COSEWIC
Assessment and Status Report

on the

Northern Oak Hairstreak
Satyrium favonius ontario

in Canada

THREATENED
2022

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Northern Oak Hairstreak — Photograph by Bob Yukich.

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COSEWIC
Assessment Summary

Assessment Summary – May 2022

Common name
Northern Oak Hairstreak

Scientific name
Satyrium favonius ontario

Status
Threatened

Reason for designation
This species is a closed canopy (>60% cover) oak woodland specialist. Only a few, isolated subpopulations remain within a small range of southwestern Ontario although there are likely a few undocumented occurrences for this difficult-to-survey species. Within this range, the habitat that this species is dependent on is also declining in extent and quality. The primary threat is the application of broad-spectrum lepidopteran insecticides to control outbreaks of the non-native moth species, and other ecosystem changes which impact this species directly and further reduce habitat quality.

Occurrence
Ontario

Status history
Designated Threatened in May 2022.

COSEWIC
Executive Summary

Northern Oak Hairstreak
Satyrium favonius ontario

Wildlife Species Description and Significance

Northern Oak Hairstreak (*Satyrium favonius ontario*) is a small (wingspan 24-38 mm) brownish-grey butterfly with hindwing tufts (also called tails). Wing undersides are brownish grey with prominent orange patches near the hindwing margins and a blue patch below the lower tail. There is a series of white and black dashed lines on the hindwing undersides and the white median line forms an obvious “W” marking above the blue patch. Larvae are yellowish and slug-like with green dorsal stripes and a yellow lateral stripe. Pupae are dark brown and mottled with fine hairs. Northern Oak Hairstreak is of interest to entomologists because of its association with rare oak-dominated woodlands of southern Ontario.

Distribution

Northern Oak Hairstreak (*S. f. ontario*) ranges from Massachusetts to Georgia and west to extreme southern Ontario and Michigan, Iowa, Oklahoma, and southcentral Texas. Globally, there are four subspecies of Oak Hairstreak, although only one subspecies, the Northern Oak Hairstreak, ranges in Canada. Northern Oak Hairstreak is considered widespread but localized and becomes increasingly scarce towards the northern edge of its range. In Canada, it is restricted to six subpopulations in southwestern Ontario: Port Stanley (#1, historical); Grimsby (#2, historical); Lambton County (#4, extant); Walpole Island (#5, unconfirmed), Windsor (#6, extant), and Middlesex (#7, extant). One individual was recorded from Point Pelee (#3, vagrant); however, there are no additional records from this habitat and this sighting is not considered representative of a viable subpopulation.

Habitat

In Canada, Northern Oak Hairstreak inhabits oak woodlands with > 60% canopy cover. Adults are nectar generalists and visit floral resources within forest openings or meadows adjacent to the oak forest edges. Larval food plant(s) are unconfirmed in Canada, although suspected to be White Oak (*Quercus alba*). In the northern portion of its range in the United States, females have been observed ovipositing on White Oak, which also occurs at habitats where extant Northern Oak Hairstreak subpopulations are recorded in Canada. Early instar larvae feed on pollen from buds and flowers but switch to chewing on young leaves as it develops through its five instars. Adults also feed on aphid honeydew and on pip gall honeydew secretions. Pip galls are created by small cynipid wasps that are

parasitic on oak trees. The developing larva, within an oak acorn, is within a little gall that protrudes between an acorn and its cap. The gall excretes a sugary solution that covers the surface of the gall; hairstreaks consume this excretion or honeydew.

Biology

Northern Oak Hairstreak has a short flight period (mid-June to mid-July) and one generation per year in Canada. Adult lifespan is unknown but is likely less than two weeks. Adults likely spend most of their time in the canopy of oak woodlands; a life history trait that makes surveys and abundance counts a challenge to accurately document. Eggs are laid on twigs in the oak woodland canopy, the eggs overwinter and hatch the following spring. Pre-pupal larvae crawl from the canopy, down the trunk of the tree and pupation occurs in the leaf duff at the base of oak trees. Male hairstreaks defend their mating territories and demonstrate hilltopping behaviour (mate-location behaviour where males create a territory on a hilltop and wait for females). When threatened, Northern Oak Hairstreaks rub their tailed hindwings to produce a distracting false head display. Records suggest that Northern Oak Hairstreak expanded its range further into southern Ontario and northeastern United States by several hundred kilometres in the last half of the 20th century and, with climate change, further northward range expansion is expected.

Population Sizes and Trends

Little information on population trends and fluctuations is available for Northern Oak Hairstreak in Canada or the United States. Records suggest the species is not abundant although it is likely under-detected. All observations in Canada have been adults, most often observed nectaring. Ground-level sightings are not considered a reliable indicator of subpopulation abundance.

Threats and Limiting Factors

Threats to Northern Oak Hairstreak are inferred from general threats to Lepidoptera in southwestern Ontario and the extent and quality of the habitat at known sites. The main direct threat to Northern Oak Hairstreak is broad-spectrum pesticide application to control outbreaks of non-native/invasive Spongy Moth (*Lymantria dispar dispar*). Other threats include ecosystem modifications resulting from inappropriate management of oak woodlands (e.g., long-term fire suppression), residential development, recreational activities that compact overwintering sites and trample nectar plants, oak wood harvesting, invasive species, and climate change. The main limiting factors for Northern Oak Hairstreak are speculative but likely include small subpopulation size, limited dispersal ability, and natural parasitic enemies.

Protection, Status and Ranks

Northern Oak Hairstreak and its host plant(s) are not protected by the Canadian *Species at Risk Act* or the Ontario *Endangered Species Act*. The species has a global rank of Apparently Secure to Secure (G4G5T4) and a national (Canada) and provincial (ON) rank of Critically Imperilled (S1). The United States national rank is Apparently Secure (N4) and in Michigan (closest subpopulation to Canada), it is considered Critically Imperilled.

TECHNICAL SUMMARY

Satyrium favonius ontario

Northern Oak Hairstreak

Thècle méridionale d'Ontario

Range of occurrence in Canada: Ontario

Demographic Information

Generation time	1 year
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations, whichever is longer up to a maximum of 100 years]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any period [10 years, or 3 generations, whichever is longer up to a maximum of 100 years], including both the past and the future.	Unknown
Are the causes of the decline a.) clearly reversible and b.) understood, and c.) ceased?	a.) No b.) Yes, in part c.) No
Are there extreme fluctuations in number of mature individuals?	Unknown if observed fluctuations represent true population fluctuations

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	1183 km² (extant subpopulations only) 12,853 km² (all subpopulations)
Index of area of occupancy (IAO) (2x2 grid value).	24 km²; includes extant (#4a, 4b, 6a, 6b, 7) and unconfirmed (#5) subpopulations only 32 km²; includes historical (#1, 2), extant (#4a, 4b, 6a, 6b, 7) and unconfirmed (#5) subpopulations

Is the population “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a.) No b.) No
Number of “locations”*	3-8 (see **Number of Locations**)
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes, observed, inferred, and projected decline in EOO based on threat 7.3 (other ecosystem modifications)
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes, observed, inferred, and projected decline in IAO based on threat 7.3 (other ecosystem modifications) and the potential pesticide spray to control Spongy Moth over multiple years (9.3) in the ten-year assessment timeframe
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes, observed, inferred, and projected decline in subpopulations based on threat 7.3 (other ecosystem modifications) and the potential pesticide spray to control Spongy Moth over multiple years (9.3) in the ten-year assessment timeframe
Is there an [observed, inferred, or projected] decline in number of “locations”*?	Yes, inferred, and projected decline based on the potential pesticide spray to control Spongy Moth (9.3) over multiple years in the ten-year assessment timeframe
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, inferred, and projected decline in quality of habitat based on threats from other ecosystem modifications (7.3) that includes invasive native plant growth (due to fire suppression) and the spread and competition from non-native plants; and habitat fragmentation
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of “locations”*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

* See Definitions and Abbreviations on COSEWIC website and IUCN for more information on this term.

Number of Mature Individuals (in each subpopulation)

Subpopulations	Number of Mature Individuals
#1 Port Stanley (historical) #2 Grimsby (historical) #3 Point Pelee (vagrant) #4a Reid Conservation Area (extant) #4b Moore Wildlife Management Area (extant) #5 Walpole Island (unconfirmed) #6a Brunet Park (extant) #6b Lasalle (extant) #7 Middlesex (extant)	Unknown
Total	Unknown

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations whichever is longer up to a maximum of 100 years, or 10% within 100 years]?	Unknown, insufficient data

Threats (direct, from highest impact to least, IUCN Threats Calculator)

Was a threats calculator completed for this species? Yes. A threats teleconference call was completed on December 17, 2020. Threat impact Very High – High.

Threats (in order of highest threat):

9.3 Agricultural and forestry effluents. High impact.
8.1 Invasive non-native/alien species/diseases. High-low impact.
7.1 Fire and fires suppression. Low impact.
7.3 Other ecosystem modifications. Unknown impact.
1.1 Housing and urban areas. Unknown impact.
5.3 Logging and wood harvesting. Unknown impact.
6.1 Recreational activities. Unknown impact.
6.3 Work and other activities. Unknown impact.
8.2 Problematic native species/diseases. Unknown impact.
11.1 Habitat alteration and shifting. Unknown impact.
11.2 Droughts. Unknown impact.
11.3 Temperature extremes. Unknown impact.

What additional limiting factors are relevant?

- Small population size and fragmented subpopulations
- Abundance and health of larval host plant(s)
- Poorly understood relationship with cynipid wasps

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	S1 Critically imperilled (Michigan)
Is immigration known or possible?	Not known, may be possible
Would immigrants be adapted to survive in Canada?	Yes

Is there sufficient habitat for immigrants in Canada?	Unknown
Are conditions deteriorating in Canada?[+]	Yes
Are conditions for the source (i.e., outside) population deteriorating?[+]	Unknown
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC: Designated Threatened in May 2022.

