COSEWIC
Assessment and Status Report

on the

Hine's Emerald
Somatochlora hineana

in Canada

ENDANGERED
2011

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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COSEWIC would like to acknowledge Colin Jones for writing the status report on Hine's Emerald (*Somatochlora hineana*) in Canada, prepared under contract with Environment Canada. This report was overseen and edited by Paul Catling, Co-chair of the COSEWIC Arthropods Specialist Subcommittee. For the cover photo taken in Minesing Swamp, Ontario, we thank Chris Evans.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

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Hine's Emerald — Photo by C.D. Jones

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COSEWIC
Assessment Summary

Assessment Summary – May 2011

Common name
Hine's Emerald

Scientific name
Somatochlora hineana

Status
Endangered

Reason for designation
This dragonfly, which is rare throughout its range, is known from only one Canadian location where habitat decline is considered likely due to urban development and invasive species.

Occurrence
Ontario

Status history
Designated Endangered in May 2011.

COSEWIC
Executive Summary

Hine's Emerald
Somatochlora hineana

Wildlife species description and significance

Somatochlora hineana, the Hine's Emerald, is a dragonfly (Order Odonata) in the family Corduliidae, the emeralds. Adults have brilliant green eyes, a metallic green thorax with two lateral yellow stripes, and a blackish-brown abdomen. Hine's Emerald is a globally rare species.

Distribution

The extant global range of Hine's Emerald includes Ontario and four states in the United States: Wisconsin, Michigan, Illinois and Missouri. Historically, it was also known from Ohio, Indiana and Alabama, where it is now thought to be extirpated. In Ontario, Hine's Emerald is known from only a single site – the Minesing Wetlands in Simcoe County, west of Barrie.

Habitat

Hine's Emerald is restricted to calcareous wetlands (marshes, sedge meadows, and fens) dominated by graminoid vegetation and fed primarily by groundwater from intermittent seeps. Most sites have an underlying layer of dolomitic bedrock close to the surface. Some biologists believe that the habitat in Minesing Wetlands has become increasingly dry over the past 35 years and anticipated urban development in the surrounding region is considered a serious threat as a result of loss of groundwater recharge. On the other hand development appears to be restricted. There is more general agreement that invasive plants such as European Common Reed and Glossy Buckthorn are serious threats. The presence of crayfish burrows likely represents a critical component of Hine's Emerald habitat and may be a factor limiting its distribution.

Biology

Hine's Emerald undergoes incomplete metamorphosis involving three stages: egg, larva (nymph) and adult. Mated females lay eggs in muck and/or shallow water and the eggs hatch into aquatic larvae that live in the wetland for 3-5 years before emerging as adults. The larvae are generalist predators and feed upon a variety of other invertebrates. Once mature, larvae crawl from their aquatic environment onto an emergent plant where the adult emerges from the larval skin. The timing of adult emergence in the Canadian portion of the range likely begins somewhere between early to mid-June. Following a week-long pre-reproductive period, adults choose breeding sites and use these areas to mate and lay eggs. Adult dragonflies are aerial predators and feed on a variety of insects.

Population sizes and trends

Population size at the single known site in Canada is unknown. Likewise, there are no data on year-to-year fluctuations or trends in this population.

Threats and limiting factors

Changes in surface and sub-surface hydrology could be detrimental to populations of Hine's Emerald if alterations of water regimes affect water to reduce or eliminate potential larval habitat. The aquifer that is believed to be the principal source of groundwater supplying the eastern portion of the Minesing Wetlands (where the only known Canadian population of Hine's Emerald is found) is located in the uplands to the east. Proposed housing developments in these uplands are expected to reduce the baseflow of water to the wetlands, thus impacting larval habitat.

Contamination of groundwater is also a potential threat to Hine's Emerald habitat. The uplands containing the aquifer that supplies the Minesing Wetlands are primarily comprised of permeable sand and gravel formations. As a result, the source of the water supplying the eastern portion of Minesing could be contaminated by agricultural pesticides and nutrient management, faulty or degraded septic beds and potential future development pressures.

Yet another threat is the likely invasion of European Common Reed, which forms dense stands in fens, virtually eliminating native biodiversity.

Protection, status, and ranks

Hine's Emerald is listed as Endangered in the United States federally and by the states of Illinois, Michigan, Ohio and Wisconsin. The species is currently not protected under the *Species at Risk Act* in Canada or Ontario's *Endangered Species Act*, *2007.* It is ranked by NatureServe as Imperiled to Vulnerable globally G2G3, and nationally as N1 in Canada, and provincially as S1 in Ontario. It is listed as Near Threatened in the International Union for Conservation of Nature Red List of Threatened Species.

The Minesing Wetlands are protected from development and site alteration by a number of provincial and municipal natural heritage designations, regulations and policies. Much of the area is owned by the Nottawasaga Valley Conservation Authority.

TECHNICAL SUMMARY

Somatochlora hineana
Hine's Emerald — Cordulie de Hine
Range of occurrence in Canada: Ontario

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2008) is being used)	3-5 years (complete life span)
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	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
Inferred, or suspected percent reduction in total number of mature individuals over any 10 years period, over a time period including both the past and the future.	unknown
Are the causes of the decline clearly reversible and understood and ceased?	n/a
Are there extreme fluctuations in number of mature individuals?	unknown

Extent and Occupancy Information

Estimated extent of occurrence *The extent of occurrence (EO) in Canada based on a minimum convex polygon encompasses 10 km^2. By COSEWIC convention, when the EO is less than the IAO, the value of the EO should be set to the larger of the two, which in this case is 28 km^2.*	28 km²
Index of area of occupancy (IAO) (based on a 2 km x 2 km grid) *The maximum index of area of occupancy (IAO) is 11 km^2 based on a 1 km x 1 km grid and 28 km^2 based on a 2 km x 2 km grid.*	28 km²
Is the total population severely fragmented? *[one location in Canada, severely fragmented throughout the range]*	no
Number of "locations∗"	1
Is there an observed, inferred, or projected continuing decline in extent of occurrence?	no
Is there an inferred continuing decline in index of area of occupancy?	no
Is there an observed, inferred, or projected continuing decline in number of populations?	no
Is there an inferred continuing decline in number of locations?	no
Is there an inferred continuing decline in quality of habitat?	yes
Are there extreme fluctuations in number of populations?	unknown
Are there extreme fluctuations in number of locations∗?	unknown
Are there extreme fluctuations in extent of occurrence?	unknown
Are there extreme fluctuations in index of area of occupancy?	unknown

∗ See definition of location.

Number of Mature Individuals (in each population)

Population	N Mature Individuals
	unknown
Total	unknown

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	n/a

Threats (actual or imminent, to populations or habitats)

Proposed housing developments in the uplands to the east of the known population could reduce the baseflow of water to the wetlands, thus impacting larval habitat. Contamination of the groundwater is also a threat. However there is reason to believe that developments may be restricted, and a more serious threat is invasive plants such as European Common Reed and Glossy Buckthorn.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Probably stable but rare and endangered in adjacent areas.	
Is immigration known or possible?	possible
Would immigrants be adapted to survive in Canada?	probably
Is there sufficient habitat for immigrants in Canada?	yes
Is rescue from outside populations likely?	no

Current Status

COSEWIC: Designated Endangered in May 2011.

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Endangered	B1ab(iii)+2ab(iii)

Reasons for designation:
This dragonfly, which is rare throughout its range, is known from only one Canadian location where habitat decline is considered likely due to urban development and invasive species.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable as the number of mature individuals is unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1ab(iii)+2ab(iii) based on a very small extent of occurrence and index of area of occupancy (both 28 km^2) and because it is known from only a single location where habitat decline is projected due to invasive species and urban development.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable as the number of mature individuals is unknown.
Criterion D (Very Small or Restricted Total Population): Meets Threatened D2 as there is only one location and the threats noted for this location could result in extinction in a short time period.
Criterion E (Quantitative Analysis): Not done.

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
(2011)

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.

Canada

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

COSEWIC Status Report

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Somatochlora hineana

in Canada

2011

TABLE OF CONTENTS

List of Figures

List of Tables

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and classification

Kingdom Animalia – Animal, animals, animaux
Phylum Arthropoda – arthropodes, arthropods, Artrópode
Subphylum Hexapoda – hexapods
Class Insecta – hexapoda, insectes, insects, inseto
Subclass Pterygota – insects ailés, winged insects
Infraclass Palaeoptera – ancient winged insects
Order Odonata Fabricius, 1793 – damselflies, dragonflies, libélula
Suborder Anisoptera Seyls, 1854 – dragonflies, libellules
Family Corduliidae – emeralds, green-eyed skimmers
Subfamily Corduliinae
Genus *Somatochlora* Selys, 1871
Species *Somatochlora hineana* Williamson, 1931 – Hine's Emerald, cordulie de Hine

Somatochlora hineana Williamson 1931, or Hine's Emerald, is a dragonfly in the order Odonata (dragonflies and damselflies) and the family Corduliidae (emeralds). Williamson (1931) described the species based upon adult specimens. Many years later, Cashatt and Vogt (2001) described the larva.

