COSEWIC
Assessment and Status Report

on the

Reversed Haploa Moth
Haploa reversa

in Canada

ENDANGERED
2019

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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Reversed Haploa Moth, Walsingham, Ontario July 2015; by Mary Gartshore.

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COSEWIC
Assessment Summary

Assessment Summary – November 2019

Common name
Reversed Haploa Moth

Scientific name
Haploa reversa

Status
Endangered

Reason for designation
This rare moth is restricted to four areas of southwestern Ontario, which are considered separate subpopulations (Lambton County, Norfolk County, London, and Essex County). It has only been detected in proximity to oak savanna, oak woodland and dunes. In Ontario, up to 98% of oak savanna has been lost and remaining oak woodlands are small and fragmented. The quality of remaining habitat continues to decline as a result of fire suppression and invasive plants. Other potential threats include insecticide spraying during Gypsy Moth outbreaks which kills both the pest and the caterpillars of this moth.

Occurrence
Ontario

Status history
Designated Endangered in November 2019.

COSEWIC
Executive Summary

Reversed Haploa Moth
Haploa reversa

Wildlife Species Description and Significance

Reversed Haploa Moth (*Haploa reversa*) is medium-sized (wingspan of 33 – 48mm) and with a dorsal wing pattern of brown bands and white patches, including a distinctive white triangular basal patch extending from the thorax through to the forewings; and three similarly sized, distinctive white costal patches (patches on the leading edge of the forewing). The larvae are black with yellow to orange longitudinal stripes and an orangish to reddish dorsal stripe; and are covered in bristly spines.

In Canada, Reversed Haploa Moth is associated with oak savanna, oak woodland and dune habitats within the Carolinian zone of southwestern Ontario. These habitats are among the most endangered habitats in Canada; approximately 98% have been lost and 2256ha is all that remains. The decline and extirpation of several rare lepidoptera, which occurred in the same geographic areas as Reversed Haploa Moth, has been attributed to the loss of these oak savanna habitats.

Distribution

Reversed Haploa Moth ranges in North America from southeast Minnesota to Texas and western Arizona, east to portions of southwestern Ontario, Ohio and North Carolina.

In Canada, Reversed Haploa Moth is restricted to four geographically separated areas of southwestern Ontario which are considered four separate subpopulations: Lambton County, Norfolk County, Essex County and the London area. The dispersal between known subpopulations is unlikely. However the subpopulation in the London area may be connected to known subpopulations in Michigan, which have records approximately 11-21km away and rescue may be possible.

Habitat

The habitat requirements of Reversed Haploa Moth are not fully understood. *Haploa* moth larvae are polyphagous (able to feed on many plant species), and early instars are commonly associated with *Eupatorium* species (bonesets, thoroughworts or snakeworts), a genus native to temperate regions of the Northern Hemisphere and occurring in mesic habitats. To date, there have been two larvae observed in Canada: one larva feeding on Hairy Puccoon (*Lithospermum caroliniense*) and the other not feeding.

Biology

Reversed Haploa Moth has one generation per year and adults fly from late June to late July and peak in mid-July. Mating, oviposition and larval feeding behaviour is undescribed but in other *Haploa* species, courtship is initiated when the female releases sex attractant pheromones and females oviposit directly on host plants. Pupation occurs in the spring. Larvae may not be dependent on a unique host plant for feeding and observations in other *Haploa* species suggest that different larval instars may feed on different plant species. Reversed Haploa Moth is non-migratory and its dispersal abilities are unknown.

Population Sizes and Trends

In Canada, search effort has included capturing adults in light traps and/or flushing them from vegetation during general insect net sweeping in wet meadow habitat (within an oak woodland/savanna and sand dune landscape), larval searches and photographs posted to online naturalist forums.

No population estimates are available for Reversed Haploa Moth. The species is known from four extant subpopulations and has only been regularly recorded at the Lambton County subpopulation (sites in Grand Bend, Port Franks, and Ipperwash). There are two records for Walsingham (Norfolk County), two records for Ojibway Prairie (Windsor, Essex County), and one record from London (The Coves). Individuals were confirmed at all four subpopulations during 2018 and 2019.

Threats and Limiting Factors

Threats to Reversed Haploa Moth are associated with the historical decline in the oak woodland and savanna habitats (including dunes within these habitats) in which the moth has been recorded, and the resulting impacts associated with this historical habitat fragmentation. Wide-scale pesticide spraying of *Bacillus thuringiensis* (*Bt*) to control the non-native European Gypsy Moth (*Lymantria dispar dispar*) is ongoing within the local municipalities where this moth occurs, and is considered the highest threat to Reversed Haploa Moth subpopulations. Recreational activities and inappropriate habitat management, leading to competition with invasive plant species and/or canopy closure, are possible at all subpopulations. It is unknown how climate change will affect Reverse Haploa Moth subpopulations, which may make the timing of emergence of larvae asynchronous with the availability of their larval host plants.

Protection, Status and Ranks

Reversed Haploa Moth is not listed under the Canada *Species at Risk Act* or the Ontario *Endangered Species Act*. It is not protected by any federal or state legislation in the United States. The species is globally ranked as Secure (G5) and nationally in Canada as Vulnerable to Imperiled (N2N3). In Ontario, it is also considered Vulnerable to Imperiled (S2S3) and its status is not ranked subnationally in the United States.

TECHNICAL SUMMARY

Haploa reversa

Reversed Haploa Moth

Haploa inversé

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?	Yes; however a continuing decline could be inferred based on 98% historical habitat loss and continuing decline of habitat quality.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period 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 (historical); No (current) c. Unknown
Are there extreme fluctuations in number of mature individuals?	No. Regular trapping over a decade in Lambton County has not revealed subpopulation fluctuations.

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	EOO = 9 098 km² (based on minimum convex polygon around extant observations, within Canada's extent of jurisdiction) EOO = 9 509 km² (based on minimum convex polygon around extant observations)
Index of area of occupancy (IAO)(2x2 grid value)	36 km²
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. Yes

Number of "locations"*	5, based on the spraying of *Bacillus thuringiensis* (*Bt*) pesticides to control non-native Gypsy Moth (*Bt* is lethal to all lepidoptera larvae) within the geographic areas where Reversed Haploa Moth occurs.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes, inferred based on habitat decline and potential *Bt* pesticide spray
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes, inferred based on habitat decline and potential *Bt* pesticide spray
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes, inferred based on habitat decline and potential *Bt* pesticide spray
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Yes, inferred based on habitat decline and potential *Bt* pesticide spray
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes; continuing decline of habitat quality.
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

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Total	Unknown

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Unknown

*See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term.

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

Was a threats calculator completed for this species? Yes, threats assessment conference call completed on December 20, 2018 and updated December 17, 2019 (Table 3).

9.3 Agriculture and forestry effluents (High impact)
6.1 Recreational activities (Low impact)
7.1 Fire (Low impact)

What additional limiting factors are relevant?

- Small subpopulation size.
- Limited dispersal ability.
- Host plant specificity.
- Natural parasites.
- Vulnerability to weather patterns.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Unknown
Is immigration known or possible?	Possible for Ojibway Prairie subpopulation; however, dispersal capability and status of nearest populations in Michigan are unknown
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Unknown
Are conditions deteriorating in Canada?[+]	Yes; based on slow changes to habitat quailty from the spread of invasive species (e.g., Gypsy Moth and invasive plants).
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?	Possible for Ojibway Prairie subpopulation; however, dispersal capability and status of nearest populations in Michigan are unknown

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC: Designated Endangered in November 2019.

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

Status and Reasons for Designation:

Status:	**Alpha-numeric codes:**
Endangered	B2ab(iii,v)
Reasons for designation: This rare moth is restricted to four areas of southwestern Ontario, which are considered separate subpopulations (Lambton County, Norfolk County, London, and Essex County). It has only been detected in proximity to oak savanna, oak woodland and dunes. In Ontario, up to 98% of oak savanna has been lost and remaining oak woodlands are small and fragmented. The quality of remaining habitat continues to decline as a result of fire suppression and invasive plants. Other potential threats include insecticide spraying during Gypsy Moth outbreaks, which kills both the pest and the caterpillars of this moth.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered, B2ab(iii,v), as IAO (36 km²) is under 500 km², exists at 5 locations, and there is inferred decline in number of mature individuals based on decline of habitat quality.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable.
Criterion D (Very Small or Restricted Population): Not applicable.
Criterion E (Quantitative Analysis): Not applicable.

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 (2019)

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 Arthropods – Arthropoda

Class Insecta – Insects

Order Lepidoptera – Butterflies and Moths

Superfamily Noctuoidea – Owlet Moths and kin

Family Erebidae – tussock moths, tiger moths, underwings and relatives

Subfamily Arctiinae – Tiger and Lichen Moths

Tribe Tiger Moths – Arctiini

Subtribe – Callimorphina

Genus – *Haploa*

Species – *Haploa reversa* – Reversed Haploa Moth

Synonyms: *Callimorpha reversa* Stretch, 1885
Callimorpha suffusa Smith, 1887
Callimorpha suffusa Smith, 1888

Type Locality: Unknown

Type Specimens: Unknown

French common name: Haploa inversé

English common name: Reversed Haploa Moth

Reversed Haploa Moth (*Haploa reversa*) was first described by Stretch (1885). Following taxonomic revisions by Lafontaine and Schmidt (2010), the traditional Arctiidae have been transferred to family Erebidae as a subfamily (Arctiinae). The circumscription of Arctiinae remains virtually identical to recent circumscriptions of Arctiidae (NatureServe 2018).

