COSEWIC
Assessment and Status Report

on the

Massasauga
Sistrurus catenatus

Great Lakes / St. Lawrence population
Carolinian population

in Canada

Great Lakes / St. Lawrence population - THREATENED
Carolinian population - ENDANGERED
2012

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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Previous report(s):

COSEWIC. 2002. COSEWIC assessment and update status report on the massasauga *Sistrurus catenatus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. viI + 23 pp.

Rouse, J.D., and R.J. Willson. 2002. Update COSEWIC status report on the massasauga *Sistrurus catenatus* in Canada, *in* COSEWIC assessment and update status report on the massasauga *Sistrurus catenatus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-23 pp.

Weller, W.F. and H.J. Parsons. 1991. COSEWIC status report on the eastern massasauga *Sistrurus catenatus catenatus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 53 pp.

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COSEWIC
Assessment Summary

Assessment Summary – November 2012

Common name
Massasauga - Great Lakes / St. Lawrence population

Scientific name
Sistrurus catenatus

Status
Threatened

Reason for designation
The number of adults may be fewer than 10,000 and is declining because of continued degradation and loss of habitat, increasing mortality on roads and ongoing persecution of this venomous species.

Occurrence
Ontario

Status history
The species was considered a single unit and designated Threatened in April 1991. Status re-examined and confirmed in November 2002. Split into two populations in November 2012. The Great Lakes / St. Lawrence population was designated Threatened in November 2012.

Assessment Summary – November 2012

Common name
Massasauga - Carolinian population

Scientific name
Sistrurus catenatus

Status
Endangered

Reason for designation
The population is reduced to two highly isolated and restricted areas surrounded by intense threats from neighbouring development and subject to illegal exploitation. The sub-populations are small and subject to genetic and demographic stochasticity that endangers future growth. Habitat quality also continues to decline.

Occurrence
Ontario

Status history
The species was considered a single unit and designated Threatened in April 1991. Status re-examined and confirmed in November 2002. Split into two populations in November 2012. The Carolinian population was designated Endangered in November 2012.

COSEWIC
Executive Summary

Massasauga
Sistrurus catenatus

Great Lakes / St. Lawrence population
Carolinian population

Wildlife Species Description and Significance

The Massasauga (*Sistrurus catenatus*) is a relatively small, thick-bodied rattlesnake with a segmented rattle on its tail tip. It is grey, tan or light brown with dark brown, bow-tie shaped blotches on its back and is often confused with other banded or blotched Ontario snakes. The Massasauga has elliptical pupils and a pair of heat-sensitive pits between the eyes and nostrils. The Massasauga is Ontario's only remaining venomous snake and provides a unique opportunity for us to respect and co-exist with a creature that can cause us harm. Despite widespread persecution, Massasaugas pose little threat to public safety. In First Nations traditions, Massasaugas are the medicine keepers of the land, a reminder to tread lightly and to take only what we need.

Distribution

The Massasauga ranges from Canada (Ontario) south into northern Mexico, but only the eastern subspecies (*S. catenatus catenatus*) is found in Canada. In Ontario, the Massasauga occurs as two designatable units: (1) in the Georgian Bay region, mostly on the northern Bruce Peninsula and along the eastern shore of Georgian Bay, and (2) in the Carolinian region of southwestern Ontario, at Ojibway Prairie in Windsor/LaSalle and at Wainfleet Bog near Port Colborne. The size of the Canadian range of the Massasauga has decreased considerably in comparison to its historical range and continues to shrink.

Habitat

Massasauga habitat in Canada varies from wet prairie and old fields to peatlands, bedrock barrens, and coniferous forests. Massasaugas require a semi-open habitat or small openings in forest to provide both cover from predators and opportunities for thermoregulation. Hibernation sites are often damp or water-saturated, and include mammal or crayfish burrows, rock fissures and other depressions that allow access below the frost line. Quantity and quality of Massasauga habitat in the Carolinian region continue to decline. Habitat surrounding Georgian Bay, although relatively widespread and intact, is subject to moderate levels of degradation and loss.