The species is distinct and there are no subspecies or species forms.

Morphological description

Hine's Emerald is a relatively large corduliid dragonfly. Like all dragonflies, it progresses through three stages of development: egg, larva and adult.

Like all insects, an adult Hine's Emerald (Figures 1 and 2) has three main body parts: head, thorax and abdomen. For the first few days in the adult stage, the eyes of Hine's Emerald are brown, but they eventually become a brilliant green, a feature that is present in most of the members of the emerald family. The thorax, the middle part of the body, bears three pairs of legs and two pairs of wings. It is metallic green with two distinct yellowish stripes on each side. The wings are usually clear, although they can sometimes have a yellowish hue towards the bases. The long thin abdomen is blackish-brown and composed of ten segments and a set of terminal appendages. Adults have a body length of 58-63 mm (Needham *et al*. 2000) and a wingspan of 90-95 mm (USFWS 2001).

Figure 1. Adult male Hine's Emerald from the Minesing Wetlands (44.38˚N 79.85˚W) on June 27. 2007. Photo by C.D. Jones.

Figure 2. Adult female Hine's Emerald from the Minesing Wetlands (44.38˚N 79.85˚W) on June 27. 2007. Photo by C.D. Jones.

In Canada, there are 20 species in the genus *Somatochlora* and many of them are very similar in general appearance. The shape of the terminal appendages in adult males is, however, distinctive; those of the Hine's Emerald are clamp-shaped in lateral view (Figure 3). These appendages are somewhat similar in shape and appearance to those of the Clamp-tipped Emerald (*Somatochlora tenebrosa* (Say) but those of the latter gradually taper to a sharp point (Figure 4), whereas those of Hine's bend near the tip before ending in a hook-like shape. Identification of females in the genus *Somatochlora* is problematic, but by examining a combination of size, thoracic pattern and the shape of the genital plate (located on the underside of the 9th abdominal segment – towards the tip of the abdomen) one can make a positive identification. The genital plate in Hine's Emerald is scoop-shaped (Figure 5) whereas that of the Clamp-tipped Emerald (the species most likely to be confused with Hine's Emerald) is triangular and projects downward, perpendicular to the abdomen (Figure 6).

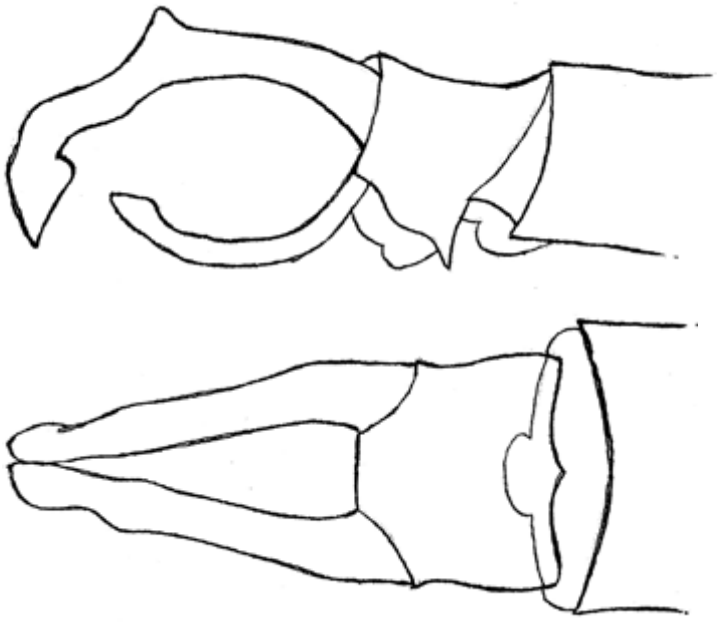

Figure 3. Lateral (above) and dorsal (below) view of the terminal appendages of a male Hine's Emerald. Illustrations by Peter Burke from Jones *et al*. (2008).

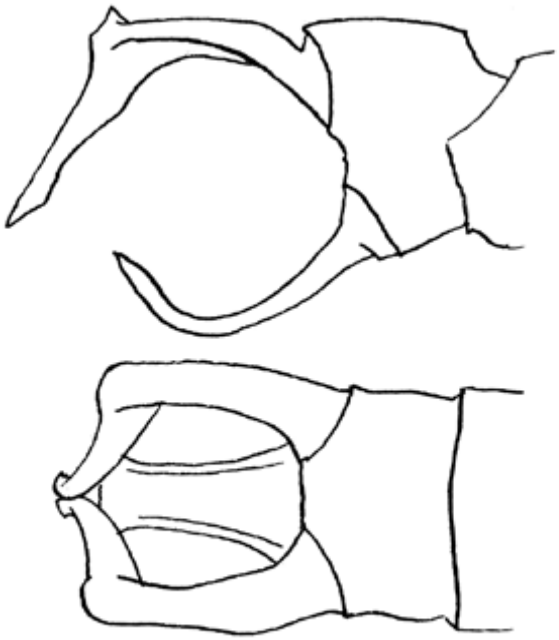

Figure 4. Lateral (above) and dorsal (below) view of the terminal appendages of a male Clamp-tipped Emerald. Illustrations by Peter Burke from Jones *et al.* (2008).

Figure 5. Lateral view of the abdominal tip of a female Hine's Emerald. Note the scoop-shaped genital plate. Illustration by Peter Burke from Jones *et al.* (2008).

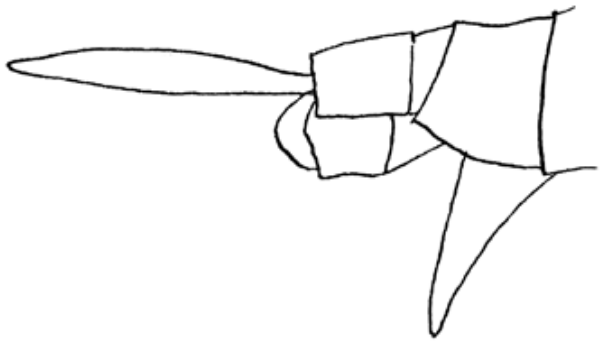

Figure 6. Lateral view of the abdominal tip of a female Clamp-tipped Emerald. Note the triangular genital plate projecting perpendicularly from the abdomen. Illustration by Peter Burke from Jones *et al.* (2008).

The larval stage (Figure 7) is much more difficult to identify, as larvae of species in the genus *Somatochlora* are extremely similar. Reliable identification can only be made in final instar larvae or exuviae and requires careful examination of a number of characters including: the presence of a mid-dorsal hook on the third abdominal segment (usually present on Hine's Emerald); the number of papal setae (8-9); the number of crenulation setae (9-12); the total length (23.5-25.0 mm); the width of the head (6.7-6.8 mm); the length of the metatibia (8.1-8.4 mm); and the metatibia length/head width ratio (1.19-1.25). These characters and a key to larvae of the genus *Somatochlora* are provided in Cashatt and Vogt (2001).

Figure 7. Larval Hine's Emerald from the Minesing Wetlands (44.38˚N 79.85˚W) on July 7, 2008. Photo by C.D. Jones.

Population spatial structure and variability

There is no information available on population spatial structure and variability in the Canadian population of Hine's Emerald. Genetic studies have been conducted on some of the U.S. populations (Purdue *et al.* 1996, Purdue *et al.* 1999). The Illinois population has the highest genetic diversity with six different haplotypes; whereas populations in Michigan and Wisconsin have only a single haplotype, differing from those found in Illinois.

Designatable units

The only known Canadian population is found within Ontario in the Great Lakes Plains National Ecological Area (COSEWIC 2009) and there is one designatable unit in Canada.

Special significance

Hine's Emerald is a globally rare species with a restricted range in North America (NatureServe 2009). Aboriginal and Traditional knowledge was not found for this species.

DISTRIBUTION

Global range

The extant global range of Hine's Emerald includes Ontario and four states in the United States: Wisconsin, Michigan, Illinois and Missouri (Figure 8). Historically, it was also known from Ohio, Indiana and Alabama, where it is now thought to be extirpated (Vogt and Cashatt 1994). The global extent of occurrence encompasses 338,857 km^2.

