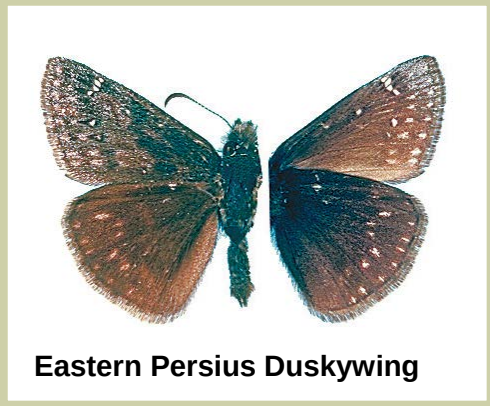
Species at Risk Act
Recovery Strategy Series

Recovery Strategy for the Karner Blue (*Lycaeides melissa samuelis*), Frosted Elfin (*Callophrys irus*), and Eastern Persius Duskywing (*Erynnis persius persius*) in Canada

Karner Blue
Frosted Elfin
Eastern Persius Duskywing


Karner Blue


Frosted Elfin


Eastern Persius Duskywing

2019

Government of Canada
Gouvernement du Canada

Canada

Recommended citation:

Environment and Climate Change Canada. 2019. Recovery Strategy for the Karner Blue (*Lycaeides melissa samuelis*), Frosted Elfin (*Callophrys irus*) and Eastern Persius Duskywing (*Erynnis persius persius*) in Canada. *Species at Risk Act* Recovery Strategy Series. Environment and Climate Change Canada, Ottawa. xv + 71 pp.

For copies of the recovery strategy, or for additional information on species at risk, including the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Status Reports, residence descriptions, action plans, and other related recovery documents, please visit the Species at Risk (SAR) Public Registry[1].

Cover photos: Left: Karner Blue photo taken by Bob Yukich, Allegan State Game Area, Michigan; Center: Frosted Elfin photo taken by Ann B. Swengel, Jackson, Wisconsin; Right: Male Eastern Persius Duskywing showing dorsal (left) and ventral (right) views (specimen plate prepared by John Fowler).

Également disponible en français sous le titre
« Programme de rétablissement du bleu mélissa (*Lycaeides melissa samuelis*), du lutin givré (*Callophrys irus*) et de l'hespérie Persius de l'Est (*Erynnis persius persius*) au Canada »

ISBN 978-0-660-28326-5
Catalogue no. En3-4/299-2019E-PDF

[1] http://sararegistry.gc.ca/default.asp?lang=En&n=24F7211B-1

Preface

The federal, provincial, and territorial government signatories under the Accord for the Protection of Species at Risk (1996)[2] agreed to establish complementary legislation and programs that provide for effective protection of species at risk throughout Canada. Under the *Species at Risk Act* (S.C. 2002, c.29) (SARA), the federal competent ministers are responsible for the preparation of recovery strategies for listed Extirpated, Endangered, and Threatened species and are required to report on progress within five years after the publication of the final document on the SAR Public Registry.

The Minister of Environment and Climate Change is the competent minister under SARA for Karner Blue, Frosted Elfin and Eastern Persius Duskywing and has prepared this strategy, as per section 37 of SARA. To the extent possible, it has been prepared in cooperation with the Ontario Ministry of Natural Resources and Forestry, as per section 39(1) of SARA.

Success in the recovery of these species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this strategy and will not be achieved by Environment and Climate Change Canada, or any other jurisdiction alone. All Canadians are invited to join in supporting and implementing this strategy for the benefit of Karner Blue, Frosted Elfin and Eastern Persius Duskywing and Canadian society as a whole.

This recovery strategy will be followed by one or more action plans that will provide information on recovery measures to be taken by Environment and Climate Change Canada and other jurisdictions and/or organizations involved in the conservation of the species. Implementation of this strategy is subject to appropriations, priorities, and budgetary constraints of the participating jurisdictions and organizations.

The recovery strategy sets the strategic direction to support the recovery of the species, including identification of critical habitat to the extent possible. It provides all Canadians with information to help take action on species conservation. When critical habitat is identified, either in a recovery strategy or an action plan, SARA requires that critical habitat then be protected.

In the case of critical habitat identified for terrestrial species including migratory birds SARA requires that critical habitat identified in a federally protected area[3] be described in the *Canada Gazette* within 90 days after the recovery strategy or action plan that identified the critical habitat is included in the public registry. A prohibition against destruction of critical habitat under ss. 58(1) will apply 90 days after the description of the critical habitat is published in the *Canada Gazette*.

[2] http://registrelep-sararegistry.gc.ca/default.asp?lang=en&n=6B319869-1#2

[3] These federally protected areas are: a national park of Canada named and described in Schedule 1 to the *Canada National Parks Act*, The Rouge National Park established by the *Rouge National Urban Park Act*, a marine protected area under the *Oceans Act*, a migratory bird sanctuary under the *Migratory Birds Convention Act, 1994* or a national wildlife area under the *Canada Wildlife Act* see ss. 58(2) of SARA.

For critical habitat located on other federal lands, the competent minister must either make a statement on existing legal protection or make an order so that the prohibition against destruction of critical habitat applies.

If the critical habitat for a migratory bird is not within a federal protected area and is not on federal land, within the exclusive economic zone or on the continental shelf of Canada, the prohibition against destruction can only apply to those portions of the critical habitat that are habitat to which the *Migratory Birds Convention Act, 1994* applies as per SARA ss. 58(5.1) and ss. 58(5.2).

For any part of critical habitat located on non-federal lands, if the competent minister forms the opinion that any portion of critical habitat is not protected by provisions in or measures under SARA or other Acts of Parliament, or the laws of the province or territory, SARA requires that the Minister recommend that the Governor in Council make an order to prohibit destruction of critical habitat. The discretion to protect critical habitat on non-federal lands that is not otherwise protected rests with the Governor in Council.

Acknowledgments

The initial draft of this recovery strategy was written by Jessica Linton (Natural Resource Solutions Inc.) and received input, review, and suggestions from David Stephenson and Elaine Gosnell (Natural Resource Solutions Inc.). Subsequent drafts were developed by Lauren Strybos, Angela McConnell, Angela Darwin and Elisabeth Shapiro (Environment and Climate Change Canada, Canadian Wildlife Service – Ontario) and benefitted from input, review, and suggestions from Judith Girard, Christina Rohe, Ken Corcoran and Elizabeth Rezek (Environment and Climate Change Canada, Canadian Wildlife Service – Ontario Region), Marie-Andrée Carrière, Paul Johanson, Carolyn Seburn (Environment and Climate Change Canada – National Capital Region), Amelia Argue, Eric Snyder, Kristina Hubert, Leanne Jennings, Megan McAndrew, Melody Cairns, Glenn Desy (Ontario Ministry of Natural Resources and Forestry); Karen Yukich, Brenda Kulon, (Karner Blue Ontario), Dr. Sheila Colla (York University) and Clint Jacobs (Walpole Island First Nation). Dale Schweitzer (NatureServe), Laurence Packer (York University), and Gard Otis (University of Guelph) are acknowledged for providing valuable information on the ecology and conservation of Karner Blue. The following people are acknowledged for contributing to the document: Peter Carson (St. Williams Nursery and Ecology Centre), Wasyl Bakowsky, Colin Jones (Ontario Ministry of Natural Resources and Forestry), Janine McLeod (Alderville First Nation), George Kyei-Poku (Natural Resource Canada), and Tom Mason.

Acknowledgment and thanks are given to all other parties that provided advice and input used to help inform the development of this recovery strategy including various Indigenous organizations and individual citizens, and stakeholders who provided input and/or participated in consultation meetings.

Executive Summary

This is a recovery strategy for three butterfly species at risk in Canada. Karner Blue *(Lycaeides melissa samuelis)* and Frosted Elfin (*Callophrys irus*) are small, non-migratory butterflies of the Family Lycaenidae. Eastern Persius Duskywing (*Erynnis persius persius*) is a small skipper butterfly within the Family Hesperiidae. Both Karner Blue and Frosted Elfin are listed as Extirpated on Schedule 1 of the *Species at Risk Act* (SARA), while Eastern Persius Duskywing is listed as Endangered on Schedule 1. All three butterflies typically inhabit early successional habitats such as pine-oak barrens, sand dunes, savannas, prairies, dry oak woodlands, and other open habitats which support populations of Wild Lupine (*Lupinis perennis)*, the sole larval foodplant required by all three species.

The Karner Blue, Frosted Elfin and Eastern Persius Duskywing have similar needs (i.e., suitable habitat containing Wild Lupine) and share similar geographic ranges in Canada. Furthermore, these species frequently co-occur in the same areas and share many common threats and limiting factors. These similarities facilitate planning efficiencies to maximize conservation and recovery efforts through multi-species recovery planning efforts.

Historically, Karner Blue was distributed across the northeastern United States and southern Ontario, Canada. Over the last 100 years, Karner Blue has decreased in numbers by 99% over its global range. The most recent Canadian observations of the species were recorded in 1988 at Port Franks/Pinery Provincial Park (Lambton County) and the St. Williams Conservation Reserve (Norfolk County), Ontario. However, specimen records indicate it was also historically known from Toronto, London, and Sarnia. There have been unconfirmed reports of Karner Blue between 1988 and 1991. No sightings of Karner Blue have been reported in Ontario since 1991.

Frosted Elfin occurs from Florida, north to New England (and historically, southern Ontario) and west to Alabama and Wisconsin. The only known Canadian site for this species was near the St. Williams Conservation Reserve (Norfolk County), Ontario, where it was last observed in 1988.

Eastern Persius Duskywing is generally distributed in the Great Lakes region eastward to New England, New Jersey and the Appalachian Mountains. Canadian populations of Eastern Persius Duskywing are restricted to southwestern Ontario. Records supported by valid specimens have been confirmed from two widely separated and isolated sites in southern Ontario: St. Williams Conservation Reserve and near Pinery Provincial Park. Given the issues with accurate identification it is difficult to confirm this species' status in Canada with certainty. It is therefore possible that this species is extirpated from Canada, as it has not been recorded since 1987 despite concentrated efforts to find it.

Historical and current major threats to Karner Blue, Frosted Elfin and Eastern Persius Duskywing include habitat loss or degradation, habitat fragmentation and exotic and invasive species.

The feasibility of recovery for Karner Blue, Frosted Elfin and Eastern Persius Duskywing in Canada is unknown. Despite this, and in keeping with the precautionary principle, this recovery strategy has been prepared as per section 41(1) of SARA.

If determined to be biologically and technically feasible, the long-term (i.e. 50+ years) population and distribution objective for all three butterfly species is to ensure the persistence of a self-sustaining metapopulation of each species in Canada. In order to work towards this long-term objective, and to determine if it is biologically and technically feasible to achieve, medium-term objectives must first be met. The medium-term (i.e. ~15-30 years) objectives for these three butterfly species are: to maintain and/or increase sufficient suitable habitat to support a metapopulation through habitat restoration and management within the species historical Canadian range and at additional locations where suitable habitat is being restored for the purposes of recovery (20-30 years); and to investigate the biological and technical feasibility of establishing one or more new metapopulations of each of the three butterfly species within their historical Canadian range for the purposes of recovery (15-20 years). In addition to these medium-term objectives, priority recovery activities are focused on filling crucial knowledge gaps and investigating the feasibility of reintroduction to determine if population recovery in Canada is feasible for these species. These recovery activities are: to determine whether suitable, stable source populations of Karner Blue, Frosted Elfin and Eastern Persius Duskywing exist outside of Canada (5 years); to determine the minimum population viability threshold for Frosted Elfin and Eastern Persius Duskywing (5 years); and to investigate reintroduction techniques and, if determined that reintroduction is biologically and technically feasible, develop a reintroduction plan for each species (5-10 years).

The broad strategies to be taken to address the threats to the survival and recovery of Karner Blue, Frosted Elfin and Eastern Persius Duskywing are presented in the section on Strategic Direction for Recovery (section 6.2).

Critical habitat for Karner Blue, Frosted Elfin and Eastern Persius Duskywing is not identified in this recovery strategy, and will not be identified until certain recovery activities required to confirm recovery feasibility are completed (e.g., confirming whether suitable stable source populations of Karner Blue, Frosted Elfin and Eastern Persius Duskywing exist and are available for use in potential reintroduction efforts). However, there are locations that could provide suitable habitat if habitat restoration activities are undertaken. The schedule of studies (Section 7.2) outlines activities required to identify critical habitat necessary to support the population and distribution objectives for these species.

One or more action plans for Karner Blue, Frosted Elfin and Eastern Persius Duskywing will be posted on the Species at Risk Public Registry by December 2025.

Recovery Feasibility Summary

Recently, the Government of Canada published a proposed "Species at Risk Policies-Policy on Survival and Recovery" (2016) to guide consistent interpretation of major concepts applicable under Canada's *Species at Risk Act* legislation. Recovery feasibility for the Karner Blue, Frosted Elfin and Eastern Persius Duskywing was assessed following this new guidance.

Based on the best available information, Karner Blue, Frosted Elfin and Eastern Persius Duskywing were never particularly widespread or abundant within Canada and are all considered to have been historically precarious (Appendix A). For species with this historical context, the Government of Canada uses the criteria in Table 1 to determine whether recovery for this species is technically and biologically feasible.

For species that were historically precarious, recovery will be considered feasible if the extent of irreversible change[4] is such that under the best achievable scenario[5] it is technically and biologically feasible to improve the condition of the species to a point that it is approaching the historical condition[6]. One irreversible change that must be considered is the permanent loss and degradation of significant suitable habitat for these three butterfly species in Canada. Although efforts have been made to restore and manage remaining suitable habitat, it is not known if it is technically and biologically feasible to mitigate the extent of this irreversible change due to permanent loss of substantial habitat.

There are unknowns regarding the feasibility of recovery for Karner Blue, Frosted Elfin and Eastern Persius Duskywing. In keeping with the precautionary principle, a recovery strategy has been prepared as per section 41(1) of SARA, as would be done when recovery is determined to be technically and biologically feasible. This recovery strategy addresses the unknowns surrounding the feasibility of recovery. The determination of feasibility will be re-assessed if new information clarifies the feasibility.

Extent of Irreversible Change

Suitable habitats for Karner Blue, Frosted Elfin and Eastern Persius Duskywing include dry, sandy oak savanna and woodland habitats, which once covered more than

[4] a change that results in the establishment of a new set of ecological or biological conditions that constrain the ability of the species to return to its historical condition and that cannot reasonably be changed in a way that improves those conditions quickly enough to help the species. Irreversible change could include changes to the species (e.g., all male/all female; genetic incompatibility; loss of genetic diversity) or ecological changes (e.g., loss of ecological niche or of food species/host species; toxic contamination; effects of permanent infrastructure).

[5] the biologically and technically achievable scenario with the lowest possible risk of extinction to the species that can be achieved, taking into account irreversible change.

[6] an estimate of the condition (historic level of redundancy, resilience, representation, population and distribution, trend, threats and ecological role in Canada) prior to significant effects of human activity, based on best available information.

11,000,000 ha of North America, but are now the most endangered habitat type in Canada (COSEWIC 2000b). It is estimated that at least 80,000 ha, and perhaps as much as 200,000 ha, of tallgrass prairie and oak savanna vegetation existed in Ontario before European settlement (Taylor et al. 2014). After European settlement, tallgrass prairie and oak savanna were converted into agricultural land and housing developments, eliminating these habitat types from many areas. The loss of Karner Blue, Frosted Elfin and Eastern Persius Duskywing throughout their North American ranges coincides with the loss of this oak savanna habitat, which is now suggested to occupy less than 3% of its former range in North America, with less than 1% remaining in Ontario (Taylor et al. 2014).

Based on known species information, the minimum viable population size[7] for Karner Blue is 3,000 individuals during the second brood[8] (USFWS 2003); which requires just over 150 ha of suitable habitat to support seven to nine well-connected (e.g., generally less than 300m between suitable habitat patches, but the species can disperse up to 2km (Givnish 1988; Smallidge and Leopold 1997; Knutson et al. 1999)) local populations, each of which should have at least 128,000 stems of the Wild Lupine host plant (Fuller 2008). Although several potential reintroduction sites have been identified in Ontario, none of these currently meet the required criteria to support Karner Blue. Wild Lupine is the only larval foodplant which Karner Blue is known to utilize (COSEWIC 2000b), and is the main larval foodplant for both Frosted Elfin and Eastern Persius Duskywing in Canada (COSEWIC 2000a; COSEWIC 2006). Additionally, adult Karner Blue and Frosted Elfin butterflies lay eggs exclusively on the leaves and flowers of Wild Lupine. The five largest Wild Lupine populations in Ontario occur on properties in Norfolk County, with the most populous site containing approximately 180,000 stems (Otis 2017). While these estimates are encouraging, Norfolk County does not currently contain enough suitable habitat to support seven to nine well-connected local populations. Outside of Norfolk County, the Alderville Black Oak Savanna represents the next largest Wild Lupine population in Ontario with approximately 19,000 stems (Jarvis 2014). Although the Wild Lupine density at this site is comparable to sites in the United States that support Karner Blue, it would only support a single local population with a few small Wild Lupine populations at least 10 km away (Jarvis 2014). However, when sites with high reintroduction potential were evaluated a decade earlier, Alderville Black Oak Savanna had the lowest Wild Lupine density (Chan and Packer 2006) which indicates that intensive restoration efforts (e.g., Wild Lupine planting, frequent burning) were able to greatly improve habitat quality within this 10-year timeframe (Jarvis 2014). Similar restoration efforts should be considered at other sites with high reintroduction potential (e.g., St. Williams Conservation Reserve, Karner Blue Sanctuary in Port Franks, Pinery Provincial Park) and particularly properties within Norfolk County, that have the size and connectivity required to support the dispersal of Karner Blue. However, it is unknown whether an area of suitable habitat this large could become

[7] an estimate of the number of individuals required for a high probability of survival of a population over a given period of time.

[8] a brood is a generation of butterfly species. Two broods of Karner blue butterflies hatch each year, one in the spring and one in the summer.

available within a reasonable timeframe, even with intensive efforts to secure land and restore and manage suitable habitat.

Currently, the minimum Wild Lupine patch size required for both Frosted Elfin and Eastern Persius Duskywing to persist is unknown, however available information suggests that they are likely much smaller than what is required for Karner Blue. In Michigan it is thought that at least 20 m^2 of suitable habitat with an abundance of Wild Lupine would be required to support a small local population of Eastern Persius Duskywing (COSEWIC 2006), while locations that provide multiple Wild Lupine patches, particularly those which are 2.4 hectares or more in size within 2 km of each other, would likely provide adequate habitat to support populations of Frosted Elfin (Swengel 1996). However, more research is required to fully determine the minimum amount of suitable habitat size needed for each species. It should also be noted that adult Frosted Elfin males are known to be territorial, and caterpillars of Wild Lupine-feeding Frosted Elfin are cannibalistic and have been reported to consume caterpillars of other butterfly species (Shapiro 1974). The caterpillar feeding periods of the Frosted Elfin generally overlap with the feeding period of Karner Blue caterpillars and Eastern Persius Duskywing caterpillars (COSEWIC 2000a; 2000b; 2006). Due to these characteristics, reintroductions of Frosted Elfin and first brood Karner Blues may need to be carried out at different locations in order to reduce competition.

Assessing Recovery Feasibility

Once it has been established whether these species are historically precarious or not precarious, and the extent of irreversible change has been considered, the recovery feasibility of these species must be assessed. In order to determine whether recovery is technically and biologically feasible in Canada, a historically precarious species, such as these butterflies, must surpass particular criteria (Table 1).These criteria are based on fundamental species characteristics. For more information, see the Government of Canada's Policy on Survival and Recovery at: http://registrelep-sararegistry.gc.ca/document/default_e.cfm?documentID=2985

Table 1. Determination of Recovery Feasibility for Historically Precarious Species

Fundamental Species Characteristic	**Recovery Threshold for Historically Precarious Species**	**Technically and Biologically Feasible to Achieve Quickly Enough to Help the Species? (Y/N/unknown)**		
		Karner Blue	Frosted Elfin	Eastern Persius Duskywing
Population Trend	Approximating historical condition	Unknown	Unknown	Unknown
Resilience (Population size)	Approximating historical condition	Unknown	Unknown	Unknown
Redundancy (Population # / Distribution)	Approximating historical condition	Unknown	Unknown	Unknown

Fundamental Species Characteristic	Recovery Threshold for Historically Precarious Species	Technically and Biologically Feasible to Achieve Quickly Enough to Help the Species? (Y/N/unknown)		
Population Connectivity	Approximating historical condition	Unknown	Yes	Yes
Mitigation of Human-caused Threats	Significant threats avoided or mitigated to the extent that they no longer threaten the species	Yes	Yes	Yes
Species Condition (see definition)[9]	Improved over when first assessed as at risk	Yes	Yes	Yes
Representation (Species presence in appropriate ecological communities)	Approximating historical condition at a coarse scale	Unknown	Unknown	Unknown
Independent of Connectivity with populations outside of Canada	Connectivity okay if necessary	Yes	Yes	Yes
Independent of Species Interventions	Yes	Unknown	Unknown	Unknown

Narrative to Support Recovery Feasibility

Population Trend

For the purposes of determining recovery feasibility of a historically precarious species, the population trend refers to whether the species population can achieve a similar trend to what it experienced historically.

The decline of these species in Canada largely occurred before information on their population and distribution could be collected. For all three species, the decline was likely caused by destruction, fragmentation and isolation of suitable habitats. It is estimated that prior to these threats, populations for all three species were likely stable.

A stable population trend is suggested to be evaluated over a period of ten years or three generations, whichever is longer (up to 100 years). The generation time of all three butterfly species is fairly short (approximately one year for both Frosted Elfin and Eastern Persius Duskywing; approximately one year for the spring brood of Karner Blue, 5-8 weeks for the second brood), therefore ten years is the appropriate timeframe to provide information on these species population trends.

Karner Blue and Frosted Elfin are both extirpated from Canada; therefore the population trend is currently non-existent. Several stable source populations of Karner Blue and

[9] The condition of the species refers to the combination of its population size, distribution, trend, threats, ecological role and any factors that together determine the risk of extinction or extirpation of the species.

Frosted Elfin occur in the United States which could potentially be used to facilitate reintroduction efforts, however it is not known whether these individuals would be adapted to the Canadian climate, or whether the feeding ecotypes of Frosted Elfin[10] would be appropriate for reintroduction into Canada. Additionally, research into the requirements for captive breeding and reintroduction in Canada is underway for Karner Blue (L. Attard pers. comm. 2015), and could be initiated for Frosted Elfin. Reintroductions of Karner Blue have been conducted with varying degrees of success following habitat restoration in Concord, New Hampshire; West Gary, Indiana; and at the Kitty Todd Preserve in Ohio (USFWS 2003; The Nature Conservancy 2005; 2006), therefore reintroduction is known to be possible for the species. Population augmentation with captive bred individuals has also been successful after habitat restoration and management on the Albany Pine Bush Preserve in Albany, New York. The Karner Blue population there has increased from less than 1000 individuals to more than 15,000 in 10 years (New York State Department of Environmental Conservation 2017). While Eastern Persius Duskywing is listed as Endangered[11] under SARA, no individuals have been seen or collected in at least 18 years despite surveying efforts at areas where experts believe the species is most likely to be encountered (COSEWIC 2006). It is unlikely that Eastern Persius Duskywing still occurs in Canada. The species is known to be rare and declining across its entire range, and is considered threatened in Michigan which is likely the species' global stronghold (NatureServe 2015c); thus suitable stable source populations for population augmentation/reintroduction may not be available even if it still occurs at historic sites, presumably in very small numbers. Therefore, if Eastern Persius Duskywing is determined to be extirpated, it is unlikely to be technically and biologically feasible to recover the species in its former habitats and establish a stable population.

At this time, it is unknown whether stable populations of any of these three species may be achieved in Canada. Reintroduction efforts to initially establish populations are heavily dependent on whether sufficient suitable habitat can be made available through restoration efforts and/or land acquisition; and if suitable, stable source populations of individuals for reintroduction exist outside of Canada.

Resilience (Population size)

Resilience is the species' ability to recover after a disturbance and is critical to the survival of a species that is historically precarious. Although a larger population size does not protect against all threats, it is a strong predictor of resilience against increasing rates of decline due to inbreeding or chance events (e.g., early frost, severe drought) (Elphick et al. 2001; McGowan et al. 2014).