Biology

In Ontario, Massasaugas are active for half of the year (spring to fall) and hibernate for the other half. They are sit-and-wait predators and feed almost exclusively on small mammals. They are prey for a variety of raptors and medium-sized mammals. The Massasauga is shy, preferring to retreat or rely on camouflage and shrub cover to avoid detection by predators or people. Depending on the population, Massasaugas may cover distances as great as a few kilometres or exhibit limited dispersal and small daily movements. Mating occurs in late summer and young are born live the following summer. Females become sexually mature at 3-5 years of age and give birth every other year. Massasaugas can live over 10 years in the wild and have a generation time of about 8 years. Natural adult mortality rates are 25% - 40% per year.

Population Sizes and Trends

Some of the most secure populations of the Eastern Massasauga in all of North America occur in the Georgian Bay region. Population size is estimated at roughly 10 000 adults, mostly concentrated along the upper Bruce Peninsula and on the eastern shore of Georgian Bay. Although the number of subpopulations in the region appears stable, an overall long-term decline in total population size is suspected and probable. In the Carolinian region, Massasaugas are limited to several dozen adults at two small, isolated sites. The total Carolinian population size is in decline, and the range of each subpopulation has contracted significantly over the last 25 years. The Ojibway Prairie subpopulation is no longer viable and is projected to become extinct in the near future.

Threats and Limiting Factors

Historical range-wide decline of the Massasauga in Canada is attributed to habitat loss from agriculture, resource extraction and massive road expansion in combination with widespread eradication efforts. Contemporary declines in the number of mature individuals are suspected in the Great Lakes / St. Lawrence region due to a combination of habitat loss and degradation, persecution, collection, recreational development and road mortality. Habitat loss and degradation due to natural succession and urban sprawl are the greatest threats to the Carolinian population. A slow rate of reproduction and delayed maturity reduce this species' resilience to unnaturally high levels of adult mortality, and low dispersal rates dictate that extirpated subpopulations are unlikely to be recolonized naturally. The Carolinian subpopulations face the additional threat of stochastic extinction due to their small size and high degree of isolation.

Protection, Status, and Ranks

The Massasauga was assessed as 'Threatened' in Canada by COSEWIC in 1991 and 2002, and as 'Threatened' in Ontario by COSSARO in 1998. Currently, this species is listed as 'Threatened' under both the Ontario *Endangered Species Act* (ESA), 2007 and the federal *Species at Risk Act*, 2002. It is also considered a 'Specially Protected Reptile' under the Ontario *Fish and Wildlife Conservation Act,* 1999. The Massasauga is listed as 'Least Concern' by the International Union for the Conservation of Nature (IUCN), but has been assessed by NatureServe (2011) as 'Vulnerable' globally, nationally and provincially (G3G4,N3,S3). Nine of 10 states with the Eastern Massasauga designate it as S1 or S2.

TECHNICAL SUMMARY - Great Lakes / St. Lawrence population

Sistrurus catenatus
Massasauga — Massasauga
Great Lakes / St. Lawrence population — Population des Grands Lacs et du Saint-Laurent
Range of occurrence in Canada: Ontario

Demographic Information

Generation time (see BIOLOGY Life Cycle and Reproduction) An average of two methods estimates 8 years.	8 years
Is there an observed or inferred continuing decline in number of mature individuals?	Inferred decline
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 = 25 years].	A decline is inferred from the increase in roads, and residential and recreational development and from ongoing persecution. The size of the decline over the past 25 years is probably substantial, but unknown.
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Suspected future decline
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations = 25 years] period, over a time period including both the past and the future.	A decline is inferred from the ongoing increase in roads, and residential and recreational development and from ongoing persecution. The size of decline is probably substantial, but is unknown.
Are the causes of the decline clearly reversible and understood and ceased?	Many causes are understood and some can be reduced, but they are not entirely ceased and/or are not reversible
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence refer to text for explanation	37,200 km²
Index of area of occupancy (IAO) ***Note:*** *2,316 km² is conservative as IAO would likely be higher if expected areas of occupancy in suitable habitat between known observations were taken into account to create a more "continuous" IAO (IAO is more patchy along Georgian Bay).*	2,316 km²
Is the total population severely fragmented?	No