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric codes:** B1ab(iii)+2ab(iii)
Reasons for designation: This species is a closed canopy (>60% cover) oak woodland specialist. Only a few, isolated subpopulations remain within a small range of southwestern Ontario although there are likely a few undocumented occurrences for this difficult-to-survey species. Within this range, the habitat that this species is dependent on is also declining in extent and quality. The primary threat is the application of broad-spectrum lepidopteran insecticides to control outbreaks of the non-native moth species, and other ecosystem changes which impact this species directly and further reduce habitat quality.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Population trends unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): Below the threshold for Threatened (and Endangered) B1 (EOO 1183 km²), B2 (IAO = 24 km²), and the (a) number of locations is 6-8, based on different land management practices, and there is sufficient evidence for (b) continuing decline (iii) area, extent and/or quality of habitat.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Number of mature individuals unknown.
Criterion D (Very Small or Restricted Population): Comes close to meeting Threatened D2 since the IAO = 24 km² (extant and unknown status subpopulations). However, there are likely a few additional subpopulations, which increases the IAO beyond threshold.
Criterion E (Quantitative Analysis): Not applicable. Insufficient data.

V

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect).

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2022)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service
Environnement et Changement climatique Canada
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Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Phylum Arthropoda – Arthropods
Class Insecta – Insects
Order Lepidoptera – Butterflies and Moths
Papilionoidea - Butterflies and Skippers
Family Lycaenidae - Blues, Coppers, Hairstreaks, Harvesters
Subfamily Theclinae - Hairstreaks
Tribe Eumaeini
Genus *Satyrium*
Species *S. favonius* (J. E. Smith 1797)
Subspecies *S. f. ontario* (W. H. Edwards 1868)

Synonyms: *Euristrymon favonius ontario*
Fixsenia favonius ontario
Fixsenia ontario
Fixsenia ontario
Satyrium ontario

Type Locality and museum: The type specimen from Port Stanley, Ontario is housed at the Canadian National Insect Collection in Ottawa, Ontario.

French common name: Thècle méridionale d'Ontario

English common name: Oak Hairstreak, Northern Oak Hairstreak (Cassie *et al.* 2001)

Four subspecies of Oak Hairstreak (*Satyrium favonius*) (J. E. Smith 1797) are recognized: *S. f. favonius* (J. E. Smith 1797), *S. f. autolycus* (W. H. Edwards 1871), *S. f. violae* (D. Stallings and Turner 1947) and *S. f. ontario* (W. H. Edwards 1868). Only subspecies *S. f. ontario* occurs in Canada and in this status report Northern Oak Hairstreak refers to *Satyrium favonius ontario* unless otherwise noted.

Previously, Southern Hairstreak (*Satyrium favonius*) (J. E. Smith 1797) and Northern Hairstreak (*Satyrium ontario*) (W. H. Edwards 1868) were treated as separate species (Cassie *et al.* 2001). When these taxa were merged, the common name created confusion with reference to the 'Northern' Southern Hairstreak and 'Southern' Southern Hairstreak. To minimize confusion, *Satyrium favonius favonius* was renamed Southern Oak Hairstreak and *S. f. ontario* was renamed Northern Oak Hairstreak (Cassie *et al.* 2001).

Morphological Description

Like all Lepidoptera, Northern Oak Hairstreak has four distinct morphological forms: egg, larva, pupa, and adult. Hairstreak butterflies (Subfamily Theclinae) often have hair-like tails on their hindwings giving rise to their common name (Layberry *et al.* 1998). All hairstreaks in Canada sit with their hindwings dorsally folded, often roosting upside down, and rub their wings together to move their tails in a manner that resembles antennae (Layberry *et al.* 1998).

The adults of all four subspecies of Oak Hairstreak are visually similar and have the same overall distinctive markings. The following description is based on a generalized description that applies to all subspecies unless otherwise noted.

Adults

Northern Oak Hairstreak is a small (wingspan 24-38 mm) brownish-grey butterfly with the characteristic hindwing tufts or tails[1] (Layberry *et al.* 1998). The undersides of the wings are brownish grey with prominent orange patches near the hindwing margin and a blue patch posterior to (below) the lower of the two tails. Like other hairstreaks, there is a series of white and black dashed lines on the underside of the hindwings.

The main difference in appearance between Northern Oak Hairstreak and other similar *Satyrium* species is the black and white median line that forms an obvious "W", above the blue patch (Figure 2) (Layberry *et al.* 1998). The White-M Hairstreak (*Parrhasius m-album*) also displays an obvious "W" marking; however, this rare immigrant to Canada is distinguished by a prominent orange spot between the "W" mark and the hindwing tufts. Northern Oak Hairstreak is distinguished from the nominate subspecies (*Satyrium favonius favonius*) by its duller, less extensive colouring (Wadiak 2015). Northern Oak Hairstreaks rub their tailed hindwings when threatened to produce a distracting false head[2] display (Gagliardi 2013).

Eggs:

The eggs are rusty brown, flattened and disc-shaped (ABA 2020). Eggs are laid singly on host plant twigs (BMONA 2020) (see **Biology**).

Larvae:

Larvae are yellowish and slug-like with green dorsal stripes and a yellow lateral stripe (Gagliardi and Wagner 2016) (Figure 2). The ground colour is usually pale to sea green with a heartline (middorsal stripe) visible along abdomen. There are five larval instars. The body turns pink through the latter half of the last instar (Gagliardi and Wagner 2016).

[1] This refers to hair like tufts or tails on their hindwings that give hairstreaks their English common name

[2] This refers to confusing predators by acting as though their tails are antennae (often reinforced by eye or spot markings)

Figure 1. Northern Oak Hairstreak (*Satyrium favonius ontario*) larva from Great Blue Hill, Canton, Norfolk County, Massachusetts. Larva collected for captive rearing at the University of Connecticut. Photo by David Wagner.

Figure 2. Northern Oak Hairstreak (*Satyrium favonius ontario*) adult observed at Reid Conservation Area (#4a), Wallaceburg, Ontario. June 26, 2016. Specimen not collected. Photo by Bob Yukich.

Pupae:

Pupae are dark brown, mottled with fine hairs and white spiracles are visible along its sides (Gagliardi 2014).

Population Spatial Structure and Variability

There are no data on the Northern Oak Hairstreak population spatial structure, variability, or abundance, including the geographic boundaries of subpopulations. Records and natural history information indicate the butterfly is restricted to oak woodlands of the Carolinian zone of southern Ontario.

The Barcode of Life Data System (BOLD) is an online genetics data storage and analysis platform; two (*S. f. favonius* and *S. f. ontario*) of the four Oak Hairstreak subspecies have records in BOLD (deWaard pers. comm. 2020). There appears to be a division between midwestern and eastern specimens (i.e., the genetic data suggest these two groups are clearly diverged from related *Satyrium* species); however, these data are insufficient to detect population spatial structure within Northern Oak Hairstreak (i.e., the subspecies) and additional genetic and morphological analysis is required (deWaard pers. comm. 2020). No additional genetic studies have occurred elsewhere in the species' global range.

Designatable Units

Northern Oak Hairstreak has one designatable unit in Canada; only one of the four described subspecies (i.e., *S. f. ontario*) occurs in Canada. All subpopulations fall within the Great Lakes Plains National Ecological Area (COSEWIC 2007).

Special Significance

There are several rare Lepidoptera associated with the remaining oak woodlands and oak savannas of southern Ontario. Northern Oak Hairstreak is of interest to entomologists and taxonomists because of its rarity and association with oak-dominated habitats. These same habitats are home to numerous rare and endangered arthropod species. Northern Oak Hairstreak is part of Canadian ecosystems that are important to Indigenous people, who recognize the interconnectedness of all species within the ecosystem.

DISTRIBUTION

Global Range

Oak Hairstreak (*Satyrium favonius*) (J. E. Smith 1797) ranges from southeastern Colorado to Michigan, east to Massachusetts, and south into Florida and Texas (Gagliardi and Wagner 2016). Northern Oak Hairstreak ranges from Massachusetts to Georgia and west to extreme southern Ontario and Michigan, Iowa, Oklahoma, and southcentral Texas. The species becomes increasingly scarce towards the northern edge of its range (Opler 1998; BMONA 2016; NatureServe 2020) (Figure 3). The butterfly is considered widespread but localized where it occurs (i.e., associated with a defined habitat patch or small geographic area) (NatureServe 2020). The approximate global range of Northern Oak Hairstreak is 1,800,000 km^2.

Figure 3. Estimated global distribution of Northern Oak Hairstreak (*Satyrium favonius ontario*) based on records posted to BMONA (2020) and iNaturalist (2020). Map produced by Gerry Schaus, Natural Resource Solutions Inc (March 2021).

A species distribution model was built for the northeastern portion of Northern Oak Hairstreak's range in the United States (Gagliardi *et al.* 2017). The model incorporated the low probability of detection (i.e., the species tends to occupy the canopy, which limits detection) and the outputs predicted a range that extends north of documented sites.

Canadian Range

Northern Oak Hairstreak is restricted to southwestern Ontario (Figure 4). There are seven geographic areas where the species is recorded (Table 1; Figure 4). Six of the geographic localities represent six separate subpopulations[3,4]: two historical (#1, 2), one unconfirmed (#5) and three extant (#4,6,7). One geographic area (#3) is considered vagrant (Table 1; Figure 4).