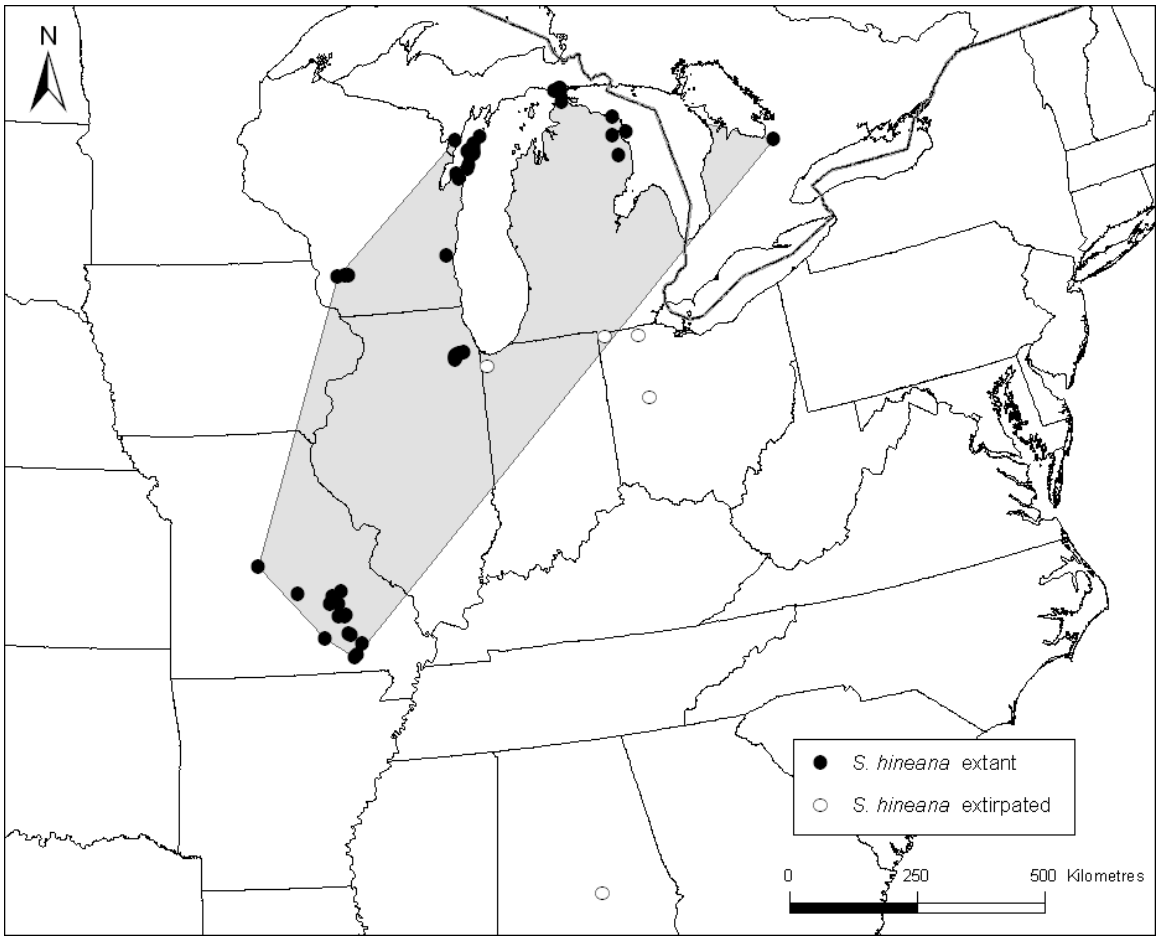

Figure 8. Global distribution of Hine's Emerald with shaded area representing the extent of occurrence.

Canadian range

Within Canada, Hine's Emerald is known from one site: the Minesing Wetlands in Simcoe County (Figure 9). This site is located within the Mixedwoods Plain Ecozone (Environment Canada 2005). The location is thought to contain a single population of interbreeding individuals and is subject to the threat of groundwater alteration throughout its area.

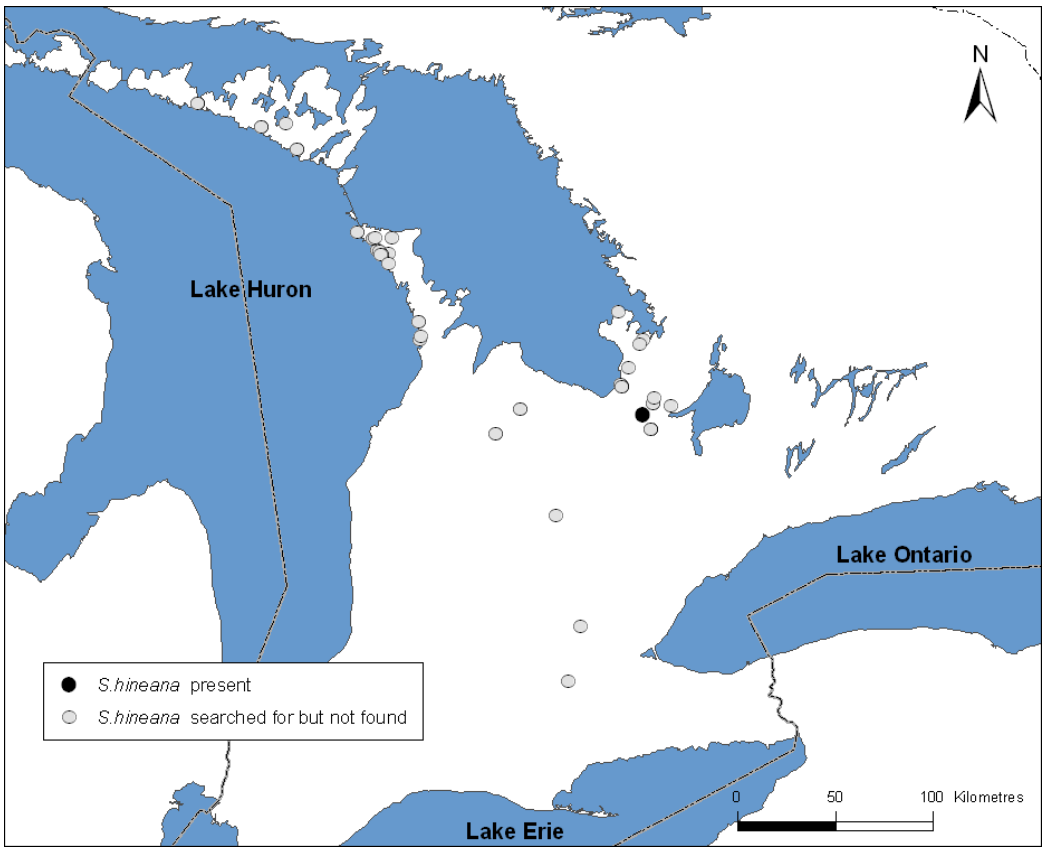

Figure 9. Distribution of Hine's Emerald in Canada showing single location where present and other locations of directed searches where it was not found.

The maximum index of area of occupancy (IAO) is 11 km^2 based on a 1 km x 1 km grid and 28 km^2 based on a 2 km x 2 km grid. The extent of occurrence (EO) in Canada based on a minimum convex polygon encompasses 10 km^2. By COSEWIC convention, when the EO is less than the IAO, the value of the EO should be set to the larger of the two values, which in this case is 28 km^2. So the EO value used for this assessment will be 28 km^2.

Search effort

The occurrence of Hine's Emerald in Ontario had been long suspected until its discovery in 2007. Directed but unsuccessful searches for the species in the province have been conducted since the mid-1990s (Steffens 2000; Jones 2003; Catling pers. comm. 2008; Marshall pers. comm.; Table 1, Figure 9). In 2007, the species was discovered at the Minesing Wetlands when a single male was caught and photographed by Chris Evans along an adjacent roadside on June 20. Subsequent searches of the wetlands in 2007 resulted in the discovery of additional adults. Since then, Colin Jones, Chris Evans and Bob Bowles, with the assistance of many others, have surveyed the population in an attempt to better delineate the adult and larval habitats.

Table 1. Dates, observers, locations and habitat of sites surveyed for Hine's Emerald in Ontario along with search effort and search results. All known positive records are listed first, followed by all known negative records. See Figure 9 for map.

Date	Observer(s)	Location	Habitat	Search effort	Search result
2007-06-20	C. Evans	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	1 adult: incidental	Positive
2007-06-27	C.D. Jones, M.J. Oldham, R. Oldham, W.D. Bakowsky	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	2 adults during 4 hours of adult surveys	Positive
2007-06-28	C. Evans	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	1 adult during 2 hours of adult surveys	Positive
2007-07-03	C. Evans, R. Bowles	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	2-7 adults during 5 hours of adult surveys	Positive
2007-07-17	C.D. Jones, C. Evans	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	2 adults during 5 hours of adult surveys	Positive
2007-07-21	C. Evans	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	1 adult during 2 hours of adult surveys	Positive
2008-06-19	C.D. Jones, C. Evans	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	3 adults during 2.5 hours of adult surveys	Positive
2008-06-20	C. Evans	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	5 adults in 3.5 hours of adult surveys	Positive
2008-06-25	C.D. Jones, C. Evans, R. Bowles	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	8 adults in 9 hours of adults surveys	Positive
2008-06-26	C. Evans, Andrew Claydon	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	1 adult during 0.5 hours of adult surveys	Positive
2008-06-27	C. Evans, Nikki Grantmyre, Nicole Gibson	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	1 adult during 2 hours of adult surveys	Positive