[10] throughout its North American range, caterpillars of nominated subspecies of Frosted Elfin have been separated into two ecotypes based on their foodplant selections: the Wild Lupine (*Lupinus* spp.) feeding populations and Wild Indigo (*Baptisia* spp.) feeding populations. It is unknown whether or not the Wild Lupine and Wild Indigo-feeding ecotypes represent different species. In Canada, Frosted Elfin has only been observed to feed on Wild Lupine (COSEWIC 2000a) and are the focus of this recovery strategy.
[11] endangered (SARA): a wildlife species that is facing imminent extirpation or extinction.

It has been identified that local populations of Karner Blue of less than 1,000 individuals during the second brood (when adult abundance is generally greater) tend not to survive in the long-term or in the face of a large disturbance (USFWS 2003). This observation holds true in Ontario, where the best known population of Karner Blue, estimated to be approximately 1,000 individuals, was wiped out by a severe drought (Carson 1997). The minimum viable population size for Karner Blue has been identified as 3,000 individuals during the larger second brood (USFWS 2003). While population sizes were not well-documented historically, it is likely that historical populations in Canada approached or possibly exceeded this minimum. Furthermore, greater resilience and overall recovery of the species may be achieved through establishment of a population that meets the identified minimum viable population size.

Although it has a broad geographic distribution, Frosted Elfin typically occurs in small, localized populations (Albanese et al. 2007b). No population studies on the Wild Lupine-feeding populations of the species have been published for the northeastern United States or Canada. In Ontario, there are only rough historical population estimates available which indicate that it did not exceed 100 individuals in any given year (Packer 1987). The minimum viable population size for Frosted Elfin is not currently known; however determining this will provide necessary information to determine if reintroduction of the species is technically and biologically feasible.

No population studies on Eastern Persius Duskywing have been published for the northeastern United States or Canada. Specimen records indicate that when it was first collected in Ontario in the late 1960s, its population was small and likely already declining. Specimen records from the United States (New England) indicate that historically it was significantly less rare before the 1940s (NatureServe 2015c). The minimum viable population size for Eastern Persius Duskywing is not known, but given its tendency to occur in relatively small numbers, it may be technically and biologically feasible to maintain species resilience through habitat management and population augmentation/reintroduction if the species is determined to still persist in Canada.

Redundancy (Population size and distribution)

Redundancy refers to the number of local populations and their distribution. If one local population is damaged or destroyed, others can act as a source to restore this missing population. Persistence of a Karner Blue, Frosted Elfin, or Eastern Persius Duskywing metapopulation[12] is governed by the balance between extirpation of local populations and recolonization of unoccupied sites of suitable habitat.

The historical condition of Karner Blue was not well documented, although observations as high as 300 individuals were reported at Port Franks throughout the 1980s. Given the estimated minimum viable metapopulation and habitat patch size for Karner Blue, recovery is likely not feasible at some historical sites due to limited land area and habitat suitability (e.g., High Park, Toronto). However, Norfolk County which contains the St. Williams Conservation Reserve, adjacent provincially-owned lands, numerous properties owned by the Nature Conservancy of Canada and some substantial private

[12] a number of independent linked populations that act as a unit, a population of populations.

land holdings has the potential to support a Karner Blue metapopulation consisting of several local populations (Jarvis 2014). Though the appropriate amount of suitable habitat is not yet available, the 24 properties owned by the Nature Conservancy of Canada have the connectivity ((e.g., generally less than 300m between suitable habitat patches, but the species can disperse up to 2km (Givnish 1988; Smallidge and Leopold 1997; Knutson et al. 1999)) which would be necessary for Karner Blue dispersal between them and could support populations of Wild Lupine, provided additional habitat is restored and managed for Lupine (e.g., areas of early successional habitat with an abundance of Lupine). There are three properties in addition to the St. Williams Conservation Reserve that already contain established populations of Wild Lupine, however two of these require further habitat management such as burning or clearing of successional growth (Jarvis 2014). Although suitable habitat containing Wild Lupine has been significantly fragmented across the Rice Lake Plains area, work to restore degraded Wild Lupine sites in proximity to Alderville Black Oak Savanna is currently underway. Alderville Black Oak Savanna, in conjunction with the restoration of these additional sites and adjacent corridors, may also have the potential to provide a connected patchwork of sites that could support local Karner Blue populations. However, achieving a sufficiently large population of Wild Lupine to support the minimum viable population of Karner Blue at this location is thought to still be at least a decade away (Jarvis 2014).

Historically, Frosted Elfin is only known from one location, the St. Williams Conservation Reserve in Norfolk County. Active management would likely enhance the quality of habitat at this location (Jarvis 2014). Currently, it is anticipated that it may be technically and biologically feasible to manage and restore habitat for reintroduction at the St. Williams Conservation Reserve, which could support the necessary local populations.

Historically, Eastern Persius Duskywing is only known from two locations, the St. Williams Conservation Reserve and Pinery Provincial Park. Although Pinery Provincial Park contains the largest remaining oak savannah in Canada, nectar availability is thought to be low in the spring, though a greater abundance and variety of sources are available during the summer (Jarvis 2014). Efforts to enhance Wild Lupine density and habitat in Pinery Provincial Park have been limited (Jarvis 2014). Active management at both sites would likely enhance the quality of habitat for these species', and it is anticipated that it may be technically and biologically feasible to manage habitat for reintroduction at these locations to support the necessary local populations.

Population Connectivity

Connectivity among local populations can be important in naturally restoring depleted populations. If connectivity between local populations is decreased (e.g. through habitat loss or population declines), remaining local populations may be too small to be viable on their own, or may become inbred due to a lack of gene dispersal. In determining the appropriate level of population connectivity required to ensure survival of the species in Canada, it is important to consider the historical level of connectivity the species is adapted to.

In this regard, population connectivity among distinct locations where Karner Blue occurred was probably low but connection between local populations was high within sites. The metapopulation structure of Karner Blue generally consists of several well-connected local populations, ideally with 500 m spacing between local populations (Fuller 2008). The Karner Blue is capable of rapidly recolonizing suitable sites if there is a colony close enough to provide pioneers. It may be technically and biologically feasible to provide population connectivity among reintroduced local populations at individual locations through restoration and habitat enhancements (provided recovery is determined to be feasible), however it is unknown whether a large enough area of suitable habitat could be restored or maintained to support multiple local populations of Karner Blue within a reasonable timeframe. Although there are no known peer-reviewed published data on dispersal for Frosted Elfin or Eastern Persius Duskywing, anecdotal[13] information suggests that the general pattern of species occurrence in eastern North America is within metapopulations with good connectivity between local populations across open landscapes or along corridors up to a few kilometers (Schweitzer et al. 2011; NatureServe 2015b; 2015c).

Mitigation of Human-caused Threats

This criterion refers specifically to those threats, as a result of human activity, that significantly increase risk to the species. The major threats to Karner Blue, Frosted Elfin and Eastern Persius Duskywing are generally well known and an appropriate level of habitat conservation and threat mitigation could help reduce the risk associated with these threats. The distribution and persistence of Karner Blue, Frosted Elfin and Eastern Persius Duskywing were historically dependent on naturally occurring disturbance (e.g., wildfires) and/or land management practices that maintained suitable conditions for Wild Lupine persistence and flowering (e.g., early successional habitats). Therefore, ongoing habitat management is likely required to maintain Karner Blue, Frosted Elfin and Eastern Persius Duskywing habitat in an early successional state in Canada. It is anticipated that habitat management that maintains early-mid successional oak woodland and savanna habitats would also be beneficial to a variety of other species that use the same habitat types (see Appendix C).

Representation in appropriate ecological communities

Historically, Karner Blue, Frosted Elfin and Eastern Persius Duskywing were locally occurring species restricted to a narrow range of habitat conditions where their larval foodplant occurred. The suitable habitat types for Wild Lupine and Karner Blue, Frosted Elfin and Eastern Persius Duskywing are restricted and rare in Canada and require management activities to ensure their persistence, as well as restoration efforts to increase their size. It may be technically and biologically feasible for Karner Blue, Frosted Elfin and Eastern Persius Duskywing to be represented in their historically known ecological communities through restoration and maintenance of suitable habitat, thus allowing for the reintroduction of several local populations if determined to be feasible.

[13] casual observations or indications rather than rigorous or scientific analysis.

Independent of connectivity with populations outside of Canada
It is unlikely that the Ontario populations of Karner Blue, Frosted Elfin or Eastern Persius Duskywing were historically reliant on populations outside of Canada for survival, as the Adirondack Mountains, Great Lakes, and large expanses of land without suitable habitat present large barriers between Canadian and American populations of these species (Rodenhouse et al. 2009). It may be technically and biologically feasible to provide population connectivity among reintroduced/augmented local populations at individual locations through restoration and habitat management.

Independent of Species Interventions
If reintroduction is deemed feasible and is pursued, it is unknown if the persistence of Karner Blue, Frosted Elfin or Eastern Persius Duskywing would be independent of further interventions, including long term continued reintroductions, after the initial species reintroductions and/or population augmentation. Habitat management would be required periodically to help maintain habitat suitability. However, this would not be considered continuous intervention, as these habitats were historically dependent on management activities by Indigenous people. It is therefore expected that habitat management activities that mimic these processes would occur, even in a recovered state.

Given the extent of irreversible change the three species have experienced (i.e., significant loss and degradation of habitat), as well as the unknowns regarding feasibility of reintroductions and the subsequent need for human interventions, it has been determined that the feasibility of recovery for all three species is unknown because it is uncertain whether it is technically and biologically possible to successfully achieve the following:

- determine whether suitable, stable source populations exist and captive breeding programs and release techniques are practicable,
- restore sufficient suitable habitat to support reintroduced metapopulations,
- reintroduce the species in a reasonable timeframe,
- maintain species resilience,
- support the required metapopulation structure,
- facilitate population connectivity between local populations,
- manage threats to the species, and
- sufficiently represent and improve the historical representation of the species in Canada.

Table of Contents

1. COSEWIC* Species Assessment Information

Date of Assessment: April 2010

Common Name (population): Karner Blue

Scientific Name: *Lycaeides melissa samuelis*

COSEWIC Status: Extirpated

Reason for Designation: *A reason for designation is not specified when a review of classification is conducted by means of a status appraisal summary**.*

Canadian Occurrence: Ontario

COSEWIC Status History: Has not been observed since 1991. Designated Extirpated in April 1997. Status re-examined and confirmed in May 2000 and April 2010.

* COSEWIC (Committee on the Status of Endangered Wildlife in Canada)
** Reason for Designation at last assessment: This species and its habitat originally occurred in a restricted range. The butterfly's population decline and the degradation of its habitat are well documented. The species has not been seen since at least 1988.

Date of Assessment: April 2010

Common Name (population): Frosted Elfin

Scientific Name: *Callophrys irus*

COSEWIC Status: Extirpated

Reason for Designation: *A reason for designation is not specified when a review of classification is conducted by means of a status appraisal summary***.*

Canadian Occurrence: Ontario

COSEWIC Status History: Extirpated by 1988. Designated Extirpated in April 1999. Status re-examined and confirmed in May 2000 and in April 2010.

*** Reason for Designation at last assessment: This butterfly is known to have occurred in one restricted area of oak savanna. It was last recorded in 1988 and has not been seen since despite repeated surveys during the last 10 years.

Date of Assessment: April 2016

Common Name (population): Eastern Persius Duskywing

Scientific Name: *Erynnis persius persius*

COSEWIC Status: Endangered

Reason for Designation: This lupine-feeding butterfly has been confirmed from only two localities in Canada. It inhabits oak savannas in southern Ontario, a habitat that has undergone substantial declines and alterations. Larval host-plant populations have been greatly reduced. There have been no confirmed reports of this butterfly since 1987, but there have been no intensive surveys for the species since 2003. This, combined with its similarity with other duskywings, makes it possible that it still occurs but has been overlooked.

Canadian Occurrence: Ontario

COSEWIC Status History: Designated Endangered in April 2006. Status re-examined and confirmed in April 2016.

2. Species Status Information

Karner Blue

Karner Blue (*Lycaeides melissa samuelis*) is a subspecies of the Melissa Blue (*Lycaeides melissa* Edwards) and is also found in the literature, as well as NatureServe, under the scientific name *Plebejus melissa samuelis* (Jarvis 2014; NatureServe 2015a). Forister et al. (2011) compared gene flow between three taxa of butterflies in the genus *Lycaeides*: Melissa Blue, Karner Blue, and Northern Blue (*Lycaeides idas* L.) and concluded Karner Blue should be recognized as a distinct species. However the classification of the species within this recovery strategy will remain consistent with the name listed under SARA, *Lycaeides melissa samuelis*.

In Canada, Karner Blue is listed as Extirpated[14] on Schedule 1 of SARA and also as Extirpated[15] under the province of Ontario's *Endangered Species Act, 2007* (S.O. 2007, c. 6) (ESA). Globally, NatureServe ranks *Lycaeides melissa* as Secure[16] (G5), however,

[14] extirpated (SARA): a wildlife species that no longer exists in the wild in Canada, but exists elsewhere in the wild.
[15] extirpated (ESA): A species that lives somewhere in the world, lived at one time in the wild in Ontario, but no longer lives in the wild in Ontario.
[16] at very low risk of extinction or elimination due to a very extensive range, abundant populations or occurrences, and little to no concern from declines or threats.

Karner Blue subspecies (*L. m*. *samuelis*) is ranked Imperiled[17] (T2) (NatureServe 2015a). The Karner Blue subspecies is Nationally Extirpated (NX) in Canada and is Nationally Imperiled (N2) in the United States (NatureServe 2015a). In Ontario, the species is listed as Extirpated (SX). Throughout its global range, Karner Blue has been assigned a number of conservation status rankings (Appendix B). The current proportion of the species' global population existing in Canada has not been assessed. However it is estimated that historically, Ontario contained approximately 5% of the habitat in the global range of Karner Blue. The International Union for Conservation of Nature (IUCN) has not assessed Karner Blue (NatureServe 2015a).

Frosted Elfin

Frosted Elfin occurs as three subspecies which have been described, however there are unresolved taxonomic issues with this species which may have conservation implications (Schweitzer et al. 2011). These include: *Callophrys irus hadra* in the southwest; *Callophrys irus arsace* from coastal areas in the southeastern part of the species' range; and *Callophrys irus irus,* the nominate subspecies[18] and the focus of this recovery strategy, which occupies the remainder of the area inland in the southeast. However the classification of the species within this recovery strategy will remain consistent with the name listed under SARA, *Callophrys irus*. Throughout its North American range, caterpillars of different subspecies feed on two plants which are defined as Wild Lupine (*Lupinus* spp.) feeding populations and Wild Indigo (*Baptisia* spp.) feeding populations. In Canada, Frosted Elfin has only been observed to feed on Wild Lupine (COSEWIC 2000a).

In Canada, Frosted Elfin is listed as Extirpated on Schedule 1 of SARA and under the provincial ESA. Globally, Frosted Elfin is ranked as Vulnerable[19] (G3) (NatureServe 2015b). It is Nationally Extirpated (NX) in Canada and is Nationally Vulnerable (N3) in the United States (NatureServe 2015b). In Ontario, the species is listed as Extirpated (SX). Conservation status rankings are shown in Appendix B. The proportion of the species' global population existing in Canada has not been assessed; however it is estimated that historically, Ontario only contains a small percentage of the known suitable habitat in the global range of Frosted Elfin. The IUCN has not assessed Frosted Elfin (IUCN 2015).

Eastern Persius Duskywing

Eastern Persius Duskywing (*Erynnis persius*) was first described in 1863, but the original description (Scudder 1863) is ambiguous and likely confused with similar species such as Wild Indigo Duskywing (*E. baptisiae*) and the Columbine Duskywing

[17] at high risk of extinction or elimination due to very restricted range, very few populations, steep declines, or other factors.
[18] when a species is split into subspecies, the originally described population is retained as the "nominate subspecies", which is referred to by the same name as the species.
[19] at moderate risk of extirpation in the jurisdiction due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors.

(*E. lucilius*), neither of which were described at the time (COSEWIC 2006). Currently, four subspecies of the Persius Duskywing have been described, three of which may occur in Canada: *E. p. persius*, *E. p. borealis* and *E. p. avinoffi* (COSEWIC 2006). Further work on the taxonomy of this *E. persius* complex is needed to clarify spatial boundaries and distribution of its taxa (COSEWIC 2006), however it is generally accepted that *E. persius persius,* the focus of this recovery strategy*,* refers to all populations of the species in the eastern United States and extreme southern Ontario (NatureServe 2015c).

In Canada, Eastern Persius Duskywing is listed as Endangered on Schedule 1 of SARA. In Ontario, the species is listed as Extirpated under the provincial ESA.

Globally, NatureServe ranks *Erynnis persius* as Secure (G5) however the subspecies (*E. p. persius*) has a rounded Global Status of Imperiled (T2) (NatureServe 2015c). It is considered Nationally Extirpated (NX) in Canada by NatureServe (2015c) and is Nationally Critically Imperiled to Vulnerable (N1N3) in the United States (NatureServe 2015c) (Appendix B). The proportion of the species' global population existing in Canada has not been assessed; however Ontario only contains a small percentage of the known suitable habitat in the global range of the species. The IUCN has not assessed Eastern Persius Duskywing (IUCN 2015).

3. Species Information

3.1 Species Description

Karner Blue

Karner Blue is a small (wingspan of 22-32 mm) butterfly in the family Lycaenidae. The upper (dorsal) side of the male wing is an iridescent light blue with a black, usually continuous, margin and white-fringed edge (COSEWIC 2000b; USFSW 2003) (Figure 1). The female's upper side ranges from dull violet to bright purplish-blue near the body and central portions of the wings, and the remainder of the wing is a light or dark gray-brown, with marginal orange crescents typically restricted to the hindwing (COSEWIC 2000b; USFSW 2003) (Figure 2). The underside (ventral) of both sexes is grayish in colour. The undersides of both the fore and hindwings have orange crescents and metallic spots (Figure 3).

Figure 1. Karner Blue male, upper side. Photo credit: Beverly Paulan

Figure 2. Karner Blue female, upper side. Photo credit: Karen Yukich.

Figure 3. Karner Blue male, underside. Photo credit: Bob Yukich.

Adult Karner Blues have two flight periods[20] in Ontario: from late May to late June and from mid-July to mid-August, with fewer individuals in the first brood than in the second (COSEWIC 2000b). Adults are active all day if temperatures are warm, and can generally be found nectaring and reproducing (Lawrence and Cook 1989). Adults can live for up to two to three weeks but the average lifespan in the wild is five days (COSEWIC 2000b, USFWS 2003). Although most adults stay within 100 m of where they hatch, some individuals do move further (Schweitzer et al. 2011). First brood females lay eggs on leaves and leaf petioles[21] of Wild Lupine, and eggs hatch within approximately seven days (Cryan and Dirig 1978). The eggs of Karner Blue are tiny, radially symmetric and pale greenish-white in colour (Dirig 1994). The caterpillars that emerge feed on the leaves of the Wild Lupine for 18-21 days (Cryan and Dirig 1978). At the conclusion of its fifth instar[22], the caterpillar enters its chrysalis stage which is eight days in length (Cryan and Dirig 1978). Young caterpillars are a pea-green colour,

[20] refers to the period of time in which adult butterflies are active.
[21] leaf stalk or the stalk that joins a leaf to a stem.
[22] a phase between two periods of molting in the development of a larva.

pubescent[23] and dorsally flattened, with a brown-black to black head capsule while older caterpillars have pale green (to white) lateral stripes, and a dark-green longitudinal stripe dorsally (USFWS 2003). Second brood females oviposit low down on Wild Lupine plants, often near the position of the first leaf petiole (Packer 1990), and the eggs drop to the ground when leaves are shed in the autumn (Hess 1983). Eggs deposited by second brood females enter a period of diapause[24] and will overwinter until they hatch the following April, forming the first brood of the following year (Jarvis 2014).

Frosted Elfin

Frosted Elfin (*Callophrys irus*) is a small (22-24 mm wingspan) hairstreak butterfly in the family Lycaenidae (Layberry et al. 1998). The upperside of its wings are largely uniform brown while the underside is variegated[25] (COSEWIC 2000a) (Figure 4). There is less contrast on the underside between the colour at the base and the outer part of the wings than in other Elfin subspecies (Layberry et al. 1998). There is a greyish dusting of scales towards the base of the wings, a short "tail" on the hindwing, and a dark "thecla"[26] spot near the base of the tail (Layberry et al. 1998, COSEWIC 2000a).

Figure 4. Male Frosted Elfin showing dorsal or upper side (left) and ventral or the underside (right) views (specimen plate prepared by John Fowler).

The adult Frosted Elfin has one flight period in the spring, peaking in May within the northern parts of its range (COSEWIC 2000a). In eastern North America the species is generally observed from late April until the end of May but can persist into June,

[23] covered with short soft hair; downy.
[24] a period of suspended development, especially during unfavourable environmental conditions.
[25] exhibiting different colours, especially as irregular patches or streaks.
[26] hairstreak butterflies commonly have this dark spot above the tails on the undersurface of the wing.

depending on weather conditions (Cook 1906). Abundance and flight period is reported to vary considerably in some years, which has implications for targeted survey work (Swengel and Swengel 1999). In Ontario, the flight period was historically reported to occur in May and early June (Packer 1990). Adult females lay eggs on the flower buds of Wild Lupine (COSEWIC 2000a). Well-studied populations in Wisconsin show a preference for partially shaded or well-shaded sites (A. Swengel pers. comm. 2015). Eggs are flat and circular in shape (Scudder 1898). The duration of the egg and larval stages varies with temperature, but caterpillars generally hatch within two weeks of spring adult emergence (Schweitzer et al. 2011). During a period of approximately three months, caterpillars feed on Wild Lupine flower parts including the petals, stamens[27], pistils[28] and carina[29] and pass through three instars (Cook 1906). It has also been reported that caterpillars of Wild Lupine-feeding Frosted Elfin are cannibalistic and will also consume caterpillars of other butterfly species (Shapiro 1974). Mature caterpillars are pale green with a grey-green or yellowish-green head with several white lines down the back, one on the side, and oblique white dashes in between (Layberry et al. 1998; COSEWIC 2000a). Pupation[30] occurs in leaf litter within a constructed silk cocoon at the base of the plant or below the surface of the soil (COSEWIC 2000a). The pupal stage is the longest stage in the life cycle of the species, lasting from late summer until the following spring. After emerging as adults, Frosted Elfin may live two to three weeks based on flight time but the average lifespan is unknown. The entire lifecycle of Frosted Elfin is estimated to be up to one year due to the overwintering period of the pupa.

Adult male Frosted Elfins are known to demonstrate territorial behavior (COSEWIC 2000a). Males will actively defend Wild Lupine patches which makes them well adapted to small patches of habitat (Packer 1990). Assuming that only territorial males obtain mates and that the number of suitable territories is limiting, this may have implications in terms of the number of individuals successfully mating within a population. This behavior also makes population estimates difficult because males without territories are extremely difficult to locate and the females are secretive (Packer 1990).

Eastern Persius Duskywing

The Eastern Persius Duskywing is a small (24-31 mm wingspan) greyish-brown skipper[31] with four white flecks on the costa[32] arranged in an almost perfectly straight line at right angles to the costa (Layberry et al. 1998) (Figure 5). A fifth white fleck may be present at the lower border of the forewing's grey patch (COSEWIC 2006). Despite statements in the literature to the contrary (e.g. Balogh 1981), the pattern and shape of

[27] the usually long, protruding male reproductive organ of a flower that produces pollen.
[28] the seed-bearing female reproductive part of a flower.
[29] the two conjoined lower petals of a pea or bean flower that enclose the stamen and style.
[30] the life stage in which a larva transforms into an adult insect. This lifestage usually occurs within a protective covering, such as a cocoon.
[31] a skipper or skipper butterfly is a butterfly of the family Hesperiidae named for their quick, darting flight habits.
[32] the leading edge of a butterfly's forewing

the forewing spots are not diagnostic[33] (COSEWIC 2006). The head, thorax[34], and abdomen are dark brown (COSEWIC 2006). The hindwings are brown with lighter brown spots throughout. Fine hair-like scales cover most of the upper forewing surface, a variable portion being white (COSEWIC 2006).

Figure 5. Male Eastern Persius Duskywing showing dorsal or upper side (left) and ventral or the underside (right) views (specimen plate prepared by John Fowler).