Number of locations∗ (Appendix 1) Note: the term "location" is not used consistently in this report according to the COSEWIC definition: **Location:** The term 'location' defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations. It has proved difficult to apply this definition consistently across this designatable unit's (DU) distribution	37 extant "locations" (see Appendix 1)
Is there an observed continuing decline in extent of occurrence?	No
Is there an observed continuing decline in index of area of occupancy?	No
Is there an observed continuing decline in number of populations/locations*?	No
Is there an observed continuing decline in area, extent and/or quality of habitat?	Yes. In northern parts of the range habitat decline is possibly less than in southern areas where development is extensive and where the species originally occurred in higher numbers. These declines in habitat extent and quality are expected to continue and may decline more rapidly into the future
Are there extreme fluctuations in number of populations/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 population)

Population	**N Individuals**
Georgian Bay Islands National Park and Killbear Provincial Park	94 (67-120)
Upper Bruce Peninsula	2500 (1600-3200)
Remainder (32) of "locations"	13,440 (7446-18874)
Total (see **Abundance,** Appendix 7**)** these numbers are likely overestimates for reasons given in the text and Appendix 7.	16034 (9113-22194)

Quantitative Analysis

Probability of extinction in the wild	Probably low (Middleton and Chu 2004; Miller 2005)

Threats (actual or imminent, to populations or habitats)

Habitat loss and degradation Road mortality Intentional killing/persecution Collection for the pet trade

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? The subspecies is in decline across its North American range, is protected in almost every jurisdiction, and is S1 or S2 in all jurisdictions where it has been assessed except Michigan and Ontario. Even in

∗ See Definitions and Abbreviations on COSEWIC website and IUCN 2010 for more information on this term.

Michigan, they are “uncommon” and in scattered local sites (Harding 1997; Holman 2012).	
Is immigration known or possible?	Not likely
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	No

Status History

COSEWIC: The species was considered a single unit and designated Threatened in April 1991. Status re-examined and confirmed in November 2002. Split into two populations in November 2012. The Great Lakes / St. Lawrence population was designated Threatened in November 2012.

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Threatened	C2a (i)
Reasons for designation: The number of adults may be fewer than 10,000 and is declining because of continued degradation and loss of habitat, increasing mortality on roads and ongoing persecution of this venomous species.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): No criteria are met due to lack of precise trend information; however, it is possible that the species meets A4(c) based on an observed, estimated, projected or suspected reduction in total number of mature individuals over a three-generation period including both the past and future, and where the reduction or its causes may not have ceased or may not be reversible.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable as EO and IAO exceed thresholds and would not meet “severe fragmentation” and there are no extreme fluctuations in population size.
Criterion C (Small and Declining Number of Mature Individuals): C2a(i) applies because there is a continuing decline and, based on genetic research into population structuring, no population is estimated to contain >1000 mature individuals.
Criterion D (Very Small or Restricted Total Population): Not applicable.
Criterion E (Quantitative Analysis): Not applicable.

TECHNICAL SUMMARY - Carolinian population

Sistrurus catenatus

Massasauga — Massasauga

Carolinian population — Population carolinienne

Range of occurrence in Canada: Ontario

Demographic Information

Generation time (see **BIOLOGY Life Cycle and Reproduction**)	8 years
Is there an observed or inferred continuing decline in number of mature individuals?	Yes, observed and projected
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].	A significant decline has occurred, probably > 25%
[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 clearly reversible and understood and ceased?	Many causes are understood, but not ceased and mostly not reversible
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	865 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	40 km²
Is the total population severely fragmented?	Yes
Number of locations∗	2 extant (Appendix 1)
Is there an observed continuing decline in extent of occurrence?	Yes
Is there an observed continuing decline in index of area of occupancy?	Yes
Is there an observed continuing decline in number of populations/locations*?	Yes
Is there an observed continuing decline in area, extent and/or quality of habitat?	Yes
Are there extreme fluctuations in number of populations/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 population)

Population	**N Mature Individuals**
Ojibway Prairie	10-40
Wainfleet Bog	40-70
Total	~80 (50 - 110)

∗ See Definitions and Abbreviations on COSEWIC website and IUCN 2010 for more information on this term.