Date	Observer(s)	Location	Habitat	Search effort	Search result
2008-07-07	C.D. Jones, C. Evans, R. Bowles, T. Vogt, D.A. Sutherland	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	4 adults during 6 hours of adult surveys; 2 larvae while pumping 5 crayfish burrows (~1 hour)	Positive
2008-07-12	Rob Foster, Al Harris, Mark Stabb	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	10 adults hours of adult surveys unknown	Positive
2008-08-06	C. Evans	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	2 adults during 2 hours of adult surveys	Positive
2009-06-10	C. Evans	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	1 adult during 1 hours of adult surveys	Positive
2009-06-22	Peter Mills	Minesing Wetlands Lat: 44.38 Long: -79.84	Vast wetland complex comprised of fen, swamp, marsh bordered by terraced upland.	1 adult during 1 hours of adult surveys	Positive
2008-06-22	R. Bowles, Rebecca Ivanoff, Tim Tully	Awenda Provincial Park Lat: 44.855 Long: -79.994	Seeps surrounded by conifer woods at base of ancient Lake Algonquin bluff. Habitat probably unsuitable for Hine's Emerald.	3 hours	Negative
2008-06-24	C.D. Jones, C. Evans, R. Bowles	Beaverdale Bog Lat: 44.409 Long: -80.635	Poor fen with slightly richer attributes at the southern edge. Burrowing crayfish not detected. Habitat likely unsuitable for Hine's Emerald	9 hours	Negative
2008-07-11	C.D. Jones, C. Evans, R. Bowles, T. Vogt	Beaverdale Bog Lat: 44.409 Long: -80.635	Poor fen with slightly richer attributes at the southern edge. Burrowing crayfish not detected. Habitat likely unsuitable for Hine's Emerald	6 hours	Negative
2009-09-01	C.D. Jones, C. Evans, K. Ballantyne, T. Zammit	Brantford Perched Fen Lat: 43.158 Long: -80-342	Rich perched fen on a relatively steep slope. No burrowing crayfish detected. Habitat likely unsuitable for Hine's Emerald.	1 hour	Negative
2008-07-10	C.D. Jones, C. Evans, R. Bowles, T. Vogt, D.A. Sutherland	Brinkman's Creek, wetland N of Lat: 45.122 Long: -81.486	Sedge marsh with crayfish burrows. No larvae found within crayfish burrows. Habitat likely unsuitable for Hine's Emerald.	4 hours	Negative

Date	Observer(s)	Location	Habitat	Search effort	Search result
2002-07-23	C.D. Jones	Cape Hurd Road, Bruce Peninsula Lat: 45.22 Long: -81.69	Sedge marsh with open pools. Potential Hine's Emerald habitat.	1 hour	Negative
2002-08-07	C.D. Jones, D.A. Sutherland	Cape Hurd Road, Bruce Peninsula Lat: 45.22 Long: -81.69	Sedge marsh with open pools. Potential Hine's Emerald habitat.	1 hour	Negative
2002-07-22	C.D. Jones	Corisande Bay, Bruce Peninsula Lat: 45.14 Long: -81.56	Large, shallow, marl-bottomed pond with numerous seeps feeding the pond. Burrowing crayfish not detected. Habitat likely unsuitable for Hine's Emerald.	20 minutes	Negative
2002-08-06	C.D. Jones, D.A. Sutherland	Corisande Bay, Bruce Peninsula Lat: 45.14 Long: -81.56	Large, shallow, marl-bottomed pond with numerous seeps feeding the pond. Burrowing crayfish not detected. Habitat likely unsuitable for Hine's Emerald.	3.5 hours	Negative
2008-07-08	C.D. Jones, C. Evans, R. Bowles, T. Vogt, D.A. Sutherland, S.M. Robinson, A. Dwyer	Corisande Bay, Bruce Peninsula Lat: 45.14 Long: -81.56	Large, shallow, marl-bottomed pond with numerous seeps feeding the pond. Burrowing crayfish not detected. Habitat likely unsuitable for Hine's Emerald.	4 hours	Negative
2002-07-16	C.D. Jones	Dean's Bay area, Lake Huron Drive, Manitoulin Island Lat: 45.70 Long: -82.33	Roadside adjacent to open fen bordered by cedar/tamarack woods. Potential Hine's Emerald habitat.	3 hours	Negative
2002-07-18	C.D. Jones	Dean's Bay area, Lake Huron Drive, Manitoulin Island Lat: 45.70 Long: -82.33	Roadside adjacent to open fen bordered by cedar/tamarack woods. Potential Hine's Emerald habitat.	2 hours	Negative
2002-07-19	C.D. Jones	Dean's Bay area, Lake Huron Drive, Manitoulin Island Lat: 45.70 Long: -82.33	Roadside adjacent to open fen bordered by cedar/tamarack woods. Potential Hine's Emerald habitat.	2 hours	Negative
1999-07-22	W.P. Steffens	Dorcas Bay, Bruce Peninsula Lat: 45.19 Long: -81.59	Rich fen with mineral substrate. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	3 hours	Negative
2002-07-22	C.D. Jones	Dorcas Bay, Bruce Peninsula Lat: 45.19 Long: -81.59	Rich fen with mineral substrate. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	1.5 hours	Negative

Date	Observer(s)	Location	Habitat	Search effort	Search result
2002-07-23	C.D. Jones	Dorcas Bay, Bruce Peninsula Lat: 45.19 Long: -81.59	Rich fen with mineral substrate. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	1 hour	Negative
2002-07-24	C.D. Jones	Dorcas Bay, Bruce Peninsula Lat: 45.19 Long: -81.59	Rich fen with mineral substrate. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	3 hours	Negative
2002-08-06	C.D. Jones, D.A. Sutherland	Dorcas Bay, Bruce Peninsula Lat: 45.19 Long: -81.59	Rich fen with mineral substrate. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	2 hours	Negative
2002-08-08	C.D. Jones, D.A. Sutherland	Dorcas Bay, Bruce Peninsula Lat: 45.19 Long: -81.59	Rich fen with mineral substrate. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	4 hours	Negative
2008-07-08	C.D. Jones, C. Evans, R. Bowles, T. Vogt, D.A. Sutherland	Dorcas Bay, Bruce Peninsula Lat: 45.19 Long: -81.59	Rich fen with mineral substrate. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	4 hours	Negative
2008-06-23	C.D. Jones, C. Evans, R. Bowles	Dornoch Swamp Lat: 44.296 Long: -80.797	Gravel road with forest/swamp/creek on both sides and small marly pond on S side. Habitat likely unsuitable for Hine's Emerald.	1 hour	Negative
2008-07-11	C.D. Jones, C. Evans, R. Bowles, T. Vogt	Dornoch Swamp Lat: 44.296 Long: -80.797	Gravel road with forest/swamp/creek on both sides and small marly pond on S side. Habitat likely unsuitable for Hine's Emerald.	3 hours	Negative
2007-08-14	C. Evans	Essa Twp., 25th SR beaver pond Lat: 44.312 Long: -79.795	Beaver pond on small vegetation-covered creek coming from dense cedar swamp at base of hill, Pond somewhat stagnant. Habitat likely unsuitable for Hine's Emerald.	2 hours	Negative
2007-09-26	C. Evans	Essa Twp., 25th SR beaver pond Lat: 44.312 Long: -79.795	Beaver pond on small vegetation covered creek coming from dense cedar swamp at base of hill, Pond somewhat stagnant. Habitat likely unsuitable for Hine's Emerald.	2 hours	Negative

Date	Observer(s)	Location	Habitat	Search effort	Search result
2008-08-05	C. Evans	Essa Twp., 25th SR beaver pond Lat: 44.312 Long: -79.795	Beaver pond on small vegetation covered creek coming from dense cedar swamp at base of hill, Pond somewhat stagnant. Habitat likely unsuitable for Hine's Emerald.	2 hours	Negative
2008-08-21	C. Evans	Essa Twp., 25th SR beaver pond Lat: 44.312 Long: -79.795	Beaver pond on small vegetation covered creek coming from dense cedar swamp at base of hill, Pond somewhat stagnant. Habitat likely unsuitable for Hine's Emerald.	1 hour	Negative
2008-07-09	C.D. Jones, C. Evans, R. Bowles, T. Vogt, D.A. Sutherland	George Lake inlet from Lower Andrew Lake Lat: 45.199 Long: -81.465	Fen bordering stream. Main portion of fen not accessed. Burrowing crayfish present according to reports from other biologists (S. Brinker, pers. comm.). Potential Hine's Emerald habitat.	16 hours	Negative
2008-07-01	C. Evans, Kate Evans	George Parkway wetlands Lat: 44.428 Long: -79.782	Meadow adjacent to beaver pond, creeks, swamp, *Typha/Phragmites* marsh and seeps. Habitat not assessed for the presence of burrowing crayfish. Potential Hine's Emerald habitat.	2 hours	Negative
2009-06-23	C. Evans	George Parkway wetlands Lat: 44.428 Long: -79.782	Swamp, seepage fen with *Carex* and cattails. Habitat not assessed for the presence of burrowing crayfish. Potential Hine's Emerald habitat.	2 hours	Negative
2002-07-22	C.D. Jones	Lake Scugog area, Bruce Peninsula Lat: 45.12 Long: -81.53	A number of habitat types in this area including: coastal sedge marsh with some seeps and some slightly marly pools; several small fens; Lake Scugog itself is a shallow lake with many floating and emergent plants and a bay with some fen-like qualities. There is habitat up the Crane River (which feeds Lake Scugog) that may be more suitable for Hine's Emerald (Marshall pers. comm.).	1.5 hours	Negative