Eastern Persius Duskywing is extremely difficult to distinguish from other persius subspecies, particularly the commonly encountered Wild Indigo Duskywing and Columbine Duskywing. Although association with different host plants and flight period may assist with identification (Wild Indigo Duskywing and Columbine Duskywing fly with Eastern Persius Duskywing in the spring but also have a second brood in the summer), positive identification requires a specimen and is usually based on male genitalia which is diagnostic (COSEWIC 2006; NatureServe 2015c). The genitalia can only be examined with the help of a dissecting microscope after the hairs and scales that cover them are removed with a brush (COSEWIC 2006)[35]. Males also have an abundance of white, raised, curved, hair-like scales on the forewings which can be seen with assistance from a dissecting microscope (Schweitzer et al. 2011). This characteristic can be difficult to interpret however, because male Wild Indigo Duskywings also have a few hair-like scales on the forewing although they are positioned flat against the wing (Schweitzer et al. 2011).

Detailed information on the life cycle of Eastern Persius Duskywing is lacking and no reports on breeding behaviour, copulation, or oviposition[36] are known from Ontario

[33] a distinctive characteristic
[34] the middle section of the body of an insect, between the head and the abdomen, bearing the legs and wings.
[35] detailed references and a comparative illustration of the male genetalia can be found in the 2006 COSEWIC report on the species.
[36] to deposit or lay an egg.

(COSEWIC 2006). Hilltopping[37] is reported as part of this species reproductive strategy (Scott 1968; KBBHCP 2009), but details on this behaviour are unknown (COSEWIC 2006). Males are not territorial (NatureServe 2015c). There is one brood of adults each year whose flight period occurs during May and early June (COSEWIC 2006). Females will oviposit single eggs on the undersides of leaves directly on larval host plants (COSEWIC 2006) and are reported to prefer plants in full sun (Shuey et al. 1987; MSUBT 2007). It is unknown how long it takes for eggs to fully develop, however it is anticipated to be similar to other *Erynnis* species which typically takes five to seven days. After eggs hatch, caterpillars construct leaf nests which provide protection while feeding (COSEWIC 2006). Caterpillars continue to feed on the host plants until they reach maturity in July (COSEWIC 2006). The Eastern Persius Duskywing caterpillar is green with a brown head having paler blotches (Schweitzer et al. 2011). Individuals overwinter as mature caterpillars in leaf litter and pupate in the spring without further feeding (COSEWIC 2006; Schweitzer et al. 2011; NatureServe 2015c). Adults may live two to three weeks based on flight time but the average lifespan of an individual is unknown. The entire lifecycle of the Eastern Persius Duskywing lasts up to one year due to the overwintering period of the mature caterpillar.

3.2 Species Population and Distribution

Karner Blue

Historically, Karner Blue was distributed across northeastern United States and southern Ontario from Indiana and Michigan and southern Ontario, to New Hampshire and New York (COSEWIC 2000b). Over the last 100 years, Karner Blue has decreased in numbers by 99% over its global range, the majority of which has occurred over the past few decades. It is currently considered extirpated from 7 of the 12 states where it was known to occur (Hess and Hess 2015), and is considered extirpated from Ontario and therefore Canada (COSEWIC 2000b; Government of Canada 2015).

The most recent confirmed Canadian observations of the species were recorded in 1988 at two well-known locations: Port Franks/Pinery Provincial Park and St. Williams/St. Williams Conservation Reserve, Ontario. However, infrequent and unconfirmed reports of Karner Blue were recorded until 1991. Specimen records indicate it was also historically known from Toronto, London, and Sarnia (Konecny 1986) (Figure 6). It is also possible that the species occurred in the Rice Lake Plains area near Cobourg (Catling and Brownell 2000) based on a literature report by Bethune (1894) and the presence of Wild Lupine, although there are no specimens to confirm its occurrence there. Three specimens, previously thought to be collected near Orillia, housed at the University of Guelph insect collection, are likely inaccurately labelled as suitable habitat for the species did not occur in this locality (Carson pers. comm. 2015). In Ontario, historical population estimates are only available for the Port Franks/Pinery Provincial Park location (Hess 1981; Crabe 1984; Schweitzer 1985). In 1980, Hess (1981) estimated a population of 200-300 Karner Blue individuals at the

[37] a mate-location behaviour where males patrol hilltops seeking out females.

Port Franks location during the first brood, while Crabe (1984) reported up to 200 individuals at the same site in 1983. In 1984, this population was estimated to be around 1,000 individuals during the second brood (Packer 1990). However, in the following years, observations of Karner Blue declined significantly (Packer 1990). The largest portion of this population was found in the Karner Blue Sanctuary at Port Franks, with several smaller habitat patches or local populations in Port Franks and Pinery Provincial Park.

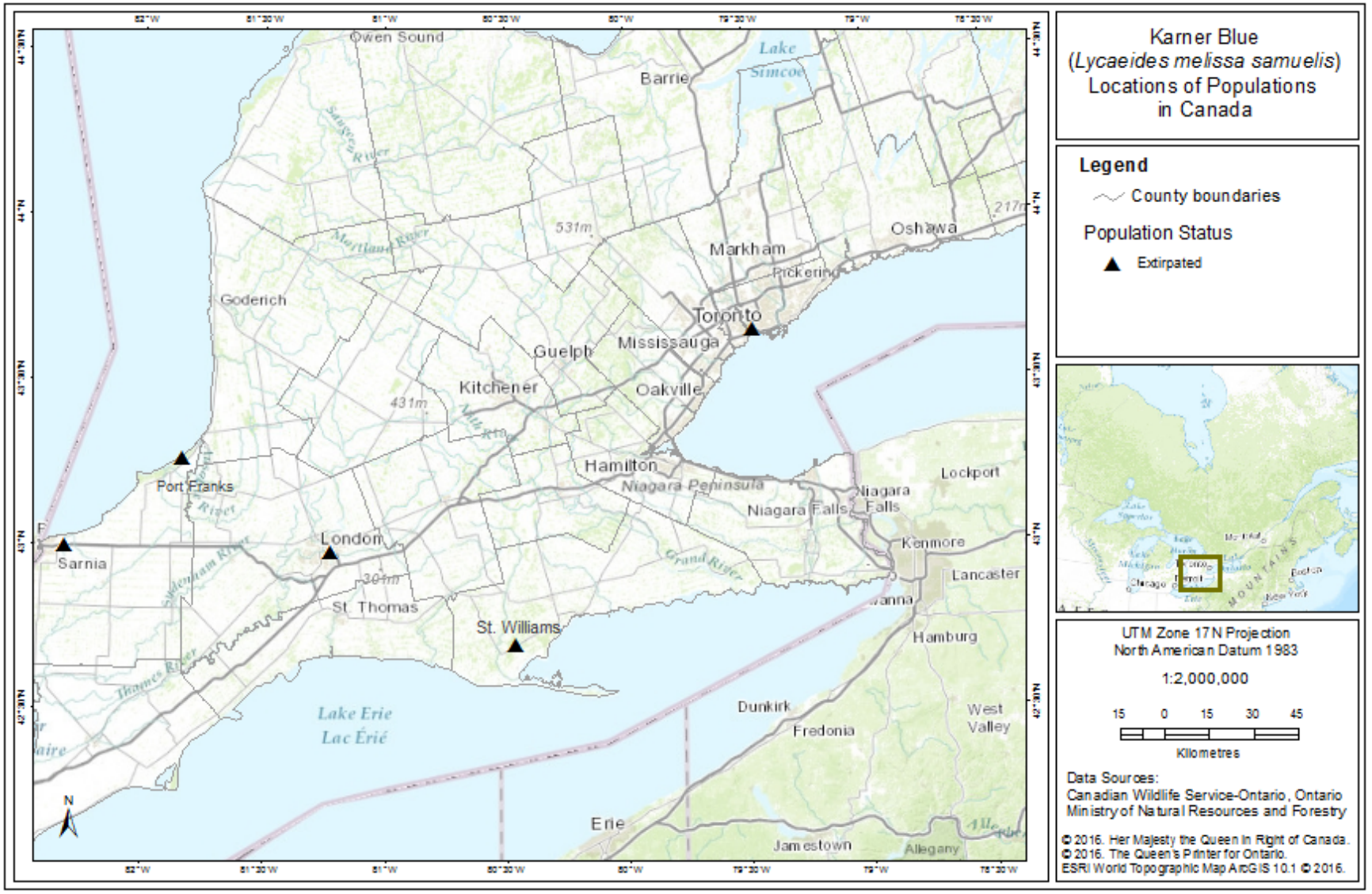


Figure 6. Locations of Karner Blue populations in Canada.

The persistence of Karner Blue populations is dependent on a metapopulation structure consisting of a number of local populations (Fuller 2008) which must be sufficiently connected to allow for recolonization following local extirpations (COSEWIC 2000b). In the United States, Karner Blue occurs in large metapopulations with colonies scattered over at least 1,000 ha. However, at some sites, Karner Blue has been reduced to small discrete areas where its larval foodplant occurs (Schweitzer et al. 2011). It has been suggested that Ontario may eventually become one of the only suitable regions for Karner Blue within its eastern North American range as a result of global climate change (USFWS 2012). As unassisted colonization of Ontario sites is highly unlikely, the reintroduction of this species in Ontario may be critical to its long-term survival (Chan and Packer 2006).

Frosted Elfin

Frosted Elfin occurs as three subspecies with *Callophrys irus hadra* restricted to Arkansas, Louisiana and Texas and *Callophrys irus arsace* found in the coastal regions of the southeastern United States (COSEWIC 2000a). *Callophrys irus irus,* the nominate subspecies, occurs from Florida north to New England (and historically, southern Ontario) and west to Alabama and Wisconsin (COSEWIC 2000a). 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 and New York. Populations that feed on Wild Indigo occur closer to the Atlantic coast (Schweitzer et al. 2011). However, there is some controversy as to whether or not the Wild Lupine and Wild Indigo-feeding ecotypes of the nominate subspecies represent different species. Until recently, there had been no documentation that individuals found at sites where both foodplants occur would use both species (Frye and Robbins 2015). In Canada, Frosted Elfin has only been documented to feed on Wild Lupine. Therefore, the recovery and reintroduction of Frosted Elfin discussed in this recovery strategy will refer only to Wild Lupine-feeding individuals.

When larval foodplants are distributed in patches, butterflies often occur in metapopulations which is thought to be the case for Frosted Elfin (NatureServe 2015b). Frosted Elfin is most commonly reported to occur in areas with a number of habitat patches that are sufficiently close enough together to allow for recolonization following local extirpations (COSEWIC 2000a). A two year study of a Wild Indigo-feeding population of Frosted Elfin by Albanese et al. (2007b) in Massachusetts suggests that small local populations are probably more short-lived than larger local populations as it was observed that some local populations disappeared while others were established. Frosted Elfin has often been documented to undergo considerable population fluctuations (Swengel 1996; Glassberg 1993; Swengel and Swengel 1999) however some report stable numbers (COSEWIC 2000a). Observations suggest that the species does not consistently occupy the same habitat patches year after year indicating that in addition to fluctuating in abundance, resident populations may be temporary (Swengel and Swengel 1999).

The only known Canadian site for this species, where it was last observed in 1988, was near the St. Williams Conservation Reserve in Norfolk County, Ontario (Figure 7). An earlier record from the Pinery Provincial Park has been shown to be based upon a misidentification (COSEWIC 2000a).

The only information on the population biology of Frosted Elfin has been collected by Swengel and Swengel who have studied this species in Wisconsin since the late 1980's (see Swengel 1996; 2015 and Swengel and Swengel 1999; 2014). No population studies on the Wild Lupine-feeding populations of the species have been published for the northeastern United States or Canada. In Ontario, there are only rough historical population estimates available (Packer 1990). The Ontario population was estimated not to exceed 100 individuals in any given year with a maximum of 12 individuals observed in one day (Toronto Entomologists' Association 1979). The second highest count of Frosted Elfin was recorded by Packer (1987), with a total of 8 individuals observed in one day. This population was known to occupy a small portion of the St. Williams Conservation Reserve, a small adjacent property, and along the edges of dirt roads in close proximity (Packer 1990).

Available information suggests that Frosted Elfin occurs in smaller numbers than other Wild Lupine-feeders such as Karner Blue, however it should also be noted that they exhibit behavior patterns that make them more difficult to detect (A. Swengel pers. comm. 2015). For example, individuals are drab in colour, fly in partially shaded sites, are often remarkably sedentary and disinclined to flush[38] (i.e., tend to stay put even when disturbed) (A. Swengel pers. comm. 2015).

Frosted Elfin is extremely local and usually rare across its range and continues to experience on-going declines. In many states where it is known to occur, the species is ranked as critically imperiled or threatened, including two of three major stronghold states (NatureServe 2015b). However, there are viable populations of Frosted Elfin that remain extant in a few states, and some states have not yet been ranked.

[38] to drive an animal from its cover and/or force it into the open.

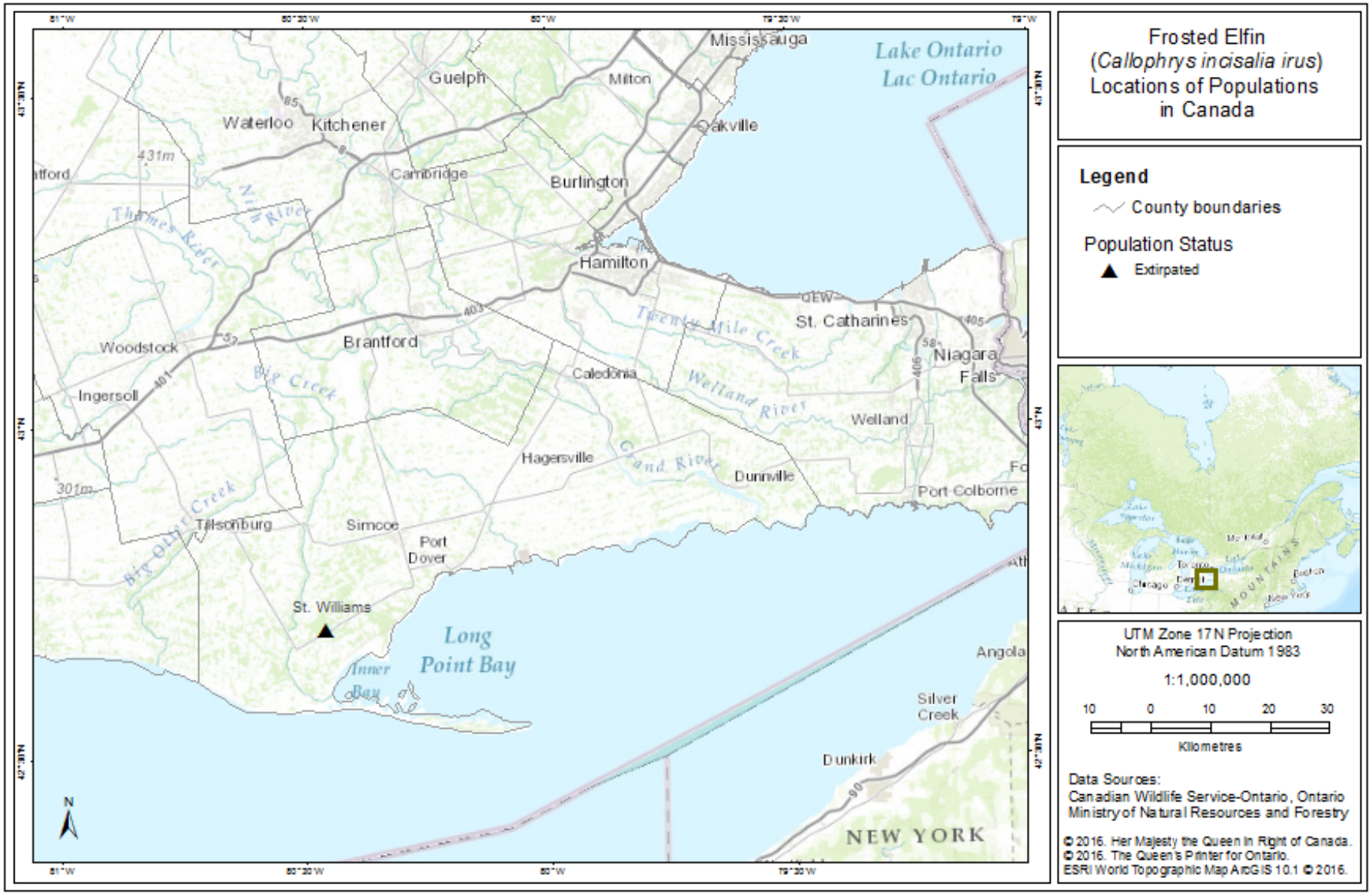


Figure 7. Locations of Frosted Elfin populations in Canada.

Eastern Persius Duskywing

Eastern Persius Duskywing (*Erynnis persius persius)* occurs throughout the northeastern United States from the Great Lakes to New England and New Jersey and as far north as Ontario (COSEWIC 2006). Canadian populations of Eastern Persius Duskywing are restricted to southwestern Ontario. Very little is known regarding Canadian populations, which were sporadically but reliably reported (i.e., confirmed by valid specimens) in the late 1970's and 1980's from only two widely separated and isolated sites; St. Williams (Norfolk County) and Pinery Provincial Park (Lambton County) (COSEWIC 2006) (Figure 8). The species was last recorded in 1987 and it is possible that it is now extirpated as concentrated surveys since have been unsuccessful. However, due to its extreme similarity to other Duskywing species, it is possible that it still occurs but has been overlooked (C. Jones pers. comm. 2015). The decline of this subspecies in Canada largely occurred before information on its population and distribution could be collected. This was likely caused by destruction, fragmentation and isolation of suitable habitats (COSEWIC 2006).

Reports of the Eastern Persius Duskywing from elsewhere in southern Ontario, including Muskoka District Municipality, Manitoulin Island, Walpole Island, other sites in Lambton County and Norfolk Township, Middlesex County, Essex County, Niagara Regional Municipality, Hamilton, Toronto and Ottawa are not supported by validated specimens or are based on misidentified specimens (COSEWIC 2006). Despite this, it almost certainly occurred from pre-settlement times as scattered populations in southern Ontario (COSEWIC 2006).

Additional sites where the species may have once occurred based on available habitat include Walpole Island, a number of sites in the St. Williams area, Toronto, and the Rice Lake Plains east of Peterborough (Catling and Brownell 2000; COSEWIC 2006).

Eastern Persius Duskywing has experienced substantial declines within the eastern parts of its range and in Ontario. Fewer than 20 extant populations are known to exist, with far fewer metapopulations known. The species is considered threatened at its global stronghold, Michigan, and is ranked as Imperiled, Extirpated or Historical in all states where it is known to occur (NatureServe 2015c).

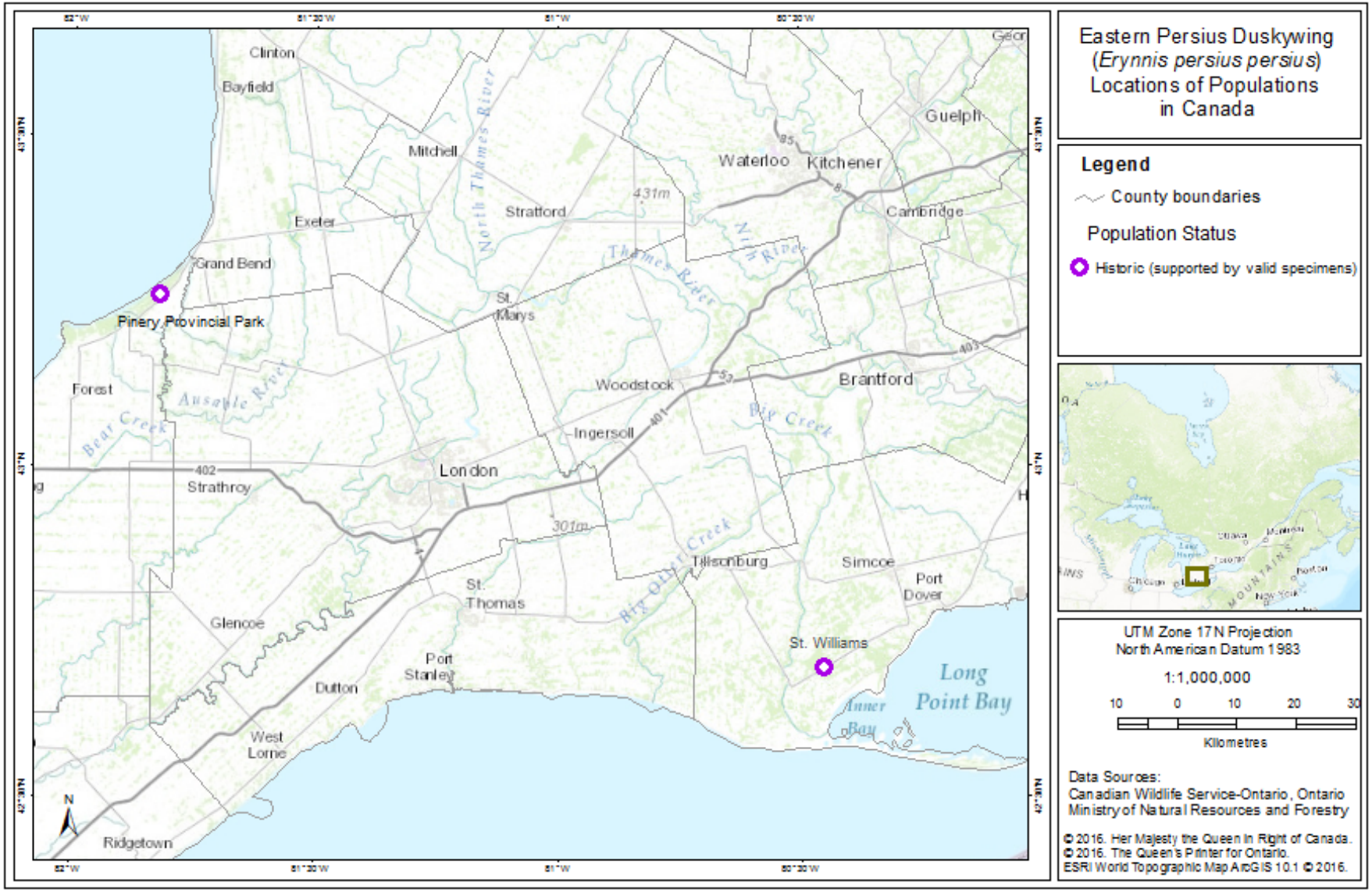


Figure 8. Locations of Eastern Persius Duskywing populations in Canada.

3.3 Needs of Karner Blue, Frosted Elfin and Eastern Persius Duskywing

All three butterflies have fairly similar needs in terms of larval foodplants, canopy cover, availability of nectar and other nutrients, larval-tending ants (Karner Blue and Frosted Elfin), habitat area, and habitat maintenance and disturbance.

Karner Blue, Frosted Elfin and Eastern Persius Duskywing are known to occur in sand dunes, savanna, prairie and dry oak woodlands where canopy cover is open to semi-open, with partial shading (Boyonoski 1992; Peterson and Reich 2001; Corry et al. 2008). In eastern North America, Frosted Elfin is also known to occur in pine barrens, oak barrens, oak savannas, sandhills, dry acid oak woods, and more often along powerlines through such places (Schweitzer et al. 2011). Woodland edges, roadsides, powerlines or similar edge habitats are frequently listed as the preferred habitat for the species (Opler and Krizek 1984; Swengel 1996; Allen 1997). In Ontario, it was only known to occur in one location characterized by open second-growth oak-pine woods and dry oak savanna with nearby roadside patches of larval foodplants (Packer 1990; Layberry et al.1998).

Similar to Frosted Elfin, Eastern Persius Duskywing occurs in pine barrens, pine-oak barrens, oak savannas and other open woodland with populations of Wild Lupine or Wild Indigo (COSEWIC 2006; NatureServe 2015c). In the United States, the species is also reported to occur in scrubby habitats associated with ridge tops or powerlines (NatureServe 2015c). Swengel (1994) and others have identified that open woodland habitat, principally sandy areas with sparse vegetation interspersed with oak saplings, is ideal habitat for the species. Adult Eastern Persius Duskywings are believed to nectar at a variety of plant species, but because the presence of the larval host plants is necessary for oviposition, the species should be considered a habitat specialist (COSEWIC 2006).