Only three specimens have had their mitochondrial DNA barcoded, none of which are from Canada (deWaard pers. comm. 2018). Barcodes alone, which use a single gene, are unable to distinguish Reversed Haploa Moth from three other *Haploa* species in North America: Leconte's Haploa Moth (*H. lecontei*, Guérin-Méneville 1844) and Confused Haploa Moth (*H. confusa*, Lyman 1887), which also occur in Ontario, and Colona Moth (*H. colona*, Hübner 1803), which occurs from southeastern Virginia south to Florida and west to Texas. Further genetic analysis (e.g. microsatellites) is required to distinguish these species beyond the genus level.

Morphological Description

Like all Lepidoptera, Reversed Haploa Moth has four distinct morphological forms: egg, larva, pupa, and adult.

Adult:

Reversed Haploa Moth has an average forewing length of 21 - 23mm (Figure 1). The forewing inner margin, costa (leading edge of forewing), and outer margin have broad dark brown bands, interrupted at the apex by a white patch. There is a distinctive white, triangular forewing basal patch extending from the thorax; and three similarly sized, distinctive white costal patches. There are two to four white submarginal patches on the forewings which together form a triangular shape. The hindwings are entirely white with some individuals displaying one to two small brown submarginal spots. Ventrally, the dark markings appear faded or washed out, with a distinct yellow ochre tinge corresponding to the dorsal dark markings, and along the veins and costa of fore- and hindwing. The head, prothorax (segment of the thorax near the head) and palpi are ochre yellow, the latter with black tips. The thorax is white with a broad dorsal brown stripe; the abdomen is white and with or without a broken, narrow dorsal stripe. The legs are ochre yellow, and lined with brown along the outer surface.

Figure 1. Reversed Haploa Moth (*Haploa reversa*) specimens from Lambton County (Ken Stead personal collection). Photo by Jessica Linton (with permission).

In Canada, adults may be confused with Leconte's Haploa Moth (*H. lecontei*) and the Confused Haploa Moth (*H. confusa*). All three of these moths display similar colour patterns and identification errors can occur. However, the shape and extent of the white basal forewing patch, in combination with the size and shape of the three costal white patches, usually distinguishes these three species. A colour form of Confused Haploa Moth (form *triangularis*), with an extended basal white patch that lacks the dark sub-basal brown bar that is usually present in that species, is very similar to Reversed Haploa Moth and often misidentified as such. This form can be distinguished from Reversed Haploa Moth by the more irregular shape of the basal white patch, smaller costal white patches, broader dark border of the inner (anal) wing margin, and overall smaller size (forewing length usually fewer than 20mm). A pure white colour form of Reversed Haploa Moth also occurs, which cannot be reliably distinguished from white colour forms of other *Haploa* species. However, pure white forms occur further south in the range of Reversed Haploa Moth, and have not been documented from Canada (Schmidt pers. comm. 2018).

Larva:

The larvae are covered in setae (bristly spines). The body is black with longitudinal stripes ranging from yellow to orange and an orangish to reddish dorsal stripe which is diagnostic among *Haplo*a larvae within the Canadian range of Reversed Haploa Moth (Schmidt pers. comm. 2018) (Figure 2). The number of instars is unknown but *Haploa* species (e.g., *H. colona*) usually have six instars (Dyar 1897).

Figure 2. Larva of Reversed Haploa Moth (*Haploa reversa*) from Minnesota. Photo by Brad Bolduan (with permission).

Pupa:

The pupa is undescribed; however, species in the Subtribe Callimorphina have a delicate pupa made of fine silk with a cremaster (hooklike tip which serves as an anchorage point) (Weller *et al.* 2009).

Egg:

The eggs are undescribed. In related species (e.g., *H. colona*), eggs have been described as 0.6mm in diameter, flat at the base, and roughly spherical (Dyar 1897).

Population Spatial Structure and Variability

The population structure of Reversed Haploa Moth, including the geographic boundaries of subpopulations boundaries, structure variability or size, is poorly understood. Specimen records indicate the moth is restricted to oak woodland, dune, and savanna habitats of the Carolinian zone of southwestern Ontario, where it is currently known from four geographically isolated areas (see Canadian Range). The known distribution suggests that the Canadian population may be composed of subpopulations that are connected through dispersal at a local scale, but are isolated at a regional scale. The Ojibway Prairie subpopulation may not be geographically isolated from known subpopulations in Michigan, which have reported records 11-21km away (iNaturalist 2018).

Designatable Units

Reversed Haploa Moth has one designatable unit in Canada. All subpopulations fall within the Great Lakes Plains National Ecological Area (COSEWIC 2007). No subspecies have been described and there is no evidence to suggest they represent discrete and evolutionarily significant populations.

Special Significance

In Canada, Reversed Haploa Moth has a restricted geographic range due to its close association with the highly fragmented and at risk oak savanna, oak woodland and dune system habitats in the Carolinian zone of southwestern Ontario. Oak savanna habitats once covered more than 11,000,000 hectares (ha) of North America, but are now one of the most endangered habitat types in Canada (Rodger 1998). The decline and extirpation of several rare lepidoptera (e.g., Karner Blue [*Lycaena melissa samuelis*], Frosted Elfin [*Callophrys irus*] and Eastern Persius Duskywing [*Erynnis persius persius*]) have been attributed to the loss of oak savanna habitat in Canada and these three butterflies once occurred in some of the same geographic areas as Reversed Haploa Moth.

Tallgrass and dune habitats in the Carolinian Zone of southwestern Ontario represent one of a small number of areas in Canada where every remaining habitat patch is important to conserve given the high proportion of species at risk and habitat specialists in these regions.

Reversed Haploa Moth is of interest to entomologists and taxonomists because of its rarity and association with the rare and endangered habitats in which they occur. There is no information that suggests that Reversed Haploa Moth has, or had, an important cultural or economic role for Indigenous peoples.

DISTRIBUTION

Global Range

Reversed Haploa Moth ranges across much of North America and occurs from southeast Minnesota to Texas and western Arizona east to portions of southwestern Ontario, Ohio and North Carolina (Figure 3).

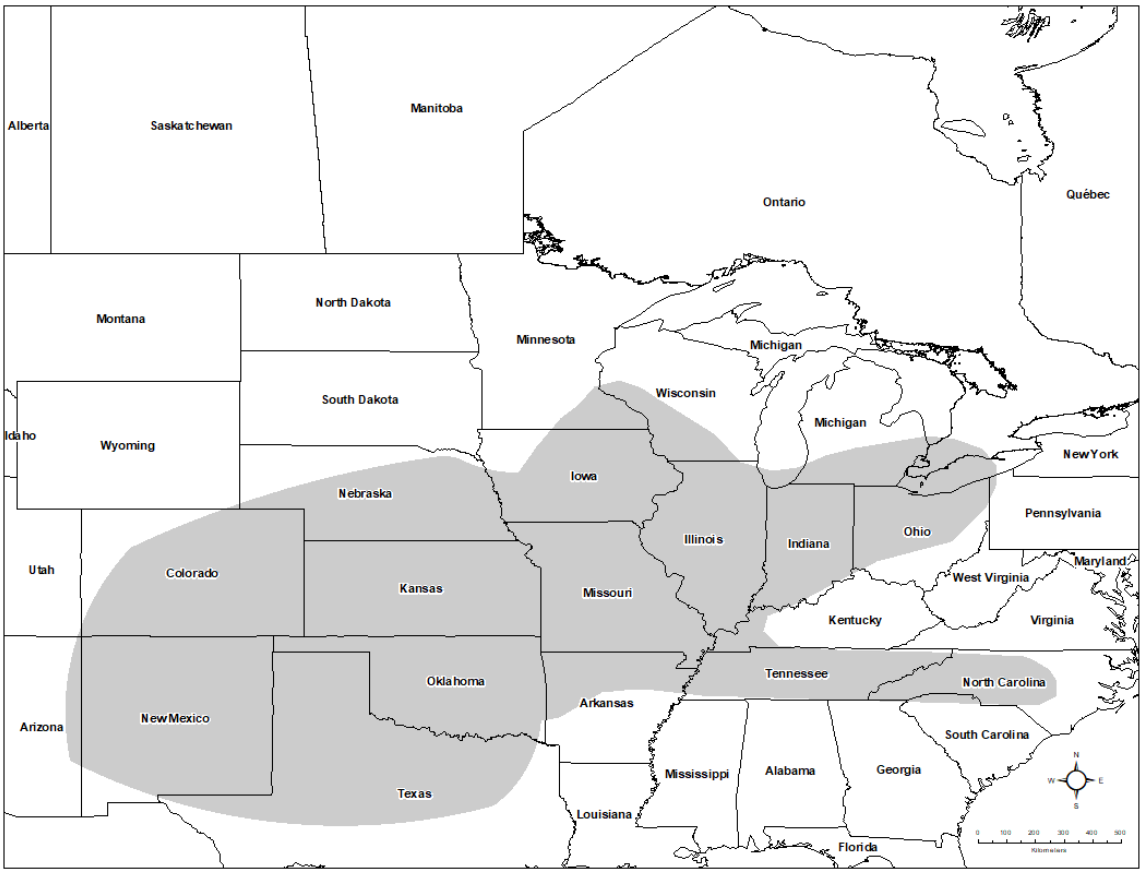

Figure 3. Global distribution of Reversed Haploa Moth (*Haploa reversa*). Map produced by Laura Hockley, Natural Resource Solutions Inc. (with permission).