Date	Observer(s)	Location	Habitat	Search effort	Search result
2002-08-07	C.D. Jones, D.A. Sutherland	Lake Scugog area, Bruce Peninsula Lat: 45.12 Long: -81.53	A number of habitat types in this area including: coastal sedge marsh with some seeps and some slightly marly pools; several small fens; Lake Scugog itself is a shallow lake with many floating and emergent plants and a bay with some fen-like qualities. There is habitat up the Crane River (which feeds Lake Scugog) that may be more suitable for Hine's Emerald (Marshall pers. comm.).	9 hours	Negative
2008-07-08	C.D. Jones, C. Evans, R. Bowles, T. Vogt, D.A. Sutherland	Lake Scugog area, Bruce Peninsula Lat: 45.12 Long: -81.53	A number of habitat types in this area including: coastal sedge marsh with some seeps and some slightly marly pools; several small fens; Lake Scugog itself is a shallow lake with many floating and emergent plants and a bay with some fen-like qualities. There is habitat up the Crane River (which feeds Lake Scugog) that may be more suitable for Hine's Emerald (Marshall pers. comm.).	6 hours	Negative
2007-08-26	C. Evans	Little Lake Park, Barrie Lat: 44.417 Long: -79.665	Lake fed by springs at base of ancient Lake Algonquin bluff, swamp and *Typha* marshes, fields, residences and highway. Habitat not assessed for the presence of burrowing crayfish. Potential Hine's Emerald habitat.	1 hour	Negative
2009-09-02	C.D. Jones, K. Ballantyne, T. Zammit	Luther Marsh, Wild Lake Bog Lat: 43.919 Long: -80.408	Poor fen. Habitat likely unsuitable for Hine's Emerald.	3 hours	Negative
2008-06-23	C.D. Jones, C. Evans, R. Bowles	Marl Lake Lat: 44.514 Long: -79.984	Small marly lake fed from seeps and springs surrounded by marsh, fen and cedar/spruce/Black Ash swamps. Burrowing crayfish present. Potential Hine's Emerald habitat.	9 hours	Negative

Date	Observer(s)	Location	Habitat	Search effort	Search result
2008-07-12	C.D. Jones, C. Evans, R. Bowles, T. Vogt	Marl Lake Lat: 44.514 Long: -79.984	Small marly lake fed from seeps and springs surrounded by marsh, fen and cedar/spruce/Black Ash swamps. Burrowing crayfish present. Potential Hine's Emerald habitat.	2 hours	Negative
2008-07-25	C. Evans, Nikki Grantmyre, Nicole Gibson	Marl Lake Lat: 44.514 Long: -79.984	Small marly lake fed from seeps and springs surrounded by marsh, fen and cedar/spruce/Black Ash swamps. Burrowing crayfish present. Potential Hine's Emerald habitat.	3 hours	Negative
2008-07-25	C. Evans, Nikki Grantmyre, Nicole Gibson	Marl Lake Lat: 44.514 Long: -79.984	Small marly lake fed from seeps and springs surrounded by marsh, fen and cedar/spruce/Black Ash swamps. Burrowing crayfish present. Potential Hine's Emerald habitat.	3 hours	Negative
2008-08-15	C. Evans, Nikki Grantmyre, Amanda Dwyer	Marl Lake Lat: 44.514 Long: -79.984	Small marly lake fed from seeps and springs surrounded by marsh, fen and cedar/spruce/Black Ash swamps. Burrowing crayfish present. Potential Hine's Emerald habitat.	6 hours	Negative
1999-07-21	W.P. Steffens	Michael's Bay, Manitoulin Island Lat: 45.60 Long: -82.09	A large ridge and swale complex adjacent to Lake Huron. The swales closer to the lake are largely coastal meadow marsh, while those further inland have more peat and are more fen-like. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	3.5 hours	Negative
2002-07-17	C.D. Jones	Michael's Bay, Manitoulin Island Lat: 45.60 Long: -82.09	A large ridge and swale complex adjacent to Lake Huron. The swales closer to the lake are largely coastal meadow marsh, while those further inland have more peat and are more fen-like. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	4 hours	Negative

Date	Observer(s)	Location	Habitat	Search effort	Search result
2009-07-21	C.D. Jones, S. Brinker	Michael's Bay, Manitoulin Island Lat: 45.60 Long: -82.09	A large ridge and swale complex adjacent to Lake Huron. The swales closer to the lake are largely coastal meadow marsh, while those further inland have more peat and are more fen-like. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	4 hours	Negative
2009-07-28	C.D. Jones, C. Evans, F. Heesen	Midhurst Station, wetland N of, W of Nursery Rd. Lat: 44.455 Long: -79.774	Former beaver pond, now a mixture of swamp and open wet meadow. Habitat likely not suitable for Hine's Emerald.	2 hours	Negative
1999-07-23	W.P. Steffens	Misery Bay Fen, Manitoulin Island Lat: 45.80 Long: -82.75	Rich fen with mineral substrate and very shallow peat layer. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	3.5 hours	Negative
2002-07-15	C.D. Jones, Margo Holt	Misery Bay Fen, Manitoulin Island Lat: 45.80 Long: -82.75	Rich fen with mineral substrate and very shallow peat layer. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	7 hours	Negative
2002-07-19	C.D. Jones	Misery Bay Fen, Manitoulin Island Lat: 45.80 Long: -82.75	Rich fen with mineral substrate and very shallow peat layer. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	1.5 hours	Negative
2009-07-22	C.D. Jones, S. Brinker	Misery Bay Fen, Manitoulin Island Lat: 45.80 Long: -82.75	Rich fen with mineral substrate and very shallow peat layer. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	4 hours	Negative
2009-07-21	C.D. Jones, S. Brinker	Mud Lake, Manitoulin Island Lat: 45.715 Long: -82.170	Extensive sedge marsh with some open pools. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	1 hour	Negative

Date	Observer(s)	Location	Habitat	Search effort	Search result
2002-08-09	C.D. Jones, D.A. Sutherland	Oliphant Fen, Bruce Peninsula Lat: 44.73 Long: -81.28	Rich fen with mineral substrate. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	1 hour	Negative
2008-07-10	C.D. Jones, C. Evans, R. Bowles, T. Vogt, D.A. Sutherland	Oliphant Fen, Bruce Peninsula Lat: 44.73 Long: -81.28	Rich fen with mineral substrate. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	1.5 hours	Negative
2002-08-09	C.D. Jones, D.A. Sutherland	Petrel Point Nature Reserve, Bruce Peninsula Lat: 44.81 Long: -81.29	Rich fen with mineral substrate. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	1 hour	Negative
2008-07-10	C.D. Jones, C. Evans, R. Bowles, T. Vogt, D.A. Sutherland	Petrel Point Nature Reserve, Bruce Peninsula Lat: 44.81 Long: -81.29	Rich fen with mineral substrate. Burrowing crayfish appear to be absent and habitat may not be suitable for Hine's Emerald.	3 hours	Negative
2002-07-23	C.D. Jones	Pine Tree Harbour, Bruce Peninsula Lat: 45.08 Long: -81.49	Small fen with some marl-bottomed pools. Potential habitat.	1 hour	Negative
2009-09-01	C.D. Jones, C. Evans, K. Ballantyne, T. Zammit	Puslinch Bog Lat: 43.408 Long: -80.261	Poor fen. Habitat likely unsuitable for Hine's Emerald.	2 hours	Negative
2008-08-15	R. Bowles, Nicole Gibson	Tiny Marsh Lat: 44.594 Long: -79.938	Largely cattail marsh. Habitat likely unsuitable for Hine's Emerald.	4 hours	Negative
2009-07-29	C.D. Jones, C. Evans, S.M. Robinson, F. Heesen, S. Meyer	Wye Marsh, NE fen Lat: 44.723 Long: -79.843	Open sedge fen. No burrowing crayfish detected but water levels were high. Potential habitat.	4 hours	Negative
2009-07-29	C.D. Jones, C. Evans, S.M. Robinson, F. Heesen, S. Meyer	Wye Marsh, S fen Lat: 44.703 Long: -79.864	Open sedge fen. No burrowing crayfish detected but water levels were high. Potential habitat.	4 hours	Negative

In 2008, Jones, Evans and Bowles (again, with the assistance of others) also surveyed many additional sites in the counties of Bruce, Grey and Simcoe but failed to discover any new occurrences. In 2009, Jones, with assistance from others, surveyed additional sites in the municipalities of Brant, Simcoe, Waterloo, Wellington and in Manitoulin District but again failed to discover any new sites.

