because larvae are restricted to the host plant on which they hatch and a greater number of apical shoots on larger plants results in more young foliage available to the larvae. Once the larva defoliates the shoot it hatched on, it moves to other shoots on the same plant and feeds on younger foliage there rather than risk moving to another plant (Albanese et al. 2007b).

The total larval period lasts for approximately 36 days. Once larvae cease feeding, they burrow into dry leaf litter and pupate at the surface of the soil. They construct a thin pad of silk which they rest on, dorsal side down, with the surrounding leaf litter held together with strands of silk and forming a loose envelope around the pupa (Albanese et al. 2007a).

Two hypotheses exist to explain why only late-instar larvae girdle the host plant. One is that more extensive tissue damage than is produced by early-instar larvae may be required to activate the defense. Another is the fresh tissue fed upon by early-instar larvae does not yet have high enough concentrations of defensive compounds, but as the plant matures it will synthesize and accumulate to a concentration that becomes detrimental to larvae by the late-instar stage (Albanese et al. 2007a).

Female frosted elfins appear to lay eggs indiscriminately. However, different vegetative and environmental features do enhance production. Host plants in partly shaded areas appear to be better than those in full sun, as canopy cover moderates temperature extremes and water stress for both the plant and the larvae. Karner blue (*Lycaeides Melissa samuelis*) females also prefer to oviposit on partially shaded lupine (check the recovery plan) and larvae fed shade-grown leaves from wild lupine (*Lupinus perennis*) in a captive study by Grundel et al. (1998b) had significantly higher growth rates. Tree canopy cover may also have some correlation with late-instar occupancy of host plants. In a study by Albanese et al. (2008), large host plants (>0.6 m^2) were occupied when canopy cover was as low as >8%. Smaller host plants (<0.6 m^2) were used when more canopy cover was available (>19%). The only time that larvae consistently occupied host plants with less than 8% canopy cover was when host plants were large (>0.6 m^2). These plants were also usually in close proximity to trees (≤6m) and likely influenced by some canopy shade, though not direct, from those trees. These effects also may not be mutually exclusive, as larger host plants may provide some supplemental shade (Albanese 2008).

The structure of a plant, as well as the surrounding vegetation, can also affect the visibility of the host plant and therefore the susceptibility of the larvae to threats such as predation and parasitism. A butterfly may use a host plant with lower nutritional quality if the pressure of predation and parasitism are lower on that plant (Ohsaki and Sato 1994). In one study, the most important difference in the survivorship of larvae of three species of swallowtail among suitable host plants was the inability of braconid parasitoids to locate the larvae on host plants that were overshadowed by other vegetation (Sato and Ohsaki 1987). It is very possible that increased larval mortality within smaller and/or non-shaded host plants due to facilitated search efficiency of parasitoids and predators under open conditions may be responsible for the strong association between late-instar larvae and large, shaded host plants.

Late-instar larvae are also known to interact with ants. Interactions are loose facultative and mutualistic. Whether the ants defend the larvae from predators or parasitoids is unknown. Ants are typically found on the dorsal surface of late-instar larvae with their heads proximal to the larva's posterior end, near the seventh abdominal segment and dorsal nectar organ (Albanese et al. 2007a).

When being tended to by ants, larvae tend to remain on the main stem of the host plant, where they rest or feed on epidermal and cortex tissues. Larvae are often circled on their dorsal surface by the ants, which periodically stop and tap the larva with their mouthparts or antennae. In this study by Albanese et al. (2007a), ants would frequently approach the larva's head and then return to the seventh abdominal segment, where it was presumed that they received a secretion from the dorsal nectary organ (Albanese et al. 2007a).

By consuming excess water and carbohydrates, it is thought that larvae are able to produce honeydew without compromising their own growth and metabolism. When larvae girdle the host plant, the increased availability of water and carbohydrates provided by that behavior may allow larvae to produce honeydew in greater quantities or of greater quality due to the higher carbohydrate concentration. This increases the larva's chance of attracting a larger sentry of ants, which results in increased protection from predators and parasitoids (Pierce et al. 2002).

Another benefit believed to result from the larva-ant association is improved feeding conditions that result from the deactivation of an induced phytochemical defense. Girdling of wild indigo may deactivate a phytochemical defense that is otherwise induced by leaf consumption (Albanese et al. 2007a).

VI. Threats:

The same factors that are leading in the decline of the Karner blue are also leading to the decline of the frosted elfin including vegetative succession, fire suppression, and a loss of historical habitat (State of New York Endangered Species Working Group 1994). The *Baptisia* feeder has suffered from the same factors as the lupine feeder and probably also was greatly reduced by gypsy moth spraying of Long Island in 1957 (Schweitzer 1993a, State of New York Endangered Species Working Group 1994).