Canadian Range

In Canada, Reversed Haploa Moth has a range restricted to the oak savanna, oak woodland and dune habitats of southwestern Ontario (Figure 4). The species is known from four geographically separate subpopulations (Table 1, Figure 5): Lambton County (six collection sites), Walsingham (Norfolk County, one site), London (one site), Ojibway Prairie (Windsor, one site[1]). All known subpopulations are considered extant (presence confirmed in 2018 or 2019) and there are no known historical collection sites where this species is no longer detected.

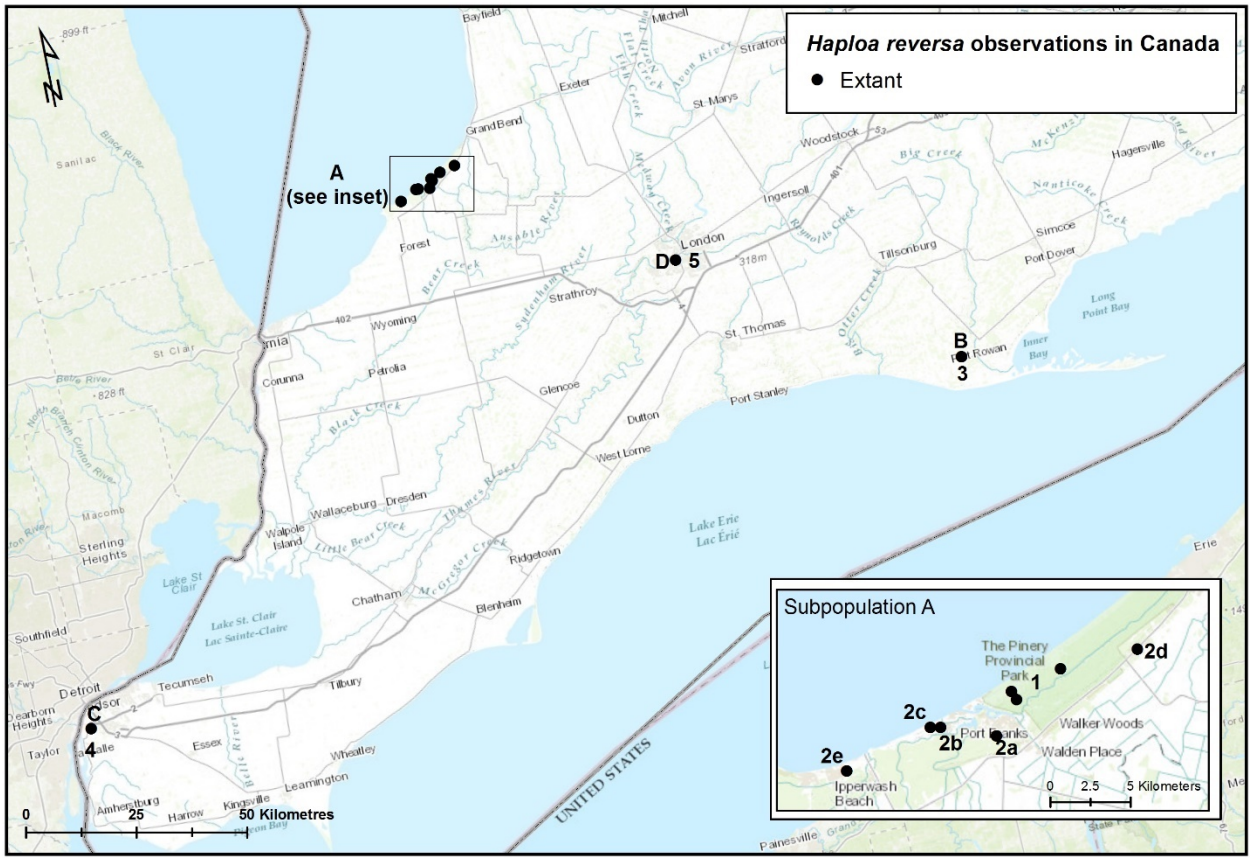

Figure 4. Reversed Haploa Moth (*Haploa reversa*) subpopulations in Canada. Capital letters correspond to the four subpopulations and numbers correspond to five locations (see Table 1). Map created by the COSEWIC secretariat.

[1] The exact location of one record is obscured on iNaturalist; however, it is within close proximity of Ojibway Prairie, which provides the only known suitable habitat in the area.

Table 1. Subpopulation, location (threat-based) and site information for Reversed Haploa Moth (*Haploa reversa*). Locations are based on the threat of potential aerial spraying of *Bacillus thuringiensis* (*Bt*) to control the non-native Gypsy Moth outbreaks within the four counties where Reversed Haploa Moth occurs. The timing of these programs (May-June) is consistent with the larval stage of Reversed Haploa Moth, and therefore represent a serious threat if applied to areas where it occurs.

Subpopulation Name (four subpopulations)	Location #	Site Name and Closest Municipality	Habitat	Spatial Area	Land Ownership	Potential Threat(s)
Lambton County Subpopulation A	1	Pinery Provincial Park (Lambton County)	dune, savanna and oak woodland	>2500 ha (park); collected from at least 4 sites within the park (assumed to occur throughout park)	Crown (Provincial Park) Actively managed to promote oak savanna health	-Recreational activities -Fire -Invasive plant growth (scored under 7.3) - pesticide spray to control Gypsy Moth are unlikely at this property.
Lambton County Subpopulation A	2a	Karner Blue Sanctuary, Port Franks (Lambton County)	dune, savanna and oak woodland	15 ha	Private (protected area owned by Lambton Wildlife Inc.)	- Fire suppression - Recreational activities - Invasive plant growth (scored under 7.3) - *Bt* pesticide spray to control Gypsy Moth
Lambton County Subpopulation A	2b	Port Franks residence (Lambton County)	residential area with nearby oak woodland and wetlands	>1ha	Private	
Lambton County Subpopulation A	2c	Port Franks Sand Dune (Lambton County)	sand dune	>18 ha	In the process of being transferred to First Nations, currently owned by federal Department of National Defence.	
Lambton County Subpopulation A	2d	Grand Bend residence (Lambton County)	savanna and oak woodland	>10 ha	Private	
Lambton County Subpopulation A	2e	Ipperwash Dune (Lambton County)	sand dune	<2ha	Owned by Province of Ontario, designated as Open Space (Floodplain).	
Norfolk County Subpopulation B	3	Walsingham (Norfolk County)	oak woodland	Unknown. Contiguous woodland > 900 ha adjacent to collection site.	Specific record from private land. Adjacent areas include a large matrix of oak woodland/savanna and prairie restoration sites owned by Nature Conservancy Canada and other conservation bodies.	None identified on the private property; however, threats to the adjacent property (habitat where the moth may also occur) include - invasive plant growth (scored under 7.3) - fire suppression - *Bt* pesticide spray to control Gypsy Moth

Subpopulation Name (four subpopulations)	Location #	Site Name and Closest Municipality	Habitat	Spatial Area	Land Ownership	Potential Threat(s)
Essex County Subpopulation C	4	Ojibway Prairie, Windsor (Essex County)	savanna, prairie, and oak woodland	66 ha (Tallgrass Prairie Heritage Park, Black Oak Heritage Park, and Spring Garden Natural Area; the total area of potential habitat may be up to 105 ha)	City of Windsor (Parks and Recreation Department)	- Recreational activities - Fire -Invasive plant growth (scored under 7.3) - *Bt* pesticide spray to control Gypsy Moths
City of London Subpopulation D	5	The Coves ESA (City of London)	deciduous hardwood forest and oak woodland	85ha (deciduous woodland, oak woodland, wetland surrounding oxbow lakes)	Private and City of London	- Fire suppression - Recreational activities - Invasive plant growth (scored under 7.3) - *Bt* pesticide spray to control Gypsy Moths