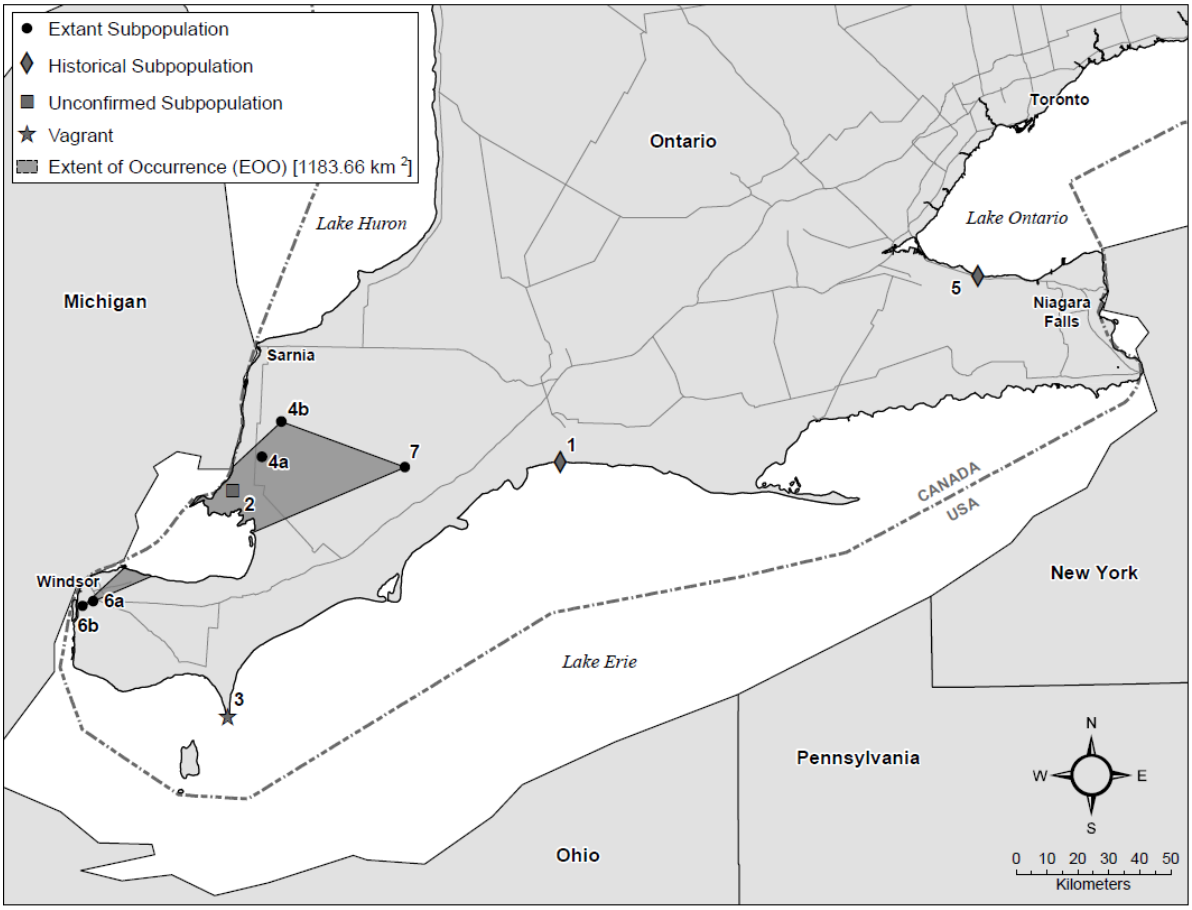

Figure 4. Northern Oak Hairstreak (*Satyrium favonius ontario*) subpopulations in Canada (Table 1). Map produced by Gerry Schaus, Natural Resource Solutions Inc (May 2022).

[3] Subpopulations are defined as geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less) (IUCN 2001).

[4] The separation distance for subpopulations in unsuitable habitat is 2 kilometres and 10 kilometres in suitable habitat (NatureServe 2020).

Table 1. Summary of specimen and sight records for Northern Oak Hairstreak (*Satyrium favonius ontario*) in Canada.

Sub-population # and status	Subpopulation Name	Search Effort	Date	# Individuals observed	Notes	Surveyor(s)
1 Historical	Port Stanley	Unknown	1868-07	1	Type specimen. Recorded nectaring on Spiraea.	Edmund Baynes Reed
2 Historical	Grimsby	Unknown	1894-06-24	1	Collected.	William Metcalfe
3 Vagrant	Point Pelee	Previous search effort unknown. 5 hours 2021	1999-06-14	1	Worn male. Nectaring on the flowers of Staghorn Sumac (*Rhus typhina*). Considered a rare stray.	Alan Wormington Jessica Linton (2021)
4a Extant	Reid Conservation Area	55+ hours	2008-2021	100+	Only site where individuals observed regularly	Blake Mann Jessica Linton and Mary Gartshore (2021)
4b Extant	Moore Wildlife Management Area	17+ hours	2008-2021	5 (2008 and 2021)	Approximately 10km from Reid Conservation Area	Blake Mann Jessica Linton and Mary Gartshore (2021)
5 Unconfirmed	Walpole Island	Unknown	2015	1	Incidental sighting	Blake Mann
6a Extant	Brunet Park	220+hrs*	2009-2019	2 (2009 and 2014)	NABA Count	Jeff Larson, Paul Desjardins Jessica Linton (2021)
6b Extant	LaSalle		2009-2019	1 (2005)	Observed day before NABA count	Paul Pratt Jessica Linton (2021)
7 Extant	Middlesex (Skunk's Misery)	1hr	2021	1	Observed nectaring with other hairstreaks	Donald Pye
Outside of currently known range of Northern Oak Hairstreak	Pinery Provincial Park (Lambton County)	287+hrs*	2009-2019	0	NABA Counts	Multiple observers
	Long Point Area (Norfolk County)	516+hrs*	2009-2019	0	NABA Counts	Multiple observers
	Long Point Land Trust Property (Norfolk County)	2hrs	July 7, 2021	0	Hairstreaks abundant (4 species observed)	Jessica Linton (2021)
	St. Williams Forestry Reserve, Manestar Tract (Norfolk County)	2hrs	July 9, 2021	0	Hairstreaks abundant (3 species observed)	Jessica Linton (2021)
	St. Williams Forestry Reserve, various sites (Norfolk County)	5hrs	July 2021	0	Plot-based butterfly surveys	Emily Kubesheskie (2021)
	"Butterfly Block" Nature Conservancy Property (Norfolk County	4hrs	July 2020, July 2021	0	Plot-based butterfly surveys	Emily Kubesheskie
	Windsor (Black Oak Heritage Woods)	1hr	July 6, 2021	0	No hairstreaks observed	Jessica Linton (2021)

*Based on person-hours recorded during an annual North American Butterfly Association Count (NABA) during the flight period of Northern Oak Hairstreak which includes these areas and nearby suitable habitats including the Ojibway Prairie Complex (Kamstra, pers. comm. 2020).

Figure 5. Northern Oak Hairstreak (*Satyrium favonius ontario*) habitat at Reid Conservation Area (#4a). View from an open meadow adjacent to oak-hickory woodland where Northern Oak Hairstreak butterflies have been observed nectaring. Photo by Jessica Linton (September 2020).

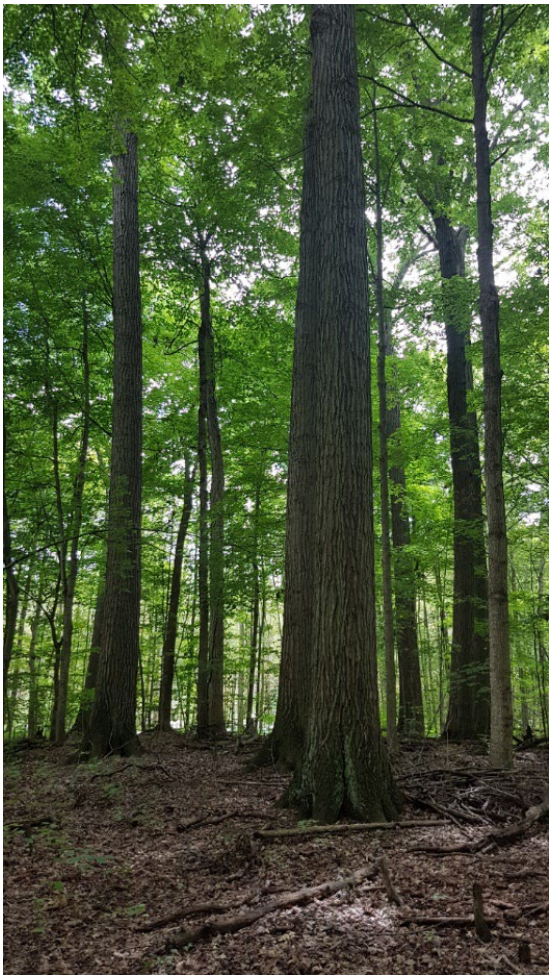

Figure 6. Northern Oak Hairstreak (*Satyrium favonius ontario*) interior oak-hickory woodland habitat at Reid Conservation Area (#4a). Photo by Jessica Linton (September 2020).

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EOO) is 1183 km^2 using a convex polygon around extant subpopulations (#4, 6, 7). When the subpopulation of unconfirmed status (#5) is included, the EOO does not change. The index of area of occupancy (IAO) (2 km x 2 km grid) is 24 km^2, when the three extant (#4a, 4b, 6a, 6b, 7) and unconfirmed status (#5) subpopulations are included. When historical subpopulations (#1, 2) are included, the EOO increases to 12,853 km^2 and the IAO increases to 32 km^2.

Search Effort

Northern Oak Hairstreak records in Canada date from 1868-2021 (Table 1). There are a minimum of 150 museum specimen and sight records from the seven separate geographic areas (Table 1).

In general, butterfly surveys follow a wandering transect and target habitats with abundant flowering adult nectar plants, larval host plants, and/or other habitat attributes, depending on the species. Surveys occur on warm sunny days between 0900-1500. Hairstreaks are often observed on sunny, low wind and warm days, and nectaring on small flowers such as asters (Asteraceae), dogbanes (*Apocynum* spp.), hawkweeds (*Hieracium* spp.), and fleabanes (*Erigeron* spp.) (see **Habitat Requirements**).

Northern Oak Hairstreak adults primarily reside in the canopy and are not frequently observed at ground-level. Therefore, butterfly surveys based solely on floral visitations may produce inaccurate abundance estimates (Gagliardi *et al.* 2017).

The best series of observations is from Reid Conservation Area (#4a) in Lambton County. This area is a well-known habitat for observing Northern Oak Hairstreak and was surveyed annually from 2008 – 2021 using ground-level detection surveys. Surveys have detected the butterfly every year except 2012, which was considered a low-abundance year for all hairstreaks (Mann 2013). Each year of surveys, fewer than 5 individuals were observed except 2008 when over 50 individuals were observed, a particularly good year for hairstreak abundance (Mann 2013).

To inform this status report, targeted field surveys were undertaken in 2021 at Point Pelee (#3, vagrant), Reid Conservation Area (#4a, extant), Moore Wildlife Management Area (#4b, extant), Brunet Park (#6a, extant), and Lasalle (#6b, extant). Sites with suitable habitat in Lambton County, Norfolk County, and Windsor were also surveyed with null results (Table 1).

Ground-level surveys in 2021 confirmed Northern Oak Hairstreak at Reid Conservation Area (#4a); the maximum number observed on one survey day was five adults. All individuals were observed nectaring on Hemp Dogbane (*Apocynum cannabinum*) with other hairstreaks (*S. calanus* and *S. caryaevorum*). Banded Hairstreak (*S. calanus*) was abundant (n=150+ observed) at this site in 2021.