The greatest threat is residential and commercial development, which reduces potential habitat and/or fragments the landscape, preventing subpopulations from interacting. The second greatest threat is the suppression of natural processes that create and maintain lupine and frosted elfin habitat. This leads to the habitat degradation as trees or other shading vegetation gradually close in; while lupine may continue to persist for a time as non-flowering plants or become dormant, such heavily shaded plants appear of little utility to the butterflies (O'Brien, unpublished report).

Non-native species encroachment is another threat that can either stand alone or in conjunction with the threat of development, fire suppression and/or canopy closure. Relative to other biota, Lepidoptera respond quickly to environmental changes, so the impact of non-native species may be rapid and severe, especially for oligophaous species like frosted elfins (Thomas et al. 2004).

Non-native vegetation may affect frosted elfin populations more dramatically than normal succession of open habitat. This may be due to the fact that some non-native species can alter the soil characteristics and change them from the xeric, nutrient-poor conditions that are characteristic of lupine and wild indigo habitat (e.g. black locust) (Malcolm et al. 2008) . This suggests that other factors which correlate with non-native shrub cover, such as management regime and site history, are also important (Albanese et al. 2007b).

Even some native species can out-compete lupine and other components of suitable frosted elfin habitat in the absence of natural and anthropgenic disturbance regimes. Scrub oak (*Quercus ilicifolia, Q. prinoides), c*reeping dewberry, a native *Rubus* species, can overgrow lupine and grasses very quickly, developing mats or thickets that eliminate sunlight reaching larval host plants. (APBPC, 2010; O'brien unpublished 2009).

Invasive species that pose a threat to frosted elfin habitat include oriental bittersweet (*Celastrus orbiculatus*), spotted knapweed (*Centaurea maculosa*) , Japanese knotweed (*Polygonum cuspidatum*), European swallow-wort (*Cynanchum rossicum*), garlic mustard (*Alliaria petiolata*), and invasive grasses. Black locust (*Robinia pseudoacacia*) is an especially problematic species in the Albany Pine Bush Karner Recover Unit; it also occurs in the Saratoga Sandplains but at a much lower density (O'Brien unpublished 2009).

Even where habitat is maintained in an open condition, incompatible management and other activities can destroy the ability of the butterflies and their host plants to survive. Lupine patches along roadsides may be affected by poorly timed municipal mowing. If patches are mowed during the active lupine growing period, larvae may be crushed or deprived of food. Herbicide application at this time can also kill lupine plants. In addition, these areas are often used as opportunistic dumping grounds for yard waste or other debris which buries lupine and encourages the spread of invasive plants (O'Brien unpublished 2009).

Pesticide use is another direct threat. Herbicides are dangerous to host plants when used both on powerline right-of-ways and for personal use in backyards (O'Brien, pers. comm. 2010), as well as insecticides including mosquito spraying, which may be done to eradicate Triple E (Eastern equine encephalitis) (Williams, pers. comm. 2010).

Although presently discontinued, the Town of Wilton routinely used aerial spraying to control mosquitoes in the past. Hand or truck spraying by landowners is much more difficult to control and may pose a threat to small subpopulations (O'Brien, pers. comm. 2010) and the potential exists for this threat to resurface on a larger scale again if demand increases for sprays to kill mosquitoes, EEE, ticks, and other threats to human health.

Frosted elfin larvae are also susceptible to *Bacillus thuringienesis* (Bt), which is used to control gypsy moths (*Lymantria dispar*). Currently, the New York State Department of Environmental Conservation prohibits aerial spraying within 100 feet of a Karner blue butterfly subpopulation, but if frosted elfins are affected by the spray as well, populations of elfins persisting where the Karner has vanished are vulnerable.

Although secondary to most other threats in some areas (Bried, pers. comm. 2010), overgrazing of host plants can also impact frosted elfin populations. Lupine flowers and leaves are often eaten by deer (*Odocoileus virginianus*), wood chucks (*Marmota monax*), and rabbits (*Sylvilagus floridanus*). Feeding deer may pull young plants right out of the ground and a loss of plants and flowers reduces the ability of lupine to spread and maintain a continual recruitment of young plants. Over a period of time a patch may die out entirely. Browse on lupine and other flowers also causes deprivation of nectar sources during the adult flight (O'Brien unpublished 2009).