Larval Foodplants

Wild Lupine is the only larval foodplant which Karner Blue is known to utilize (COSEWIC 2000b). Although caterpillars of different Elfin subspecies feed on different foodplants in the legume family (Fabaceae) throughout its North American range, in Canada, Frosted Elfin has only been observed to feed on Wild Lupine (COSEWIC 2000a). Adult Frosted Elfin females are highly specialized as they exclusively oviposit on Wild Lupine flowers. At the St. Williams Conservation Reserve, Frosted Elfin was observed to persist where small patches of Wild Lupines occurred (COSEWIC 2000a). In the years prior to its extirpation, these patches became heavily overgrown and the resulting shade conditions deterred Wild Lupines from flowering which had severe consequences for reproduction (COSEWIC 2000a).

Wild Lupine is also considered the main host plant for Eastern Persius Duskywing in Canada (COSEWIC 2006), however Eastern Persius Duskywing caterpillars are also known to eat Wild Indigo (COSEWIC 2006). Wild Indigo is currently ranked S2 by the NHIC, meaning it is considered very rare in Ontario and is represented by

between 6 and 20 occurrences in the province, or only a few remaining hectares (Bradley 2013). In Ontario, Wild Indigo is reported as a declining species of prairies, savannas, dry open sandy woods and thickets and is restricted to the counties of Chatham, Essex, Hamilton, Lambton, Niagara, and Norfolk (Oldham and Brinker 2009). Although Wild Lupine is known as the predominant host plant for the species in Canada, Wild Indigo is also found at the St. Williams Conservation Reserve (COSEWIC 2006). Adult Karner Blue, Frosted Elfin and Eastern Persius Duskywing butterflies deposit their eggs upon Wild Lupine, which provides the caterpillars of all three species with nourishment and enough energy to pupate. Wild Lupine is currently ranked S2S3 by the Natural Heritage Information Centre (NHIC), meaning it is considered rare to uncommon in Ontario (Bradley 2013). In Ontario, Wild Lupine is associated with habitats with sandy soils typically associated with sand dunes, savanna, prairie and dry oak woodlands where canopy cover is open to semi-open, with partial shading (Boyonoski 1992; Peterson and Reich 2001; Corry et al. 2008). These habitat types are vulnerable to succession in the absence of disturbance, and Wild Lupine is dependent on fire or other disturbances to maintain early successional habitat conditions (e.g., to eliminate shrubs and trees which lead to closed canopy) (Corry et al. 2008). Karner Blue, Frosted Elfin and Eastern Persius Duskywing are dependent on Wild Lupine which in turn is dependent on habitat characterized by an early successional stage community.

Presently, Wild Lupine only occurs in small isolated sites in Ontario (Jarvis 2014). The most substantial extant populations of Wild Lupine occur in the St. Williams Conservation Reserve and several other sites across Norfolk County, including the Karner Blue Sanctuary and Pinery Provincial Park. Outside of Norfolk County, Wild Lupine occurs on Walpole Island First Nation, , the Alderville Black Oak Savanna on Alderville First Nation, and in High Park in Toronto (Jarvis 2014; W. Bakowsky pers. comm. 2015). The Karner Blue Sanctuary in Port Franks, Ontario is a 15 ha tract of land managed by Lambton Wildlife Inc. and contains approximately 0.31 ha of Wild Lupine. This land has not been thoroughly burned in a decade, though small patches are burned on occasion (Jarvis 2014). Pinery Provincial Park, which encompasses a total area of 2,532 ha and is managed by Ontario Parks, contains the largest area of oak savanna in Ontario that is maintained using controlled burns, thus mimicking the ecosystem's natural fire regime. This location contains approximately 0.72 ha of Wild Lupine (Jarvis 2014). High Park in Toronto contains 79 ha of oak savanna, with Wild Lupine occurring in several areas as scattered populations totaling approximately 0.64 ha (Jarvis 2014).

In spring 2017, Wild Lupine surveys were completed throughout Norfolk County and found the number of stems to be much higher than what was originally estimated in Jarvis 2014. The properties surveyed had Wild Lupine populations ranging from 1000 to 180,000 stems (Otis 2017); eclipsing the 19,403 stems counted at Alderville Black Oak Savanna (Jarvis 2014). While it is thought that the surveyed properties may one day contain enough larval foodplant to support several reintroduced populations of Karner Blue, Frosted Elfin and Eastern Persius Duskywing, several more years of active property management and Wild Lupine growth are necessary before a reintroduction could be successful.

Prior surveys in Norfolk County indicated that of the sites containing Wild Lupine, the St. Williams Conservation Reserve had the lowest Wild Lupine density (Jarvis 2014). However, it was thought that the total number of Wild Lupine plants, along with the presence of many patches of Wild Lupine scattered throughout a relatively large natural area of suitable habitat might be more important to these species than Wild Lupine density alone (Lane and Andow 2003; USFWS 2003; Jarvis 2014). The combined tracts of St. Williams Conservation Reserve total approximately 1,035 ha, and several other properties in the area are owned by the Nature Conservancy of Canada. Although the habitat has been reported as severely degraded for Wild Lupine persistence and flowering in the past, it has been suggested that these areas together represent the best potential for the expansion of Wild Lupine habitat in Norfolk County (Jarvis 2014 Based on what is currently known about the species' minimum habitat patch size, it is possible that a sufficiently large area of suitable habitat could be made available to support viable populations of Karner Blue, Frosted Elfin and Eastern Persius Duskywing through management and restoration activities. Prior to these recent surveys, the largest Wild Lupine populations were thought to occur at the Alderville Black Oak Savanna, a 61 ha tract of land owned by the Alderville First Nation. Conservation activities have been implemented to actively plant Wild Lupine and a regular burn regime has been implemented to maintain habitat (Jarvis 2014). Currently there is approximately 0.87 ha of Wild Lupine at this location. Several sites, including Pinery Provincial Park, Port Franks and Alderville Black Oak Savanna, are anticipated to provide adequate larval food plant abundance that could potentially support reintroduced populations of Karner Blue, Frosted Elfin and Eastern Persius Duskywing, once additional restoration is completed and if recovery is determined to be feasible.

Canopy Cover

Canopy cover plays a complex role in determining habitat suitability for Karner Blue, Frosted Elfin and Eastern Persius Duskywing because of their dependence on Wild Lupine as both its sole larval foodplant and an important nectar source (Jarvis 2014). Wild Lupine prefers open to semi-open habitats with partial to full sunlight, as growth and flowering is inhibited in areas with closed canopies (COSEWIC 2000a). However, some degree of shade can also be beneficial to Wild Lupine and Karner Blue in that it delays the terminal phase of plant growth (senescence), may improve host plant nutritional quality and increases larval survival rates (Grundel et al. 1998; Lane 1999; Albanese et al. 2008; Pfitsch and Williams 2009; Hess 2013). Areas with open canopies generally support greater populations of both butterflies and Wild Lupines, however these areas are more susceptible to drought when there is insufficient canopy cover to mitigate water loss (Lane 1999).

One study suggested that sites with a range of canopy cover from 16-75% provided benefits to both Wild Lupine and Karner Blue (Lane 1999). The range of percent canopy cover for Karner Blue habitat recommended by the United States Fish and Wildlife Service (USFWS) is slightly narrower at 20-60% (USFWS 2012). Sites with Wild Lupine in Ontario were examined by Jarvis in 2014 and met this latter requirement, with the

exception of the St. Williams Conservation Reserve which is heavily wooded. Eastern Persius Duskywing has been reported to occur in both open and shady woodland habitat indicating a range of canopy cover may be desirable (Maxwell and Ferge 1994). It is likely that open areas with patches of Wild Lupine are necessary for oviposition, but forested areas are not barriers to dispersal between patches (COSEWIC 2006).

Canopy cover is typically provided by trees and other woody vegetation, however some research suggests that shade provided by herbaceous vegetation also plays a vital role in Wild Lupine health (Pickens 2006; Plenzler 2008). One study in northwest Ohio found that 37% of the variance in nutritional quality (i.e. nitrogen and water content) of Wild Lupines was directly related to herbaceous plant density, while woody canopy cover explained only 8% of the variance (Pickens 2006). A heterogeneous vegetation structure can provide beneficial, intermediate levels of shade to Wild Lupine seedlings and prevent water loss; and should be promoted through prescribed burning, particularly in areas with high leaf litter (>3.5 cm) (Pickens 2006; Plenzler 2008). Additionally, a study conducted at Alderville Black Oak Savanna found that a minimum of 10% tree cover was required for Wild Lupine establishment (Clark and Francis 2008).

Availability of Nectar and Other Nutrients

Adult butterflies feed on nectar produced by flowering plants. This nectar provides nourishment to butterflies and increases lifespan and reproductive success.

For Karner Blue, nectaring plant availability during the second brood is particularly important. This is because adult butterflies must compensate for reduced host plant nutrition (water and nitrogen) during second brood larval stage (Pickens 2006). Second brood Karner Blue butterflies will spend substantially more time foraging than first brood butterflies to meet their nutritional requirements (USFWS 2012).

In Ontario, Karner Blue has been documented to use a number of species of flowering plants for nectaring including Butterfly Weed (*Asclepias tuberosa*), New Jersey Tea (*Ceanothus americana*), Chokecherry (*Prunus virginiana*), ragworts (*Packera plattensis, Senecio aureus*), Common Hawkweed (*Hieracium caespitosum*), and others. Although lack of nectar sources is one factor that has been attributed to the decline and subsequent extirpation of Karner Blue in Ontario (Packer 1994), current research suggests that nectar source availability, particularly during the flight time of the second brood, should not be a limiting factor any more in Ontario at sites where Wild Lupine occurs (Jarvis 2014). This is due mainly to restoration efforts. Nectar availability during the spring flight period (first brood) at Pinery Provincial Park may be limiting, but not during the second brood where adult abundance is greatest (Jarvis 2014). Karner Blue is known to visit a variety of nectar sources and its preference is likely to change depending on species availability (USFWS 2012).

Frosted Elfin and Eastern Persius Duskywing, are generalists when it comes to flower selection for nectaring (COSEWIC 2000a; 2006). It is probable that floral morphology which prohibits access to nectar resources is the greatest limiting factor to Frosted Elfin

(Opler and Krizek 1984). Adult Frosted Elfin butterflies are reported to primarily feed on Wild Lupine flowers, but also on moist sand, violet flowers (Swengel 1996) and *Rubus* spp. (Allen 1997). Drinking from moist sand or soil is a common practice among butterfly species, and provides salt and essential minerals (Schweitzer et al. 2011). This behavior is called 'puddling' and is mostly seen in male butterflies which incorporate the salts and minerals into their sperm. Following mating, the nutrients males get from the soil are transferred to the female through the sperm. These salts and minerals improve the viability of the female's eggs.

Larval-Tending Ants

Associations between butterfly species in the family Lycaenidae and ants (Formicidae) are fairly common, with approximately 75% of the species known to associate with ants (Fiedler 2006; Albanese et al. 2007a). These associations range from loose facultative[39] to obligate[40] (Pierce et al. 2002). The larval stage of Karner Blue has a close association with ants. The caterpillars have secretory glands which produce a sugary secretion rich in amino acids collected by ants (Haack 1993). In exchange for this resource, ants guard caterpillars and pupae, increasing survivorship presumably because the ants protect them from predators and parasitoids[41] (Savignano 1990, 1994). At least four larval-tending ant species are known from five Wild Lupine sites examined in Ontario (Jarvis 2014). This diversity of ant species is close to the acceptable minimum of five species identified by Chan and Packer (2006) and it is likely that the abundance of tending ants is more important than the number of species. Although not documented in Canada, it is likely that Frosted Elfin had some association with larval-tending ants. A study of a Wild Indigo-feeding population of Frosted Elfin in southeastern Massachusetts documented an association with five species of ants and late-instar caterpillars (Albanese et al. 2007a). Eastern Persius Duskywing is not known to associate with larval-tending ants.

Studies that assessed the presence of ant species in the St. Williams area (Chan and Packer 2006; Jarvis 2014), indicated that there has been an overall decrease in ant diversity. Although not confirmed, this may be due to the colonization of exotic species of ant (*Myrmica rubra* and *Tetramorium caepitum*), one of which is the European Fire Ant (*Myrmica rubra*), which is known to severely reduce the abundance of all other ant species within its vicinity (Groden et al. 2005; Naumann & Higgans 2015). A recent study examining the relationship between larval-tending ants and Karner Blue butterflies (Pascale & Thiet 2016) found a strong relationship between the butterflies and ants in areas containing native Wild Lupine during the Karner Blue first brood, regardless of whether that area had been burned or not. Furthermore, ant species were found in much higher abundance in areas that had been restored with Wild Lupine than native Wild Lupine areas during both Karner Blue broods. This suggests that it may be beneficial to consider a combination of both native and restored Wild Lupine in future habitat management and restoration efforts, thus accommodating both the butterflies and appropriate ant species.

[39] occurring optionally in response to circumstances rather than by nature.
[40] restricted or compelled to a particular function or mode of life.
[41] an insect whose larvae live as parasites that eventually kill their hosts.

Habitat Area

The area identified to maintain a minimum viable metapopulation of Karner Blue is just over 150 ha, distributed among seven to nine well-connected sites supporting local populations, each of which must have 128,000 or more Wild Lupine stems (Fuller 2008). Within this area the minimum habitat standards have been identified as: Wild Lupine density of at least 1.50 stems/m², nectar plant density of 47.25 stems/m² and 47.85 stems/m² during the first and second broods respectively, the presence of larval tending ant species, and a specific set of light conditions required for the optimal growth of Wild Lupine (standard deviation of integrated light intensity[42] of at least 16.82%; Chan and Packer 2006). Most studies demonstrate Karner Blue has fairly limited dispersal abilities (a few hundred meters) although it has been documented as having the ability to disperse over distances up to 2 km (Smallidge and Leopold 1997). However it has been suggested by Knutson et al. (1999) that conservation planning should aim for a landscape with habitat patches suitable for Karner Blue butterfly occupancy separated by less than 300 m. This is consistent with an Ontario-based study which found that Karner Blue movement was limited to a few hundred metres (Givnish et al. 1988).

Collectively, the Ontario sites containing suitable habitat for Karner Blue as identified by Jarvis (2014) total approximately just over 30 ha, far less than the 150 ha that is required. Additionally, this total area includes several isolated, widespread sites that do not have the connectivity required for a single metapopulation. Therefore, the current habitat (i.e., Wild Lupine density and distribution) available in Ontario is not adequate to support the metapopulation structure required by Karner Blue (Jarvis 2014). However, as demonstrated at several sites in the United States (USFWS 2003; The Nature Conservancy 2005; 2006), adequate habitat could potentially be made available through restoration and additional land securement. The St. Williams Conservation Reserve, along with dozens of properties in the area owned and managed by the Nature Conservancy of Canada, as well as private land holdings that contain savanna, are considered to have the greatest potential to support the reintroduction of multiple local populations of Karner Blue. The Nature Conservancy of Canada began actively restoring their Norfolk County properties in 2009, by planting savanna trees and herbaceous species, but these activities must continue in order to create and maintain habitat suitable for the reintroduction and survival of all three butterfly species (Otis 2017). Additionally, Wild Lupine has been planted annually since the early 2000s at Alderville Black Oak Savanna to create suitable butterfly habitat. More recently, the Nature Conservancy of Canada has begun restoring additional parcels of land in Northumberland County to increase the amount of available savanna habitat (Jarvis 2014).

No studies are available which identify the minimum habitat patch size required to support a viable metapopulation of Frosted Elfin, however the species was known to survive in Ontario within areas where Wild Lupine populations are divided into small pockets (Packer 1990). One study in the United States found that only 3% of

[42] integrated light intensity refers to the heterogeneity of light conditions required for the optimal growth of Wild Lupine populations.

individuals observed occurred in Wild Lupine patches of ~ 0.4 hectares, with 97% in patches of 0.8-32 hectares, and 50% in patches ~ 2.4 hectares (Swengel 1996). This study concluded that Wild Lupine abundance at both the micro-site and landscape scales is more important than the size of the particular Wild Lupine patch occupied (Swengel 1996). Another study in Albany, New York, suggested that Frosted Elfin was more likely to use patches with limited shrub cover and greater host plant density (Bried et al. 2012). In this study, the likelihood that the species would use a patch was 20% lower at sites that exceeded the 16% shrub cover threshold (Bried et al. 2012). Despite their preference for greater Wild Lupine density, Frosted Elfin had a good chance (≥ 76%) of using smaller patches (< 1 hectare), even if they had a relatively sparse density of host plant (< 1000 individuals) (Bried et al. 2012). It has been known to persist in relatively small but stable numbers at some sites with small Wild Lupine populations such as at the Kitty Todd Nature Preserve in Ohio and in Rome Sand Plains New York (Otis 2017). This suggests that the species may not need as large a Wild Lupine population as the Karner Blue to support a viable population (Otis 2017). Otis (2017), has suggested that of the Norfolk County properties surveyed in 2017, the eastern ones managed by Nature Conservancy of Canada may already be suitable for Frosted Elfin reintroduction if the species can be shown to survive at sites with moderate Wild Lupine populations and if larvae aren't dependent on shade for survival.

The minimum habitat patch size required for Eastern Persius Duskywing to persist is unknown, however in Michigan it is thought that at least approximately 20 m^2 of suitable habitat with an abundance of Wild Lupines would be required to support a small metapopulation (COSEWIC 2006). Very little is known regarding dispersal and movement capabilities of Eastern Persius Duskywing, though circumstantial evidence suggests it is a fairly good short-range colonizer (NatureServe 2015c). This is evidenced by specimens which have been collected in the United States a fair distance away from known Wild Lupine or Wild Indigo locations (COSEWIC 2006). Supporting this observation, Kons and Borth (1997) found individuals 8 km from the closest known Wild Lupine population. A spatially structured population or a metapopulation structure is likely common for this species (Givnish et al. 1988), however, the spatial scale at which populations interact is unknown (COSEWIC 2006).

Habitat Maintenance/Disturbance

Karner Blue, Frosted Elfin and Eastern Persius Duskywing are dependent on habitat characterized by an early successional stage community (COSEWIC 2000a; 2000b; 2006). The long term persistence of these habitats requires occasional fires or other disturbance to eliminate shrubs and trees which lead to habitat no longer being suitable for these species (e.g., closed canopy) (COSEWIC 2000b). Suppression of both natural and human-induced fires following European settlement threatens these species by the expansion of shrub and tree species which effectively shade out foodplants and other native forbs. Burning by First Nations allowed for the persistence of savannahs over the last several of thousand years, by preventing the successional development of forest.

The timing and type of habitat restoration and management activities (as described below) is an important consideration. Karner Blue has been reported to be susceptible

to fire in all of its life stages and Frosted Elfin are vulnerable to fire in its juvenile stages, while colonies are vulnerable to local extirpation by burning (COSEWIC 2000a; 2000b). Nevertheless, Karner Blue is capable of rapidly recolonizing areas which have been disturbed, if another local population is close by (COSEWIC 2000b). Disturbance activities, including those for habitat restoration or management, should avoid the growing season and the fall in order to protect invertebrate larvae and individuals and preserve nectar sources. Fire can be beneficial to Wild Lupine, as it both reduces the woody vegetation that competes with the plant for light and converts plant biomass into nutrients (COSEWIC 2000b). Wild Lupine is able to quickly recover from disturbance if the fire occurs early enough in the growing season that the plants don't lose too much growth (COSEWIC 2000b). Sites could be suitable for recolonization by the butterfly species the year of a burn if larval foodplants are able to quickly recover (COSEWIC 2000b).

Frosted Elfin is often reported in habitats where vegetation is managed to prevent tree and shrub growth, such as along powerlines and road sides. Swengel (1996) documented detailed observations of sites surveyed in Wisconsin and analyzed the effects of habitat management methods on the relative abundance of Frosted Elfin. The results of this study indicate that Frosted Elfin was found more often than expected in areas that had a recreational use, were disturbed by mowing or natural fires, or had undergone natural fires combined with some other form of disturbance; but less often than expected in areas that were retained for forestry purposes, received mixed cutting or rotational burns, or received no management whatsoever.

Studies have found that fewer Frosted Elfins are associated with areas which have received rotational, prescribed burns, than are associated with areas that had received natural fires as long as these had occurred at least four to six years previously (Swengel 1996; 2015). Additionally, a study by Vogel et al. (2010) suggests that post-fire recovery times may be even longer for some species, including both habitat-specialist and habitat-generalist butterflies. Managed prairie sites often repeat burns within five years or less, which suggests that more information is needed to determine the recovery rates of Karner Blue, Frosted Elfin and Eastern Persius Duskywing to ensure that the frequency of burning is in fact beneficial. Although it was observed at non-burned nearby sites, Frosted Elfin was not observed in fire-managed sites of seemingly excellent habitat and range, with the exception of one site where a few individuals were observed several years after the fire occurred (Swengel 2015). This could be attributed to the fact that fire managed sites have more frequent fires, whereas a single wildfire creates new habitat to be colonized over many years (Swengel 2015).

In contrast, Schweitzer (1992) observed that the species can survive fires that occur directly over pupation sites when he found adults flying in a site that had been burned two weeks previously. This is likely because individuals at this site pupated in fire-resistant areas underground where they were protected. Laboratory reared caterpillars have been reported to pupate well under the soil surface, but not all do so in the field, instead pupating in leaf litter at the soil surface (COSEWIC 2000a). The very slow colonization of burned areas documented by Swengel (2015) indicates that in

Wisconsin, Frosted Elfin pupate above ground making them susceptible to fire (A. Swengel pers. comm. 2015).

Selective tree removal may be more effective in maintaining habitat for Frosted Elfin, particularly in areas where their pupation strategy is not known. In a New York-based study, experimental removal of trees resulted in improved Wild Lupine flowering and an expansion of habitat for Frosted Elfin (Pfitsch and Williams 2009). 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).

Several studies have also explored the concept of maintaining an unburned refugia[43] as a means of mitigating the potential negative effects of fire on specialist butterfly species (Swengel and Swengel 2007; Minnesota Department of Natural Resources 2013; Thom et. al 2015). This involves specifying a management unit within a site that is not burned throughout several cycles of rotational fire management; and is instead managed through other methods such as mowing or brush-cutting to maintain suitable habitat. A study by Swengel and Swengel (2007), which included Karner Blue, Frosted Elfin and Eastern Persius Duskywing as focal species, found this type of management to have generally positive results, with a higher or similar abundance of butterflies 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. Minnesota Department of Natural Resource's guidelines (2013) provide additional habitat management recommendations for prairie butterflies and other invertebrates.

3.4 Limiting Factors

Karner Blue, Frosted Elfin and Eastern Persius Duskywing exhibit several traits that will put these species at greater risk due to a rapidly changing climate (Foden et al. 2008; Thomas et al. 2011). These include traits such as specialized habitat requirements, narrow environmental tolerances or thresholds, dependence on environmental or specific cues/triggers that are disrupted by climate change, dependence on interactions with particular species, poor ability to disperse to or colonize suitable new habitats, and small population size, area of occupancy, or extent of occurrence.

Due to small population size and fragmentation, another important factor to consider is lack of genetic variation in populations (Packer et al. 1998). Habitat loss and fragmentation of the landscape can result in reduced dispersal, which in turn can lead to reduced genetic diversity through increased probability of inbreeding among butterflies

[43] an area in which a population of organisms can survive through a period of unfavorable conditions.

in isolated patches. Genetic drift[44] can also greatly contribute to reduced genetic diversity within small isolated populations. In considering reintroductions of these species, it is important to consider the minimum viable population size required to avoid inbreeding which adversely effects larval survival, adult longevity, and the rate of egg-hatching success (Saccheri et al. 1998) to ensure the metapopulations of each species are sustained over the long term. At this time, the minimum viable population size of Frosted Elfin and Eastern Persius Duskywing is unknown, but both species have been reported to occur in self-sustaining metapopulations characterized by relatively low numbers. Although immigration between sites such as individual reintroduction locations would be an important component of maintaining Karner Blue, Frosted Elfin and Eastern Persius Duskywing numbers, translocation between reintroduction locations or outside source populations may be required to avoid mutational meltdown[45] and ensure individual metapopulations are sustained over the long term.

[44] 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.
[45] the accumulation of harmful mutations in a small population which leads to loss of fitness and decline of the population size.

4. Threats

4.1 Threat Assessment

Threats are defined as the proximate activities or processes that have caused, are causing, or may cause in the future the destruction, degradation, and/or impairment of the entity being assessed (population, species, community, or ecosystem) in the area of interest (global, national, or subnational) (Salafsky et al. 2008). Threats presented here do not include biological features of the species or population which are considered limiting factors.

The threat classification used in this document is based on the IUCN-CMP (World Conservation Union-Conservation Measures Partnership) unified threats classification system. For a detailed description of the threat classification system, see the Conservation Measures Partnership website (CMP 2010).