Ground-level surveys in 2021 confirmed the hairstreak at Moore Wildlife Management Area (#4b); the maximum number observed on one survey day was two adults. All individuals were observed nectaring on Hemp Dogbane or Daisy Fleabane (*Erigeron annuus*) with other hairstreaks (*S. calanus, S. caryaevorum, S. titus*). Like Reid Conservation Area (#4a), other hairstreaks were abundant.

Bickford Oak Woods (Lambton County) is approximately 8 km from Moore Wildlife Management Area (#4b) and provides suitable oak woodland and adjacent planted prairie habitat for Northern Oak Hairstreak. Banded Hairstreak was observed in low numbers during 2021 surveys; however, the conditions were not considered ideal (e.g., high winds) for surveying. No Northern Oak Hairstreak were observed.

Point Pelee (#3) was surveyed for Northern Oak Hairstreak and to assess habitat quality for this hairstreak. Approximately 5 hours over 2 survey days were spent looking for hairstreaks; none were observed. In general, habitat quality is suboptimal; White Oak is not abundant and nectar resources were limited. It is not unusual for rare stray butterflies to show up at Point Pelee (Linton pers. comm. 2021).

The Lasalle area including Brunet Park (#6a) and woodlands adjacent to Gilbert Park (#6b) was searched with null results; however, suitable habitat remains present at these sites. Surveys at Black Oak Heritage Park, within the Ojibway Prairie Complex in Windsor and approximately 6 km from Lasalle, did not record the butterfly.

Several sites in Norfolk County were surveyed (Table 1). During these surveys hundreds of hairstreaks were observed (*S. calanus, S. caryaevorum, S. titus, S. edwardsii*) but no Northern Oak Hairstreaks were detected.

Northern Oak Hairstreak was documented at a new site in Middlesex County (#7) in 2021 by a casual observer photographing hairstreaks. The observation was along a woodland edge in Skunk's Misery Natural Area. This area is frequented by naturalists and six other species of hairstreak are documented at this site (*S. calanus, S. caryaevorum, S. titus, S. edwardsii, S. liparops, and S. acadica)* (iNaturalist 2021).

If non-nectar sugar consumption is regular this behaviour could explain the unreliable appearance of Northern Oak Hairstreaks at flowers, across days, and across years (Wagner and Gagliardi 2015). Hard rains and fluctuations in aphid and cynipid populations would lower availability of non-floral sugar resources and during these conditions the frequency of flower visitation would be expected to increase (Wagner and Gagliardi 2015).

There are many keen butterfly observers and naturalists in southern Ontario. Online platforms such as the Ontario Butterfly Atlas and iNaturalist collate citizen science observations and make records readily available. From 2009–2019, 4,316 *Satyrium* records were submitted to the Ontario Butterfly Atlas. Fifty-two Northern Oak Hairstreak were recorded from two of the five known subpopulations (#4, 6) (MacNaughton *et al.* 2019). In the last eleven years (2010–2020), 290 users submitted 994 *Satyrium* observations to iNaturalist, and only seven were Northern Oak Hairstreak (iNaturalist 2020). Ontario's

larger intact oak-dominated habitats, including Pinery Provincial Park, Norfolk County, Windsor, and Point Pelee National Park, are regularly visited by butterfly observers throughout the season and each area has an annual butterfly count. Although Northern Oak Hairstreak is a canopy-dwelling species, it is highly probable its presence would have been detected during these surveys. It was recorded only once at Point Pelee in 1999 and considered to be a stray.

In Massachusetts, larval surveys have been successful in documenting Northern Oak Hairstreak. Methods for detecting larval presence include both wrapping burlap sacks around tree trunks and visual surveys on host plant trees. These methods capture mature larvae as they crawl down the tree trunk to the base of the tree to find a suitable pupation site. Other methods include beating sheets which knock larvae out of the canopy onto a white sheet below (Gagliardi and Wagner 2016). These survey methods have not been used to confirm the host plant for Northern Oak Hairstreak larvae in Canada.

HABITAT

Habitat Requirements

In Canada, Northern Oak Hairstreak habitats are characterized by closed canopy oak (*Quercus* spp.) forests with > 60% canopy cover that is adjacent to open meadows and forest edges with abundant nectar sources. In Ontario, these Deciduous Forest Ecosites (as per the provincial Ecological Land Classification System for Southern Ontario) are typically characterized as Fresh – Moist (FOD9) or Dry – Fresh (FOD2) Oak – Maple (*Acer* spp.) – Hickory (*Carya* spp.) vegetation communities (Lee *et al.* 1998). Northern Oak Hairstreak is commonly observed at forest edges or in open areas with nectar resources adjacent to these forest types, but likely spends most of its time in the oak canopy.

At Reid Conservation Area (#4a), the forest habitat is oak-hickory-maple-pine woodland with a mix of oak and hickory species with smaller numbers of White Pines (*Pinus strobus*) and Sugar Maples (*Acer saccharum*). All observations at ground-level have been in an open meadow area with abundant Hemp Dogbane, its preferred nectar plant at this site. At Moore Wildlife Management Area (#4b) the forest habitat is similarly characterized by oak-hickory-maple-pine woodland with groves of Black Walnut (*Juglans nigra*). There is an adjacent planted prairie area with patches of Hemp Dogbane and Daisy Fleabane where Northern Oak Hairstreak has been observed nectaring. Throughout its range in the United States, Northern Oak Hairstreak is recorded from oak woodlands, oak-pine woods, coastal groves, shale barrens, and oak groves (Layberry *et al.* 1998; NatureServe 2020) and has been reported in urban areas supporting low densities of oak trees (Wagner pers. comm. 2020).

In the northern portion of its range in the United States, females specifically oviposit on White Oak (*Quercus alba*) and targeted field surveys for larvae in Massachusetts detected Northern Oak Hairstreak only on White Oak despite surveys of several oak species (Gagliardi and Wagner 2016). Early instar larvae feed on the buds and flowers of White Oak, suggesting pollen is important to its diet, but switch to young leaves as larvae mature (Allen 1997). Additional research is needed to clarify host specificity and dietary preferences through its five instars (Gagliardi and Wagner 2016). White Oak prefers full sun, and in forested areas generally prefers edge habitats or canopy openings.

Northern Oak Hairstreak adults are nectar generalists, visiting a variety of flowers (Gagliardi and Wagner 2016). In the northeastern United States, Northern Oak Hairstreak is most frequently documented on milkweeds (*Asclepias* spp.), New Jersey Tea (*Ceanothus americanus*), dogbanes (*Apocynum* spp.), Thistles (*Cirsium* spp.), Yarrow (*Achillea millefolium*) and Gray Dogwood (*Cornus racemosa*) and other flowering plants (Gagliardi and Wagner 2016). In Ontario, it is most frequently observed on Hemp Dogbane (*Apocynum cannabinum*) at Reid Conservation Area (#4a) (Mann pers. comm. 2020). All these plants are native.

Northern Oak Hairstreak adults feed on aphid honeydew (Wagner and Gagliardi 2015) and likely on the sugary secretions from pip galls (little galls protruding between an acorn and its cap) made by cynipid wasps (see **Interspecific Interactions**).

Habitat Trends

Indigenous peoples of southern Ontario influenced the overall land cover but in general, natural wetlands and forests remained extensive prior to European settlement (Butt *et al.* 2005). Indigenous peoples used fire as a tool for clearing land for camping and travel, improving habitat for game animals, and preparing agricultural land (Bakowsky 1993). In the early 1800s, widespread European settlement resulted in significant changes to the landscape in southern Ontario; natural vegetation was cleared for agriculture and timber. As time passed, urban development expanded. Native oak savanna, prairie and woodland habitats once covered more than 11,000,000 hectares of North America but are now among the most endangered habitat types in Canada. It is estimated that 800 to 2,000 km^2 of these vegetation community types existed in the southern Ontario landscape before European settlement and subsequent land conversion (Rodger 1998). Now these habitats occupy less than 3% of their former range in Ontario and what remains is under constant threat due to fire suppression and inadequate ecosystem management which does not support maintenance of forest successional stages (Taylor *et al.* 2014).

Prior to European settlement in southern Ontario, a diverse mix of vegetation and site conditions supported a range of fire regimes (Nowaki and Abrams 2008). As a result of fire suppression policies becoming more prevalent in the 1920s, there was a major shift (decline) in fire regimes that had unforeseen ecological consequences (Nowaki and Abrams 2008). This included compositional and structural changes to ecosystems, whereby open country habitats (e.g., grasslands, savannas, and woodlands) succeeded to closed-canopy forests, followed by the eventual replacement of fire-dependent plants by shade-

tolerant, fire-sensitive vegetation (Nowaki and Abrams 2008). This trend continues today with ongoing fire suppression and a decline in oak and pine recruitment, which in the absence of fire, are out-competed by a variety of highly competitive, later-successional, gap-opportunistic, mesophytic[5] hardwoods such as maples (*Acer* spp.), beeches (*Fagus* spp.), cherries (*Prunus* spp.), and birches (*Betula* spp.).

The historical widespread loss of oak woodland habitats in Ontario results in geographical isolation of habitat patches throughout the landscape. Except for a few larger areas of habitat, most patches are less than 0.5 hectares and are poorly connected within the landscape. Despite a high proportion of these areas being designated as protected lands, they are still likely in decline in both area and quality unless there is ongoing maintenance and management; their fragmentation impairs the quality of their ecological function for the diverse number of rare and declining species which depend on them. Their small size and isolation increase resource competition, decrease resilience, reduce genetic flow, increase the risk of mortality for mobile wildlife species attempting to move between patches, and do not necessarily provide adequate habitat for the long-term viability of species.

Today most woodlands in southern Ontario are small, fragmented, patches which are influenced by human pressures including logging, agriculture, invasive species, recreational use, and pollution (see **Threats**).

Lambton County (#4, 5) was predominantly forested, but as settlers moved into the region large tracts of forest were cleared and wetlands were drained for agriculture (Ontario Woodlot Association 2005). Lambton County has approximately 10% forest cover remaining, including several large oak-dominated forests at Walpole Island, Pinery Provincial Park, and Bickford Oak Forest (Ontario Woodlot Association 2005). The Lower North Sydenham subwatershed (#4) has only 9.6% forest cover, while the St. Clair Tributaries subwatershed (#5) has 14.1% (SCRCA 2018). Similarly, the initial forest loss in the Windsor-Essex region (#3, 6), because of European settlement (1830s) was dramatic because of incentives given to clear land for agriculture. Today, Windsor-Essex supports approximately 6% forest cover which includes terrestrial woodlands and treed swamps (Essex Region Conservation Authority 2013). Similar loss in forest cover was experienced in Elgin County (#1) and Niagara Region (#2) where only 13% and 12% forest cover remain respectively (Ontario Woodlot Association 2005). In Middlesex County (#7), 12.3% of forest cover remains intact and this includes both upland forests and treed swamps (UTRCA 2014).