Although the problem does not appear to be huge or widespread, a number of observations have supported this hypothesis. McCabe (1995) believed that overgrazing by deer may have contributed to the decline of lupine in the Albany Pine Bush between 1975 and 1987. Schweitzer (pers. obs. *in* McCabe 1995) suspected overgrazing by deer as the cause of the extirpation of the frosted elfin and mottled duskywing skipper at 2 serpentine barrens in Pennsylvania. Wagner (unpublished data) observed New Jersey tea grazed to nearly ground level in a small remnant barrens habitat in Connecticut (Wagner et al. 2003).

Unplanned wildland fire is another less-frequent threat. The Saratoga Sandplains unit has a history of fire due to the railroad that cuts through the western part of the recovery unit from northeast to southwest in Wilton. As recent as 2006, two separate incidences of fires occurred in early spring, both caused by railroad activities. One of the fires burned into Karner-occupied habitat. When wild fire does occur, the impacts can involve not only direct burning of vegetation and butterflies, but also crushing vegetation and butterflies by the fire suppression personnel, and firefighting equipment (O'Brien unpublished 2009).

ATV use negatively impacts populations where host plants are crushed and/or uprooted. This problem is most prevalent along powerline right-of-ways, where bans from ATV use are not always enforced. This is a major problem in Queensbury, as much of the habitat is along powerline right-of-ways (O'Brien, pers. comm. 2010). In more controlled areas, use by ATVs can be discouraged by installing blockades and fences at trail heads, as has been done in the Albany Pine Bush (Bried, pers. comm. 2010).

Invertebrate herbivores can compete for host plant resources and are a threat that may continue to increase in coming years due to climate change. An exotic thrip (*Odontothrips loti*) was found in the Saratoga Sandplains recovery unit in 2007 and has spread, as it can be very easily transported between sites by contamination of clothing. The thrip feeds in the developing flower buds and can deform the flower and stem, resulting in reduced seed production, and it may also cause the leaves to be stunted and yellow (O'Brien unpublished report 2009).

Other invertebrate herbivores that feed on lupine may pose a threat if they out-compete larvae for food, cause lupine to senesce early, or interfere with flowering and seed production. In some years, heavy aphid (Aphididae) infestations were evident on many lupine plants. Mildew (*Erysiphe polygoni*) appears on lupine leaves in early summer. Introduced helical bagworm (*Apterona crenulla* form *helis* Siebold) affects many lupine plants in the Albany Pine Bush, but at this time as not been seen on lupine in the Saratoga Sandplains (O'brien unpublished report 2009). There may be other diseases that attack lupine which are, as yet unknown, and the threat may increase with climate change.

Climate change is signicant concern as an increasingly significant contributor to the global extinction crisis. Although global society is attempting to control climate change through actions such as regulatory mechanisms to reduce greenhouse gas emissions, the earth will continue to experience changes in its climate for 1,000 or more years after emissions stop (Solomon et al. 2009). For living organisms, the impacts of climate change may be direct (i.e. heat stress) or indirect (i.e. change in habitat) (LeDee, unpublished) and frosted elfins are likely to respond to both.

The frosted elfin was classified as "extremely vulnerable" (EV) to predicted climate change in an assessment of vulnerability conducted by the New York Natural Heritage Program. Its abundance and/or range extent within geographical area assessed is extremely likely to substantially decrease or disappear by 2050 (Schlesinger et al. 2011).

Like the Karner blue, the survival of frosted elfin eggs and larvae are central to population persistence and their host plant is essential to larval survival, as that stage is sensitive to both the availability and the quality of lupine. The emergence of wild lupine is linked to ambient temperature (Pavlovic and Grundel 2008) and high temperatures advance the senescence , or seasonal aging, of wild lupine, which reduces its nutritional quality (Grundel 1998a). Droughts or conditions of low precipitation also reduce lupine availability and quality. There is a clear link between lupine quality and Karner blue larval survival where a diet of poor quality lupine reduces larval survival considerably (Grundel et al. 1998b). The same effects can probably be expected from frosted elfins.

In addition to larval mortality, increases in adult mortality are expected. Karner blues exhibit heat stress at 35-36^{0}C and reduce foraging activity (LeDee unpublished report 2010). Pupal mortality also appears significant when ambient temperatures exceed 35^{0}C (N. Gifford unpublished data). Although frosted elfin densities co-vary strongly with increasing temperature, individuals exhibit heat minimizing behaviors such as perching within shaded vegetation at temperatures >27^{0}C (Swengel 1996).

Are there regulatory mechanisms that protect the species or its habitat in New York?

__ ____ No   _____ Unknown

__X____ Yes

The frosted elfin is protected by its status as state-listed Threatened.