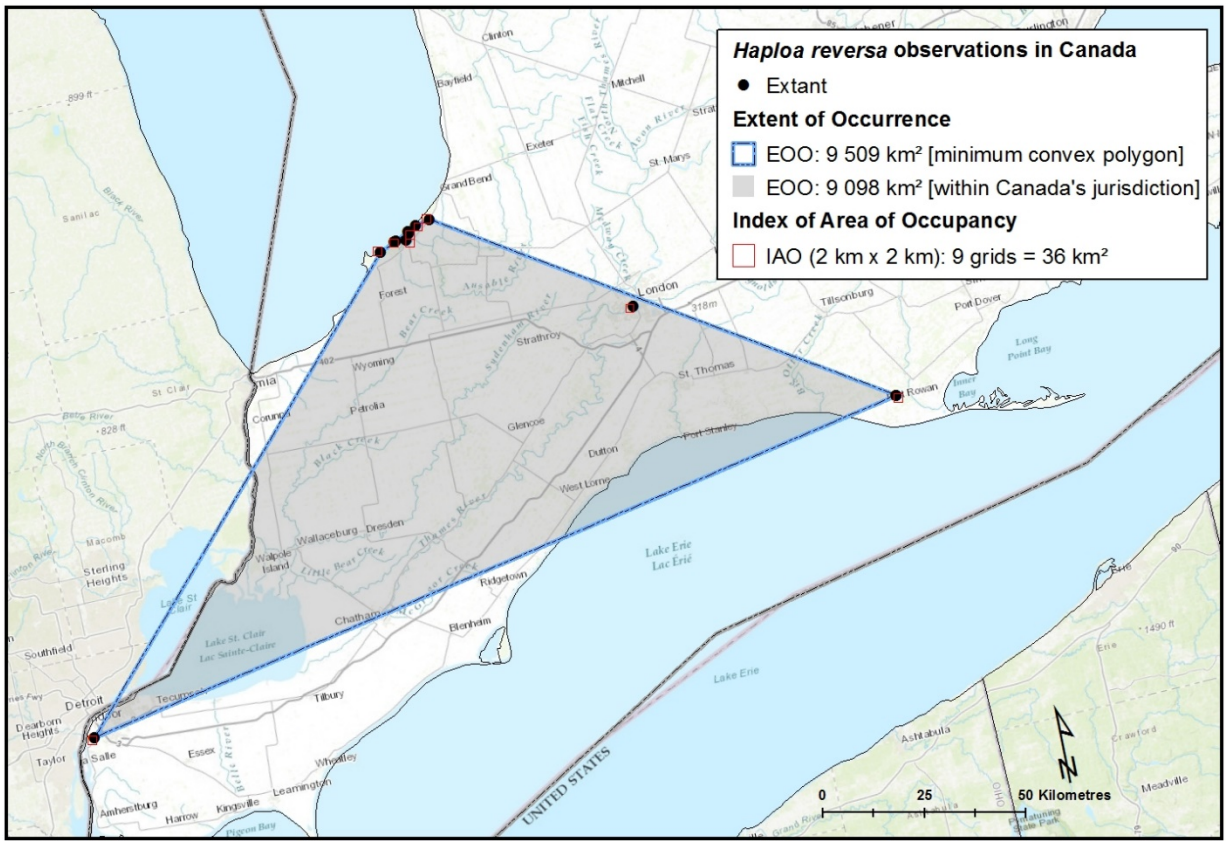

Figure 5. Extent of occurrence for Reversed Haploa Moth (*Haploa reversa*). Includes the four subpopulations and all known sites where the moth has been recorded (Table 1). Map created by the COSEWIC secretariat.

Extent of Occurrence and Index of Area of Occupancy

The extent of occurrence (EOO) is approximately 9,509 km^2 using a minimum convex polygon encompassing all known sites. The EOO within Canada's extent of jurisdiction is 9,098 km². The index of area of occupancy (IAO) is 36 km^2, based on a fixed 2 x 2 km grid.

Search Effort

Reversed Haploa Moth was first recorded in Canada in 1885 in the species' original description (Stretch 1885) and the most recent records are from 2018 (Table 1). There are a minimum of 78 museum specimen and sight records of the moth collected from four separate geographic areas in Ontario: Lambton County (various dates and sites from 1993 - 2018), Walsingham in Norfolk County (one site in 2015 and 2018), London (one site in 2019) and Ojibway Prairie outside Windsor in Essex County (one site in 2015 and 2018) (Table 1). Moth observing is popular among the professional and amateur entomologists in southwestern Ontario and there have been 646 observations of *Haploa* moths added to iNaturalist from across the province since 2015, the majority of which have been from southwestern Ontario. Of those 646 observations, fewer than 20 are of Reversed Haploa Moth and are from three of the known sites.

During the flight season and within suitable habitat, Reversed Haploa Moth is readily captured at black/ultraviolet and mercury vapour light traps. This search effort method is considered appropriate for this and other *Haploa* moth species (Troubridge pers. comm. 2018). The species has also been incidentally captured during the day when flushed from vegetation. Larval surveys on host plants are also considered an appropriate survey method (Schmidt pers. comm. 2018), but to date have not produced records in Canada.

To date, Reversed Haploa Moth has primarily been detected through light trapping (Table 1 and 2). It is considered relatively common during its flight period in Lambton County and is regularly encountered in light traps (Troubridge pers. comm. 2018). However, there has been substantially more light trapping in the Lambton County area than in any other area of Ontario, which may account for its higher detection rate. This included light trapping in the Grand Bend area and the Manestar Tract at the St. Williams Forestry Reserve in Norfolk County; and targeted surveys for mature larvae on puccoon plants in Norfolk County, Grand Bend, Port Franks, Point Pelee, and Ojibway Prairie.

Reversed Haploa Moth has been documented from several sites along the shore of Lake Huron in Lambton County including Pinery Provincial Park, several sites in Port Franks, and a site in Ipperwash (Figure 4). There are photographic records of two individuals from Norfolk County in 2015 and 2018 (Beadle pers. comm. 2018; Gartshore pers. comm. 2018), London in 2019 (Jackson pers. comm. 2019), and individuals from Ojibway Prairie in 2015 (Preney pers. comm. 2018) and 2018 (Foy 2018).

In 2018, daytime net sweep surveys by several observers in Pinery Provincial Park flushed the species from wet meadow vegetation (Linton pers. obs. 2018), suggesting it was breeding in that area, presumably on a plant other than Hairy Puccoon (Schmidt pers. comm. 2018). Malaise traps at Pinery Provincial Park (and other sites) have failed to detect Reversed Haploa Moth, although this is not considered an optimal survey method. Larval surveys on host plants are also considered an appropriate survey method (Schmidt pers. comm. 2018). To date only two mature larvae have been observed; one was observed on a thistle plant in Ojibway Prairie (2019) but not actively feeding (Preney pers. comm. 2019) and one in Pinery Provincial Park (2019) was feeding on Hairy Puccoon (King 2019 pers. obs.).

Additional search effort in Long Point and Walpole Island may yield additional sites for Reversed Haploa Moth; these areas are within the species' known range and have appropriate habitat.

HABITAT

Habitat Requirements

In Canada, Reversed Haploa Moth has been recorded from oak woodland, oak savanna, and/or sand dune habitats. The species has been recorded within a large oak woodland rural residential property in Walsingham, in oak woodland in London, and within an oak woodland and sand dune habitat cottage property in Port Franks. Adults have been flushed from vegetation in Pinery Provincial Park during general insect net sweeping in wet meadow habitat (within an oak woodland/savanna and sand dune landscape) (Figure 7). More specific habitat requirements are undocumented. In general, *Haploa* moths tend to prefer mesic habitats, not dry sandy areas (Schmidt pers. comm. 2018).

Figure 6. Reversed Haploa Moth (*Haploa reversa*) collection site in Port Franks. Photo by Jessica Linton (with permission).

Figure 7. Reversed Haploa Moth (*Haploa reversa*) collection site in Pinery Provincial Park. Photo by Jessica Linton (with permission).

Reversed Haploa Moth is dependent on larval food resources during its life cycle. To date, there is one larval feeding observation in Canada on Hairy Puccoon. *Haploa* moth larvae are polyphagous (i.e., feed on numerous plant species), which is common in postdiapause larvae (i.e. larvae that break diapause and begin feeding), although early instars commonly feed on *Eupatorium* species that are associated with wetlands or watercourses (Wagner 2009). Members of this genus are commonly associated with plants in the sunflower (Asteraceae) and borage (Boraginaceae) families but forage widely after hibernation (Wagner 2009). In other parts of its range Reversed Haploa Moth has been observed feeding on Hoary Puccoon (*Lithospermum canescens*) (Maxson 2013; Molano-Flores 2001) and Hairy Puccoon (*Lithospermum caroliniense*) (Hatfield 2018).

In Ontario, Hoary Puccoon and Hairy Puccoon occur in areas with sand and dunes, fields, prairies, and open woods (Oldham and Brinker 2009). Both plants are present in Lambton County and Norfolk County, while only Hoary Puccoon is found in the Windsor area of Essex County. Puccoon distribution in Ontario was mapped (see Ramcharan 1975) and both plants are of high conservation priority (conservation status rank of S3, Vulnerable) by the Natural Heritage Information Centre (NHIC 2018). Both species co-occur within shoreline areas of the Great Lakes south of the Canadian Shield, but Hairy Puccoon

has a larger geographic range. Hairy Puccoon is found in its highest densities in the Point Pelee, Grand Bend, Port Franks, Long Point, Rondeau, and Wasaga Beach areas (Bakowsky pers. comm. 2018; Deacon pers. comm. 2018; Oldham pers. comm. 2018). Hoary Puccoon also occurs in Grand Bend, Port Franks, Long Point, and Wasaga Beach in addition to the Ojibway Prairie (Ramcharan 1975). Puccoon plants are present (or in close proximity) to all Reversed Haploa Moth sites in Lambton County and Ojibway Prairie where the moth has been captured in light traps. However, at the Walsingham site, where Reversed Haploa Moth has been captured twice, the nearest known puccoon occurrence is approximately 10km from the collection site (Gartshore pers. comm. 2018). Both puccoon species appear to have been historically present in London based on maps in Ramcharan (1975), but there are no recent records in iNaturalist© or in the NHIC database.