A threats classification table (Government of Canada 2014) was not completed as no extant or recently confirmed locations in Canada are known for Karner Blue, Frosted Elfin and Eastern Persius Duskywing. Without extant locations threats could not be scored for scope or severity as per the standardized approach; nor was it possible to estimate the overall threat impact at this time. Instead, existing and future threats were examined and described using the IUCN-CMP threat categories. A number of historical and current threats have contributed to habitat loss and fragmentation which is considered a “stress” under the IUCN-CMP threats classification system.

4.2 Description of Threats

In addition to the anticipated IUCN-CMP threats outlined within this section, Karner Blue, Frosted Elfin and Eastern Persius Duskywing have experienced a number of historical threats that are unlikely to return, but have resulted in significant effects on historical populations and habitats. This includes residential and commercial development, land conversion for agriculture, and pesticide spraying.

Like many butterflies with specialized feeding strategies, the decline of Karner Blue, Frosted Elfin and Eastern Persius Duskywing throughout each of their Canadian ranges appears to be the result of habitat loss and lack of disturbance in areas where larval foodplants occur. Habitats which support populations of Wild Lupine such as dry, sandy oak savanna and woodland habitats once covered more than 11,000,000 ha of North America, but are now the most endangered habitat type in Canada (COSEWIC 2000b). It is estimated that at least 80,000 ha, and perhaps as much as 200,000 ha, of tallgrass prairie and oak savanna vegetation existed in Ontario before European settlement (Taylor et al. 2014). After European settlement, tallgrass prairie and oak savanna were converted into agricultural land and housing developments, eliminating these habitat types from many areas. The loss of Karner Blue throughout its North American range coincides with the loss of this oak savanna habitat, which is now

suggested to occupy less than 3% of its former range in North America, with less than 1% remaining in Ontario (Taylor et al. 2014). Although this widespread threat is considered historical, what remains of this habitat type is under constant threat due to fire suppression and inadequate management (Taylor et al. 2014) which has implications for reintroduction sites.

Another historical threat is insecticide spraying for Gypsy Moths (*Lymantria dispar dispar*), which is thought to have contributed to the decline of several species of butterfly in Ontario known to historically occupy the same areas as Karner Blue, Frosted Elfin, and Eastern Persius Duskywing (*Erynnis p. persius*) (COSEWIC 2006) and Mottled Duskywing (*Erynnis martialis*) (Linton 2015). *Bacillus thuringiensis* (Bt) is a broad-spectrum insecticide that has been used to control invasive Gypsy Moths (*Lymantria dispar dispar*) in Ontario and is particularly lethal to lepidopteran[46] caterpillars (Butler 1998). In Ontario, spraying of Bt to control Gypsy Moths began shortly after the introduction of Gypsy Moth in 1969 (Linton 2015). The last Bt spraying by the province occurred in 1991, and the program was cancelled in 1992. Aerial spraying using Bt is no longer directed by the province although private landowners and some municipalities treat forested areas, particularly urban forests and oak woodlands, to reduce the chance of defoliation by Gypsy Moth in outbreak years (Linton 2015). Currently, Gypsy Moth populations are considered to be under control and spraying for this species is unlikely to be a significant threat to Karner Blue, Frosted Elfin and Eastern Persius Duskywing at present day.

IUCN Threat 5. Biological resource use

Threat 5.1 Hunting & collecting terrestrial animals

Excessive collecting of butterflies may have contributed to the decline of some species in Ontario (D. Sutherland, pers. comm. 2015). Anecdotal information suggests that Karner Blue collection at the Port Franks site was problematic and difficult to control in the past (B. Kulon pers. comm. 2015). Due to the extremely small population size which occurred in Canada, Frosted Elfin was also vulnerable to overcollecting and there is evidence that fairly large numbers were collected from the St. Williams area between the 1960's and 1990's (Campbell et al. 1991; Packer 1990). Although the collection of Eastern Persius Duskywing has not been documented, it could easily be collected accidentally when other species are targeted since proper identification is difficult for the species. Although not as popular as it once was, specimen collection is still a threat to rare butterflies in Ontario. This is an important threat to consider in the event of future reintroduction, particularly given the beautiful coloration and status of Karner Blue as a 'poster species' for endangered species in Ontario, which may make it highly valuable to collectors.

[46] the order of insects that includes moths and butterflies.

IUCN Threat 6. Human intrusions & disturbance

Threat 6.1 Recreational activities

If Karner Blue is reintroduced in Canada, recreational use of its potential habitats (e.g. biking, hiking, motorized off-road vehicles, etc.), which is common in the St. Williams Conservation Reserve and to some extent at other Wild Lupine sites such as Pinery Provincial Park and the Karner Blue Sanctuary, has the potential to directly harm juvenile butterfly life stages as well as larval foodplants. Also, a study by Bennett et al. (2013) found that Karner Blue adults react to intruding humans in the same way they react to potential predators, by rapidly flying away from the perceived threat. Therefore, regular off-road vehicle use has the potential to displace Karner Blue from its habitat.

Some research suggests that Frosted Elfin may not be as susceptible to this type of disturbance at low intensities. Swengel (1996) reported that Frosted Elfin was found more often than expected in areas that had a recreational use. In this case, the disturbance was low in intensity and benefits to Wild Lupines outweighed the direct impacts to the species (A. Swengel pers. comm. 2015).

It is anticipated that activities that damage or destroy Wild Lupine patches would also be detrimental to Eastern Persius Duskywing. Some Wild Lupine specialist butterflies, such as Karner Blue, have demonstrated direct avoidance of areas where recreational activities occur (Bennett et al. 2013) while others such as Frosted Elfin (*Callophrys irus*) seem to be less disturbed (Swengel 1996).

IUCN Threat 7. Natural system modifications

Threat 7.1 Fire & fire suppression

Karner Blue, Frosted Elfin and Eastern Persius Duskywing all rely on a disturbance regime that maintains habitats in an early to intermediate successional stage, suitable for growth of Wild Lupine and a variety of nectar plants. In Ontario, a combination of fire suppression and extensive planting of trees, which accelerates detrimental habitat alterations, occurred between 1950 and 1970 (Catling 2013). During this time, extensive tree planting led to widespread loss of native open habitat in Ontario, which at the time was viewed as unused land that could be improved through planting pine trees (Catling 2013). Many areas that supported colonies of Karner Blue and other rare butterfly species, such as the oak savannas of Pinery Provincial Park, were planted extensively with pines (Catling 2013). Although the value of open habitats is now recognized, the desire to plant trees still persists. Disturbances that reduce tree cover and allow Wild Lupine to persist, including fire, are an important factor in habitat maintenance.

The St. Williams Conservation Reserve was managed by the Ontario government as Canada's first forestry station from 1908 to 1998 with a goal of stabilizing soils and reforesting land (OMNR 2005). During the 1980's the habitat quality for Frosted Elfin

was observed to be of low quality due to overcrowding and canopy shading (COSEWIC 2000a). These factors combined prevented flowering of most Wild Lupine plants which would have severely limited resources for adult and larval Frosted Elfin butterflies. The St. Williams Conservation Reserve is now managed by the St. Williams Conservation Reserve Community Council, a volunteer-led non-profit organization, in cooperation with the Ontario Ministry of Natural Resources and Forestry. . In addition to the reserve itself, there are dozens of properties in the area owned and managed by the Nature Conservancy of Canada, as well as private land holdings that contain savanna. The St. Williams Conservation Reserve in combination with these additional properties represents the best potential for the expansion of Wild Lupine habitat in Norfolk County (Jarvis 2014).

Although historically associated with habitats maintained through fire, Eastern Persius Duskywing has been reported to be at risk from prescribed fires in the United States unless adequate refugia are provided (Schweitzer et al. 2011). This is because this species spends no part of the year underground, produces only one brood per year, and has poor dispersal ability (Swengel 1993). One study (Swengel and Swengel 1997) indicated a significant increase in the species with less frequent fire and with other disturbances, especially mowing. Soil disturbance however, can be beneficial to the species (KBBHCP 2009). In Ohio, a bulldozed firebreak[47] in oak barrens produced Wild Lupine populations that were colonized the following years by Eastern Persius Duskywing (Chapman et al. 1993).

According to NatureServe (2015a), Karner Blue has become dependent on management across its entire range, and is unlikely to persist for more than a decade or two if management is not continued. Some locations where Karner Blue, Frosted Elfin and Eastern Persius Duskywing were historically known to occur (e.g. St. Williams Conservation Reserve) have not received active management such as burning or mowing in many years, thus the understory and canopy cover has increased leading to relatively low Wild Lupine density (Jarvis 2014). Many sites are also likely to need continued management in order to persist, as these habitats are dependent on periodic disturbance. Therefore, succession and canopy closure due to fire suppression and lack of disturbance is still an ongoing threat to these species' habitats and to the recovery of these species as well.

Threat 7.3. Other ecosystem modifications

Geographic isolation, brought about by human-caused (e.g. land conversion, urban sprawl, etc.) habitat fragmentation in Ontario, eliminates the potential ability for Karner Blue, Frosted Elfin and Eastern Persius Duskywing butterflies to move among suitable sites. As with other rare butterflies, populations of these three species are sustained through a metapopulation structure with several local populations living in close enough proximity to recolonize habitat patches after temporary local extirpations. Studies on Karner Blue dispersal have varying results and continue to find that dispersal distances

[47] a gap in vegetation or other combustible material that acts as a barrier to slow or stop the progress of a bushfire or wildfire.

are influenced by habitat composition and the degree of habitat fragmentation between sites (USFWS 2012). In Ontario, the majority of historical Karner Blue locations which once supported local populations are now completely isolated from each other. Although there are no known peer-reviewed published data on dispersal for Frosted Elfin or Eastern Persius Duskywing, it is likely that geographic isolation due to habitat fragmentation may also pose a threat to these butterfly species, as observations suggest that they have limited dispersal abilities and require a pattern of suitable habitats in the landscape which are close enough in distance to allow for recolonization (Schweitzer et al. 2011).

IUCN Threat 8. Invasives & other problematic species & genes

Threat 8.1 Invasive non-native/alien species

Like some other rare butterflies in the eastern United States, Karner Blue, Frosted Elfin and Eastern Persius Duskywing populations may be highly sensitive to the invasion and establishment of non-native plant species (Albanese et al. 2007b, Bried and Gifford 2010). A variety of common invasive species such as Orange Hawkweed (*Pilosella aurantiaca*), Leafy Spurge (*Euphorbia esula*), Crown Vetch (*Securigera varia*), and White Sweet Clover *(Melilotus albus*) can quickly dominate early successional habitats, resulting in reduced Wild Lupine and nectar source availability (USFWS 2012). In the United States, the presence of invasive plants, many of which also exist in Ontario, remain primary threats to the species at all Karner Blue recovery sites which occur in habitats representing the same characteristics as those required by Frosted Elfin and Eastern Persius Duskywing (USFWS 2012). Alderville Black Oak Savanna, Pinery Provincial Park and St. Williams Conservation Reserve have experienced an invasion of Spotted Knapweed (*Centaurea maculosa*), a Eurasian member of the aster family (St. Williams Conservation Reserve 2009; Jarvis 2014). Control of invasive species capable of outcompeting native nectar plants and Wild Lupines is therefore an important threat to consider.

The exotic European Fire Ant, which preys on ant species known to tend to Karner Blue caterpillars, have been documented at historical Karner Blue and Frosted Elfin sites in Ontario (Jarvis 2014). It is unknown what the potential implications of this species is and/or whether European Fire Ant would tend to the caterpillars of Karner Blue and Frosted Elfin (Jarvis 2014). Additionally, this invasive ant species might indirectly reduce host plant populations due to their facilitation of non-native plant introductions. A study in southern Ontario found that the introduction of the European Fire Ant helped to facilitate the expansion of invasive plants, due to the species' efficient seed dispersal abilities (more so than native ant species) accompanied by a strong positive response to this dispersal from the invasive plant (Prior et al. 2015). A review by Hoffmann et al. (2016) discusses invasive ant management and available ant eradication methods, some of which may be useful to conservation practitioners in mitigating this threat.

Threat 8.2 Problematic native species

Excessive mammal and insect browsing on Wild Lupine has been documented to negatively affect Wild Lupines (USFWS 2003; USFWS 2012). White-tailed Deer (*Odocoileus virginianus*) have been reported to have impacts on other Wild Lupine feeding butterflies; particularly species whose caterpillers emerge in the spring, as this is the preferred time to browse upon Wild Lupines (Schweitzer 2003; Golden and Pettigrew 2005; COSEWIC 2006; St. Mary 2007; Schweitzer et al. 2011; USFWS 2012) and may also affect Karner Blue, Frosted Elfin and Eastern Persius Duskywing through the direct consumption of the butterfly's eggs and caterpillars while feeding on vegetation (Frye 2012). In Ontario, it has been documented that White-tailed Deer (*Odocoileus virginianus*) consumed 30-90% of the Wild Lupine plants in some areas and caused direct mortality by ingestion of the caterpillars (Boyonoski 1992; Packer 1994**;** Schweitzer 1994). In Ontario, excessive deer browsing of Wild Lupine is likely no longer a significant threat due to deer management programs in suitable habitats.

There are several species of butterflies that feed on Wild Lupine as caterpillars which are known to co-occur with Karner Blue, Frosted Elfin and Eastern Persius Duskywing and may compete for resources. Shapiro (1974) assessed the probable extent of interspecific competition between Karner Blue and Frosted Elfin (*Callophrys irus)* (extirpated) and also between them and two additional common butterflies in Ontario, the Eastern Tailed-blue (*Cupido comyntas*) and the Wild Indigo Duskywing (*Erynnis baptisiae)*. All of these species are documented Wild Lupine-feeders. Some of these species are leaf feeders (Karner Blue and Wild Indigo Duskywing) while others show a preference for flowers and seed pods (Frosted Elfin and Eastern Tailed Blue). Given that the caterpillars of Karner Blue show a preference for Wild Lupine leaves and they occupy the same habitat as other Wild Lupine-feeders, they are expected to compete for food on some level, however the extent of this interspecific competition is unknown (COSEWIC 2006). Because Frosted Elfin caterpillars are cannibalistic on one another and will also feed on caterpillars of other species that feed on Wild Lupines, the study concluded that these two species are in direct competition for the food resource and are involved in competition through predation (Shapiro 1974). It is not known if caterpillars of Eastern Persius Duskywing show a preference for Wild Lupine leaves or flowers but given that they occupy the same habitat as other Wild Lupine-feeders, they are expected to compete for food on some level, however the extent of this interspecific competition is unknown (COSEWIC 2006). Competition from the increasingly abundant Wild Indigo Duskywing has been reported in the United States as possibly having contributed to its decline (Schweitzer et al. 2011). This species was previously uncommon in Ontario, though it is rapidly expanding its range using Crown Vetch (*Securigera varia*) as a larval foodplant, and is now one of the most common Duskywing species observed in some years.

Naturally-occurring *Wolbachia* bacteria are known to infect more than half of all insect species and are common parasites in Lepidoptera that can interfere with reproduction (Schweitzer et al. 2011). Several strains of the bacteria occur naturally in Lepidoptera

but not all are harmful to their reproductive success (G. Kyei-Poku pers. comm. 2015). The bacteria are only transmitted through mating and therefore cannot be passed between different species (G. Kyei-Poku pers. comm. 2015). *Wolbachia* infection is a known problem for Karner Blue in the United States, causing various health effects including inability to reproduce (Nice et al. 2009). Although studies pertaining to this bacterium have focused on its impact to Karner Blue recovery, it may also have implications for other butterfly species including Frosted Elfin and Eastern Persius Duskywing. Depending on the particular strains, this parasite could have serious implications for potential Karner Blue, Frosted Elfin and Eastern Persius Duskywing captive breeding programs and the release and re-introduction of individuals into wild populations (Schweitzer et al. 2011). Nice et al. (2009) concluded that conservation management plans, particularly reintroduction and/or population augmentation programs for threatened and viability threshold arthropods, should include screening for the presence of *Wolbachia* and possible other bacterial endosymbionts[48].

IUCN Threat 9. Pollution

Threat 9.3 Agricultural & Forestry Effluents

Pesticide application is important to consider when assessing habitat suitable for reintroduction. Pesticide drift from farmlands may affect adjacent habitats, including those that have been identified as potential reintroduction sites. Pesticides reduce insect abundance and have the potential to reduce Wild Lupine pollination and seed set. The presence of agricultural pesticides in potential reintroduction sites requires mitigation early on (e.g., prior to reintroduction, if recovery is determined to be feasible), and will likely involve stewardship efforts to promote cooperation and consultation with local farmers to improve habitat suitability.

In addition, agricultural and ornamental herbicides may pose a threat to the host and nectaring plants on which these three butterfly species depend. Given the agricultural landscape in which much of these butterflies' historical habitat is located, and the potential benefits of using conservation headlands (6 m unsprayed buffer strip between crop edge and hedgerow (Longley et al. 1997)) to mitigate this threat, current practices of widespread herbicide application may pose a threat to providing sufficient suitable habitat for reintroduction if recovery is determined to be feasible.

IUCN Threat 11. Climate change & severe weather

Threat 11.1 Habitat shifting & alteration

The species-specific response that Karner Blue, Frosted Elfin or Eastern Persius Duskywing will have to climate change is not known. It is also unknown if the butterfly species and the larval host plants on which they are dependent will respond differently to climate change. Karner Blue overwinters in diapausing[49] eggs and snow cover is

[48] organisms that live within the body or cells of another organism.
[49] A period of suspended development during unfavourable environmental conditions

extremely important to winter survival (USFWS 2003). As Frosted Elfin caterpillars feed only (or mostly) on the developing flowers of Wild Lupine, this habit makes the species highly specialized and dependent on not only one plant species, but the phenology of that species as well. A study of Elfin butterflies emergence times indicates that butterflies that typically emerge earlier in the year (including Frosted Elfin subspecies) have advanced emergence dates in response to climate warming (Polgar et al. 2013; Swengel and Swengel 2014).

Although the specific response to climate change that Karner Blue will have is not known, it has been identified that Ontario may eventually become one of the only suitable regions for Karner Blue within its eastern North American range as a result of global climate change (USFWS 2012). A northward shift in distribution of many other butterfly species (e.g., Short-tailed Blue (*Everes argiades*), Green-underside Blue (*Glaucopsyche alexis*), Sooty Copper (*Heodes tityrus*), Field Skipper (*Atalopedes campestris*) has been observed (e.g. Parmesan et al. 1999; Crozier 2003); however, there are several significant impediments to Karner Blue migration between occupied sites in the United States and known historical sites in Ontario. This includes the Adirondack Mountains, Great Lakes, and expanses of land without suitable habitat (Rodenhouse et al. 2009). Unassisted colonization of Ontario sites is therefore not a realistic assumption. The reintroduction of this species in Ontario may be critical to its long-term survival (Chan and Packer 2006).

Threat 11.2/11.3 Droughts/Temperature extremes

The State of Ontario's Biodiversity 2015 Report examined trends in vegetative phenology across Ontario from 1982-2010 to assess climate change impacts. The results of this report show a trend to an earlier growing season start and increase in the growing season duration in three of Ontario's major ecozones: Hudson Bay Lowlands, Ontario Shield, and Mixedwood Plains (Ontario Biodiversity Council 2015). Such changes may cause the timing of butterfly emergence and the flowering of larval foodplants to become unsynchronized, and plants that begin to grow earlier in the year may also be more susceptible to damage or mortality from frost. Additionally, if the eggs of any of the three butterfly species break diapause too early because of changing environmental cues, there may not be adequate larval foodplants and/or nectar plants available at the right time to nourish individuals and provide them with enough energy to pupate.

A hotter and drier climate may lead to periods of extreme drought which may threaten Wild Lupine survival, as well as a reduction in butterfly activity (COSEWIC 2000b). In the summer of 1988, the populations of Karner Blue at both the St. Williams and Port Franks locations rapidly declined (COSEWIC 2000b). This population decline has been attributed to an extended hot and dry season which desiccated the Wild Lupine plants before the second brood of Karner Blue could lay their eggs (Carson 1997; COSEWIC 2000b). Conversely, a significant positive relationship has been observed between net population growth of Karner Blue and early summer precipitation (Guiney et al. 2010).

Preliminary results of a study focused on the effects of climate change on Karner Blue in the United States indicate that warmer temperatures generally lead to less development time for butterflies. As rapidly growing individuals spend less time nectaring, they develop into smaller than usual butterflies, which have been found to produce fewer eggs (National Park Service 2014). Observations of third brood Karner Blue adults in the United States have also been reported (USFWS 2012). It is possible that third brood flights may occasionally occur during warmer years, particularly when timing of Karner Blue first flight is earlier than average (USFWS 2012). If third brood adults have insufficient resources or temperatures drop severely before they are able to lay eggs, this may have serious implications for overwintering survival. Increasing evidence suggests that a changing climate has the potential to directly alter the development and overwintering survival of individuals as well as indirectly affect survival by altering the range, development, and/or nutritional value of larval foodplants (Moir et al. 2014).

5. Population and Distribution Objectives

The long-term (i.e. 50+ years) population and distribution objective for Karner Blue, Frosted Elfin and Eastern Persius Duskywing is to ensure the persistence of a self-sustaining[50] metapopulation in Canada, if determined to be biologically and technically feasible. This long-term objective may be subject to revision or may not apply as new information becomes available regarding the feasibility of recovery for these three butterfly species.

In order to work towards this long-term objective, and to determine if it is biologically and technically feasible to achieve, several medium-term objectives must first be achieved. The medium-term (i.e. ~15-30 years) objectives for Karner Blue, Frosted Elfin and Eastern Persius Duskywing are:

- To maintain and/or increase sufficient suitable habitat (based on minimum population viability threshold) to support a metapopulation through habitat restoration and management within the species historical Canadian range and at additional locations where suitable habitat is being restored for the purpose of recovery (20-30 years);
- To establish one or more new metapopulations of each of the three butterfly species at suitable habitats within their historical Canadian range and at additional locations where suitable habitat is being restored for the purpose of recovery, through reintroduction and/or population augmentation (if determined to be feasible) (15-20 years).

[50] self-sustaining means a population that is: 1) on average stable or growing (i.e., more births than deaths), 2) is large enough to survive random events (severe weather) and human-caused pressures, 3) does not need on-going management (e.g., captive-breeding, subsequent re-introductions), and 4) survives over the long-term (i.e., 50 years).

As it is presently unknown whether recovery of these three butterfly species is feasible, upon conclusion of the following recovery activities, it may be determined that recovery is not feasible and the population and distribution objectives do not apply. Although numerous recovery activities are identified in section 6.2, the following are considered priority short-term activities that are required to achieve the medium-term objectives and better assess recovery feasibility:

- Determine whether suitable, stable source populations of Karner Blue, Frosted Elfin and Eastern Persius Duskywing exist outside of Canada (5 years);
- Determine the minimum population viability threshold for Frosted Elfin and Eastern Persius Duskywing (5 years);
- Investigate reintroduction techniques for Karner Blue, Frosted Elfin and Eastern Persius Duskywing and, if recovery is determined to be biologically and technically feasible, develop a reintroduction plan for each species (5-10 years).

Currently, Karner Blue and Frosted Elfin are both extirpated from Canada. Historically, Karner Blue occurred in several geographically distinct locations within southern Ontario, while Frosted Elfin was only documented at one location in the St. Williams area. Based on the historic extent of suitable habitat, it is likely that Frosted Elfin occurred in additional localities but was extirpated prior to discovery. Eastern Persius Duskywing is considered Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), however under the ESA the species is considered extirpated in Ontario and therefore Canada. It has not been observed or collected in nearly three decades, however due to the difficulty in identifying the species it cannot be determined with certainty that it no longer occurs in Canada according to COSEWIC's criteria. It has only been documented at two geographically distinct locations within southern Ontario with no information available on population size. Therefore, reintroduction and/or population augmentation to establish a metapopulation, consisting of several well-connected local populations, would be required for all three species to achieve the long-term objective of ensuring the persistence of a self-sustaining metapopulation of each species in Canada.

Southern Ontario represented the edge of all three species' northern distribution in North America and contained a small portion of the habitat available within their North American range. It is important to note that based on the rarity of oak woodland and savanna habitat in Canada, these three butterfly species will likely always be considered rare in Canada; particularly Frosted Elfin and Eastern Persius Duskywing which tend to occur in small populations. However, a self-sustaining metapopulation of each species could potentially be recovered through reintroduction and/or augmentation and allow these species to persist in Canada; provided the short-term recovery activities are completed successfully and recovery is determined to be feasible. As noted in section 4.2, the USFWS (2012) suggests that Ontario may eventually become one of the only suitable regions for Karner Blue within its eastern North American range as a result of global climate change. Therefore, reintroduction of this species in Ontario may be critical to its long-term survival (Chan and Packer 2006).