Describe knowledge of management/conservation actions that are needed for recovery/conservation, or to eliminate, minimize, or compensate for the identified threats:

All suitable habitats require disturbance, such as fire or mowing, to impede succession. Where fire is used, unburned habitat patches, or refugia, are needed since Indigo (Baptisia spp.) feeders will usually have very high mortality in these areas. Although Lupine (Lupinus perennis) feeders, which pupate in the sand, may not have the same high mortality rates, they may leave the burned areas. Winter mowing is a proven management option, but the footprint of the machinery should be minimized in order to avoid crushing the pupae. Populations can be maintained for decades with mowing. Generally, management that works for the Karner Blue (*Plebejus melissa samuelis)* should work for the co-occurring Frosted Elfin,. Shelter from wind and the proximity of trees may be important for Wild Indigo feeders, although the adjacent habitat may be brushy with few trees. Maintaining connectivity of colonies where they are clustered is important and is likely to be critical for long term persistence of populations (New York Natural HeritageProgram 2009).

VII. References

Albanese, G., M.W. Nelson, P.D. Vickery, and P.R. Sievert. 2007a. Larval feeding behavior and ant association in frosted elfin, *Callophrys irus* (Lycaenidae). Journal of the Lepodopterists' Society 61:61-66.

Albanese, G., P.D. Vickery, and P.R. Sievert. 2007b. Habitat characteristics of adult frosted elfins(*Callophrys irus*) in sandplain communities of southeastern Massachusetts. Biological Conservation 136:53-64.

Albany Pine Bush Preserve Commission. 2010. Management Plan and Final Environmental Impact Statement for the Albany Pine Busn Preserve. Albany, NY. 128 pp.

Bried, J. T., J. E. Murtaugh, and A. T. Dillion. 2012. Local distribution factors and sampling effort guidelines for the rare frosted elfin butterfly. Northeastern Naturalist 19: 673-684.

Glassberg, J. 1993. Butterflies through binoculars: a field guide to butterflies in the Boston-New York- Washington region. Oxford University Press, New York, New York, USA.

Grundel, R., N.B. Pavlovic, and C.L. Sulzman. 1998a. Habitat use by the endangered Karner blue butterfly in oak woodlands: the influence of canopy cover. Biological Conservation 85:47-53.

Malcolm, G.M., Bush, D.S., Rice, S.K., 2008. Soil nitrogen conditions approach preinvasion levels following restoration of nitrogen-fixing black locust (*Robinia pseudoacacia*) stands in a pine oak ecosystem. Restor. Ecol. 16, 70–78.

NatureServe. 2009. NatureServe Explorer. <http://natureserve.org>. Accessed 30 November 2012.

Nelson, M.W., 2002. Element abstract: *Callophrys irus*. Massachusetts Natural Heritage Program and Endangered Species Program, Division of Fisheries and Wildlife. Westborough, Massachusetts, USA.

New York Natural Heritage Program. 2009. Frosted elfin conservation guide. New York Natural Heritage Program, Albany, New York, USA.

Opler, P.A., and G.O. Krizek. 1984. Butterflies east of the Great Plains. Johns Hopkins University Press, Baltimore, Maryland, USA.

Opler, P.A., and V. Maniikul. 1992. A field guide to eastern butterflies. Houghton Mifflin Company, Boston, Massachusetts, USA.

Pfitsch, W.A., and E.H. Williams. 2009. Habitat restoration for lupine specialist butterflies. Restoration Ecology 17:226-233.

Pierce, N.E., M.F. Braby, A. Heath, D.J. Lohman, J. Mathew, D.B. Rand, and M.A. Travassos. 2002. The ecology and evolution of ant association in the Lycaenidae (Lepidoptera). Annual Review of Entomology 47:733-771.

Schlesinger, M.D., J.D. Corser, K.A. Perkins, and E.L. White. 2011. Vulnerability of at-risk species to climate change in New York. New York Natural Heritage Program, Albany, NY, USA.

Swengel, A.B. 1996. Observations of *Incisalia irus* (Lepidoptera: Lycaenidae) in Central Wisconsin 1988-95. The Great Lakes Entomologist 29:41-62.

Swengel, A.B., and S.R. Swengel. 2000. Variation in timing and abundance of elfins (Callophrys) (Lepidoptera: Lycaenidae) in Wisconsin during 1987-1999.

Xerces Society for Invertebrate Conservation (Xerces Society). 2012. Species Profile: *Callophrys* *irus*. <http://www.xerces.org>. Accessed 30 November 2012.

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