Most *Haploa* moth species prefer mesic habitats, not dry sandy areas, and may use more than one larval foodplant during their larval development (Schmidt pers. comm. 2018). It is possible that Reversed Haploa Moth is using an alternate foodplant in Canada, given larvae have been observed feeding on *Lithospermum* (see Search Effort). However, plants in this genus are not present at all observation sites. Early instar larvae may be feeding on plants such as *Eupatorium*, which are associated with mesic habitats. This is possible based on observations of the adult moths flushed from a wet meadow area at Pinery Provincial Park. However, larvae may move from damp dune sloughs and other wet areas to dryer habitats in proximity to known sites, to feed on plants such as puccoon as they mature (Schmidt pers. comm. 2018).

Habitat Trends

Oak savanna habitats have almost disappeared from the Mixedwood Plains Ecozone of southwestern Ontario; approximately 2,256 ha of prairie and savanna habitat remains within the province (Ontario Biodiversity Council 2015). The largest remaining example (over 900 hectares) is located in the Grand Bend and Port Franks area of Lambton County (ESTR Secretariat 2016). The two next largest sites (Windsor and Walpole Island First Nation) together total approximately 600 hectares (ESTR Secretariat 2016). These three large sites represent only 1.8 percent of the estimated historical extent of prairie and savanna habitat in Ontario (ESTR Secretariat 2016). Most remaining fragments are fewer than 0.5 hectares (ESTR Secretariat 2016). Ontario's coastal dune areas have been classified as a provincially rare vegetation type (occurring along the Great Lakes shorelines of Ecoregion 7E, Taylor *et al.* 2014). Six key dune areas found within 7E include Pinery Provincial Park, Pelee Island (Fish Point), Point Pelee National Park, Rondeau Provincial Park, Long Point and Point Abino.

More than half (61%) of the remaining prairie and savanna ecosystems in southwestern Ontario are legally protected; and 75% of freshwater coastal dune systems are in protected areas (Ontario Biodiversity Council 2015). More than half of these mapped communities (by the Ontario National Heritage Network) have been identified as having good to excellent predicted viability (Ontario Biodiversity Council 2015). However, the factors considered when assessing the quality of these vegetation communities are based solely on physical characteristics and processes, not ecological function for Reversed Haploa Moth.

Oak savanna and dune habitats in southwestern Ontario support a high proportion of national species at risk and provincially rare species. The current extent and spatial distribution of these habitat patches is not necessarily adequate to support viable populations of all the species which depend on them. For example, in the Long Point Walsingham Forest area of Norfolk County, there are 2,274 Open Country habitat patches mapped (CWS 2019). Of these patches, 88.5% are fewer than 1ha in area and 98% are fewer than 5ha in area. Although the majority of habitat patches in Ontario are protected physically, specific habitat suitability for Reversed Haploa Moth is likely decreasing due to invasive species ingrowth leading to lower abundance of host plants and competition with other herbivores for these resources; limited dispersal opportunities due to the increased plant growth, and thus lower genetic interchange; compromised ecological resilience; and decreased refugia availability associated with periodic disturbances required to maintain the habitat.

BIOLOGY

The biology of Reversed Haploa Moth is poorly understood; information below is inferred from related species in the same genus.

Life Cycle and Reproduction

Reversed Haploa Moth produces a single generation a year and the adult flight period is between late June to late July, peaking in mid-July (Stead and Zufelt 2017).

Male moths in the family Erebidae possess some of the most morphologically elaborate scent-disseminating structures known in the Lepidoptera (Birch *et al.* 1990). These structures are usually displayed immediately before mating and are thought to play a role in sexual selection (Eisner and Meinwald 1995). Mating behaviour for Reversed Haploa Moth is undescribed but in other *Haploa* species courtship is initiated by the female through the release of typical sex attractant pheromones (Davidson *et al.* 1997). When males reach the female they expose large abdominal pheromone signalling structures (coremata) near female antennae prior to copulation (Davidson *et al.* 1997). These pheromones are derived from compounds sequestered from their larval food plants (Davidson *et al.* 1997). In one study on Clymene's Haploa Moth (*H. clymene*), exposure of the coremata during the courtship process was critical to successful mating (Davidson *et al.* 1997).

Oviposition and larval feeding for Reversed Haploa Moth is undescribed but other species of *Haploa* oviposit directly on host plants (Nagle and Wagner 2009). The early instar larvae of Clymene's Haploa Moth feed in clusters on *Eupatorium* before dispersing to feed solitarily on a wide range of herbaceous and woody plants (Nagle and Wagner 2009). In *Haploa,* the common number of larval instars is six with hibernation occurring in the fourth or fifth instar. Hibernation likely occurs under leaves or bark; however, in at least one related species, completely exposed larvae have been observed during hibernation under bridges (Eichlin and Cunningham 1972). Pupation occurs in the spring after hibernation.

Physiology and Adaptability

Little is known about the physiology and adaptability of Reversed Haploa Moth. Observations to date indicate that it may not be dependent on a unique larval host plant for feeding or oviposition and observations in other *Haploa* species suggest that different larval instars may feed on different plant species.

Many tiger moth caterpillars are conspicuous in habit (i.e. readily apparent on plants), diurnally active, and brightly coloured, suggesting a lineage of chemical or physical protection (Wagner 2009). Deterrents or toxins to insects such as alkaloids commonly occur in the food plants of *Haploa* species, thus larvae probably have physiological or biochemical adaptations that enable them to avoid the effects of these potentially toxic compounds (Lindroth 1987). The apparent aposematic colouration of Reversed Haploa Moth larvae (i.e., black with bright yellow, orange or reddish longitudinal stripes) indicates that they may sequester alkaloids, an adaptation that is reported in the closely related Neighbour Moth, from its early instar stages feeding on *Eupatorium* (Davidson *et al.* 1997).

Dispersal and Migration

The dispersal abilities of Reversed Haploa Moth are unknown. The remnant dunes, oak woodland and savanna habitats where it has been recorded in Canada are geographically isolated by unsuitable habitat and dispersal between these habitats is unlikely. Reversed Haploa Moth is non-migratory and the species overwinters in Canada.

Interspecific Interactions

Interspecific interactions such as disease, predation, and/or parasitism have not been reported for Reversed Haploa Moth. Similar to all lepidoptera, Reversed Haploa Moth are undoubtedly subject to competition, predation and parasitism by a variety of other animals during all life stages (e.g., insects, spiders, birds). Although it is unknown if Reversed Haploa Moth directly compete for larval food resources with other species, or if they are feeding on puccoons in Canada (as reported in other parts of their range), larvae of other *Haploa* species (*H. contigua* and *H. confusa*) have been observed on puccoon plants at known sites for Reversed Haploa Moth in Ontario (Linton pers. obs.).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Light trapping appears to be an effective method for detecting Reversed Haploa Moth at known sites in Lambton County (see Table 2). The moth has also been flushed from vegetation during its inactive diurnal period, suggesting that daytime net sweeping may also be an effective survey method. *Haploa* larvae are generally conspicuous diurnal feeders; however, the uncertainty about larval food plants for Reversed Haploa Moth makes this detection method problematic.

Table 2. Search Effort for Reversed Haploa Moth (*Haploa reversa*). UVL = ultraviolet light trap; BL = black light trap; MVL = mercury vapour light trap; all three light traps are adjacent to white sheets; if not specified the type of light trapping is unknown.

Site	Search Effort	Date	#	Notes	Surveyor(s)
Point Pelee (*L. caroliniense, L. incisum* present along West Beach Trail)					
Point Pelee	9 UVL	Unknown dates in 2008 and 2010	0	BIObus Summary report	BIObus (University of Guelph)
Point Pelee	BL (2 hrs)	July 8, 2017	0	1 light trap at Visitor's Centre	Maurice Bottos (public event with Park Staff)
*Point Pelee	3 person hrs visual search	June 6, 2018	0	350+ puccoon plants checked along west beach trail	Jessica Linton and Rachel Winsor
Point Pelee	1 night (1 light trap)	July 21, 2018	0	1 light trap along west beach trail	Tom Preney and Maurice Bottos
Port Franks (*L. caroliniense*)					
Port Franks	Unknown # nights (1 light trap)	July 5, 1993	1	Specimens in the University of Guelph Insect Collection	Ken Stead
Karner Blue Sanctuary	Unknown # nights (1 light trap)	July 24, 1993	1	# of negative trapping dates not recorded (centroid of Karner Blue Sanctuary)	Ken Stead
Port Franks	Unknown # nights (1 light trap)	July 5, 6 and 8, 1994	3	# negative trapping dates not recorded (Private Property)	Ken Stead
Port Franks	Unknown # nights (1 light trap)	June 30, July 12, 1995	2	# negative trapping dates not recorded (Private Property)	Ken Stead
Port Franks	Unknown # nights (1 light trap)	July 7, 1996	1	# negative trapping dates not recorded (Private Property)	Ken Stead
Port Franks	Unknown # nights (1 light trap)	July 16, 25, 28, 1997	3	# negative trapping dates not recorded (Private Property)	Ken Stead
Port Franks	Unknown # nights (1 light trap)	July 3, 6, 7, 1999	4	# negative trapping dates not recorded (Private Property)	Ken Stead
Port Franks	Unknown # nights (1 light trap)	July 6, 2010	1	# negative trapping dates not recorded (Private Property)	Ken Stead
Port Franks	14 BL once / week or every other week	2014 to 2018	**	Exact spots not documented but extensive trapping in area done and no *Haploa reversa* detected	Jim Troubridge