Reintroduction is dependent on several factors, including whether viable source populations exist in the United States which can be used for reintroduction, and whether sufficient suitable habitat can be made available through restoration efforts and/or land acquisition. Due to the uncertainty surrounding feasibility of the long-term and medium-term objectives, several priority recovery activities have been identified to emphasize the work that needs to be conducted initially. Once the identified short-term recovery activities have been completed, or if it is determined that these objectives are not attainable, recovery feasibility of all three species will be re-assessed accordingly.

As a result of substantial recovery work conducted for the species, there are several large populations of Karner Blue in the United States which likely contain individuals suitable for reintroduction in Canada. Currently, Frosted Elfin is in decline across most of its range, mainly occurring in remnant habitats which are dependent on management activities. However, available information suggests that there are still several viable populations that are still extant in the United States, or could be recovered (NatureServe 2015b). Similarly, Eastern Persius Duskywing has declined across most of its range, and is widely considered to be rare; with fewer than 20 extant populations known. It is unknown whether these populations would be suitable for use in reintroduction efforts. If no suitable stable source population is successfully identified for either Frosted Elfin or Eastern Persius Duskywing, recovery will be deemed not feasible.

Determining the minimum population viability threshold and habitat requirements (e.g., size, Wild Lupine density) for Frosted Elfin and Eastern Persius Duskywing is required to determine whether reintroduction and/or augmentation, and therefore recovery, is feasible for these two species. As there are no recent observations of either Frosted Elfin or Eastern Persius Duskywing available in Canada, this determination will likely require the use of best available species information based on populations from the United States. Following this, efforts to investigate captive breeding requirements and reintroduction techniques for each species will be required to eventually develop thorough reintroduction plans for use if recovery is determined to be feasible (e.g., if suitable stable source populations are found, sufficient suitable habitats are available and are being maintained, and minimum population viability thresholds for each species have been determined).

There are several challenges associated with the potential reintroduction of these species, including the maintenance of Wild Lupine in populations large enough in size to ensure successful reproduction of butterflies in the wild. The medium-term objective to maintain and/or increase sufficient suitable habitat through habitat restoration and management, within the species historical Canadian range (including additional locations where the species may not have been confirmed, but suitable habitat is being restored for the purposes of recovery; e.g. Alderville First Nation), is vital to the recovery of these three species. Currently, Wild Lupine only occurs in small isolated sites in Ontario (Jarvis 2014). In order for reintroduction to occur, it is important that Wild Lupine habitat in Ontario is conserved, created and well-connected on a sufficiently large scale to allow for self-sustaining metapopulations of Karner Blue, Frosted Elfin and Eastern Persius Duskywing. The area of suitable habitat required to support the metapopulation

structure of the Karner Blue is much more than what is currently available at all Ontario sites, where Wild Lupine patches are generally isolated and do not occur within 2 km of each other. Frosted Elfin and Eastern Persius Duskywing likely require much less suitable habitat, however this will be assessed once the minimum viable population size for both species has been determined. However, promoting local yard-based plantings of host and native nectaring plants through outreach and communication efforts may facilitate increased connectivity among existing suitable habitat patches (Goddard et al. 2010).

In the United States, potted Wild Lupine plants used for captive breeding efforts were found to have experienced considerable stress due to caterpillar feeding and were usually unable to recover, which required the propagation of new plants from seed every year to ensure a sufficient supply existed (Soorae 2008). Additionally, co-evolution may be needed between butterflies sourced from the United States and the Wild Lupine genotypes at the potential Canadian reintroduction sites, so that the butterflies may adapt to their new food source (USFWS 2003). Another important risk to consider is the potential impact of pathogens in captive breeding facilities. In the United States, individuals infected with Wolbachia bacteria, as discussed in Section 4.2, occur in some of the largest populations of Karner Blue which would likely be used as a source for individuals to be used in captive breeding efforts. The risk of inadvertent introduction of Wolbachia to uninfected individuals may therefore be significant, however several sterilization protocols exist (Webb 2010) and screening for Wolbachia strain prior to reintroduction is highly recommended (Nice 2009).

Finally, if recovery is determined to be feasible on the completion of the identified priority recovery activities and medium-term objectives, a detailed and comprehensive plan to implement reintroduction will be required to ensure long-term survival of these species and outline specific objectives for monitoring reintroduced populations and their habitat. This information may be included in a subsequent action plan.

6. Broad Strategies and General Approaches to Meet Objectives

6.1 Actions Already Completed or Currently Underway

A draft joint recovery strategy for Karner Blue and Frosted Elfin in Canada was previously prepared by the Karner Blue Recovery Team in partnership with the Canadian Wildlife Service and Ontario Ministry of Natural Resources (Carson 2006). However, this draft document was never finalized. The recovery goals and objectives were focused on creating enough suitable habitat for the Karner Blue in three geographically distinct areas in order for the species to be reintroduced into Canada. Karner Blue has a large (i.e., 3,000 individuals) minimum viable population size and requires relatively large areas of habitat (USFWS 2012) compared to Frosted Elfin and Eastern Persius Duskywing. It was anticipated that by completing recovery actions for the Karner Blue, especially involving the restoration of oak savanna and tallgrass prairie habitat, Frosted Elfin would also benefit, as they depend on the same habitat and larval

foodplant. The same assumption could be made for Eastern Persius Duskywing which historically occurred with these species. However, some suggest that conservation programs for Karner Blue may not be providing sufficient benefit for Frosted Elfin, which has narrower vegetative and management tolerances (Swengel and Swengel 1997). Although the official Karner Blue Recovery Team, established in 1992, is not active, many of its original members and several new members are still actively pursuing restoration and habitat management activities as a non-government group called Karner Blue Ontario.

Substantial development on the recovery of Karner Blue has been made in the United States, and reintroductions of Karner Blue have been conducted at several locations following habitat restoration, including at the Kitty Todd Preserve in Ohio, in West Gary, Indiana, Concord, New Hampshire and in southeastern Minnesota (USFWS 2003; The Nature Conservancy 2006; Jarvis 2014).

Recovery efforts and focus for the Karner Blue in Canada are much more advanced than for Frosted Elfin and Eastern Persius Duskywing, largely due to the significant progress made on recovery of this species in the United States (Government of Canada 2015). Currently, Ontario is not considered to support enough habitat to allow for the persistence of a viable population of Karner Blue (Jarvis 2014). However, in an effort to restore suitable habitat for Karner Blue in Ontario, a number of activities are currently underway or have been completed. Many of these would also be mutually beneficial to Frosted Elfin and Eastern Persius Duskywing.

St. Williams Conservation Reserve and Surrounding Area (Norfolk County)

Within the St. Williams Conservation Reserve and surrounding area of Norfolk County, a number of Wild Lupine habitat management and restoration activities are occurring. The St. Williams Conservation Reserve is currently managed by the St. Williams Conservation Reserve Community Council; a volunteer led non-profit organization, in cooperation with the Ontario Ministry of Natural Resources and Forestry. The current mandate of the conservation reserve is based on an extensive Area of Natural and Scientific Interest (ANSI) report and is focused on restoring native habitats to the area and which takes into consideration habitats previously known to support Karner Blue, Frosted Elfin and Eastern Persius Duskywing (Draper et al. 2003; P. Carson pers. comm. 2015). The majority of the reserve (approximately 70%) supported oak-savanna ecosystems during early European settlement and the area has undergone restoration to reclaim habitat for the three butterfly species (St. Williams Conservation Reserve 2009). One of the management objectives for the reserve is to maintain and restore the native ecological communities (including oak savanna, oak woodland, and other tallgrass communities) and their associated species and ecological processes (OMNR 2005). Habitat restoration activities that have been undertaken to date include: prescribed burns to promote oak woodland and Wild Lupine, woody successional species removal, thinning of conifer plantations, invasive species control, public outreach and education and enforcement to reduce unauthorized recreational activities (Heagy pers. comm. 2017). These lands, in combination with extensive areas of land in

close proximity which are owned and managed by the Nature Conservancy of Canada, have the greatest potential for Karner Blue habitat restoration (Jarvis 2014).

The Rice Lake Plains Joint Initiative (Northumberland County)

Suitable habitats exist for Frosted Elfin and Eastern Persius Duskywing where habitat restoration efforts are also ongoing for Karner Blue. In Northumberland County, the Rice Lake Plains Joint Initiative (RLPJI) is an ongoing multi-partner conservation and stewardship project between local people, conservation groups and government agencies which actively identifies and restores prairie habitat along with other significant ecosystems in the Rice Lake Plains (Northumberland County 2015; RLPJI 2015).

With assistance from the Aboriginal Fund for Species at Risk (Environment and Climate Change Canada), field reclamation measures to improve or create tallgrass prairie and savanna habitat have been undertaken at Alderville First Nation, including restoring original vegetation by planting native prairie seeds, removing encroaching successional growth, and conducting controlled burns (Government of Canada 2015). In this area, there are currently over 60 hectares of savanna and tallgrass habitat in various levels of restoration and Wild Lupine plantings have occurred annually since 2002 to increase the population and density for Karner Blue butterfly habitat.

Port Franks and Pinery Provincial Park (Lambton County)

At Pinery Provincial Park, habitat improvement initiatives have been underway since 1997. The Park has regularly collected and planted Wild Lupine seeds since 1993 to increase regeneration and also to connect park sites with sites in Port Franks to facilitate dispersal between populations. Seeds from nectar producing flowers, such as Butterfly Milkweed *(Asclepias tuberosa)* and New Jersey Tea *(Ceanothus americanus)* have been planted to provide a food source for adult butterflies. Outreach material on Karner Blue butterfly is on display at the visitor's centre and park tabloids/newsletters are released regularly to inform the public of recovery activities.

Lambton Wildlife Inc. (LWI), a non-profit, volunteer, naturalist organization, founded in 1966 owns and manages Karner Blue Sanctuary in Port Franks where the last individuals of the species were observed in Canada. This property has undergone habitat restoration since 1992 to encourage growth of the former oak savanna vegetation (LWI 2015) and a management plan for the property was produced in 1994 and revised in 1995 and 2001 (LWI 2015). The goal of the plan is to re-establish a self-perpetuating, sustainable metapopulation of Karner Blue in a healthy, high quality oak savanna habitat; however, the goals are mutually beneficial to Frosted Elfin and Eastern Persius Duskywing as well. Lambton Wildlife Inc. is in the process of initiating a full review of the existing management plan.

Additionally, a recovery feasibility strategy for the Mottled Duskywing at Pinery Provincial Park is currently in development. While the strategy will not focus on the Wild Lupine feeding butterflies, it may beneficially impact these species. The project will include Wild Lupine mapping, and will engage Karner Blue Ontario to strategize overall

oak-woodland butterfly recovery habitat restoration and recovery efforts (Linton pers. comm. 2017).

Toronto Zoo

The Toronto Zoo worked on a captive rearing protocol for Karner Blue for several years using Eastern Tailed-blue (*Cupido comyntas*) as a surrogate species (T. Mason pers. comm. 2015), however the program was eventually terminated. A comprehensive propagation handbook for Karner Blue has been developed by the USFWS (Webb 2010) which has been used by several zoos in the United States for reintroduction projects. The Toronto Zoo is currently looking into drafting a rearing protocol for Karner Blue based on what has already been written and successfully achieved by various zoos in the United States in consultation with key individuals (L. Attard pers. comm. 2015). This will require Wild Lupine propagation and study which presents the opportunity to also study the requirements for Frosted Elfin and Eastern Persius Duskywing captive breeding.

6.2 Strategic Direction for Recovery

Due to the unknowns regarding recovery feasibility for Karner Blue, Frosted Elfin and Eastern Persius Duskywing, certain recovery activities related to filling existing knowledge gaps, as identified in section 5 (Population and Distribution Objectives), must first be completed successfully in order to begin subsequent recovery activities and furthermore achieve the population and distribution objectives (e.g., investigation into the necessity/biological and technical feasibility of establishing one or more new metapopulations of each species within its historical Canadian range must be conducted prior to developing or implementing a comprehensive reintroduction plan).

Table 2. Recovery Planning Table for Karner Blue and Frosted Elfin

Threat or Limitation	Priority[a]	Broad Strategy to Recovery	General Description of Research and Management Approaches
6.1, 7.1, 7.3	High	Protect, manage, and where appropriate restore habitat	• Prioritize historical sites for restoration based on capacity to support metapopulation • Develop and implement site-specific restoration and management plans for historical Karner Blue sites to maintain and expand suitable habitat. • Building on the existing St. Williams Conservation Reserve Management Plan, develop species-specific restoration and management goals for Frosted Elfin. • Create or restore dispersal habitat to connect suitable habitat. • Where possible and appropriate, secure additional land adjacent to historically known habitat to increase habitat available for habitat restoration and/or creation and to allow for expansion of existing historic locations in order to meet the medium-term population and distribution objective. • Identify additional sites which provide habitat for Frosted Elfin and Karner Blue, and develop and implement site-specific management and restoration plans including: ➢ Restoration/management plans which provide connectivity between the St. Williams Conservation Reserve and other suitable habitats. ➢ Restoration/management plans which allow for reintroduction at additional non-historic locations where

Threat or Limitation	Priority[a]	Broad Strategy to Recovery	General Description of Research and Management Approaches
			suitable habitat is already being restored for the purpose of recovery. • Restore additional habitat areas to meet long term population and distribution objective through known restoration techniques (e.g., controlled burns, vegetation clearing, and planting of Wild Lupines). • Implement mitigation measures to reduce or prohibit recreational activities that degrade suitable habitat. • Implement mitigation measures to reduce potential threat of pesticide/herbicide drift in suitable habitat areas. • Control excessive Wild Lupine browsing. ➢ Prevent and/or mitigate future loss of suitable habitat.
8.1, 11.1, 11.2/11.3	High	Conduct research activities	• Conduct research on the following: <u>Karner Blue</u> ➢ efficient Wild Lupine seed germination and requirements for maintenance of large populations. ➢ implications of the exotic European Fire Ant to Karner Blue. ➢ further understanding of the minimum viable population size necessary to fully recover Karner Blue at potential reintroduction site(s). ➢ abundance and diversity of larval tending ant species associated with potential reintroduction sites. ➢ emergence timing, Wild Lupine/nectar plant availability, and weather-linked changes in Karner Blue activity at potential reintroduction sites. ➢ extent of interspecific competition for food resources during caterpillar life stage. ➢ Wild Lupine abundance and habitat suitability at sites not recently studied by Jarvis (2014) such as Ojibway Prairie, Windsor, and Walpole Island.

Threat or Limitation	Priority[a]	Broad Strategy to Recovery	General Description of Research and Management Approaches
			<u>Frosted Elfin</u> ➢ minimum viable population size necessary to fully recover Frosted Elfin at potential reintroduction site(s). ➢ associations with larval-tending ants and the potential implications of the exotic European Fire Ant to Frosted Elfin. ➢ habitat patch size and movement patterns within and between patches by Frosted Elfin. ➢ habitat interactions at potential reintroduction site(s) such as oviposition sites, larval development success and relation to canopy cover, nectar plant associations, etc. ➢ extent of interspecific competition for food resources during caterpillar life stage, including impact of the cannibalistic nature of Frosted Elfin caterpillars on other butterfly species. ➢ potential impacts of recreational activities on reintroduced populations. ➢ understanding the biophysical attributes of pupation sites, emergence timing, Wild Lupine/nectar plant availability, and weather-linked changes in Frosted Elfin activity at potential reintroduction sites. ➢ captive-breeding requirements and reintroduction techniques to help inform feasibility of reintroduction
All	Medium	Conduct stewardship activities	• Develop and deliver stewardship initiatives to protect suitable habitat. • Work collaboratively with stakeholders including landowners, conservation authorities, municipalities, government and non-government organizations, and First Nations to protect and manage suitable habitat. • Develop and implement Best Management Practices for Karner Blue and Frosted Elfin suitable habitat. • Develop and implement site-specific invasive species management plans according to Best Management Practices

Threat or Limitation	Priority[a]	Broad Strategy to Recovery	General Description of Research and Management Approaches
			for Karner Blue and Frosted Elfin.
6.1, 8.1, 8.2	Medium-low	Survey and monitor habitat and threats	• Monitor the success of habitat restoration and management activities (e.g., whether sufficient suitable habitat has been restored/ managed to support a metapopulation of Karner Blue and/or Frosted Elfin). • Monitor the status of threats, such as invasive species, larval foodplant defoliation, pesticide/herbicide drift unauthorized collection, and off-road vehicle use in suitable habitat.
All	Medium-low	Conduct education and outreach activities	• Engage landowners, land managers and First Nations in discussions about Karner Blue and Frosted Elfin, in the importance of recovery, threats, and techniques to recover the species and their habitats. • Encourage the planting of Wild Lupine and appropriate native nectaring flowers by local landowners. If reintroduction is determined to be necessary and biologically and technically feasible: • Develop communication strategies for the reintroduction of Karner Blue and Frosted Elfin. • Develop a training program for wildlife enforcement officers to educate them on the location of potential reintroduction sites and the identification of the species.

[a] *"Priority" reflects the degree to which the broad strategy contributes directly to the recovery of the species or is an essential precursor to an approach that contributes to the recovery of the species.*

Table 3. Recovery Planning Table for Eastern Persius Duskywing

Threat or Limitation	Priority[a]	Broad Strategy to Recovery	General Description of Research and Management Approaches
5.1, 7.1, 7.3, 8.1	High	Conduct research activities	• Conduct research on the following: ➢ presence/abundance of Eastern Persius Duskywing in Ontario using DNA Barcoding as an alternative identification method. ➢ minimum viable population size necessary to fully recover Eastern Persius Duskywing at site(s). ➢ habitat patch size and movement patterns within and between patches by Eastern Persius Duskywing. ➢ habitat interactions such as oviposition sites, host plant selection, larval development success and relation to canopy cover, etc. ➢ extent of interspecific competition for food resources during caterpillar life stage. ➢ response of species to different disturbances (e.g. fire, selective tree removal, recreational activities, larval foodplant browsing/ competition). ➢ emergence timing, Wild Lupine/nectar plant availability, and weather-linked changes in Eastern Persius Duskywing activity. ➢ captive-breeding requirements and reintroduction techniques to help inform feasibility of reintroduction
7.1, 7.3, 8.2,	High	Protect, manage, and where appropriate, restore habitat	• Building on the existing Management Plans for St. Williams Conservation Reserve and Pinery Provincial Park, develop species-specific restoration and management goals for Eastern Persius Duskywing. • Where possible and appropriate, secure additional land adjacent to historically known habitat to increase habitat available for habitat restoration and/or creation and allow for expansion of existing historic locations in order to meet the medium-term population and distribution objective.

Threat or Limitation	Priority[a]	Broad Strategy to Recovery	General Description of Research and Management Approaches
			• Identify additional sites which provide habitat for Eastern Persius Duskywing and implement site-specific management and restoration plans, including: ➢ Restoration/management plans which provide connectivity between the St. Williams Conservation Reserve and other suitable habitats and Pinery Provincial Park and other suitable habitats. ➢ Restoration/management plans which allow for reintroduction at additional non-historic locations where suitable habitat is already being restored for the purpose of recovery. • Implement mitigation measures to reduce potential threat of pesticide/herbicide drift in suitable habitat areas. • Control excessive Wild Lupine browsing by White-tailed Deer. • Prevent and/or mitigate future loss of suitable habitat.
All	Medium	Conduct stewardship activities	• Work collaboratively with stakeholders including landowners, conservation authorities, municipalities, government and non-government organizations, and First Nations to protect and manage suitable habitat. • Develop and implement conservation guidelines and best management practices for Eastern Persius Duskywing and its suitable habitat. • Develop and deliver stewardship initiatives to protect suitable habitat. • Develop and implement site-specific invasive species management plans according to Best Management Practices for Eastern Persius Duskywing. • Promote the integration of habitat protection into the policies and practices of responsible agencies, First Nations, and jurisdictions where appropriate.
All	Medium-low	Conduct education and outreach activities	• Engage landowners, land managers and First Nations in discussions about Eastern Persius Duskywing, in the importance of recovery, threats, and techniques to

Threat or Limitation	Priority[a]	Broad Strategy to Recovery	General Description of Research and Management Approaches
			recover the species. • Encourage the planting of Wild Lupine, Wild Indigo and appropriate native nectaring flowers by local landowners. If augmentation/reintroduction is determined to be necessary and biologically and technically feasible: • Develop a communication strategy for the augmentation/reintroduction of Eastern Persius Duskywing. • Develop a training program for wildlife enforcement officers to educate them on the location of potential reintroduction sites and the identification of the species.
5.1, 7.1, 7.3, 8.2	Medium-low	Survey and monitor habitat, threats and populations (if confirmed to occur)	• Monitor the success of habitat restoration and management activities (if applicable). • Develop and implement a standard monitoring/identification protocol for Eastern Persius Duskywing. • Monitor the status of threats, such as invasive species, larval foodplant defoliation, pesticide/herbicide drift, unauthorized collection, and off-road vehicle use in suitable habitat.

[a] *"Priority" reflects the degree to which the broad strategy contributes directly to the recovery of the species or is an essential precursor to an approach that contributes to the recovery of the species.*

6.3 Narrative to Support the Recovery Planning Tables

As Eastern Persius Duskywing is the only one of the three butterfly species that is not nationally identified as extirpated from Canada, it must first be established whether the species still occurs in Canada. Through targeted survey work it should be feasible to make this determination. Although butterfly enthusiasts have visited the two known sites many times to conduct targeted inventories, they have not encountered Eastern Persius Duskywing in almost 30 years (e.g., no specimens were collected or confirmed through examination of their genitalia (C. Jones pers. comm. 2015)). Because this method requires specimen collection and examination under a dissection microscope, it is not considered desirable. However, DNA barcode sequencing is a relatively inexpensive, quick, and non-invasive technique that could be used to confirm the presence and abundance of Eastern Persius Duskywing. This method requires that only a very small tissue sample be collected (e.g. a leg) and is non-lethal to the specimen. It is anticipated that even if Eastern Persius Duskywing does still occur in Canada, population augmentation through introductions from a suitable stable source population (or, if a captive breeding program is deemed feasible, introductions of captive bred Canadian individuals) will be required to increase the abundance of the species. In this regard it is also necessary to fill in other knowledge gaps which surround this species through specific studies to ensure the completion of the long term population and distribution objective.

Once the status of Eastern Persius Duskywing in Canada is determined and research activities to inform the recovery feasibility of all three butterflies have been conducted, approaches should focus primarily on managing, protecting, and restoring habitat in a manner that is conducive to species augmentation/reintroduction in Canada. The distribution and population density of Karner Blue, Frosted Elfin and Eastern Persius Duskywing are limited by the extent and health of suitable habitat which supports its larval foodplant: Wild Lupine. Habitat restoration and management which sustains a variety of early successional habitats supporting Wild Lupine and nectar sources, remains the primary need of these species to potentially achieve their recovery. Because these butterflies are very closely associated with the flowers of Wild Lupine, the presence of the plant in itself is not enough. Plants are required to flower in sufficient abundance to support the population.

Planting Wild Lupine in different combinations of shading, vegetation cover, and litter cover that create moderate light levels, moisture levels and soil temperatures is likely beneficial for establishment and survival. A nine-year long Wild Lupine reintroduction experiment conducted by Pavlovic and Grundel (2009) found that seedling survival was much higher in openings and in partial shade than in dense shade, suggesting that some vegetation cover had a positive influence on survival in openings. Additionally, higher amounts of leaf litter had a negative effect on survival, especially when combined with higher amounts of vegetation cover. Overall, survival and flowering of Wild Lupine seedlings was greatest in partial shade (moderate canopy cover) with reduced vegetation cover and low litter cover (Pavlovic and Grundel 2009). Therefore, activities to restore butterfly habitat through the planting or reintroduction of Wild Lupine should

consider the effects of canopy cover, vegetation cover, and litter cover, as well as interactions between all three.

Habitats require restoration which facilitate the metapopulation structure of this species in order to avoid geographic isolation and reduced genetic variability. Other threats to consider within these habitats include off-road vehicle use, potential for illegal collection, introduction or persistence of invasive species, and larval foodplant competition and defoliation, thus it will be important that a proactive, integrated approach be taken to limit threats on Karner Blue, Frosted Elfin and Eastern Persius Duskywing.