In southern Ontario, oak-pine-hickory woodland has become rare due to fire suppression, the introduction and spread of non-native plants, and inappropriate tree planting regimes (Tallgrass Ontario 2019). Oak-hickory-pine forests are fire-dependent but require infrequent and low-intensity fires (Tallgrass Ontario 2019). This fire requirement is unlike most southern Ontario deciduous forests which are composed of fire-intolerant trees (e.g., Sugar Maple, ash [*Fraxinus* spp.] and American Beech [*Fagus grandifolia* and have

[5] Terrestrial plants adapted to neither particularly dry nor particularly wet environments.

successional tallgrass oak-dominated communities (e.g., oak savanna, tallgrass prairie) that require frequent fire (Tallgrass Ontario 2019). Woodland habitat protection in Ontario is governed by local municipal official plans and tree cutting by-laws, and the habitat trends at all subpopulations are historically different based on these different management objectives/regimes. In Middlesex County (#7), there have been increases in the relative dominance of maples, ashes, tamarack, hickory and aspen and decreases in beech, black cherry, oak and white elm. This trend is like that found in other areas in southern Ontario (Middlesex County 2014). Despite there being large, mature oak trees in Skunk's Misery Natural Area (#7), recruitment is not occurring due to the density of the canopy and competition with maples (Koscinski pers. comm. 2021).

In Massachusetts, Northern Oak Hairstreak is found in both intact oak woodlands, and urban sites where White Oak trees are present (Wagner pers. comm. 2020). To date, the butterfly has not been observed in urban sites in Ontario.

BIOLOGY

Life Cycle and Reproduction

Northern Oak Hairstreak has one generation per year. In Canada, adults have been recorded from June 14 - July 11 (MacNaughton *et al.* 2019), although in southern parts of its range in the United States, the flight period is longer. It is unknown if females and males emerge at the same time. Northern Oak Hairstreak adults likely live a week to ten days; data are not available on adult lifespan.

Male hairstreaks often defend their mating territories by perching and engaging other males that enter their territory in spiraling skyward displays before returning to the same or a nearby perch (Pyle 1981, Opler and Krizek 1984, Tveten and Tveten 1996, Allen 1997, Cech and Tudor 2005). They demonstrate hilltopping behaviour to locate mates and males have been observed to show increased territorial behaviour in the evening (Wagner pers. comm. 2020). Hilltopping refers to mate-location behaviour where males create a territory on a hilltop and wait for females to approach.

There is no specific information on Northern Oak Hairstreak oviposition or egg development; however, Southern Oak Hairstreak lays eggs singly on oak twigs (BMONA 2020).

Eggs overwinter and hatch the following spring. Larvae have five instars, although the duration of each instar is unknown. Pupation occurs in the leaf duff at the base of oak trees and pre-pupating larvae turn pinkish (Gagliardi and Wagner 2016).

Physiology and Adaptability

Adult *Satyrium* hairstreaks (*S. calanus, S. caryaevorus, S. edwardsii,* and *S. liparops*) of both sexes have been documented feeding at acorn pip galls made by a cynipid wasp (*Callirhytis balanacea*) in Massachusetts (Gagliardi and Wagner 2016) (see **Habitat Requirements**). The observers noted the greatest feeding activity was coincident with warmer and sunnier conditions and that nearby flowers had only modest visitation by these same *Satyrium* hairstreak species on the days when the butterflies were feeding at the pip galls. Based on their observations and reports of Northern Oak Hairstreak feeding on aphid honey dew, Gagliardi and Wagner (2016) suspect that these and other non-nectar resources in the canopy are the primary nutrient sources for Oak Hairstreak, and that flower feeding is of secondary importance (Wagner and Gagliardi 2015). The presence of adults at flowers may reflect reduced availability of sugars and other nutritional resources in the canopy (e.g., during hot weather, drought conditions, after heavy rains, presence of competitors, etc.) and may explain why they are not always detectable at ground level.

There are approximately 600 gall-producing cynipid species that are host specific to North American oaks (Eisman 2011); and five of these species are confirmed in Canada (*Callirhytis favois, C. quercusfutilis, C. lanat, C. piperoides, C. seminator*) (Bennett pers. comm. 2021, S. Marshall pers. comm. 2021). Several species associated with oaks have been reported on iNaturalist 2020, although the validity of these records is unknown (i.e., individual wasps, and the galls produced from these wasps can be difficult to identify). The extent to which Northern Oak Hairstreak is dependent on pip galls, or particular species of cynipid wasps is unknown. In general, this group of wasps is understudied in Canada but may be restricted by host tree species.

Pip galls appear as growths of plant tissue and contain the larvae of a *Callirhytis* wasp (Miller 2020). These galls are formed to protect the wasp's eggs or larvae and to protect and feed the adult wasps (Miller 2020). These are one of few known cynipid genera known to induce the exudation of sugary solutions over the surface of their galls (Wagner and Gagliardi 2015). These exudates attract ants, which collectively protect the developing wasp larva from attack by parasitoids and inquilines[6] that might otherwise enter the gall (Weld 1959, Washburn 1984, Inouye and Agrawal 2004). A large proportion of cynipid wasps parasitize oak trees, and several species associated with oaks have been reported in Ontario (iNaturalist 2020). These wasps tend to be associated with oaks in the red-black group.

The first report for gall-feeding by hairstreaks (and all New World butterflies) was in 2015 (Wagner and Gagliardi 2015). If non-nectar sugar consumption is regular this behaviour could explain the unreliable appearance of Northern Oak Hairstreaks at flowers, across days, and across years (Wagner and Gagliardi 2015). Hard rains and fluctuations in aphid and cynipid populations would lower availability of non-floral sugar resources and during these conditions the frequency of flower visitation would be expected to increase (Wagner and Gagliardi 2015).

[6] Animal that lives commensally in the nest, burrow, or dwelling place of an animal of another species.

Northern Oak Hairstreaks rub their tailed hindwings when threatened to produce a distracting false head[7] display (Gagliardi 2013).

Dispersal and Migration

In Canada, Northern Oak Hairstreak is observed near oak woodlands, most commonly on wildflowers. Records suggest that Northern Oak Hairstreak expanded its range further into southern Ontario and northeastern United States by several hundred kilometres in the last half of the 20th century (NatureServe 2020). There are no data on dispersal capability, but it seems likely that adults disperse 10 km to new habitats. It is likely that the Northern Oak Hairstreak will continue to expand its range further north in response to climate change (Wagner pers. comm. 2020). The six subpopulations in Canada are not considered severely fragmented because habitat patches are apparently large enough to support viable subpopulations.

Interspecific Interactions

Northern Oak Hairstreak may have an interspecific relationship with pip galls made by cynipid wasps. Pip galls appear as growths of plant tissue and contain the larvae of a *Callirhytis* wasp (Miller 2020). These galls are formed to protect the wasp's eggs or larvae and to protect and feed the adult wasps (Miller 2020). These are one of few known cynipid genera known to induce the exudation of sugary solutions over the surface of their galls (Wagner and Gagliardi 2015). These exudates attract ants, which collectively protect the developing wasp larva from attack by parasitoids and inquilines[8] that might otherwise enter the gall (Weld 1959; Washburn 1984; Inouye and Agrawal 2004).

In Massachusetts, *Satyrium* hairstreak adults (*S. calanus, S. caryaevorus, S. edwardsii, and S. liparops*) of both sexes were documented feeding at acorn pip galls made by a cynipid wasp (*Callirhytis balanacea*) (Gagliardi and Wagner 2016). The study documented greater hairstreak feeding activity at pip galls during warmer and sunnier conditions than at nearby flowers at ground level (Gagliardi and Wagner 2016). Pip gall sugars, aphid honey dew and other non-nectar resources in the canopy may be preferential nutrient sources for Oak Hairstreak, and flower feeding may be secondary when these other options are readily available (Wagner and Gagliardi 2016).

[7] This refers to confusing predators by acting as though their tails are antennae (often reinforced by eye or spot markings).

[8] Animal that lives commensally in the nest, burrow, or dwelling place of an animal of another species.

There are approximately 600 gall producing cynipid wasp species dependent on North American oaks (Eisman 2011), and most tend to be associated with oaks in the red-black group. Cynipid wasps are understudied in Canada; only five species are confirmed (*Callirhytis favois, C. quercusfutilis, C. lanat, C. piperoides, C. seminator*) (Bennett pers. comm. 2021; Marshall pers. comm. 2021). Cynipid wasps associated with oaks have been reported in Ontario (iNaturalist 2020); however, species identification from photos is challenging. The extent to which Northern Oak Hairstreak is dependent on pip galls, or particular species of cynipid wasps is not well understood.

Additional interspecific interactions such as disease, predation, and/or parasitism have not been reported for Northern Oak Hairstreak. Like all Lepidoptera, they are subject to competition, predation, and parasitism by a variety of other animals (e.g., insects, spiders, birds) during all life stages. Although it is unknown if Northern Oak Hairstreak directly compete for larval food resources with other species, there are many other species of Lepidoptera, including other hairstreaks that feed on White Oak.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

No systematic sampling effort or datasets exist to inform subpopulation sizes or trends for Northern Oak Hairstreak in Canada, Reid Conservation Area (#4a) has been surveyed annually since 2008. All observations in Canada have been of adult butterflies, most often observed nectaring.

Abundance

There are no data on the abundance of Northern Oak Hairstreak subpopulations in Canada. Adults likely spend much of their lives in the canopy (Gagliardi and Wagner 2016) and ground-level sightings are not a reliable abundance metric. In general, the tendency of a butterfly to spend most of its time in the tree canopy may result in a conclusion of false rarity (Schweitzer *et al.* 2011). Through the extensive range in the United States where host oaks are common, sightings remain infrequent and colonies transient (Ogard and Bright 2010). The species has not been reported as abundant (< 5 records per year), except for 2008 when over 50 individuals were observed at Reid Conservation Area (#4a) (Mann 2013).