Site	Search Effort	Date	#	Notes	Surveyor(s)
Port Franks Sand Dune	Unknown # nights (1 light trap)	2017	1+	Captured at this site on several occasions but abundance not recorded	Ken Stead
Port Franks	1 BL	July 6, 2018	4	Private property	Jim Troubridge
*Port Franks Sand Dune	2 person hrs visual search	June 7, 2018	0	80-100 puccoon plants checked	Jessica Linton and Ken Stead.
Port Franks	1 BL	June 30, 2018	1+	Abundance not documented. Private property	Jim Troubridge
Port Franks	1 night (1 MVL)	July 18, 2018	1	Private property	Ken Stead
Pinery Provincial Park (*L. caroliniense, L. canescens*)					
Pinery Provincial Park	Unknown # nights (1 light trap)	July 12, 1993	1	# negative trapping dates not recorded; 1 trap at visitors' centre	Ken Stead
Pinery Provincial Park	Unknown	July 10, 1993	1	University of Guelph Insect collection	G. Vogg
Pinery Provincial Park	Unknown	July 15, 1994	1	University of Guelph Insect collection	Jeff Skevington
Pinery Provincial Park	Unknown	July 25, 1994	1	University of Guelph Insect collection	G. Vogg
Pinery Provincial Park	Unknown # nights (1 light trap)	June 19, 1995	1	# negative trapping dates not recorded	Ken Stead
Pinery Provincial Park	1 Malaise Trap for 20 weeks (included entire flight period of *H. reversa*)	April 30 to September 17, 2014	0	*Haploa contigua* was captured	Centre for Biodiversity Genomics
Pinery Provincial Park	1 light trap ran daily during flight period (30+ nights)	July 5-7, 9, 13-15, 21-27, 2016	24	# negative trapping dates not recorded; 1 trap at visitors' centre	Ken Stead
Pinery Provincial Park	1 light trap ran daily during flight period (30+ nights)	June 28, July 1, 4, 10, 13, 2017	6	# negative trapping dates not recorded; 1 trap at visitors' centre	Ken Stead
Pinery Provincial Park	1 light trap ran daily during flight period (30+ nights)	July 5 and 6, 2018	5	# negative trapping dates not recorded; 1 trap at visitors' centre	Ken Stead
*Pinery Provincial Park	2 person hrs visual search	June 7, 2018	0	100+ puccoon plants checked behind visitors' centre where Ken has trapped *H. reversa*	Jessica Linton and Ken Stead
*Pinery Provincial Park	15.5 person hrs visual search	June 14, 2018	0	750+ puccoon plants checked; other species of *Haploa* observed (large savanna; savanna behind maintenance area; along ski trail; beach dunes between oak woodlands and dunes around visitors' centre).	Jessica Linton, Pat Deacon, Gard Otis

Site	Search Effort	Date	#	Notes	Surveyor(s)
*Pinery Provincial Park	6 person hrs visual search	June 15, 2018	0	1000+ puccoon plants checked; other species of *Haploa* observed (centroids of larger areas checked: large savanna; beach dunes between dune behind visitors' centre).Surveys started in early morning in case larvae feeding during cooler temperatures.	Jessica Linton and Pat Deacon
*Pinery Provincial Park	2.5 person hrs visual search	June 16, 2018	0	300+ puccoon plants checked	Pat Deacon and Alyssa Roth
*Pinery Provincial Park	1 night (4 BL bucket traps)	July 18, 2018	0	2 traps at hydro cut at new lupine patch hill; 1 trap at Group camp; 1 trap on Pine Trail near entrance	Mary Gartshore
*Pinery Provincial Park	1 night (3 MVL bucket traps)	July 18, 2018	0	1 trap at maintenance yard; 1 trap at visitors' centre; 1 trap at Pinery Guest House	Mary Gartshore and Ken Stead
*Pinery Provincial Park	1 night (3 MVL)	July 18, 2018	0	1 trap at maintenance yard; 1 trap at visitors' centre; 1 trap at Pinery Guest House	Mary Gartshore and Ken Stead
*Pinery Provincial Park	MVL (checked 1x after dark)	July 18, 2018	0	maintenance yard	Mike Burrell and Colin Jones
*Pinery Provincial Park	1 light trap (2 light traps)	July 18, 2018	3	1 Trap	Mike Burrell and Colin Jones
*Pinery Provincial Park	Incidental	July 18, 2018	2	Incidental daytime observations during general sweep net surveys	Mike Burrell
*Pinery Provincial Park	MVL (checked 1x after dark)	July 18, 2018	0	1 sheet at 711 Section 4 Riverside Campground; 1 sheet at Ontario Parks Guest House across road from Pinery Park entrance	Mary Gartshore
*Pinery Provincial Park	Incidental	July 19, 2018	3	Incidental daytime observations during general sweep net surveys	Mike Burrell, Colin Jones, Jessica Linton
Grand Bend					
Grand Bend	Unknown # nights (1 light trap)	July 15, 1996	1+	# negative trapping dates and abundance not recorded (Private Property)	Ken Stead
Ipperwash					
Ipperwash Dunes	Unknown # nights (1 light trap)	July 5,9, 1993	1+	# negative trapping dates and abundance not recorded	Ken Stead
Norkfolk County (Long Point Area)					
Norfolk Area	14 BL run once every week or every other week	2014 to 2018	0	Exact spots not documented but extensive trapping in area and *Haploa reversa* not detected	Jim Troubridge

Site	Search Effort	Date	#	Notes	Surveyor(s)
Walsingham	1 light trap night	2015 (date not recorded)	1	Private Property. Photo record (confirmed by Jim Troubridge). No puccoon plants present (closest at Manestar tract 10+km distance)	Mary Gartshore
Manestar Tract	7.5 person hrs visual search	June 4, 2018	0	350+ puccoon plants checked; other species of Haploa observed (NW corner of site)	Jessica Linton, Gard Otis, Mary Gartshore
Walsingham	1 light trapping night	2018	1	Private Property	David Beadle
*Manestar Tract	3 light traps (2 nights)	August 9 and 10, 2018	0	Traps in savanna	Mary Gartshore
Walsingham	2 MV traps all night every 2 to 3 days during flight period and MV with sheets 1 to 2 times a week	June-July 2019	2	Private Property. Photo records. No puccoon plants present (closest at Manestar tract 10+km distance) Two individuals from June 28, 2019 and July 4, 2019.	Mary Gartshore
Manestar Tract	2 MVL (checked twice)	July 18, 2019	0	2 sheets with MVL ran in northeast portion of tract	Colin Jones, Mike Burrell, Peter Burke, Jessica Linton, Mary Gartshore, Peter Carson, Ryan Norris
Rondeau					
Rondeau Provincial Park	1 Malaise Trap for 20 weeks (entire flight period of *H. reversa*)	April 29 to September 16, 2014	0	No *Haploa* spp. were captured; 4 individual Erebidae documented.	Centre for Biodiversity Genomics
Windsor-Essex Prairie					
Ojibway Prairie	1 Malaise Trap for 20 weeks	May 1 to September 17, 2014	0	Surveys the entire flight period of *H. reversa*. No *Haploa* spp. were captured, although other Erebidae documented.	Centre for Biodiversity Genomics
Ojibway Prairie Nature Centre	1 light trapping night (during BioBlitz)	July 18, 2015	1	Photo record (confirmed by Jim Troubridge and Chris Schmidt)	Tom Preney
*Ojibway Prairie	1.5 person hrs visual search	June 7, 2018	0	No larval host plants found (*L. canescens* present)	Jessica Linton
Ojibway Prairie	Unknown	July 1, 2018	1+	iNaturalist observation: https://www.inaturalist.org/observations/13980332	Laura Foy
Ojibway Prairie Nature Centre	1 light trapping night	July 18, 2019	1	Photo record (confirmed by Chris Schmidt and Colin Jones)	Tom Preney
Ojibway Prairie Nature Centre	Unknown	May 21, 2019	1	Photo record of mature larvae on a thistle (no feeding behaviour observed)	Tom Preney

Site	Search Effort	Date	#	Notes	Surveyor(s)
London					
The Coves	1 MVL with sheet	July 18, 2019	1	iNaturalist observation: https://www.inaturalist.org/observations/29196542	Andrew Jackson

*data collected to inform preparation of status report.

** noted as observed; however, number of specimens observed unknown.

Abundance

No abundance estimates are available for Reversed Haploa Moth. The species has only been regularly encountered at one subpopulation, Lambton County, in the past two decades and only two records exist in Walsingham and Ojibway Prairie, and one record in London.

Fluctuations and Trends

No information on population trends or fluctuations are available for Reversed Haploa Moth in Canada or the United States. It is inferred subpopulations declined over the last century as oak woodland, dune, and savanna habitat declined.

Rescue Effect

The potential for rescue effect from populations in the United States is unknown, but unlikely in relation to the known sites in Lambton County, London, and Norfolk County. There may be potential for rescue effect for the Ojibway Prairie (Windsor, Essex County) subpopulation from populations in Michigan (see Population Structure and Variability).