All of these approaches should be implemented through a unified, integrated approach engaging various stakeholders (e.g., landowners, land users, land managers, First Nations, non-government organizations, and government). In order to inform these stakeholders on specific techniques, as well as begin to mitigate specific threats (e.g., introduction of invasive species, illegal collection), communication and outreach needs to be undertaken. It is also necessary to fill the knowledge gaps which surround these three species through specific studies on reintroduced populations to ensure the completion of the medium and long-term population and distribution objectives for each species.

7. Critical Habitat

7.1 Identification of the Species' Critical Habitat

Section 41 (1)(c) of SARA requires that recovery strategies include an identification of the species' critical habitat, to the extent possible, as well as examples of activities that are likely to result in its destruction. Under SARA, critical habitat is "the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species".

Although general habitat requirements are known for each species (see Section 3.3), critical habitat has not been identified in this recovery strategy because, as explained in Section 5 (Population and Distribution Objectives), there are a number of recovery activities that must be successfully completed before recovery feasibility can be confirmed. A schedule of studies (section 7.2) has been developed to provide the information necessary to begin the identification of critical habitat for Karner Blue, Frosted Elfin and Eastern Persius Duskywing in Canada. Critical habitat may be identified in the future, either in a revised recovery strategy or action plan.

7.2 Schedule of Studies to Identify Critical Habitat

The schedule of studies listed in Table 4 is designed to gather information required to identify critical habitat for recovery if the recovery of Karner Blue, Frosted Elfin and/or Eastern Persius Duskywing is determined to be feasible, and these species are reintroduced into Canada.

If it is determined that recovery is not feasible for Karner Blue, Frosted Elfin and/or Eastern Persius Duskywing, critical habitat will not be identified and the studies listed below will not be undertaken.

Table 4. Schedule of Studies to Identify Critical Habitat

Description of Activity	Rationale	Timeline
Conduct targeted surveys at the two locations where Eastern Persius Duskywing was last known to occur and in nearby suitable habitats. Document habitat use if and where it occurs.	Fill knowledge gaps including species presence and distribution in Canada, and suitable habitat.	2019-2024
If Eastern Persius Duskywing is found in Canada, conduct research to quantify habitat requirements (biophysical attributes of suitable habitat).	Fill knowledge gaps including, habitat associations, biophysical habitat attributes and extent of suitable habitat. Ensure critical habitat is identified.	Needed within 2 years of Eastern Persius Duskywing being confirmed in Canada.
Determine current extent of suitable habitat at the historical locations where Karner Blue, Frosted Elfin and Eastern Persius Duskywing were known to occur.	Determine biophysical habitat attributes and extent of suitable habitat.	2019-2024
Identify and work with landowners to secure areas where restoration should be focused to create suitable habitat and/or enhance existing habitat to be used to: support seven to nine well-connected local populations as required for a viable Karner Blue metapopulation and support multiple well-connected local populations as required for viable Frosted Elfin and Eastern Persius Duskywing metapopulations, if feasibility of recovery is confirmed and reintroduction is deemed appropriate.	Using existing information on the minimum size and number of habitat patches required to support the Karner Blue metapopulation structure (which in turn may support Frosted Elfin and Eastern Persius Duskywing metapopulations), identify locations which could become critical habitat if any of the three butterflies is reintroduced into Canada.	2019-2024
Should feasibility of recovery be confirmed and habitat restoration activities be completed, confirm extent of suitable habitat at identified locations.	Identify extent of suitable habitat in Canada.	2019-2029

8. Measuring Progress

The performance indicators presented below provide a way to define and measure progress toward achieving the population and distribution objectives. Due to the uncertainty around the recovery feasibility of Karner Blue, Frosted Elfin and Eastern Persius Duskywing, as new information to inform recovery feasibility becomes available it may be determined that recovery is not feasible and the population and distribution objectives do not apply.

Success of recovery strategy implementation will be measured against the following performance indicators:

- The completion of the following short-term (~5-10 years) priority recovery activities:
  - it has been determined whether suitable stable source populations of Karner Blue, Frosted Elfin and Eastern Persius Duskywing exist outside of Canada (5 years);
  - the minimum population viability threshold for Frosted Elfin and Eastern Persius Duskywing has been determined (5 years);
  - captive breeding requirements are understood for Karner Blue, Frosted Elfin and Eastern Persius Duskywing (5-10 years);
  - reintroduction techniques have been investigated for Karner Blue, Frosted Elfin and Eastern Persius Duskywing (5-10 years);

- In the medium-term (i.e. 15-30 years):
  - suitable habitat has been maintained and/or increased through habitat restoration and management within the species historical Canadian range and at additional locations where suitable habitat is being restored for the purposes of recovery
  - the biological and technical feasibility of establishing one or more new metapopulations of each of the three butterfly species has been investigated and recovery feasibility has been re-assessed.

9. Statement on Action Plans

One or more action plans will be completed for Karner Blue, Frosted Elfin and Eastern Persius Duskywing by December 31, 2029.

10. References

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

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

Albanese G., P.D. Vickery, P.R. Sievert. 2008. Microhabitat use by larvae and females of a rare barrens butterfly, Frosted Elfin (Callophyrs irus). Journal of Insect Conservation 12: 603-615.

Allen, T. 1997. The butterflies of West Virginia and their caterpillars. University of Pittsburgh Press Elkins, West Virginia.

Arnold, P.M. and H.J Michaels. 2017. Nectar sampling for prairie and oak savanna butterfly restoration. Applications in Plant Sciences. 5(6): 1600148.

Attard, L. pers. comm. 2015. *Email correspondence to J. Linton*. August 2015. Curatorial Keeper of Invertebrates, Toronto Zoo, Toronto, Ontario.

Bakowsky, W. pers. comm. 2015. *Email correspondence to J. Linton*. September 2015. Community Ecologist, Natural Heritage Information Centre, Ministry of Natural Resources and Forestry.

Balogh, G. 1981. *Erynnis persius* (Scudder) in Ontario. Pp. 39-41. In Q.F. Hess and A.J. Hanks. 1981. Butterflies of Ontario and Summaries of Lepidoptera Encountered in Ontario in 1980. Toronto Entomologists' Association Occasional Publication #12-81.

Bennett, V. J., V. S. Quinn and P. A. Zollner. 2013. Exploring the implications of recreational disturbance on an endangered butterfly using a novel modeling approach. Biodiversity Conservation 22:1783-1798.

Bethune, C.J.S. 1894. The butterflies of the eastern provinces of Canada. Twenty-Fifth Annual Report of the Entomological Society of Ontario, 1894: 29–44.

Bradley, D. J. 2013. Southern Ontario vascular plant species list 3rd edition. Southern Science and Information Section Ontario Ministry of Natural Resources Peterborough, Ontario. 78 pp.

Boyonoski, A. M. 1992. Factors affecting the establishment and maintenance of *Lupinus perennis* (wild lupine). M.Sc. Thesis, University of Guelph, Ontario, Canada.

Bried, J.T. and N.A. Gifford. 2010. Mowing and herbicide of scrub oaks in pine barrens: Baseline data (New York). Ecological Restoration 28:245–248.

Butler, L. 1998. Non target impact of Gypsy Moth insecticides. University of West Virginia. Website: http://www.wvu.edu/~agexten//ipm/insects/nigmi.htm [Accessed July 2014].

Campbell, C.A., A.A Bryant and D.P. Coulson. 1991. Status, distribution and life history characteristics of some uncommon butterflies of the Carolinian forest zone. In: Allen, G.M., P.F.J. Eagles, and S.D. Price. (eds.). Conserving Carolinian Canada. University of Waterloo Press, Waterloo, Ontario.

Carson, P.J. 1997. Status report on Karner Blue butterfly *Lyceaeides melissa samuelis* Nabokov (Lepidoptera; Lycaenidae) in Canada. Ottawa. Committee on the Status of Endangered Wildlife in Canada, Ottawa. 22 pp.

Carson, P. J. 2006. Recovery strategy for Karner blue (*Lycaeides melissa samuelis*) & frosted elfin (*Callophyrs irus irus*) butterflies. Recovery of Nationally Endangered Wildlife. 27p. (Unpublished Document).

Carson, P.J. pers. comm. 2015. *Phone correspondence to J. Linton*. August 2015. Owner, St. Williams Nursery and Ecology Centre, Ontario.

Catling, P.M. 2013. The cult of the Red Pine-a useful reference for the over afforestation period of Ontario. Canadian Field Naturalist 127(2):198-199.

Catling, P.M. and V.R. Brownell. 2000. An overlooked locality for Karner Blue (*Lycaeides melissa samuelis*) in Ontario. Butterflies of Ontario & Summaries of Lepidoptera Encountered in Ontario in 1999. Toronto Entomologists Association, Toronto. 3 pp.

Chan, P. K., and L. Packer. 2006. Assessment of potential Karner Blue butterfly (*Lycaeides melissa samuelis*) (Family: Lycaenidae) reintroduction sites in Ontario, Canada. Restoration Ecology 14: 645-652.

Chapman, K.A., M.A. White, M.R. Huffman and D. Faber-Langendoen. 1993. Ecology and stewardship guidelines for oak barrens landscapes in the Upper Midwest. Rept. to Midwest Heritage Task Force, The Nature Conservancy, Minneapolis.

Clark, A. and H. Francis. 2008. Establishment, reproduction, and ecology of *Lupinus perennis* at the Alderville First Nation Black Oak Savanna in the Rice Lake Plains, Ontario, Canada. Alderville Black Oak Savanna, Alderville First Nation, Ontario. 21 pp.

CMP (Conservation Measures Partnership). 2010. Threats taxonomy. <http://www.conservationmeasures.org/initiatives/threats-actions-taxonomies/threats-taxonomy> [Accessed August, 2015].

Cook, J.H. 1906. Studies in the genus *Incisalia.* Canadian Entomologist 38:141-144.

Corry, R. C., R. Lafortezza, R. D. Brown, N. Kenny, and, P. J. Robertson. 2008. Using landscape context to guide ecological restoration: an approach for pits and quarries in Ontario. Ecological Restoration 26:120-127.

COSEWIC (Committee of the Status of Endangered Wildlife in Canada). 2000a. Assessment and status report on Frosted Elfin (*Callophrys [Incisalia] irus*) in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. 23 pp.

COSEWIC (Committee of the Status of Endangered Wildlife in Canada). 2000b. Assessment and update status report on Karner Blue (*Lycaeides melissa samuelis*) in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. 25 pp.

COSEWIC (Committee of the Status of Endangered Wildlife in Canada). 2006. COSEWIC Assessment and Status Report on the Eastern Persius Duskywing in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. 41 pp.

Crabe, T. J. 1984. The status of *Lupinis perennis* (Wild Lupine) and *Lycaeides melissa samuelis* (Karner Blue) in Pinery Provincial Park/Port Franks Area-1983. [Unpublished].

Crozier, L. 2003. Winter warming facilitates range expansion: cold tolerance of the butterfly *Atalopedes campestris*. Oecologia 135: 648–656.

Cryan, J.F. and R. Dirig, 1978. A report on the status of Karner Blue butterfly (*Lycaeides melissa samuelis* Nabokov) in New York State. Report for the New York State Department of Environmental Conservation. Unpublished. 15 pp.

Dirig, R. 1994. Lupine and Karner Blue butterfly at the Albany Pine Bush. Pp. 23-36. *in* D. A. Andow, R. J. Baker, and C. P. Lane (eds.). Karner Blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, St. Paul, Minnesota.

Draper, W. B, M. E. Gartshore, and J. M. Bowles . 2003. St. Williams Crown Land life science inventory: Distribution summary. Ontario Ministry of Natural Resources, Aylmer District. 68 pp.

Elphick, C. S., J.M, Reed, and J.M. Bonta. 2001. Correlates of population recovery goals in endangered birds. Conservation Biology 15 (5): 1285–91.

Fiedler, K. 2006. Ant-associates of Palaearctic lycaenid butterfly larvae (Hymenoptera: Formicidae; Lepidoptera: Lycaenidae) – a review. Myrmecologische Nachrichten 9:77-87.

Foden, W., G.M. Mace, J.C. Vié, A. Angulo, S.H. Butchart, and L. DeVantier. 2008. Species susceptibility to climate change impacts. Pp. 1-11. *in* V. Jean-Christophe, C. Hilton Taylor, and S.N. Stuart (eds.). Wildlife in a changing world–an analysis of the 2008 IUCN Red List of threatened species. IUCN Publishing, Gland, Switzerland.

Forister, M.L., Z. Gompert, J. A. Fordyce, and C. C. Nice. 2011. After 60 years, an answer to the question: what is Karner Blue butterfly? Biology Letters 7: 399-402.

Frye, J.A. and R.K. Robbins. 2015. Is the globally rare frosted elfin butterfly (Lycaenidae) two genetically distinct host plant races in Maryland? DNA evidence from cast larval skins provides an answer. Journal of Insect Conservation: 1-9.

Frye, J.A. 2012. The Effect of Deer Browse on Sundial Lupine: Implications for Frosted Elfins. Northeastern Naturalist 19(3):421–430.

Fuller, S. G. 2008. Population dynamics of the endangered Karner Blue butterfly (*Lycaeides melissa samuelis* Nabokov). Ph.D. Thesis. New York State University, Syracuse, New York. ix + 164 pp.

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

Givnish, T.J., E.S. Menges, and D.F. Schweitzer. 1988. Minimum area requirements for long-term conservation of the Albany Pine Bush and Karner Blue butterfly: an assessment for City of Albany, Albany, New York.

Goddard, M.A., A.J.H. Dougill, and T.G. Benton, 2010. Scaling up from gardens: biodiversity conservation in urban environments. Trends in Ecology and Evolution 25, 90-98.

Golden, D. M. and L. Pettigrew. 2005. Frosted Elfin Management Plan. New Jersey Department of Environmental Protection Division of Fish and Wildlife. Trenton, New Jersey. 27 pp.

Government of Canada. 2014. *Species at Risk Act* Implementation Guidance. Guidelines on Identifying and Assessing Threats to Species at Risk: Using the IUCN/CMP Threat Classification Standard. Ottawa.

Government of Canada. 2015. Species profile: Karner Blue. Web site: http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=293 [accessed August 2015].

Groden, E., F. A. Drummond, J. Garnas, and A. Franceour. 2005. Distribution of an invasive ant, *Myrmica rubra* (Hymenoptera: Formicidae), in Maine. Journal of Economic Entomology 98: 1774-1784.

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

Guiney, M.S., D.A. Andow, and T.T. Wilder 2010. Metapopulation structure and dynamics of an endangered butterfly. Basic and Applied Ecology-50405. Pp. 1-9.

Haack, R. A. 1993. The endangered Karner Blue butterfly (Lepidoptera: Lycaenidae): biology, management considerations, and data gaps. *in* Gillespie, A.R., G.R. Parker, P.E. Pope, G. Rink (eds). Proceedings of the 9th Central Hardwood Forest Conference, U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

Heagy, A. pers. comm. 2017. *Email correspondence to CWS-ON*. May 2017. St. Williams Conservation Reserve, St. Williams, Ontario.

Hess, A. N. and R. J. Hess. 2015. Conserving Karner Blue butterflies in Wisconsin: a development of management techniques. American Entomologist 61(2): 96-113.

Hess, A. N. 2013. Evaluating Karner Blue butterfly (*Lycaeides melissa samuelis* Nabokov) habitat selection in the state of Wisconsin, USA. Ph.D. Thesis. Michigan Technological University, Houghton, Michigan. 255 pp.

Hess, Q. F. 1981. The status of *Plebejus melissa samuelis* Nabokov and the foodplant *Lupinis perennis*. Toronto Entomologists Association Occasional Publication 12-81 butterflies of Ontario and Summaries of Lepidoptera encountered in Ontario in 1980. 9-24 pp.

Hess, Q. F. 1983. The status of *Lycaeides melissa samuelis* Nabokov and its foodplant in Ontario in 1982. Toronto Entomologists Association occasional publication 14-83 butterflies of Ontario and Summaries of Lepidoptera encountered in Ontario in 1982. 12-16 pp.

Hoffmann, B. D., G.M. Luque, C. Bellard, N.D. Holmes, and C.J. Donlan, 2016. Improving invasive ant eradication as a conservation tool: A review. *Biological Conservation*, *198*, 37-49.

IUCN. 2015. IUCN Red List of Threatened Species: Threats Classification Scheme (Version 3.2). Web site http://www.iucnredlist.org/technical-documents/classification-schemes/threats-classification-scheme [Accessed August 2015].

Jarvis, J. R. 2014. Assessing Wild Lupine (*Lupinus perennis* L.) habitat in Ontario, Canada, for the feasibly of reintroduction of Karner Blue butterfly (*Lycaeides melissa* Nabokov). M. Sc. Thesis. University of Guelph, Guelph, Ontario, Canada. x + 83 pp.

Jones, C. pers. comm. 2015. *Email correspondence to J. Linton*. September 2015. Provincial Arthropod Zoologist, Natural Heritage Information Centre, Ministry of Natural Resources and Forestry, Ontario.

KBBHCP (Karner Blue Butterfly Habitat Conservation Plan). 2009. Wisconsin Statewide Karner Blue Butterfly Habitat Conservation Plan 2010-2019, Appendix B: Species Associated with the Karner Blue Butterfly and its Habitat. Wisconsin, United States. 109 pp.

Konecny, A. 1986. A status report on the Karner Blue butterfly (*Lycaeides melissa Samuelis* Nabokov) in Canada. Ontario Ministry of Natural Resources. 48 pp.

Kons, H.L., Jr. and R.J. Borth. 1997. Study and biodiversity inventory of the Lepidoptera of the Namekagon barrens.

Knutson, R. L., J. R. Kwilosz, and R. Grundel. 1999. Movement patterns and population characteristics of Karner Blue butterfly (*Lycaeides melissa samuelis*) at Indiana Dunes National Lakeshore. Natural Areas Journal19: 109–120.

Kulon, B. pers. comm. 2015. *Email correspondence to J. Linton*. July 2015. Karner Blue Sanctuary, Port Franks, Ontario.

Kyei-Poku, G. pers. comm. 2015. *Telephone correspondence to J. Linton*. July 2015. Insect Pathologist, Great Lakes Forestry Research Centre, Natural Resources Canada, Sault Ste. Marie, Ontario.

LWI (Lambton Wildlife Inc.). 2015. Lambton Wildlife Projects. Web site: http://www.lambtonwildlife.com/projects-lwi.htm [accessed August 2015].

Lane, C. P. 1999. Benefits of heterogeneous habitat: oviposition preference and immature performance of *Lycaenides melissa samuelis* Nabokov (Lepidoptera: Lycaenidae). Ph.D. Thesis. University of Minnesota, Minneapolis, Minnesota.

Lane, C.P. and D.A. Andow. 2003. Oak savanna subhabitat variation and the population biology of *Lycaenides melissa* samuelis (Lepidoptera: Lycaenidae). Annals of the Entomological Society of America 96: 799-809.

Lawrence, W.S. and A.C. Cook, 1989. The Status and Management of Karner Blue (*Lycaeides melissa samuelis*) Populations in the Allegan State Game Area, Michigan. A report submitted to the Nature Conservancy, Michigan Field Office.

Layberry, R.A., P.W. Hall, and J.D. Lafontaine. 1998. The Butterflies of Canada. University of Toronto Press, Toronto, Canada. 208 pp.

Linton, J. 2015. Recovery Strategy for the Mottled Duskywing (*Erynnis martialis*) in Ontario. Ontario Recovery Strategy Series. Prepared for the Ontario Ministry of Natural Resources and Forestry, Peterborough, Ontario. v + 39 pp.

Linton, J. pers. comm. 2017. *Email correspondence to CWS-ON*. May 2017. Natural Resource Solutions. Waterloo, Ontario.

Longley, M., T Čilgi,, P.C Jepson, and N.W. Sotherton. (1997), Measurements of pesticide spray drift deposition into field boundaries and hedgerows: 1. Summer applications. Environmental Toxicology and Chemistry, 16: 165–172. doi:10.1002/etc.5620160210

Mason, T. pers. comm. 2015. *Telephone correspondence to J. Linton*. August 2015. Former Curator of Invertebrates (presently retired), Toronto Zoo, Toronto, Ontario.

Maxwell, J.S., and L.A. Ferge. 1994. Report on a survey of Lepidoptera at Fort McCoy, 1992-1993. Unpublished report. (As cited in Kirk 1996.)

McGowan, C.P., D.H. Catlin, T.L. Shaffer, C.L. Gratto-Trevor, and C. Aron. 2014. Establishing endangered species recovery criteria using predictive simulation modeling. Biological Conservation. 177 (2014): 220-229.

Michigan State University Board of Trustees (MSUBT). 2007. Erynnis persius persius (Scudder) Persius skipper butterfly. 2 pp.

Minnesota Department of Natural Resources (MN DNR). 2013. Invertebrate Conservation Guidelines: With an Emphasis on Prairie, Savanna, and Grassland Ecosystems.

Mohr, P. 2013. Recovery Strategy for the Virginia Goat's-rue (*Tephrosia virginiana*) in Ontario. Ontario Recovery Strategy Series. Prepared for the Ontario Ministry of Natural Resources, Peterborough, Ontario. vi + 26 pp.

Moir, M.L., L. Hughes, P.A. Vesk, and M. Chen Leng. 2014. Which host-dependent insects are most prone to coextinction under changed climates? Ecology and Evolution 4(8):1295–1312.

National Park Service. 2014. The Impact of Climate Change on the Karner Blue Butterfly. U.S. Department of the Interior, Indiana Dunes National Lakeshore. Web site: https://www.nps.gov/indu/learn/nature/upload/Karner-bulletin2014.pdf [accessed August 2016]

NatureServe. 2015a. NatureServe Explorer: *Plebejus Melissa samuelis* (Nabokov, 1944). Web site: http://explorer.natureserve.org/servlet/NatureServe?sourceTemplate=tabular_report.wmt&loadTemplate=species_RptComprehensive.wmt&selectedReport=RptComprehensive.wmt&summaryView=tabular_report.wmt&elKey=120997&paging=home&save=true&startIndex=1&nextStartIndex=1&reset=false&offPageSelectedElKey=120997&offPageSelectedElType=species&offPageYesNo=true&post_processes=&radiobutton=radiobutton&selectedIndexes=120997 [accessed August 2015].

NatureServe. 2015b. NatureServe Explorer: Callophrys irus (Godart, 1824). Web site: http://explorer.natureserve.org/servlet/NatureServe?sourceTemplate=tabular_report.wmt&loadTemplate=species_RptComprehensive.wmt&selectedReport=RptComprehensive.wmt&summaryView=tabular_report.wmt&elKey=116737&paging=home&save=true&startIndex=1&nextStartIndex=1&reset=false&offPageSelectedElKey=116737&offPageSelectedElType=species&offPageYesNo=true&post_processes=&radiobutton=radiobutton&selectedIndexes=116737&selectedIndexes=113674 [accessed August 2015].

NatureServe. 2015c. NatureServe Explorer: *Erynnis persius persius* (Scudder, 1863). Web site: http://explorer.natureserve.org/servlet/NatureServe?sourceTemplate=tabular_report.wmt&loadTemplate=species_RptComprehensive.wmt&selectedReport=RptComprehensive.wmt&summaryView=tabular_report.wmt&elKey=120042&paging=home&save=true&startIndex=1&nextStartIndex=1&reset=false&offPageSelectedElKey=118199&offPageSelectedElType=species&offPageYesNo=true&post_processes=&radiobutton=radiobutton&selectedIndexes=118199&selectedIndexes=120042

Naumann, K. and R.J. Higgins. 2015. 'The European fire ant (Hymenoptera: Formicidae) as an invasive species: impact on local ant species and other epigaeic arthropods', *The Canadian Entomologist*, 147(5), pp. 592–601.

New York State Department of Environmental Conservation. 2017. Albany Pine Bush Preserve Commission, U.S. Fish and Wildlife and New York State DEC announce endangered Karner Blue Butterfly exceeds federal recovery threshold. New York State DEC. Website: http://www.dec.ny.gov/press/110823.html [accessed August 2017].

Nice, C. C., Z. Gompert, M. L. Forister, and F. A. Fordyce. 2009. An unseen foe in arthropod conservation efforts: the case of *Wolbachia* infections in the Karner blue butterfly. *Biol. Conserv.* 142: 3137–3146.

Northumberland County. 2015. The Rice Lake Plains Joint Initiative. Web site: http://www.northumberlandcounty.ca/en/departments_countyadministration_countyforest/RLPJI.asp [accessed August 2015].