Surveys for adults consisted of visiting potential habitat (fens and fen-like habitats) during the adult flight season of Hine's Emerald (late June-early August) and using an aerial insect net to capture and confirm the identity of any dragonflies suspected of being Hine's Emerald. Surveys for larvae consisted of either: 1) using a small, wire-mesh, deep-fry basket (usually used for cooking) to sift through vegetation and muck within pools and shallow channels; or 2) locating crayfish burrows (known to be used by Hine's Emerald larvae – see section on "**Habitat**") and using a modified bilge-pump to pump out the contents of the burrow (Figure 10).

Figure 10. Using a modified bilge pump to pump out the contents of crayfish burrows can be an effective way to survey for Hine's Emerald larvae. Photo by C.D. Jones.

The surveys in 2008-2009 were not the first surveys for this species in Ontario. In 1999, Wayne Steffens conducted surveys in Bruce County and Manitoulin District (Steffens 2000) but failed to find any Hine's Emerald populations. In 2002, Colin Jones also conducted surveys in Bruce County and Manitoulin District (Jones 2003) and, like Steffens, failed to find any populations.

All of the above sites, the sampling effort per site, the date of sampling, and the search results are listed in Table 1. In total, 28 sites were visited and over 235 person-hours have been devoted to directed search.

In addition to the surveys noted above, other entomologists have looked for Hine's Emerald in Ontario but have failed to find any populations (Marshall pers. comm. 2008, Catling pers. comm. 2008). Moreover, an ongoing cooperative survey of Ontario Odonata has resulted in 40,000 records of dragonflies (unique species, location, date) over the past 10 years but only one site for Hine's Emerald has been reported.

Caution is necessary when interpreting negative survey results. Even with targeted surveys, Hine's Emerald can be very difficult to find, especially in areas with small populations. However, the search effort and the general dragonfly survey efforts in the province clearly suggest that Hine's Emerald occurs at only a very few, if any, additional Canadian locations.

HABITAT

Habitat requirements

Hine's Emerald is a species of calcareous wetlands including marshes, meadow marshes and fens dominated by graminoid vegetation (particularly by sedges) and fed primarily by groundwater from intermittent seeps. Most sites also have an underlying layer of shallow dolomitic bedrock (Cashatt and Vogt 2001, USFWS 2001).

Hine's Emerald larvae are aquatic and occur in shallow channels or sheetflow in areas of herbaceous vegetation such as cattails (*Typha* spp.) and sweetflag (*Acorus* spp.) in marshes, meadow marshes and fens (Cashatt and Vogt 2001). Soil types in these wetlands range from organic muck to mineral soils such as marl (USFWS 2001). Such seepage wetlands often dry out for a few weeks during summer months at which time Hine's Emerald larvae use the burrows of crayfish, including *Cambarus diogenes* (sites in the U.S.) and *Fallicambarus fodiens* (at Minesing Wetlands in Ontario) (Cashatt and Vogt 2001, Pintor and Soluk 2006, Soluk *et al*. 2000, C.D. Jones pers. obs. 2008). The larvae also use crayfish burrows during the winter months (Pintor and Soluk 2006, Soluk *et al.* 2000). The presence of crayfish burrows likely represents a critical component of Hine's Emerald habitat and may be a factor limiting its distribution (Vogt pers. comm. 2008).

Hine's Emerald adults require open, vegetated areas (including uplands) as places to forage as well as nearby or adjacent forest, which provide protected, shaded areas for perching and roosting (USFWS 2001).

In Ontario, Hine's Emerald larvae have been found within crayfish burrows dug into the peat and muck (Figure 11) in the open string fens (elongated openings) of the Minesing Wetlands (Figure 12). These openings are dominated by Bog Buckbean (*Menyanthes trifoliata*), Twig Rush (*Cladium mariscoides*), Beaked Spike-rush (*Eleocharis rostellata*), sedges (*Carex limosa, C. livida, C. chordorrhiza*), Common Bog Arrow-grass (*Triglochin maritima*) and Common Reed (*Phragmites australis* ssp. *americanus*). Adjacent to the openings are "string islands" with Tamarack (*Larix laricina*) and Eastern White Cedar (*Thuja occidentalis*).

Figure 11. Crayfish burrow (entrance hole indicated by red arrow) within the peat and muck of the open string fen of the Minesing Wetland (44.38˚N 79.85˚W) on July 7. 2008. Note the excavated contents of the burrow surrounding the entrance. Photo by C.D. Jones.

Figure 12. The open string fen within the Minesing Wetlands (44.38˚N 79.85˚W) on June 27. 2007 – confirmed larval habitat for Hine's Emerald. Photo by C.D. Jones.

The open string fens at Minesing Wetlands are a portion of the "Boreal Wetland Complex" (Hanna 1982). This complex is maintained by a regular flow of groundwater discharge from the base of the Nipissing bluff (the shoreline of post-glacial Lake Nipissing) along the southeast boundary of the wetland (Hanna 1982). Larval habitat at Minesing Wetlands may also include the seepage channels that flow through openings below the Nipissing bluff through the "Payette terrace" to the east of the string fens (Figure 13). Such seepage channels are similar to those used by Hine's Emerald larvae at sites in Illinois (Vogt pers. comm. 2008).

Figure 13. Seepage channels flowing through openings below the Nipissing bluff through the “Payette terrace” of the Minesing Wetlands (44.38˚N 79.85˚W) are probable sites for Hine’s Emerald larvae.

Bedrock in the Minesing Wetlands is limestone of the Verulam Formation with overlying soil ranging in depth between 60 to 90 metres (Hanna 1982). As such, Minesing Wetlands differs from most of the other Hine’s Emerald sites in that the limestone bedrock is not close to the surface. Hydrological processes are similar, however, and it is assumed that lateral flow of water (i.e., sheetflow) occurs in the Boreal Wetland Complex of Minesing Wetlands as a result of underlying, thick, relatively laterally continuous glaciolacustrine silts and clays that floor the wetland complex (Post 2009). Like the limestone bedrock close to the surface at most U.S. sites, the silts and clays flooring Minesing Wetlands act as an impermeable layer, directing the flow of water laterally.

Adults have been found foraging in open areas within and adjacent to the Minesing wetlands. Such openings include the open string fen, those located within the Payette terrace, fallow farm fields, and openings along trails (such as the Ganaraska Trail) and roadsides. Treed areas in and adjacent to the wetlands are likely important sites for roosting adults.

Habitat trends

Areas surrounding the Minesing wetlands have been subject to urban and agricultural development since the early 1800s, and some areas of Minesing Wetlands have been influenced by clearing, drainage and burning. However, much of the wetland complex itself exists in a near-natural state (Bowles *et al*. 2007, Hanna 1982).

Because the Boreal Wetland Complex at Minesing Wetlands is sustained primarily by groundwater inflow, maintenance of the wetland's current hydrogeological functionality is dependent on future effective management of recharge areas in the adjacent uplands (Post *et al*. 2010). Some biologists believe that the habitat in the Minesing wetlands has become increasingly dry over the past 35 years (Catling, pers. comm. 2010). Drying of the wetland may be related to groundwater levels as well as other factors including changing surface water patterns, higher summer temperatures and reduced snow load resulting in a smaller spring freshet. Although groundwater levels in 2009 did not differ significantly from those in 1999 (Post *et al*. 2010), it is thought that rapid development in these recharge areas, most notably the Snow Valley Uplands area to the southeast, may alter important groundwater recharge (Post *et al*. 2010). The fact that development in the southwest uplands may be restricted suggests that this threat is less imminent. A greater threat may be European Common Reed and Glossy Buckthorn. Both of these plants have recently invaded a variety of wetlands in the Great Lakes region, changing ecological conditions and resulting in the loss of most native species (Mitrow and Catling 2009). They are now spreading at an exponential rate (Catling and Mitrow 2009, 2011).

BIOLOGY

Since the Hine's Emerald was listed as Endangered in the United States, it has been the subject of a great deal of research and, as a result, its biology is better known than that of many other species of dragonfly.

Life cycle and reproduction

Like all dragonflies, Hine's Emerald is hemimetabolous, lacking a pupal stage; its development involves three stages - egg, larva and adult. The larval stage may exist for 3-5 years and adults live for a maximum of a few months.

The egg stage has not been described, but egg-laying has been observed and reported in the literature (Vogt and Cashatt 1994, 1997, 1999, Soluk *et al*. 1996, 1998). Mated females likely lay up to 500 eggs during their lives by repeatedly dipping the tip of their abdomens up to 200 times in muck and/or shallow water (USFWS 2001). Egg-laying has not been observed in Ontario. At sites in the United States, females have been observed laying eggs in cattail seepage marshes, seepage sedge meadows, sedge hummocks near marshy stream edges, near the edge of a swale, in muck in sluggish water at the edge of a spring, in small puddles, in streamlets, and in small marl/muck bottomed pools (Vogt and Cashatt 1994, Soluk *et al*. 1996, 1998, USFWS 2001).