THREATS AND LIMITING FACTORS

Threats

The threats classification for Reversed Haploa Moth in Canada is based on the IUCN-CMP (World Conservation Union–Conservation Measures Partnership) unified threats classification system (see Salafsky *et al.* 2008; Master *et al.* 2012). In general, the threats to Reversed Haploa Moth are poorly understood. Most threats are inferred from the extent and quality of the oak woodland and savanna habitats (including dunes within these habitats) in which the moth has been recorded.

The cumulative loss of oak woodland and savanna habitat is historical; however, the fragmentation, increased resource pressure and decreased resilience of these ecosystems are ongoing. The threats listed below have been identified as threats based on existing research information from other species at risk within similar habitats in Ontario. Details are discussed below under the IUCN-CMP unified threats classification system headings and numbering scheme from highest to lowest impact; the threat impact score is High (Table 3).

Table 3. Results for the Reversed Haploa Moth threats assessment in Canada. The classification below is based on the IUCN-CMP (World Conservation Union–Conservation Measures Partnership) unified threats classification system. For a detailed description of the threat classification system, see the 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.

Species Scientific Name	Reversed Haploa Moth, *Haploa reversa*	
Date:	2018-12-20	
Assessors:	Jessica Linton (report writer), Dave Fraser (moderator), Jenny Heron (Arthropods SSC Co-chair), David McCorquodale (Arthropods SSC Co-chair), John Klymko (Arthropods SSC), Rob Longair (Arthropods SSC), Jenny Wu (COSEWIC Secretariat), Al Harris (Arthropods SSC), Colin Jones (Ontario Rep.), Jeremy deWaard (Arthropods SSC), Ruben Boles (CWS)	
Overall Threat Impact Calculation	**Level 1 Threat Impact Counts**	
Threat Impact	**high range**	**low range**
A. Very High	0	0
B. High	1	1
C. Medium	0	0
D. Low	2	2
Calculated Overall Threat Impact:	High	High
Assigned Overall Threat Impact:	B = High	
Impact Adjustment Reasons:	No Change	
Overall Threat Comments	Majority of sites are in protected areas or on private lands managed for conservation values. However, municipalities may spray Bt pesticide to control non-native Gypsy Moth, which has become abundant in recent years and the public is starting to request treatment to control the pest. Uncertainty scores are high however in several categories, mostly associated with poor knowledge of host plants used and specific habitat requirements.	

Threat		**Impact (calculated)**	**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential and commercial development	Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs)	
1.1	Housing and urban areas	Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs)	See text in Threats and Limiting Factors.
1.3	Tourism and recreation areas	Negligible	Negligible (<1%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs)	See text in Threats and Limiting Factors.
2	Agriculture & aquaculture					

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual & perennial non-timber crops					Not applicable. Conversion of land for agriculture is for the most part considered a historical threat which occurred after European settlement. Agricultural activities are not considered a threat to the Lambton County and Ojibway Prairie subpopulations. The full extent of habitat range in Norfolk County is not known and this subpopulation may be at risk to agricultural activities that dominate the landscape..
4	Transportation & service corridors					Not applicable. Development of transportation and service corridors in Ontario is for the most part considered a historical threat. Localized threats from new road development in unprotected sites in Norfolk County and Lambton County are unknown.
5	Biological resource use					
5.1	Hunting and collecting terrestrial animals					Not applicable. The occasional collecting of Reversed Haploa Moth for scientific voucher specimens does not represent a threat to Canadian subpopulations. To date it has only been collected in Lambton County.
5.2	Gathering terrestrial plants					Not applicable. Host plants are not collected for Aboriginal use or economic purposes.
6	Human intrusions and disturbance	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	
6.1	Recreational activities	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	See text in Threats and Limiting Factors.
7	Natural system modifications	Low	Restricted (11-30%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs)	
7.1	Fire and fire suppression	Low	Restricted (11-30%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs)	See text in Threats and Limiting Factors.
7.3	Other ecosystem modifications	Unknown	Large (31-70%)	Unknown	High (Continuing)	See text in Threats and Limiting Factors.
8	Invasive and other problematic species and genes	Negligible	Pervasive (71-100%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs)	
8.1	Invasive non-native/alien species					Invasive species are scored under 7.3. See text in Threats and Limiting Factors on the explanation.
8.2	Problematic native species					Scored under 7.3. See text in Threats and Limiting Factors on the explanation. Deer browsing not considered a threat for Lithospermum, but potentially on the other host plant.
9	Pollution	High	Large (31-70%)	Extreme (31-70%)	Moderate (Possibly in the short term, < 10 yrs	

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.3	Agricultural and forestry effluents	High	Large (31-70%)	Extreme (31-70%)	Moderate (Possibly in the short term, < 10 yrs)	See text in Threats and Limiting Factors.
9.6	Excess energy					Not applicable. Light pollution is not considered a threat.
11	Climate change and severe weather	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
11.1	Habitat shifting and alteration	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Potential impacts include altered phenology disrupting the timing of emergence, host plant development, and other critical stages, reduced survival of overwintering larvae, and altered fire regimes and vegetation dynamics. The impacts of climate change on savanna vegetation are difficult to predict in Ontario where most savanna is in protected areas and is actively managed with prescribed burning. The broad geographical distribution suggests that it tolerates a wide range of climatic conditions including warmer temperatures than currently experienced in Canada.
11.2	Droughts	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
11.3	Temperature extremes	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	

Classification of Threats adopted from IUCN-CMP, Salafsky *et al*. (2008).

[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.

Threat 9. Pollution (High impact)

9.3 Agricultural and forestry effluents (High impact)

The potential of aerial spray of *Bacillus thuringiensis* (*Bt*) to control non-native Gypsy Moth outbreaks within the range of Reversed Haploa Moth is considered probable within the next ten years. *Bacillus thuringiensis* is a broad-spectrum insecticide that uses the spores of this naturally occurring pathogenic bacterium to control defoliating larvae, and has historically been used to control invasive Gypsy Moths in Ontario. The bacterium is also particularly lethal to lepidopteran larvae (Butler 1998). In Ontario, spraying of *Bt* to control Gypsy Moths began shortly after this species' introduction in 1969. However, the last *Bt* spray led by the province occurred in 1991 and the provincial program was cancelled in 1992 (Linton 2015). Insecticide spraying of *Bt* for Gypsy Moths is thought to have contributed to the decline of several species of lepidoptera in Ontario known to historically occupy Pinery Provincial Park, Karner Blue Sanctuary, and oak woodland and savanna areas in Norfolk County (COSEWIC 2006; Linton 2015).

Within the past few years, particularly in Gypsy Moth outbreak years, there has been increased use of *Bt* by some conservation authorities and municipalities to control the non-native moth. In 2019, outbreaks of Gypsy Moth were reported throughout Ontario and aerial spraying occurred in Toronto, Hamilton, St. Catharines, and the Niagara region. The timing of these programs (May-June) is consistent with the larval stage of Reversed Haploa Moth, and therefore represents a serious threat if applied in areas where it occurs.

More recent concerns have been raised about the negative effects of neonicotinoid insecticides on arthropod communities. This class of insecticides has been commonly applied to corn and soy crops in southwestern Ontario. They are systemic (i.e. water-soluble), which allows them to permeate different parts of the plant for protection (Anderson *et al.* 2015; Bonmatin *et al.* 2015; Simon-Delso *et al.* 2015). But this also means they can accumulate in runoff from agricultural landscapes (Hladik and Kolpin 2015; Main *et al.* 2015; 2016) and can be taken up by mesic plants (e.g., willows). Given that *Haploa* moths are often associated with mesic *Eupatorium* plants, it is possible neonicotinoids could be a threat to this species, particularly the Norfolk subpopulation which occurs in a landscape heavily influenced by agriculture.

Threat 6. Human Intrusions and Disturbance (Low impact)

6.1 Recreational activities (Low impact)

Most Reversed Haploa Moth habitat that is publicly accessible (see Table 1) is used recreationally for hiking, biking, and possible unauthorized motorized off-road vehicles. The species may be negatively impacted by these activities if host plants or larvae are trampled and/or if adults, which rest in vegetation during the day, are disturbed or trampled. Although this may overlap with a large proportion of the habitat and population, this is considered a low severity threat.

Threat 7. Natural System Modifications (Low impact)

7.1 Fire (Low impact)

Oak woodland and savanna habitat at the Pinery and Windsor-Essex Prairie have had regular prescribed burning (Bakowsky 1994; Paiero *et al.* 2010). Inappropriate prescribed burning can reduce populations of some Lepidoptera (Swengel *et al.* 2010). Swengel (1996) found that grassland specialist butterfly species declined immediately following a burn and that the effects were evident for 3–5 years after the fire. More recent studies (Vogel *et al.* 2010) suggest that recovery times for some species may be longer than 5 years. Information on species-specific response to fire, relationships between patch size and dispersal distances, and landscape configuration are required for local subpopulation management. Burning which is too frequent, severe, extensive, or occurs outside the natural wildfire season may negatively affect Reversed Haploa Moth. Eggs, larvae and pupae are particularly vulnerable to fires due to their limited mobility. To address the sensitivity of invertebrates in grassland habitats managed through fire, the Minnesota Department of Natural Resources (2013) has developed guidelines for prescribed burns which include emphasis on considerations such as burn cycles, unburned refugia, timing, and site-specific conditions. Because habitat requirements of Reversed Haploa Moth are unknown, it is difficult to predict effects of prescribed fire although it may benefit the species.