Oldham, M.J., and S.R. Brinker. 2009. Rare Vascular Plants of Ontario, Fourth Edition. Natural Heritage Information Centre, Ontario Ministry of Natural Resources. Peterborough, Ontario. 188 pp.

OMNR (Ontario Ministry of Natural Resources). 2005. St. Williams Conservation Reserve management plan. Aylmer District. 19 pp.

Ontario Biodiversity Council. 2015. State of Ontario's Biodiversity 2015: Summary. A report of the Ontario Biodiversity Council, Peterborough, ON.

Opler, P.A. and G.O. Krizek. 1984. Butterflies East of the Great Plains. John Hopkins University Press, Baltimore, Maryland. 312 pp.

Otis, G.W. 2017. Survey of Wild Lupine (Lupinus perennius) in 2017 in Norfolk County, Ontario. Prepared for the Nature Conservancy of Canada. Unpublished. 11 pp.

Packer, L., 1987. Status report on Karner Blue butterfly, *Lycaeides melissa samuelis* Nabokov, in Canada. A report prepared for the World Wildlife Fund and the Ontario Ministry of Natural Resources, Wildlife Branch, Nongame Program. Unpublished.
66 pp.

Packer, L. 1990. The status of two butterflies, Karner Blue (*Lycaeides melissa samuelis*) and Frosted Elfin (*Incisalia irus*), restricted to oak savannah in Ontario.
Pp. 253-271. *in* G. M. Allen, P. F. J. Eagles, and S. D. Price (eds). Conserving Carolinian Canada. University of Waterloo Press, Ontario, Canada.

Packer, L. 1994. The extirpation of Karner Blue butterfly in Ontario. Pp. 143–151. *in* D. A. Andow, R. J. Baker, and C. P. Lane (eds). Karner Blue butterfly: a symbol of vanishing landscape. University of Minnesota, St. Paul, Minnesota.

Packer, L., J. S. Taylor, D. A. Savignano, C. A. Bleser, C. P. Lane, and L. A. Sommers. 1998. Population biology of an endangered butterfly, *Lycaeides melissa samuelis* (Lepidoptera; Lycaenidae): genetic variation, gene flow, and taxonomic status. Canadian Journal of Zoology 76: 320-329.

Parmesan, C., N. Ryrholm, C. Stefanescu, J. K. Hill, C. D. Thomas, H. Descimon, B. Huntley, L. Kaila, J. Kullberg, T. Tammaru, W. J. Tennett, J. A. Thomas, and M. Warren. 1999. Poleward shifts in geographical ranges of butterfly species associated with regional warming. Nature 399: 579-583.

Pascale & Thiet. 2016. The Relationship Between Ants and *Lycaeides melissa samuelis* (Lepidoptera: Lycaenidae) at Concord Pine Barrens, NH, USA. Environmental Entomology 45:633-641.

Pavlovic, N. B. and R Grundel. 2009. Reintroduction of Wild Lupine (*Lupinus perennis* L.) Depends on Variation in Canopy, Vegetation, and Litter Cover. *Restoration Ecology* 17(6): 807-817.

Peterson, D. W., and P. B. Reich. 2001. Prescribed fire in oak savanna: Fire frequency effects on stand structure and dynamics. Ecological Applications 11: 914-927.

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

Pickens, B.A. 2006. The consequences of a management strategy for the endangered Karner Blue butterfly. MSc Thesis, Bowling Green State University, Bowling Green, Ohio. 85 pp.

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

Plenzler, M.A. 2008. Seedling recruitment and establishment of *Lupinus perennis* in a mixed management landscape. MSc Thesis, Bowling Green State University, Bowling Green, Ohio. 64 pp.

Polgar C.A, R. B. Primack, E. H. Williams, S. Stichter, and C. Hitchcock. 2013. Climate effects on the flight period of Lycaenid butterflies in Massachusetts. Biological Conservation 160: 25-31.

Prior K.M., J.M. Robinson , S.A. Meadley Dunphy and M.E. Frederickson . 2015. Mutualism between co-introduced species facilitates invasion and alters plant community structure. Proc. R. Soc. B 282: 20142846.

Rice Lake Plain Joint Initiative (RLPJI). 2015. Introducing the Rice Lake Plains. Web site: http://ricelakeplains.ca/index.htm [accessed August 2016]

Rodenhouse, N. L., L. M. Christenson, D. Parry, and L. E. Green. 2009. Climate change effects on native fauna of northeastern forests. Canadian Journal of Forest Research 39: 249-263.

Rodger, L. 1998. Tallgrass Communities of Southern Ontario: A Recovery Plan. Prepared for World Wildlife Fund Canada and the Ontario Ministry of Natural Resources February 1998. 66 pp.

Saccheri, I., M. Kuussaari, M. Kankare, P. Vikman, W. Fortelius and I. Hanski. 1998. Inbreeding and extinction in a butterfly metapopulation. Nature 392: 491-494.

Salafsky, N., D. Salzer, A. J. Stattersfield, C. Hilton-Taylor, R. Neugarten, S. H. M. Butchart, B. Collen, N. Cox, L. L. Master, S. O'Connor, and D. Wilkie. 2008. A Standard Lexicon for Biodiversity Conservation: Unified Classifications of Threats and Actions. Conservation Biology 22:897–911.

Savignano, D. A. 1990. Field investigation of a facultative mutualism between *Lycaeides melissa samuelis* Nabokov (Lycaenidae), Karner Blue butterfly, and attendant ants. Ph.D. dissertation. The University of Texas, Austin.

Savignano, D. A. 1994. Benefits to Karner Blue butterfly larvae from association with ants. Pp. 73–80. *in* D. A. Andow, R. J. Baker, and C. P. Lane (eds). Karner Blue butterfly: a symbol of vanishing landscape. University of Minnesota, St. Paul, Minnesota.

Schweitzer, D.F. 1985. A report on the status of Karner Blue butterfly *Lycaeides melissa samuelis* in Ontario. A report prepared for the Ontario Ministry of Natural Resources. 18 pp.

Schweitzer, D.F. 1992. Comments regarding *Erynnis persius persius* and *Incisalia irus.* The Ohio Lepidopterist 14:21-23.

Schweitzer, D.F. 1994. Recovery goals and methods for Karner Blue butterfly populations. *in* D. A. Andow, R. J. Baker, and C. P. Lane (eds). Karner Blue butterfly: a symbol of vanishing landscape. University of Minnesota, St. Paul, Minnesota.

Schweitzer, D.F. 2003. Panel Discussion Paper: Mitigating effects of intense deer herbivory. Pp. 16-17, *in* S. Damais, E. Stiles, and M. Dufort (Eds.). Proceedings of the State of the Forest Symposium: Ecological issues regarding Highlands Forest degradation and restoration. New Jersey Audubon Society, Bernardsville, NJ. 22 pp.

Schweitzer, D.F., M.C. Minno, and D.L. Wagner. 2011. Rare, declining, and poorly known butterflies and moths (Lepidoptera) of forests and woodlands in the Eastern United Stations. U.S. Forest Service. Forest Health Technology Enterprise Team. 517 pp.

Scott, J.A. 1968. Hilltopping as a mating mechanism to aid the survival of low density species. Journal of Research on the Lepidoptera 7(4): 191-204.

Scudder, S.H. 1863. A list of the butterflies of New England. Proceedings of the Essex Institute 3: 161-179.

Scudder, S.H. 1898. The butterflies of the eastern United States and Canada with special reference to the north east. Cambridge, published by the author. 812 pp.

Shapiro, A.M. 1974. Partitioning of resources among Lupine-feeding Lepidoptera. American Midland Naturalist 91:243-248.

Shuey, J. A., J.V. Calhoun, and D.C. Iftner. 1987. Butterflies that are Endangered, Threatened, and of Special Concern in Ohio. The Ohio Journal of Science 87(4): 98-106

Smallidge, P.J. and D.J. Leopold. 1997. Vegetation management for the maintenance and conservation of butterfly habitats in temperate human-dominated landscapes: Landscape and Urban Planning [Landscape Urban Plann.], vol. 38, no. 3-4, pp. 259-280.

Soorae, P.S. 2008. Global Re-introduction Perspectives: Re-introduction case-studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Environment Agency-Abu Dhabi, UAE and Denver Zoological Foundation, USA, pp 296.

St. Mary, M.K. 2007. A study on the effectiveness of transplanting vs. seeding of *Lupinus perennis* in an oak savanna regeneration site. M.Sc. Thesis. Bowling Green State University, Bowling Green, Ohio. 40 pp.

St. Williams Conservation Reserve. 2009. St. Williams Conservation Reserve 10-year operations plan 2009-2018. St. Williams Conservation Reserve. 34 pp.

Sutherland, D. pers. comm. 2015. *In person correspondence to J. Linton*. May 2015. Zoologist, Ministry of Natural Resources and Forestry, Peterborough, Ontario.

Swengel, A.B. 1993. Research on the community of tallgrass prairie butterflies, 1988-1993. Unpub. Rept. to USFWS and Wisconsin Dept. Natural Resources.

Swengel, A.B. 1994. Research on the barrens butterfly community, 1988-1994. Unpublished report. (As cited in Borth 1997.)

Swengel, A.B. 1996. Observations of *Incisalia irus* (Lepidoptera: Lycaenidae) in Central Wisconsin 1988-1995. Great Lakes Entomologist 29:47-62.

Swengel, A.B. pers. comm. 2015. *Email correspondence to J. Linton*. September 2015. Independent Researcher/Lepidopterist, Wisconsin, United States.

Swengel, A.B. 2015. Think globally, flutter locally: prairie butterfly conservation from a worldwide perspective. The Prairie Enthusiasts Annual Conference, March 2015, Lee Sherman Dreyfus University Center, University of Wisconsin Stevens Point. Stevens Point, Wisconsin.

Swengel, A.B. and S.R. Swengel. 1997. Co-occurrence of prairie and barrens butterflies: applications to ecosystem conservation. Journal of Insect Conservation 1:131-144.

Swengel, A.B. and S. R. Swengel. 1999. Variation in timing and abundance of Elfins (Callophrys) (Lepidoptera: Lycaenidae) in Wisconsin during 1987–1999. Great Lakes Entomologist 33(1): 45-68.

Swengel, A. B. and S. R. Swengel. 2007. Benefit of permanent non-fire refugia for Lepidoptera conservation in fire-managed sites. *Journal of Insect Conservation* 11: 263-279.

Swengel, A.B. and S. R. Swengel. 2014. Twenty years of elfin enumeration: abundance patterns of five species of Callophrys (Lycaenidae) in central Wisconsin USA. Poster at Butterfly Conservation 7th International Symposium, Southampton, England, April 2014.

Taylor, K., W.I. Dunlop, A. Handyside, S. Hounsell, B. Pond, D. MacCorkindale, J. Thompson, M. McMurtry, and D. Krahn (lead authors). 2014. Mixedwood plains ecozone status and trends assessment—with an emphasis on Ontario. Canadian Biodiversity: Ecosystem Status and Trends 2010. Canadian Council of Resource Ministers, Ottawa, Ontario, Canada. XLVIII + 344 pp.

The Nature Conservancy. 2005. The Karner Blue Reintroduction Effort. Web site: http://nature.org/wherewework/northamerica/states/indiana/preserves/art12869.html [accessed April 2016]

The Nature Conservancy. 2006. Habitat Gets a Boost at Kitty Todd Preserve. Web site: http://nature.org/wherewework/northamerica/unitedstates/ohio/explore/return-of-the-karner-blue-butterfly.xml [accessed April 2016]

Thom M. D., J. C. Daniels, L. N. Kobziar and J. R. Colburn. 2015. Can Butterflies Evade Fire? Pupa Location and Heat Tolerance in Fire Prone Habitats of Florida. *PLoS ONE* 10(5): 1-22.

Thomas, C.D., J.K. Hill, B.J. Anderson, S. Bailey, C.M. Beale, R.B. Bradbury. 2011. A framework for assessing threats and benefits to species responding to climate change. Methods in Ecology and Evolution 2: 125–142.

Toronto Entomologist's Association (TEA). 1979. Toronto Entomologist's Association Summary 1979. Web site: http://www.butterfly.ontarioinsects.org/ontbutterflyatlas/SQL.php?type=recordsAll&sp=one&area=squares&order=date&spIndex=99&areaID=17NH42&areaName=&region=4 [accessed March 2016]

Ursic, K., T. Farrell, M. Ursic and M. Stalker. 2010. Recovery Strategy for the Spotted Wintergreen (*Chimaphila maculata*) in Ontario. Ontario Recovery Strategy Series. Prepared for the Ontario Ministry of Natural Resources, Peterborough, Ontario. vi + 28 pp.

USFWS (United States Fish and Wildlife Service). 2003. Final recovery plan for the Karner Blue butterfly (*Lycaeides melissa samuelis*). U.S. Fish and Wildlife Service, Fort Snelling, Minnesota. 273 pp.

USFWS. 2012. Karner Blue butterfly (*Lycaeides melissa samuelis*) 5-year review: summary and evaluation. U.S. Fish and Wildlife Service, New Franken, Wisconsin. 129 pp.

Vogel, J.A., R.R. Koford, and D.M.J. Debinski. 2010. Direct and indirect responses of tallgrass prairie butterflies to prescribed burning. *Journal of Insect Conservation* 14: 663.

Webb, L. 2010. Propagation Handbook for Karner Blue Butterfly, *Lycaeides melissa samuelis.* New Hampshire Fish and Game Department, New Hampshire. 37 pp.

Appendix A. Historical Context for Karner Blue, Frosted Elfin and Eastern Persius Duskywing

Historical Context

The first step in determining the recovery feasibility of Karner Blue, Frosted Elfin and Eastern Persius Duskywing is to establish the historical context (whether each species' existence in Canada was historically precarious[51] or not precarious). To make this determination, Environment and Climate Change Canada uses the four criteria outlined below. A species is considered to have been historically precarious if any of the following are known or likely to have been true in Canada, prior to significant effects from human activity:

Karner Blue

1. The species was undergoing a long-term natural decline;
    - No. Species decline is associated with European settlement and subsequent conversion of suitable habitats.
2. The species consisted of fewer than 1,000 mature individuals;
    - No. The most well-documented population at the Port Franks site in 1984 consisted of just over 1,000 individuals.
3. The species existed at five or fewer locations[52] or less than 20 km^2 index of area of occupancy[53] (IAO);
    - Yes. Specimen records have only been confirmed for Karner Blue from five locations, all of which likely had an IAO of less than 20 km^2.
4. The species was dependent on connectivity with populations outside Canada for its long term presence in Canada.
    - No. There is no evidence to suggest that historic Karner Blue populations were connected to populations in the United States. Furthermore, the presence of considerable physical barriers lacking suitable habitat, such as the Adirondack Mountains and the Great Lakes, makes reliance on connectivity to populations outside of Canada highly unlikely.

[51] A species that, prior to significant effects from human activity, was below the survival threshold or was dependent on demographic connectivity with outside populations for its long-term presence in Canada according to the best available information on the species population in Canada. Such a species may be recovered by achieving a condition that approximates its historical state.

[52] 'Location' defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. (www.iucnredlist.org/technical-documents/red-list-training/red-list-guidance-docs).

[53] An estimate of the number of grid squares occupied by extant populations (http://www.cosewic.gc.ca/default.asp?lang=En&n=36C4805C-1).

Frosted Elfin

1. The species was undergoing a long-term natural decline;
    - No. Species decline is associated with European settlement and subsequent conversion of suitable habitats.
2. The species consisted of fewer than 1,000 mature individuals;
    - Yes. Total population did not exceed 100 adults in any given year.
3. The species existed at five or fewer locations or less than 20 km^2 index of area of occupancy (IAO);
    - Yes. Frosted Elfin has only been documented from one location in Canada which had an IAO of less than 20 km^2.
4. The species was dependent on connectivity with populations outside Canada for its long term presence in Canada.
    - No. There is no evidence to suggest that historic Frosted Elfin populations were connected to populations in the United States. Furthermore, the presence of considerable physical barriers lacking suitable habitat such as the Adirondack Mountains and the Great Lakes makes reliance on connectivity to populations outside of Canada highly unlikely.

Eastern Persius Duskywing

1. The species was undergoing a long-term natural decline;
    - No. Species decline is associated with European settlement and subsequent conversion of suitable habitats.
2. The species consisted of fewer than 1,000 mature individuals;
    - Unknown. Very little information is available on Canadian populations but specimen records indicate it has only ever been encountered in small numbers in Canada (e.g., maximum of 7 individuals collected, maximum of 8 individuals observed but unconfirmed (COSEWIC 2006)).
3. The species existed at five or fewer locations or less than 20 km^2 index of area of occupancy (IAO);
    - Yes. Confirmed specimens are only known from two locations in Canada which had an IAO of less than 20 km^2.
4. The species was dependent on connectivity with populations outside Canada for its long term presence in Canada.
    - No. There is no evidence to suggest that historic Eastern Persius Duskywing populations were connected to populations in the United States. Furthermore, the presence of considerable physical barriers lacking suitable habitat such as the Adirondack Mountains and the Great Lakes makes reliance on connectivity to populations outside of Canada highly unlikely.

Based on these four criteria, Karner Blue, Frosted Elfin and Eastern Persius Duskywing are all considered to have been historically precarious in Canada.

Appendix B. Subnational Conservation Ranks of Karner Blue (*Lycaeides melissa samuelis*), Frosted Elfin (*Callophrys irus*) and Eastern Persius Duskywing (*Erynnis persius persius*) in Canada and the United States

Rank Definitions (NatureServe 2015a)

	Global (G) Rank N	**National (N) Rank (Canada)**	**Sub-national (S) Rank (Canada)**	**National (N) Rank (United States)**	**Sub-national (S) Rank (United States)**
Karner Blue (*Lycaeides melissa samuelis*)	G5T2	NX	Ontario (SX)	N2	Illinois (S1), Indiana (S1), Iowa (SNR), Maine (SX), Massachusetts (SX), Michigan (S2), Minnesota (S1), New Hampshire (S1), New York (S1), Ohio (S1), Pennsylvania (SX), Wisconsin(S3)
Frosted Elfin (*Callophrys irus*)	G3	NX	Ontario (SX)	N3	Alabama (SU), Arkansas (SNR), Connecticut (S2S3), Delaware (S1), District of Columbia (SH), Florida (S1), Georgia (S2S4), Illinois (SH), Indiana (S1), Kansas (SNR), Kentucky (S1), Louisiana (S3), Maine (SX), Maryland (S1), Massachusetts (S2S3), Michigan (S2S3), New Hampshire (S1), New Jersey (S2), New York (S1S2), North Carolina (S2), Ohio (S1), Oklahoma (S1), Pennsylvania (S2), Rhode Island (S1), South Carolina (SNR), Tennessee (S1?), Texas (SNR), Vermont (S1), Virginia (S2?), West Virginia (S5), Wisconsin (S1)
Eastern Persius Duskywing (*Erynnis persius persius*)	G5T1T3	NX	Ontario (SX)	N1N3	Connecticut (S1), Indiana (S1S2), Maine (SX), Massachusetts (S1), Michigan (S3), Minnesota (S1), New Hampshire (S1), New Jersey (SNR), New York (S1), Pennsylvania (S1), Rhode Island (SH), Vermont (SNR), Virginia (S1), Wisconsin (SNR)

The conservation status of a species is designated by a number from 1 to 5, preceded by a letter reflecting the appropriate geographic scale of the assessment (G = Global, N = National, and S = Subnational). The numbers have the following meaning: 1 = critically imperiled, 2 = imperiled, 3 = vulnerable, 4 = apparently secure, 5 = secure. SX = Presumed Extirpated, SNR = Unranked, T = Representative of taxonomic subspecies.

Appendix C. Effects on the Environment and Other Species

A strategic environmental assessment (SEA) is conducted on all SARA recovery planning documents, in accordance with the *Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals*[54]. The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans, and program proposals to support environmentally sound decision-making and to evaluate whether the outcomes of a recovery planning document could affect any component of the environment or any of the Federal Sustainable Development Strategy's[55] (FSDS) goals and targets.

Recovery planning is intended to benefit species at risk and biodiversity in general. However, it is recognized that strategies may also inadvertently lead to environmental effects beyond the intended benefits. The planning process based on national guidelines directly incorporates consideration of all environmental effects, with a particular focus on possible impacts upon non-target species or habitats. The results of the SEA are incorporated directly into the strategy itself, but are also summarized below in this statement.

This recovery strategy will benefit associated habitats by promoting the recovery of Karner Blue, which has been used as a flagship species to attract public attention. The conservation of Karner Blue will result in a protective umbrella to numerous other species that rely on oak savanna habitats, many of which are considered less charismatic (Chan and Packer 2006). This provides the opportunity to take a more holistic approach to identifying, restoring, and managing habitat for these species.

As indicated within the recovery strategy, it is estimated that 80,000 ha to 200,000 ha of tallgrass prairie and oak savanna vegetation existed in Ontario before European settlement, less than 3% of which remains today (Taylor et al. 2014). These remnant habitats are under constant threat due to fire suppression, cattle grazing and agricultural uses, and land conversion (Taylor et al. 2014, Rodger 1998). Because so little of these habitats remain, many plant and animal species associated with tallgrass prairie and oak savanna communities are considered rare. More than 150 plant species which occur in tallgrass prairie communities are considered rare (Rodger 1998). A large variety of fauna are also known to occur (some entirely restricted) in these habitat types including several snake, bird, and insect species at risk as well as the American Badger (*Taxidea taxus*) (Rodger 1998). Most remnants are too small to support viable populations of animals (Rodger 1998). The recovery strategy for Karner Blue, Frosted Elfin and Eastern Persius Duskywing will help to restore the health of these communities and provide habitat for numerous other species at risk. For example, actions that restore habitat for Karner Blue, Frosted Elfin and Eastern Persius Duskywing will directly benefit a wide range of species dependent on early successional

[54] www.ceaa.gc.ca/default.asp?lang=En&n=B3186435-1
[55] www.ec.gc.ca/dd-sd/default.asp?lang=En&n=CD30F295-1

oak savanna and tallgrass prairie habitats, such as the Mottled Duskywing which only occurs in similar early successional habitats at all of the same historical sites as Karner Blue.

Other species at risk (e.g., Acadian Flycatcher (*Empidonax virescens*), Eastern Whip-poor-will (*Antrostomus vociferus*), Eastern Hog-nosed Snake (*Heterodon platyrhinos*), Spotted Wintergreen (*Chimaphila maculata*), Eastern Flowering Dogwood (*Cornus florida*), utilize similar habitat to Karner Blue and may also benefit from recovery actions which restore and/or manage oak savanna habitat. Monarch (*Danaus plexippus*) could also benefit from the restoration of oak savanna habitat, as this habitat could provide larval food hosts for caterpillars, valuable nectaring plants and oak trees used as roosts prior to migration. Nectar source availability is a strong indicator of overall butterfly richness (Arnold and Michaels 2017) and this restored habitat could also benefit a number of pollinator species which are not at risk, including butterflies, moths and bees. Additionally, the implementation of recovery activities for Karner Blue, Frosted Elfin and Eastern Persius Duskywing would also benefit their host plant, Wild Lupine, which is considered rare to uncommon (S3; NHIC) in Ontario (Bradley 2013); as well as a host of other rare and/or vulnerable plant species characteristic of the extremely rare tallgrass prairie and oak savanna vegetation types of Southern Ontario (Bakowsky 1996). The potential for this federal recovery strategy to have adverse effects on other species was considered. In order to recover Karner Blue, Frosted Elfin and Eastern Persius Duskywing in Canada, management activities such as selective thinning of the canopy or prescribed burns may be undertaken at certain sites. Although these have the potential to harm some populations of common species in the short term, the ecological risks of these management activities will be assessed before they are completed, in order to avoid potential negative effects. Recovery actions for species that share a similar habitat and range (e.g. Virginia Goat's-rue [*Tephrosia virginiana*], Spotted Wintergreen) include similar recovery actions including prescribed burns and canopy thinning (Ursic et al. 2010; Mohr 2013). As caterpillars of Wild Lupine-feeding Frosted Elfin are cannibalistic and have been reported to consume caterpillars of other butterfly species (Shapiro 1974); there is potential for their reintroduction to have a negative effect on other Lepidoptera species. However, more research on the extent of interspecific competition for food resources during caterpillar life stage, including the impact of the cannibalistic nature of Frosted Elfin caterpillars on other species, is needed. The SEA concluded that overall this strategy will benefit the environment and will not entail significant adverse effects.