Fluctuations and Trends

There is little information on subpopulation fluctuations or trends for Northern Oak Hairstreak in Canada or the United States.

In Canada, there is some evidence Northern Oak Hairstreak abundance may fluctuate from year to year. Some hairstreaks (e.g., Edward's Hairstreak, *Satyrium edwardsii*) appear to have mass emergences (i.e., simultaneous emergence in a subpopulation) (Cavasin pers. comm. 2020). It is possible that many hairstreaks demonstrate the same tendency, resulting in periodic abundance peaks. Northern Oak Hairstreak was first documented at Reid Conservation Area (#4a) in 2008 when approximately 50 adults were observed (Mann 2013); the observer suggested hairstreaks were numerous that year. Similarly, in 2021, hairstreaks (in general) were abundant (Linton pers. comm. 2021).

There are insufficient data to differentiate whether subpopulation abundance fluctuates or whether infrequent observations at a site reflect differences in activity in the canopy versus at ground level. There is evidence of daily behavioural patterns in other hairstreak species. For example, Hickory Hairstreak (*Satyrium caryaevorus*) was observed regularly in large numbers (>100) at ground-level in a backyard near Montréal in the early morning hours, with all individuals except for 1 or 2 disappearing by 9:30am (Larrivée pers. comm. 2020). This type of behaviour may falsely give the impression of annual variation in population numbers depending on the circumstances of the observation.

Rescue Effect

The potential for rescue from subpopulations in the United States is unknown, partially because Northern Oak Hairstreak distribution in the United States is unknown. Rescue may be possible at Windsor (#6a, 6b). The closest online iNaturalist record to LaSalle (#6b) is near Ann Arbor, Michigan, which is 55 km from LaSalle. It is possible there is potential intervening habitat.

Northern Oak Hairstreak appears local (NatureServe 2020); dispersal events are likely uncommon but may be facilitated by weather conditions (i.e., wind) which are known to assist dispersal in other hairstreak species (Robbins and Small 1981). For example, in Europe, White-letter Hairstreak (*Satyrium w-album*), has been documented several kilometres from suitable habitat and, in warm years, appears to disperse and form new colonies (Ellis and Wainwright 2020; Host 2020).

THREATS AND LIMITING FACTORS

The Northern Oak Hairstreak threat assessment (Table 3) is based on the IUCN-CMP (International Union for Conservation of Nature–Conservation Measures Partnership) unified threats classification system. The IUCN-CMP Threats Classification system is consistent with methods used by COSEWIC across taxa, as well as the federal, provincial, and territorial governments, and it adopts an international standard. For a detailed description, see the Open Standards website (Conservation Measures Partnership 2016a). For information on how the values are assigned, see Salafsky *et al.* (2008), Master *et al.* (2012), and Table 3 footnotes for details.

Table 2. Northern Oak Hairstreak (*Satyrium favonius ontario*) subpopulations, habitat information and spatial area of habitat, land ownership, and threat information.

Subpopulation Number (#), Name, Municipality, and status	Habitat	Spatial Area in hectares (ha)	Land Ownership	Potential Threat(s)
1. Port Stanley, Port Stanley Historical	Unknown at collection site	Unknown	Unknown	Unknown
2. Grimsby, Grimsby Historical	Unknown at collection site	Unknown	Unknown	Unknown
3. Point Pelee, Leamington Vagrant	Much of the park's interior consists of a southern Great Lakes marsh (72%). A few forest habitat types are also present in a range of successional stages, including savannah (2%) and dryland and swamp forest (21%) as well as Beech (4%) (Parks Canada 2021. White Oak Present but not numerous. Low potential for Northern Oak Hairstreak to occur as a breeding subpopulation.	Point Pelee National Park is 1500 ha, but a large proportion of the park is unsuitable Northern Oak Hairstreak habitat (e.g., marsh)	Point Pelee National Park, Government of Canada	6.1 Recreational activities 7.1 Fire suppression 7.3 Other ecosystem modifications from invasive plant growth
4a. Reid Conservation Area northeast of Port Lambton, Lambton County Extant	Oak-Hickory Woodland with areas of active agriculture (row crops) and wetlands. White Oak Present.	69 ha (approximately 28 ha of upland oak woodland)	Reid Conservation Area, St. Clair Region Conservation Authority	6.1 Recreational activities 7.1 Fire suppression 7.3 Other ecosystem modifications from invasive plant growth 9.3 Pesticide spray to control Spongy Moth and/or drift from adjacent agricultural fields.
4b. Moore Wildlife Management Area, NE of Port Lambton, Lambton County Extant	Oak Woodland with areas of active agriculture (row crops), hay fields, and restored tallgrass prairie. White Oak Present.	123 ha (approximately 44 ha of upland woodland)	Moore Wildlife Management Area, St. Clair Region Conservation Authority	6.1 Recreational activities 7.1 Fire suppression 7.3 Other ecosystem modifications from invasive plant growth 9.3 Pesticide spray to control Spongy Moth and/or drift from adjacent agricultural fields.
5. Walpole Island Independent of but within the geographic region of, Lambton County Unconfirmed	Oak woodland, savanna, and prairie, agriculture, and wetland. White Oak Present.	4000 ha of forest, savannah, and prairie	Walpole Island First Nation	6.1 Recreational activities 7.1 Fire suppression 7.3 Other ecosystem modifications from invasive plant growth 9.3 Pesticide spray to control Spongy Moth and/or drift from adjacent agricultural fields.
6a. Windsor - Brunet Park, Lasalle Extant	Oak woodland, manicured parkland. White Oak Present.	7 ha (approximately 65 ha of total woodland area contiguous to park)	Brunet Park; Town of LaSalle	6.1 Recreational activities 7.1 Fire suppression 7.3 Other ecosystem modifications because of invasive plant growth 9.3 Pesticide spray to control Spongy Moth and/or drift from adjacent agricultural fields.
6b. Windsor - Private woodland, Lasalle Extant	Oak Woodland. White Oak Present.	12 ha	Private woodland within the Town of LaSalle	6.1 Recreational activities 7.1 Fire suppression 7.3 Other ecosystem modifications from invasive plant growth 9.3 Pesticide spray to control Spongy Moth and/or drift from adjacent agricultural fields.

Subpopulation Number (#), Name, Municipality, and status	Habitat	Spatial Area in hectares (ha)	Land Ownership	Potential Threat(s)
7. Middlesex County-Skunk's Misery Natural Area Extant	Oak and Mixed Hardwood Woodland interspersed with forested swamp. White Oak Present.	Total forest area >980 ha	Thames Talbot Land Trust, Lower Thames Conservation Authority, Middlesex County, and Private land	5.3 Logging and wood harvesting 6.1 Recreational activities 7.1 Fire suppression 7.3 Other ecosystem modifications from invasive plant growth 9.3 Pesticide spray to control Spongy Moth and/or drift from adjacent agricultural fields.

Table 3. Results for the Northern Oak Hairstreak (*Satyrium favonius ontario*) threats assessment in Canada. The classification below is based on the IUCN-CMP (International Union for the Conservation of Nature–Conservation Measures Partnership) unified threats classification system. For a detailed description of the threat classification system, see the CMP web site (CMP 2010). Threats may be observed, inferred, or projected to occur in the near term. Threats are characterized here in terms of scope, severity, and timing. Threat "impact" is calculated from scope and severity. For information on how the values are assigned, see Master *et al.* (2009) and footnotes to this table.

Scientific Name	Northern Oak Hairstreak (*Satyrium favonius ontario*)
Assessment Date:	December 17, 2020
Assessor(s):	Jessica Linton (report writer), Dave Fraser (Moderator, COSEWIC Non-government member), Dave McCorquodale (Co-chair Arthropods SSC and notetaker), Jennifer Heron (Co-chair Arthropods SSC and notetaker), Gina Schalk (CWS COSEWIC Jurisdictional Rep.), Colin Jones (Ontario COSEWIC Rep. and Arthropods SSC), John Klymko (Arthropods SSC), Leah Ramsay (Arthropods SSC), Erin Carroll (St. Claire Conservation Area), Ken Tuininga (CWS-Ontario), Tammy Dobbie (Parks Canada), Al Harris (Arthropods SSC), Rosana Soares (COSEWIC Secretariat)
References:	Draft Northern Oak Hairstreak COSEWIC status report.

		Level 1 Threat Impact Counts	
Threat Impact		**high range**	**low range**
A	Very High	0	0
B	High	2	1
C	Medium	0	0
D	Low	1	2
Calculated Overall Threat Impact:		Very High	High
Assigned Overall Threat Impact:		**BC = High - Medium**	
Impact Adjustment Reasons:		Some threats may be double-counted (7.3, 8.1, 9.3) at some sites because threats occur simultaneously and are difficult to distinguish (e.g., defoliation from Spongy Moth larvae reduces host plant abundance, Spongy Moth also leave frass and webbing which may limit movement of Northern Oak Hairstreak larvae, Btk spray to control Spongy Moth and natural/invasive plant succession). The timing of some threats is unknown (and inferred) at some sites (e.g., most recent Btk pesticide spray, and timing of future sprays).	
Overall Threat Comments		There may be undetected subpopulations (potentially 1 – 3 additional subpopulations) within the potential range, and these same threats would apply (7.3, 8.1, 9.3). The likelihood of all threats acting simultaneously during a one-year time-frame is unlikely (e.g., rangewide Btk spray on the same year); however, Btk spray occurring once at each of the extant subpopulations, within the 10-year assessment timeframe, within private/municipal lands is possible. The timing of the threat of spread Oak Wilt is to assess based on the timing.	