The eggs eventually hatch into aquatic larvae that live in wetland habitats for 3-5 years before emerging as adults (Foster and Soluk 2004, Pintor and Soluk 2006). The larvae are generalist predators and feed upon a variety of other invertebrates. Fecal pellet analysis of larvae from Wisconsin and Illinois indicated that mayflies (Ephemeroptera) and caddisflies (Trichoptera) were the most common recognizable prey remains and that oligochaetes were also commonly eaten (Soluk *et al.* 1998). It is assumed that Hine's Emerald larvae are sit-and-wait predators, remaining motionless until a prey item comes within striking range (USFWS 2001). Larvae are thought to be more active at night than during the day (Pintor and Soluk 2006), which may reduce the risk of predation (USFWS 2001).

Once mature, Hine's Emerald larvae crawl from their aquatic environment usually onto an emergent plant (e.g., sedges, cattails) where the adult emerges from the larval skin. The cast-off larval skin (exuvia) is left behind and the newly emerged adult (teneral) flies away. The timing of adult emergence partially is tied to weather conditions and can be predicted using temperature and precipitation data (Mierzwa *et al.* 1995). In Illinois, adult emergence has been observed as early as late May in a warm year (Cashatt and Vogt 1992) and as late as mid- to late June in cooler years (Cashatt *et al.* 1992, Cashatt and Sims 1993). In Wisconsin, emergence probably begins in late June (Foster and Soluk 2004, Vogt and Cashatt 1994). In Ontario, the earliest record of an adult is June 10. In 2008, the first adults were not detected until June 19. Emergence in Ontario, therefore, likely begins somewhere between early to mid-June. Although emergence continues to occur throughout the summer, the vast majority of adults emerge within the first 2-3 weeks of the emergence period (Foster and Soluk 2004).

Like all dragonflies, Hine's Emerald has three stages during its adult lifespan: pre-reproductive, reproductive and post-reproductive. During the pre-reproductive stage, a newly emerged adult first flies away to the protective cover of vegetation where, over the period of a few days, its body hardens and its sexual organs mature (Corbet 1999). The pre-reproductive period likely spans 7-10 days in Hine's Emerald, during which time individuals may fly up to 3 km from sites of emergence (Cashatt *et al.* 1991, USFWS 2001). During the pre-productive period, Hine's Emeralds have been observed taking short feeding flights of 1 to 3 minutes and perching from 4-15 m high in trees (Cashatt *et al.* 1991). During the reproductive stage, which likely lasts from 2-4 weeks, adults establish breeding sites and use these areas to breed and lay eggs. Adults also

continue to forage, occasionally at distances as far as 2 km from their breeding site (USFWS 2001). Following the reproductive stage, adults may continue to survive for up to several weeks through the post-reproductive stage.

Adult dragonflies are aerial predators and probably feed on a variety of insects. Like most dragonflies, Hine's Emeralds probably feed primarily on flies (Order Diptera), as reported by Vogt and Cashatt (1994). Foraging occurs primarily in open areas such as over meadows and fields or along roads and trails, quite often along a forest edge (Vogt and Cashatt 1994). Feeding occurs at any time during the day but is most commonly observed in the morning (Mierzwa 1995, Cashatt and Vogt 1996, Soluk *et al.* 1998).

During the reproductive period, males engage in what is often described as territorial behaviour. Such behaviour involves males patrolling above potential larval habitat (e.g., streamlets and pools) by making fast flights back and forth and occasionally hovering. Territories encompass a range of 2-4 square metres and males usually fly between 0.5-2.0 m above the surface (Cashatt and Vogt 1990, Vogt and Cashatt 1994). When a female approaches a male's territory, the male intercepts the female and attempts to mate with her by clasping the back of her head with his terminal appendages. If the male is accepted, the female will then bend her abdomen tip forward so that her genital opening contacts the male's secondary genitalia (located at the base of his abdomen); sperm is then transferred.

Physiology and adaptability

The direct physiological requirements of Hine's Emerald are not documented. It is suspected, however, that Hine's Emerald larvae are more tolerant of low dissolved oxygen levels than many other species of dragonflies (Mierzwa *et al.* 1995) and that they are adapted to persist in habitats that experience periodic drying (Soluk *et al*. 1998, 2004). These adaptations likely allow Hine's Emerald to persist in sites where competitors and predators are largely eliminated by seasonal drying events (Soluk *et al.* 2004).

Dispersal and migration

Hine's Emerald is not a migratory species and little has been documented regarding dispersal. Active dispersal of adults between sites and within sites has been documented in Illinois with the farthest distance recorded as 5.4 km (Mierzwa 1995, Cashatt and Vogt 1996).

Interspecific interactions

Seepage wetlands such as those at Minesing Wetlands often dry out for a few weeks during summer months. During these times Hine's Emerald larvae use the burrows of crayfish including *Cambarus diogenes* (sites in the U.S.) and *Fallicambarus fodiens* (at Minesing Wetlands in Ontario) (Cashatt and Vogt 2001, Pintor and Soluk 2006, Soluk *et al.* 2000, C.D. Jones pers. obs. 2008). The larvae also use crayfish burrows during the winter months (Pintor and Soluk 2006, Soluk *et al*. 2000). It is very likely that the presence of crayfish burrows represent a critical component of Hine's Emerald habitat and may be a factor limiting their distribution (Vogt pers. comm. 2008).

POPULATION SIZES AND TRENDS

Sampling effort and methods

No surveys have been conducted in Ontario to estimate population sizes. The only information that is available is indicated in Table 1. Mark and recapture techniques have been used to estimate population size at several sites in Wisconsin (Kirk and Vogt 1995) and Illinois (Mierzwa 1995, Vogt and Cashatt 1997) although these estimates had high variance and have been criticized as not being appropriate for long-term monitoring (Soluk *et al*. 1998). Soluk *et al.* (1998) suggested that a more appropriate method for monitoring population size in dragonflies is a removal method. It does not appear, however, that this method has been used to monitor any populations of Hine's Emerald to date. Using exuviae has also been suggested for monitoring (Foster and Soluk 2004).

Abundance

Population size of the single known site in Canada is unknown. However adults were encountered during each directed search of the Minesing Wetlands location so that the population may not be small.

Fluctuations and trends

There are no data on year-to-year fluctuations or trends of Hine's Emerald populations in Canada.

Rescue effect

The likelihood that dispersal from an outside population could repopulate a declining or extirpated population in Ontario is relatively low given the distance of 280 km across Lake Huron between the closest Michigan site and the Minesing Wetlands. The ability of Hine's Emerald to disperse has been poorly studied, however, and so it is not known whether dispersal between populations or even subpopulations occurs. The maximum recorded dispersal distance of 5.4 km (Mierzwa 1995, Cashatt and Vogt 1996) suggests that dispersal capability in Hine's Emerald is likely limited and it is assumed that populations separated by distances of greater than 50 km would not have frequent exchange of individuals (USFWS 2001).

THREATS AND LIMITING FACTORS

Any changes to surface and sub-surface hydrology that affect the quantity and quality of groundwater flow are likely to negatively impact larval habitat and consequently reduce populations of Hine's Emerald (USFWS 2001).

The aquifer believed to be the principal source of the groundwater that supplies the eastern portion of the Minesing Wetland (including the Hine's Emerald habitat) is located in the Snow Valley Uplands to the east (Post 2009, Post pers. comm. 2010). Currently, land use in the Snow Valley Uplands is comprised of agriculture and low intensity rural residential. There are, however, proposed housing developments in the Snow Valley Uplands, the effects of which (e.g., paving, groundwater wells) could reduce the baseflow of water to Minesing Wetlands (Post pers. comm. 2010). Hypothetical urbanization impact calculations suggest that low to medium density residential development in the uplands will result in a modest decrease in baseflow to the wetland. The urbanization impact calculations further indicate that a loss of recharge in the uplands may dramatically reduce baseflow to the headwaters of local streams (Beckers 1998 as cited in Post 2009). Such decreases in baseflow to the Minesing Wetland could have direct negative impacts to Hine's Emerald breeding sites by reducing the water necessary to maintain larval habitat. Indirectly, reduced water flow could impact Hine's Emerald breeding sites by changing the composition of the vegetation community (e.g., succession in the open string fen from a graminoid-dominated habitat to a low shrub or thicket community).