7.3 Other ecosystem modifications (Unknown impact)

Fire Suppression

The threat of fire suppression activities is present throughout the range of Reversed Haploa Moth, particularly within natural tracts of land. Although fire may have direct consequences for Reversed Haploa Moth, fire is also important in maintaining early successional habitats by reducing invasive plants and overgrowth of woody shrubs and trees (Kline 1997). The extent to which Reversed Haploa Moth may benefit from fire is unknown, as their habitat specificity and larval host plant requirements are not known. However, in general species which depend on oak woodland and oak savanna systems often have a close association with fire and many herbaceous plants in these habitats require periodic disturbance to avoid overcrowding and shading.

Geographical Isolation Due to Human Factors

The historical widespread loss of oak savanna and other tallgrass habitats in Ontario has led to geographical isolation of habitat patches throughout the landscape. With the exception of a few larger areas of habitat, the majority of patches are fewer than 0.5ha and are poorly connected within the landscape. Despite a high proportion of these areas being designated as protected lands, unlikely to decline in physical quality due to 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 increases resource competition, decreases resilience, reduces

genetic flow, increases the risk of mortality for mobile wildlife species attempting to move between patches, and does not necessarily provide adequate habitat for the long-term viability of species.

Threat 1. Residential or Commercial Development (Negligible impact)

1.1 Housing and urban areas

Historical residential development in southwestern Ontario likely destroyed Reversed Haploa Moth habitat, but the extent of this habitat loss is unknown because historical records for the moth are minimal. At present day, residential development and urbanization are not considered a large threat to Reversed Haploa Moth (based on known locations). Residential development in protected areas where the species occurs [Pinery Provincial Park (Grand Bend), Karner Blue Sanctuary (Port Franks), London (The Coves), or Ojibway Prairie (Windsor)] is prohibited. In Lambton County, there are also two privately owned single residential properties where additional development is not planned, a property owned by the Department of National Defence that is being transferred to First Nations, and a property owned by the Province of Ontario which is within regulated floodplain (Stead pers. comm. 2018; Nywening pers. comm. 2018). It is unlikely that any of these properties will be subject to residential development in the next ten years. Pressure associated with cottage development around Pinery Provincial Park may pose a threat to Reversed Haploa Moth if the species occupies these areas. The extant site in Walsingham (Norfolk County) is a rural residential property and housing development is an unlikely threat.

Threat 8. Invasive and Other Problematic Species and Genes

This threat is scored under 7.3 other ecosystem modifications, because it is a proximal threat to Reversed Haploa Moth through changes to habitat quality. However, the threat is discussed under this subheading.

8.1 Invasive non-native/alien species

In general, invasive plant species negatively effect arthropod diversity and abundance (Ballard *et al.* 2013; Litt *et al.* 2014). Although there are no known direct threats to Reversed Haploa Moth from invasive species, based on evidence available on insect response to invasive plants, they have the potential to reduce habitat quality for this species. Invasive plants can degrade savanna habitat by competing with native species for space and nutrients. A variety of common invasive species such as Orange Hawkweed (*Pilosella aurantiaca*), Leafy Spurge (*Euphorbia esula*), Crown Vetch (*Securigera varia*), and White Sweet Clover (*Melilotus albus*) can quickly dominate early successional habitats (USFWS 2012). Pinery Provincial Park has experienced an invasion of Spotted Knapweed (*Centaurea maculosa*), a Eurasian member of the aster family (Jarvis 2014). Ojibway Prairie habitats are threatened by Black Locust (*Robinia pseudoacacia*), Common Reed (*Phragmites australis*), and Garlic Mustard (*Alliaria petiolata*) (Cedar pers. comm. 2016). Control of invasive species capable of outcompeting native nectar plants and known larval host plants is therefore an important threat to consider; however, the extent to which this may impact Reversed Haploa Moth is unknown.

The non-native invasive tachinid fly, *Compsilura concinnata*, was introduced in the mid-1800s to control Gypsy Moth. This generalist parasitoid infects a wide range of hosts (Arnaud 1978), including moths in the family Erebidae (although *Haploa* moths have not been explicitly identified as a host). This tachinid fly is considered a major threat to more than 200 native lepidopterans of eastern North America and has been implicated in their decline (Wagner and Driesche 2010; Wagner 2012). The extent to which this species may impact Reversed Haploa Moth is unknown, but warrants further investigation.

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

11.1 Habitat shifting and alteration, 11.2 Droughts and 11.3 Temperature extremes

The species-specific response that Reversed Haploa Moth will have to climate change is unknown, as is that of the larval host plants on which they depend. Reversed Haploa Moth overwinters as a diapausing larva. If larvae break diapause too early because of changing environmental cues, there may be an increased risk of being killed by early or late season frost or an inadequate supply of larval foodplants and/or nectar plants available. A hotter and drier climate may lead to periods of extreme drought whereas a colder and wetter climate may also threaten host plant survival.

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 Reversed Haploa Moth are speculative but are likely a combination of the following:

Small subpopulation size

Apparent association with oak-dominated dune, savanna and woodland habitats in Ontario, a habitat type with a restricted geographical range and patchy distribution. Ecological theory predicts that the risk of a subpopulation going extinct in a single patch such as an area of oak habitat is reduced with increasing numbers of surrounding subpopulations (Hanski 1982). Reversed Haploa Moth appears to occur as small or localized subpopulations, thus preventing genetic mixing between subpopulations, leading to inbreeding depression and increasing the chance of local extirpation.

Limited dispersal ability

Historically, oak, savanna and dune ecosystems were connected and more widespread; however, present-day ecosystems are isolated and fragmented. Reversed Haploa Moth is likely not able to disperse long distances through unsuitable habitat. Female moths are not highly mobile and are unlikely to disperse far owing to their heavy, egg-filled bodies. Subpopulation structure and spatially isolated habitats likely limit dispersal capabilities and population intermixing.

Natural parasitic enemies

Parasites are known to attack moths at all life stages, although no species-specific information is available for Reversed Haploa Moth.

Host plant specificity

Reversed Haploa Moth requires specific host plant(s) to complete its life cycle.

Vulnerability to weather patterns

The overall seasonal weather patterns affect the abundance and distribution of moths at all life stages. Weather factors into the degree days and subsequent emergence of the next year's generation. The previous year's weather (e.g., average temperature, average rainfall, frost) affects host plant growth, senescence, and abundance and directly impacts the larval health and abundance of the next generation. Humidity and extreme winter temperatures affect larval survival, as well as the ability of the female pheromone to distribute throughout the landscape. Temperature and rainfall impact the species' growth and adult movement.

Number of Locations

There are five locations for Reversed Haploa Moth in Canada (Table 1) based on the main threat; the potential spraying of *Bt* to control non-native Gypsy Moth at each of the four subpopulations. The decision to spray *Bt* would be made by the local municipality and/or government. The scope and severity of the threats are distinct due to different land ownership and management within these municipalities, although the timing is similar across sites (e.g., during the larval activity period). In Walsingham (Norfolk County), London (The Coves) and Ojibway Prairie (Windsor, Essex County) there is one known location each. Within the Lambton County subpopulation there are two distinct locations based on land management; Pinery Provincial Park is provincial and decisions around pesticide spray are made by provincial park managers; and all other collection sites together would fall to the decision of the county to spray (e.g., Ipperwash Dunes, three in Port Franks, and a private property in Grand Bend).

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Reversed Haploa Moth is not protected by the Canada *Species at Risk Act* or the Ontario *Endangered Species Act*. Known host plants are also not protected under these acts.

Non-Legal Status and Ranks

Reversed Haploa Moth is globally ranked as Secure (G5) and nationally ranked in Canada as Vulnerable to Imperiled (N2N3) (NatureServe 2018). In Ontario, it is considered possibly Critically Imperiled (S1?) (NHIC 2018a). It is not ranked subnationally within any jurisdictions where it occurs in the United States (NatureServe 2018). It is not protected by any federal or state legislation in the United States (NatureServe 2018).

Habitat Protection and Ownership

The majority of records for Reversed Haploa Moth are from Lambton County which includes records from Pinery Provincial Park (Grand Bend) and the Karner Blue Sanctuary (Port Franks) (both protected natural areas) and privately and publicly owned lands (Table 1). The Walsingham (Norfolk County) records are from private property. The Ojibway (Windsor, Essex County) record was from outside the Ojibway Park visitors' centre, which is owned and managed by the City of Windsor and Ojibway Prairie Provincial Nature Reserve. The London record is from a natural area called The Coves, half of which is owned and managed by the City of London while the balance is privately owned.

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Front cover photograph by Mary Gartshore (with permission), taken July 2015 on private property, Walsingham, 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 and Implementation 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

The following collections were searched for specimens of Reversed Haploa Moth:

- Canadian National Collection of Insects, Arachnids and Nematodes, Ottawa, ON (Jessica Linton and Chris Schmidt)
- University of Guelph Insect Collection, Guelph, ON (Steve Paiero)
- Biodiversity Institute, University of Guelph, Guelph, ON (Jeremy Dewaard)