Threat		Impact[1] (calculated)	Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs)	Timing[4]	Comments
1	Residential and commercial development	Unknown	Restricted (11-30%)	Unknown	High - Moderate	
1.1	Housing and urban areas	Unknown	Restricted - Small (1-30%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	See **Threats and Limiting Factors**.
1.2	Commercial and industrial areas					Not applicable.
1.3	Tourism and recreation areas					Not applicable.
2	Agriculture and aquaculture					
2.1	Annual and perennial non-timber crops					Portions of the Reid Conservation Area (#4a) and Moore Wildlife Management Area (#4b in Lambton County) are farmed (i.e., rotational crops). There are currently no plans to expand the agricultural production or footprint in these areas, and some areas will likely be a priority for habitat restoration (Payne pers. comm. 2020). The extent to which agricultural expansion threatens Northern Oak Hairstreak on Walpole Island (#5) is unknown.
2.2	Wood and pulp plantations					Not applicable.
2.3	Livestock farming and ranching					Not applicable.
2.4	Marine and freshwater aquaculture					Not applicable.
3	Energy production and mining					
3.1	Oil and gas drilling					Not applicable.
3.2	Mining and quarrying					Not applicable.
3.3	Renewable energy					Not applicable.
4	Transportation and service corridors					
4.1	Roads and railroads					Not applicable.
4.2	Utility and service lines					Not applicable.
4.3	Shipping lanes					Not applicable.
4.4	Flight paths					Not applicable.
5	Biological resource use	Unknown	Large - Small (1-70%)	Unknown	High - Moderate	

Threat			Impact[1] (calculated)	Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs)	Timing[4]	Comments
5.1	Hunting and collecting terrestrial animals		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Northern Oak Hairstreak is occasionally collected in Canada for scientific purposes but is not threatened by targeted collection. It may be a desirable species for individuals who seek out and collect rare Lepidoptera.
5.2	Gathering terrestrial plants						Not applicable. Host plants (e.g., White Oak) are common in Ontario and not collected.
5.3	Logging and wood harvesting		Unknown	Large - Small (1-70%)	Unknown	High - Moderate	See **Threats and Limiting Factors**.
5.4	Fishing and harvesting aquatic resources						Not applicable.
6	Human intrusions and disturbance		Unknown	Large - Small (1-70%)	Unknown	High (Continuing)	
6.1	Recreational activities		Unknown	Large - Small (1-70%)	Unknown	High (Continuing)	See **Threats and Limiting Factors**.
6.2	War, civil unrest and military exercises						Not applicable.
6.3	Work and other activities		Unknown	Small (1-10%)	Unknown	High (Continuing)	See **Threats and Limiting Factors**.
7	Natural system modifications	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	
7.1	Fire and fire suppression	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Fire and fire suppression are both threats to Northern Oak Hairstreak habitat. Fire is scored under this threat, and fire suppression under 7.3. See **Threats and Limiting Factors**.
7.2	Dams and water management/use						Not applicable.
7.3	Other ecosystem modifications		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	See **Threats and Limiting Factors**.
8	Invasive and other problematic species and genes	BD	High - Low	Pervasive - Large(31-100%)	Serious - Slight (1-70%)	High (Continuing)	
8.1	Invasive non-native/ alien species/diseases	BD	High - Low	Pervasive - Large(31-100%)	Serious - Slight (1-70%)	High (Continuing)	See **Threats and Limiting Factors**.
8.2	Problematic native species/diseases		Unknown	Large - Small (1-70%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	See **Threats and Limiting Factors**.
8.3	Introduced genetic material						Not applicable.
8.4	Problematic species/ diseases of unknown origin						Not applicable.

Threat			Impact[1] (calculated)	Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs)	Timing[4]	Comments
8.5	Viral/prion-induced diseases						Not applicable.
8.6	Diseases of unknown cause						Not applicable.
9	Pollution	B	High	Pervasive - Large (31-100%)	Serious (31-70%)	High (Continuing)	
9.1	Domestic and urban wastewater						Not applicable.
9.2	Industrial and military effluents						Not applicable.
9.3	Agricultural and forestry effluents	B	High	Pervasive -Large (31-100%)	Serious (31-70%)	High (Continuing)	See **Threats and Limiting Factors**.
9.4	Garbage and solid waste						Not applicable.
9.5	Air-borne pollutants						Not applicable.
9.6	Excess energy						Not applicable.
10	Geological events						
10.1	Volcanoes						Not applicable.
10.2	Earthquakes/ tsunamis						Not applicable.
10.3	Avalanches/ landslides						Not applicable.
11	Climate change and severe weather		Unknown	Pervasive (71-100%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
11.1	Habitat shifting and alteration		Unknown	Pervasive (71-100%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	See **Threats and Limiting Factors**.
11.2	Droughts		Unknown	Pervasive (71-100%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	See **Threats and Limiting Factors**.
11.3	Temperature extremes		Unknown	Pervasive (71-100%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	See **Threats and Limiting Factors**.
11.4	Storms and flooding						Not applicable.
11.5	Other impacts						Not applicable.

[1]**Impact** – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each stress is based on Severity and Scope rating and considers only present and future threats. Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: very high (75% declines), high (40%), medium (15%), and low (3%). Unknown: used when impact cannot be determined (e.g., if values for either scope or severity is unknown).

[2]**Scope** – Proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%)

[3]**Severity** – Within the scope, the level of damage to the species from the threat that can reasonably be expected to be affected by the threat within a 10-year or three-generation timeframe. Usually measured as the degree of reduction of the species' population (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%).

[4]**Timing** – High = continuing; Moderate = only in the future (could happen in the short term [< 10 years or 3 generations]) or now suspended (could come back in the short term); Low = only in the future (could happen in the long term) or now suspended (could come back in the long term); Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

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 Northern Oak Hairstreak in Canada. Limiting factors are not considered during this assessment process. For purposes of threat assessment, only present and future threats are considered. Historical threats, indirect or cumulative effects of the threats, or any other relevant information that would help understand the nature of the threats are presented under the subheadings below.

Threats for Northern Oak Hairstreak were assessed for the entire Canadian Range. The threats are poorly understood and most threats are inferred from general threats to Lepidoptera in southwestern Ontario and the extent and quality of the habitat at known sites. The overall assigned threat impact is Very High-High based on input from various regional experts and butterfly specialists (see Table 3 for full list of participants). Threats below are written highest to least impact and only those scored, or unknown are discussed; negligible/non-applicable threats are discussed in Table 3.

Threat 9. Pollution (High impact)

9.3 Agricultural and forestry effluents (High impact)

It is projected that Spongy Moth could occur or already is present in low abundance within the Northern Oak Hairstreak habitats in the next ten years. *Bacillus thuringiensis* var. *kurstaki* (*Btk*) is a broad-spectrum insecticide that is used to control non-native Spongy Moth (*Lymantria dispar dispar*)[9] outbreaks in Ontario woodlands and treed urban areas. The insecticide is lethal to lepidopteran larvae (Rastall *et al.* 2003). In Ontario, *Btk* spray to control Spongy Moth began shortly after this species' introduction in 1969. Aerial spray of *Btk* is the most common control method used by municipalities and conservation authorities in southern Ontario and if used at extant sites is a significant threat to Northern Oak Hairstreak abundance. *Btk* is applied in early spring (usually late May or June), targeting early instar larvae. The application period may overlap with the larval period of Northern Oak Hairstreak and in these instances would be lethal. In 2020 and 2021, populations of Spongy Moth in Ontario were abundant and public requests to apply pesticide spray were common in the media, including areas of Lambton County (#4), Windsor (#6), and Middlesex County (#7).

The effects of other pesticides on Northern Oak Hairstreak are unknown; however, most are detrimental to insects. Lambton County (#4) and Middlesex (#7) are adjacent to agricultural areas and pesticide drift may threaten Northern Oak Hairstreak, depending on the type of chemical used and timing of application.

[9] Former English names are European Gypsy Moth and LDD Moth. The name has recently changed (Entomological Society of Canada 2022).

Threat 8. Invasive and Other Problematic Species and Genes (High-low impact)

8.1 Invasive non-native/alien species (High-low impact)

Non-native Spongy Moth populations occasionally reach outbreak levels and continue to expand their geographic range in southern Ontario. Spongy Moth larvae are not host specific and can cause extensive defoliation, especially on oak species. In areas where Northern Oak Hairstreak occur, defoliation of oak trees would directly impact Northern Oak Hairstreak through habitat loss and competition for larval host plants. Pesticide application to control Spongy Moth is assessed under threat 9.3. The spread of non-native invasive plants is assessed under threat 7.3.

8.2 Problematic native species/diseases (Unknown impact)

Oak Wilt (*Bretziella fagacearum*) is a fungal pathogen that kills thousands of oak trees in North America each year, and is spread by underground roots, sap beetles, and bark-feeding beetles (Ontario Invasive Species Awareness Program 2012). This pathogen has not been recorded in Canada; however, it is documented in the Detroit area in the United States, across from the Windsor area and within a few kilometres of Brunet Park (#6a) and LaSalle (#6b).

Threat 7. Natural System Modifications (Low impact)

7.1 Fire and fire suppression (Low impact)

Fire and fire suppression are both threats to Northern Oak Hairstreak habitat. Fire is discussed under this threat category (7.1), and fire suppression under threat 7.3.

Oak forests at extant sites are not subject to prescribed burning, except for Walpole Island (#5). Inappropriate prescribed burning can reduce populations of some Lepidoptera (Swengel *et al.* 2010). Burning which is too frequent, severe, extensive, or occurs outside of the natural wildfire season may adversely impact Northern Oak Hairstreak subpopulations. Egg, larval and pupal life stages are particularly vulnerable to fires due to their limited mobility. Tallgrass Ontario (2019) has developed a guide for restoring tallgrass oak woodlands in southern Ontario which addresses the role of fire in managing these systems. Alternatively, fire is considered the best management approach for maintaining oak forest structure and composition (Tallgrass Ontario 2019). The extent to which Northern Oak Hairstreak may benefit from fire is unknown, as their primary habitat in the canopy is likely less impacted by fire suppression than shade-intolerant species below the canopy.

7.3 Other ecosystem modifications (unknown impact)

Several ecosystem modifications are contributing to the decline of Northern Oak Hairstreak: historical habitat fragmentation has led to a legacy of geographical isolation of habitat patches throughout the landscape, invasive non-native species are spreading throughout the remaining habitats, and fire suppression programs are changing the habitat. These are discussed under subheadings below.

Invasive non-native plant species lead to changes in the ecosystem

There are no known direct threats to Northern Oak Hairstreak from invasive species. However, in general, invasive plant species indirectly affect arthropod and plant diversity and abundance negatively (Ballard *et al.* 2013; Litt *et al.* 2014) and therefore they have the potential to reduce habitat quality for this hairstreak. Highly invasive plants in southern Ontario woodlands include Black Locust (*Robinia pseudoacacia*), European Buckthorn (*Rhamnus cathartica*), Tatarian Honeysuckle (*Lonicera tatarica*), Russian Olive (*Elaeagnus angustifolia*) and Autumn Olive (*Elaeagnus umbellata*), Privet (*Ligustrum* spp.) and Multiflora Rose (*Rosa multiflora*). Black Locust trees and these other invasive shrubs form a dense shrub layer that crowds and shades out native plant species resulting in alterations to light, moisture, and nutrient levels (Tallgrass Ontario 2019). European Buckthorn has been identified as a problematic species at Reid Conservation Area (#4a) and Moore Wildlife Management Area (#4b) (Payne pers. comm. 2020). Autumn Olive and Multiflora Rose are particularly invasive in Middlesex County (#7). The extent to which invasive species threaten to degrade Northern Oak Hairstreak habitat at other extant sites is unknown.