It has also been noted that European Common Reed (*Phragmites australis* subsp. *australis*) has been spreading in parts of the Minesing Wetlands, and may invade the open string fen (Catling pers. comm. 2010). While the variety of Common Reed present at Minesing Wetlands appears to be mainly the native subspecies *americanus*, spread of the European subspecies *australis*, which excludes native plants and animals, and eliminates bare substrate, could nonetheless have negative impacts on the hydrology and on the presence of burrowing crayfish in current Hine's Emerald breeding sites. It has vastly modified the habitat of wetlands including fens and fen-like prairies, marsh and interdunal meadows (Mitrow and Catling 2009) and is expanding at an exponential rate (Catling & Mitrow 2009, 2011). Glossy Buckthorn is also explanding rapidly and has impacted fens and fen-like habitats by developing dense stands that exclude native flora and fauna.

Contamination of groundwater is also a potential threat to Hine's Emerald habitat (USFWS 2001), including the habitat at Minesing Wetlands (Post pers. comm. 2010). The Snow Valley Uplands are primarily comprised of permeable sand and gravel formations and as a result the source of the water supplying the eastern portion of Minesing Wetlands could be contaminated by agricultural pesticide use, agricultural nutrient management, faulty or degraded septic beds and potential future development pressures (Post 2009).

Very little is known about disease and predation in this species, but there are no indications that these factors may be contributing to any declines (USFWS 2001).

Rare insects are often considered to be valuable to collectors, but in the case of Hine's Emerald, collection of adults is likely not a significant threat (USFWS 2001). The trampling of larval habitat, however, by otherwise well-meaning naturalists interested in seeing this rare species could be a potential threat.

PROTECTION, STATUS, AND RANKS

Legal protection and status

Hine's Emerald was listed as Endangered in the United States on January 26, 1995, under the provisions of the United States *Endangered Species Act of 1973* (USFWS 2001). It is also listed as Endangered in the states of Illinois, Michigan, Ohio and Wisconsin (IDNR 2008, MDNRE 2009, ODNR 2009, WDNR 2009). The species is currently not protected under the *Species at Risk Act* in Canada or Ontario's *Endangered Species Act, 2007*. It is not listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Non-legal status and ranks

This species is ranked globally as G2G3. This is a range rank between: Imperiled (at high risk of extinction or elimination due to very restricted range, very few populations, steep declines, or other factors) and Vulnerable (at moderate risk of extinction or elimination due to a restricted range, relatively few populations, recent and widespread declines, or other factors) by NatureServe (2009).

It is ranked nationally as N2N3 (Imperiled to Vulnerable) in the United States and N1 (Critically Imperiled – at very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors) in Canada (NatureServe 2009).

Subnationally, it is ranked as SX (Extirpated) in both Indiana (InDNR 2005) and Ohio (NatureServe 2009), SH (Historical) in Alabama (NatureServe 2009), S1 in Illinois (Kieninger pers. comm. 2009), Michigan (MNFI 2007), Wisconsin (WDNR 2009) and Ontario (Jones 2009), and S2 in Missouri (MNHP 2010). It is expected to be down-ranked to S2 in Michigan (Cuthrell pers. comm. 2009) and Wisconsin (Smith pers. comm. 2009) in the near future.

This species is listed as Near Threatened by the International Union for Conservation of Nature Red List of Threatened Species (Abbott and Cashatt 2007).

In Canada, it has been assigned a provincial and national General Status rank of May be at Risk (Leah Ramsay, pers. comm. 2011, Donald Sutherland, pers. com. 2011.

Habitat protection and ownership

The Minesing Wetlands spans an area of more than 6000 hectares and is recognized regionally, provincially and internationally as a significant wetland complex (Bowles *et al.* 2007). Since the early 1970s, public agencies including the Nottawasaga Valley Conservation Authority (NVCA), the Nature Conservancy of Canada (NCC) and the Ontario Ministry of Natural Resources (OMNR) have acquired land parcels within Minesing Wetlands to safeguard its significant natural features and functions (Bowles *et al.* 2007). The majority of the area (over 3900 hectares) is currently owned and/or managed by the Nottawasaga Valley Conservation Authority and additional land continues to be acquired with the assistance and support of the NCC (Bowles *et al.* 2007). The remaining areas of Minesing Wetlands are a mixture of provincial Crown Land (ca. 775 hectares), Simcoe County Forest (ca. 160 hectares) and private property (1200 hectares).

The land parcels where Hine's Emerald have actually been observed (including confirmed and suspected breeding habitat, adult foraging habitat, and adult pre-reproductive habitat) include a mixture of public and private lands as follows: provincial Crown Land (95 hectares), Nottawasaga Valley Conservation Authority property (244 hectares), Simcoe County Forest (74 hectares), Township of Springwater (15 hectares) and private property (258 hectares). The vast majority of sightings and/or suspected breeding habitat are, however, contained within the parcels of private property. Public and private lands adjacent to the above parcels likely also support Hine's Emerald.

In Ontario, the habitats of species of conservation concern (i.e., those considered provincially rare and tracked by the Natural Heritage Information Centre, Ontario Ministry of Natural Resources), including Hine's Emerald, receive policy level protection as significant wildlife habitat through the natural heritage provisions of the Provincial Policy Statement (2005) under the provincial *Planning Act*.

The Minesing Wetlands are protected from development and site alteration by a number of provincial and municipal natural heritage designations and policies. It is classified as both a provincially significant Life Science Area of Natural and Scientific Interest (ANSI) and a Provincially Significant Wetland. As such, the Minesing Wetlands also receive policy level protection through the natural heritage provisions of the Provincial Policy Statement (2005) under the provincial *Planning Act*. The Wetlands are also part of the County of Simcoe's Greenland Designation and, as such, receive policy protection through the counties' official plan (County of Simcoe 2008).

Portions of the Minesing Wetlands, including some of the Hine's Emerald habitat, are also habitat for many regionally and provincially rare species, including several species at risk such as Least Bittern (*Ixobrychus exilis*), Bald Eagle (*Haliaeetus leucocephalus*), Cerulean Warbler (*Dendroica cerulea*), Spotted Turtle (*Clemmys guttata*), Northern Ribbon Snake (*Thamnophis sauritus*) and Eastern Prairie Fringed-orchid (*Platanthera leucophaea*). The provincial *Endangered Species Act, 2007* provides habitat protection for those that are Threatened or Endangered.

Habitat protection also may be afforded by the NVCA through the Development, Interference with Wetlands and Alteration to Shorelines and Watercourses Regulations under the provincial *Conservation Authorities Act*. Aspects of the provincial *Nutrient Management Act*, *Environmental Assessment Act*, *Environmental Protection Act, Water Resources Act,* and *Source Water Protection Act* may also provide indirect protection for the habitat of Hine's Emerald.

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Alan Dextrase, Senior Species at Risk Biologist
Species at Risk Branch
Ontario Ministry of Natural Resources
Peterborough, Ontario

Dr. Tim Cashatt, Chair and Curator of Zoology
Illinois State Museum
Research and Collection Center
Springfield, Illinois

David Cuthrell, Conservation Scientist
Michigan Natural Features Inventory
Michigan State University Extension
Lansing, Michigan

Jack Dingledine
U.S. Fish and Wildlife Service
East Lansing Field Office
East Lansing, Michigan

Chris Evans, Senior Protection and Control Engineer
Hydro One
Utopia, Ontario

Sophie Foster
University of Toronto
Toronto, Ontario

Barbara Hosler
U.S. Fish and Wildlife Service
East Lansing Field Office
East Lansing, Michigan

Tara Kieninger, Database Program Manager
Illinois Natural Heritage Database
Illinois Department of Natural Resources
Springfield, Illinois

Kristopher Law, Endangered Species Coordinator
U.S. Fish and Wildlife Service
Chicago Field Office
Chicago, Illinois

Dr. Steve Marshall, Professor
Department of Environmental Biology
University of Guelph
Guelph, Ontario

Ryan Post, Hydrogeologist/Source Water Protection Coordinator
Nottawasaga Valley Conservation Authority
Utopia, Ontario

Richard Russell
Canadian Wildlife Service - Ontario
Environment Canada
Ottawa, Ontario

Dr. Daniel Soluk, Associate Professor
Department of Biology
University of South Dakota
Vermillion, South Dakota

William Smith, Zoologist
Natural Heritage Inventory Program
Wisconsin Department of Natural Resources
Madison, Wisconsin

Don Sutherland, Zoologist
Natural Heritage Information Centre
Ontario Ministry of Natural Resources
Peterborough, Ontario

Tim Vogt, Park Scientist
Division of State Parks
Missouri Department of Natural Resources
Jefferson City, Missouri

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Colin Jones has a B.Sc. in Biology from the University of Guelph and a B.Ed. from the University of Ottawa. After graduating, he worked in Algonquin Provincial Park as a Park Naturalist for five years. During that time, Colin conducted many insect surveys, especially concentrating his efforts on Lepidoptera and Odonata. Since 1999, he has worked as a biologist for the Natural Heritage Information Centre, Ontario Ministry of Natural Resources in Peterborough, Ontario where most of his work focuses on the conservation of rare species with an emphasis on invertebrates. Colin has been a member of the COSEWIC Arthropods Specialist Subcommittee since 2005.

COLLECTIONS EXAMINED

None.