Fire suppression

Management to suppress the natural fire regime is likely contributing to the spread of non-native plants and the infilling of open habitats by native oaks. Homogenization of vegetation communities is often associated with the invasion of expanding non-native generalist species, but it can occur through the spread of generalist native species (Kirk *et al.* 2020). Large scale changes in habitat structure have resulted in oak-pine dominated forests being replaced with fire-resistant hardwood forests. One study in Backus Woods, Norfolk County, showed a significant decline in White Oak over the last 30 years, while native species such as Red Maple (*Acer rubrum*) significantly increased (Kirk *et al.* 2020). This trend in vegetation composition could threaten Northern Oak Hairstreak host plants.

Threat 1. Residential and Commercial Development (Unknown impact)

1.1 Housing and urban areas (Unknown impact)

The sites in Windsor (#6) are within isolated oak woodlands adjacent to residential areas. One site (#6a) is in a public park and residential development is not a threat. The other (#6b) is on privately owned land; however, there are no active development applications filed with the municipality (Burgess pers. comm. 2020). On Walpole Island (#5), housing construction, in response to critical housing shortages, has resulted in habitat loss for other at-risk species but it is not clear to what extent this has impacted habitat for Northern Oak Hairstreak (COSEWIC 2010). Moore Wildlife Area (#4b) and Reid Conservation Area (#4a) exist within the agricultural landscape of southern Ontario and are managed by the St. Clair Region Conservation Authority and are not threatened by residential development. Similarly, a large portion of Skunk's Misery (#7) is owned by the Thames Talbot Land Trust, Lower Thames Valley Conservation Authority, and Middlesex County, and exists in an agricultural landscape where no residential development is expected.

Threat 5. Biological Resource Use (Unknown impact)

5.3 Logging and wood harvesting (Unknown impact)

Large-scale logging in southern Ontario is infrequent. Selective logging and wood harvesting for commercial sale, or for personal use, is ongoing in most managed woodlots. In general, woodlands meeting a minimum size criterion (> 4 ha) and demonstrating an important ecological function (e.g., rare plants or wildlife, low woodland cover in a planning area) are considered for protection in local municipal Official Plans. Timber harvesting in agricultural areas is generally not subject to local by-laws or tree-related policies.

The St. Clair Region Conservation Authority has no plans for logging or harvesting at Reid Conservation Authority (#4a) or Moore Wildlife Management Area (#4b) (Payne pers. comm. 2020). Both authorized and illegal logging have been documented in Middlesex County (#7) near a Northern Oak Hairstreak observation; however, only selective cutting in accordance with good silvicultural practices is expected in the future (Brown pers. comm. 2021). Forest management practices that promote openings in the canopy are required in this area to facilitate oak germination.

Threat 6. Human Intrusions and Disturbance (Unknown impact)

6.1 Recreational activities (Unknown impact)

Moore Wildlife Management Area (#4b), Reid Conservation Area (#4a), Brunet Park (#6a), and Skunk's Misery (#7) are publicly accessible (see Table 2) and are used for hiking, biking, and possible use by unauthorized motorized off-road vehicles. Hiking or biking will trample nectar plants and may adversely impact adult food sources, cause soil compaction that results in larval or pupal mortality, and enable growth of ground cover that is too dense for larvae to burrow and find suitable overwintering and pupation sites.

6.3 Work and other activities (Unknown impact)

Portions of some Northern Oak Hairstreak habitats may be managed as gardens or have manicured grounds and/or vegetation. These activities likely impact pupal sites (e.g., through ground compaction, or planting non-native grasses, which grow and infill open ground habitats).

Threat 11. Climate Change and Severe Weather (Unknown Impact)

11.1 Habitat shifting and alteration (Unknown impact)

The species-specific response that Northern Oak Hairstreak will have to climate change is unknown. Emergence of larvae may be impacted by inadequate food supply if host plants are not available due to shifts in phenology.

11.2 Droughts (Unknown impact)

A hotter and drier climate may lead to periods of extreme drought which may also threaten larval host plant survival. In Canada, warming temperatures may facilitate expansion of Northern Oak Hairstreak populations (Wagner pers. comm. 2020).

11.3 Temperature extremes (Unknown impact)

Northern Oak Hairstreak overwinters as an egg, and it is likely that temperature plays a role in the timing of emergence. If eggs hatch too early there is a risk that young larvae could be killed by sudden fluctuations in spring temperatures, or there is insufficient host plant availability to sustain larval growth.

Limiting Factors

Limiting factors are generally not human-induced and include characteristics that make the species less likely to respond to conservation efforts. The main limiting factors for Northern Oak Hairstreak are speculative. Small population size in Canada could lead to inbreeding, loss of genetic diversity and decreased resilience to threats. These factors could also be compounded by limited dispersal ability. Most Lepidoptera have natural parasitic enemies, but no data exists on the specific parasites or predators of Northern Oak Hairstreak.

Northern Oak Hairstreak may rely on non-nectar resources such as aphid honeydew and galls on oak trees (Wagner and Gagliardi 2015) (see **Interspecific Interactions**). Extreme weather events could impact aphid and cynipid populations, and drought would lower availability of these types of resources. The length of a hairstreak's proboscis (tongue) may limit the nectar flower options; the depth of the corolla cannot be greater than the length of the proboscis.

Number of Locations

There are four to six subpopulations of Northern Oak Hairstreak (Table 1) and three to eight locations[10] for Northern Oak Hairstreak in Canada (Table 2). The number of locations was calculated based on the main threat; the potential spray of *Btk* to control non-native Spongy Moth. The minimum number of locations is three because there are three extant subpopulations (#4, 6, 7). The maximum number of locations is eight, because this tally includes extant, historical, and unconfirmed subpopulations and sites (#1, 2, 4a, 4b, 5, 6a, 6b, and 7). Locations are defined based on variable management approaches to control this threat within the habitat where the subpopulations occur. The decision to spray pesticide would be made by the responsible land manager (e.g., conservation authority, township, and/or First Nation Council). The scope and severity of the threats are different between subpopulations due to different land ownership and management of the habitat within, although the timing is similar across all subpopulations (e.g., spray would occur during the larval activity period).

[10] The term 'location' defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations. Where a taxon is affected by more than one threatening event, location should be defined by considering the most serious plausible threat. Where the most serious plausible threat does not affect all the taxon's distribution, other threats can be used to define and count locations in those areas not affected by the most serious plausible threat (IUCN 2010, 2011). In the absence of any plausible threat for the taxon, the term "location" cannot be used and the sub-criteria that refer to the number of locations will not be met.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Northern Oak Hairstreak is not protected by the Canada *Species at Risk Act* or the Ontario *Endangered Species Act*. Known larval host plants are also not protected under these acts.

Non-Legal Status and Ranks

Northern Oak Hairstreak has a global conservation status rank of Apparently Secure to Secure (G4G5T4) and a rounded global status of Apparently Secure (T4[11]). The species is ranked Critically Imperilled (S1) both nationally in Canada and provincially in Ontario (NatureServe 2020, NHIC 2020).

In the United States, subspecies *ontario* has a national rank of Apparently Secure (N4). Within individual states its ranking varies: S1 (Colorado, West Virginia, Michigan), S2 (Kentucky), S3 (Arkansas, Oklahoma, Virginia), S4? (Missouri), S1S2 (Maryland), S1S3 (Illinois), S2S3 (Indiana, Kansas, North Carolina), S2S4 (New York, Georgia), S3S4 (New Jersey). In Connecticut, Florida, Pennsylvania, and Louisiana it is considered unrankable (SU) (NatureServe 2020). In Massachusetts, it receives legal protection under the Massachusetts *Endangered Species Act* as a Species of Special Concern (Gagliardi and Wagner 2016).

In Ontario, White Oak is secure (S5) (NHIC 2020).

Habitat Protection and Ownership

An extant subpopulation in Lambton County (#4a, 4b) is within habitat owned and managed by St. Clair Region Conservation Authority (Table 2), and thereby protected legally by relevant authorities. The Town of LaSalle owns Brunet Park (#6a) which is also protected. One extant site in Lasalle (#6b) is privately owned and one is owned by Walpole First Nation (#5). In Middlesex County (#7), Northern Oak Hairstreak was observed in Skunk's Misery on a tract owned and managed by the Lower Thames Valley Conservation Authority; however, contiguous habitat that forms this natural area is owned and managed privately, by Middlesex County, and by the Thames Talbot Land Trust.

[11] "T" indicates intraspecific taxon (subspecies or varieties) (NatureServe 2020).

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Some photos by Bob Yukich and David Wagner. Front cover photograph by Bob Yukich, taken June 26, 2016, at Reid Conservation Area, northeast of Port Lambton, Ontario.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Jessica Linton is a Senior Manager and Biologist at Natural Resource Solutions Inc. in Waterloo, Ontario. She manages a wide range of projects that encompass natural area inventories, scientific research, recovery planning, and impact assessments. Jessica is a member of the COSEWIC Arthropod Species Specialist Subcommittee, President of the Toronto Entomologist's Association, and the Coordinator of Ontario's Butterfly Species at Risk Recovery Team. She has completed extensive fieldwork, status assessments, and recovery planning documents for a variety of species at risk, with an emphasis on Lepidoptera with specialized adaptations to oak woodland, savanna and prairie habitats in southwestern Ontario.

COLLECTIONS EXAMINED AND ONLINE SOURCES

The following collections were searched for specimens of Northern Oak Hairstreak:

Canadian National Collection of Insects, Arachnids and Nematodes, Ottawa, Ontario (Schmidt pers comm. 2020).

Royal Ontario Museum, Toronto, Ontario (Hubley pers comm. 2020).

Biodiversity Institute of Ontario, University of Guelph, Guelph, Ontario (deWaard pers. comm. 2020).