Quantitative Analysis

Probability of extinction in the wild	A preliminary PVA suggests probability of extinction is high for Ojibway (Brennan 2004)

Threats (actual or imminent, to populations or habitats)

Habitat loss and degradation Small population size Road mortality (Ojibway) Intentional killing/persecution Illegal collection for the wildlife trade

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? The subspecies is in decline across its North American range and protected in almost every jurisdiction.	
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	No
Is rescue from outside populations likely?	No

Status History

COSEWIC: The species was considered a single unit and designated Threatened in April 1991. Status re-examined and confirmed in November 2002. Split into two populations in November 2012. The Carolinian population was designated Endangered in November 2012.

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code:** B1ab(i,ii,iii,v)+2ab(i,ii,iii,v); C2a(i); D1
Reasons for designation: The population is reduced to two highly isolated and restricted areas surrounded by intense threats from neighbouring development and subject to illegal exploitation. The subpopulations are small and subject to genetic and demographic stochasticity that endangers future growth. Habitat quality also continues to decline.	

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 as both EO and IAO meet Endangered thresholds (B1,2), the population is known to exist at only two locations (Ojibway and Wainfleet) (a), and there is a continuing decline (observed, inferred and projected) in EO, IAO, quality of habitat, and number of mature individuals (i,ii,iii,v).
Criterion C (Small and Declining Number of Mature Individuals): Meets Endangered as there are fewer than 2500 adults, there is a continuing decline, and no population is estimated to contain >250 mature individuals C2a(i).
Criterion D (Very Small or Restricted Total Population): Population is estimated to have between 40-110 mature individuals (<250 mature individuals).
Criterion E (Quantitative Analysis): Not applicable. The quantitative analysis that is available is not considered robust enough to meet this criterion.

PREFACE

The previous COSEWIC status report on the Massasauga in Canada identified four ‘populations’ of this species: Bruce Peninsula, eastern Georgian Bay, Ojibway Prairie and Wainfleet Bog (Rouse and Willson 2002). To account for historical distribution, acknowledge updated distribution information and highlight differences (genetic, ecological, etc.) among these ‘populations’ two designatable units (DU) are now proposed: the Great Lakes/St. Lawrence DU (multiple subpopulations surrounding Georgian Bay, including upper Bruce Peninsula and eastern Georgian Bay populations) and the Carolinian DU (Ojibway Prairie and Wainfleet Bog). Whereas only two ‘populations’ (Bruce Peninsula and eastern Georgian Bay) were previously identified surrounding Georgian Bay, this report proposes a single regional population (Great Lakes/St. Lawrence DU) made up of numerous “locations”, each varying in number of subpopulations, abundance, geographic extent, and level of connectivity between neighbouring subpopulations. Within this region, it is still accepted that abundance and density of Massasaugas are relatively higher in subpopulations on the upper Bruce Peninsula and the shoreline of Georgian Bay than in areas further inland from Georgian Bay.

In the Georgian Bay region, recent estimates of population trends have been attempted for some well-studied subpopulations (e.g., northern Bruce Peninsula and Beausoleil Island). Sizes of these populations are probably stable or slightly declining. The number of subpopulations in this DU appears to be stable, as new sites have been identified and presence at some historical sites has been confirmed. These new sites occur on Manitoulin and nearby islands and on the periphery of this species’ range (e.g., Blind River, Greater Sudbury and Restoule Lake). Based on updated distribution data, the total number of known sites and the extent of occurrence have increased since the last status report. Also, the known number and size of protected areas harbouring this species have increased. All these increases reflect new search effort rather than actual increases in abundance or range of distribution. Finally, an updated estimate of total population size has been conducted for the Great Lakes/St. Lawrence DU.

In the Carolinian region, since the previous status report no historical sites were confirmed to be currently occupied and all verified reports are from the two remaining extant subpopulations. New estimates were produced for historical rates of decline for the entire DU and for each of the two remaining subpopulations in an attempt to better quantify extensive historical and ongoing population declines. Extinction of the Ojibway population is imminent and, as a result, a significant decline in the extent of occurrence of the Massasauga in Canada is projected.

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
(2012)

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 Canada | Environnement Canada
Canadian Wildlife Service | Service canadien de la faune

Canada

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

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Sistrurus catenatus

Great Lakes / St. Lawrence population
Carolinian population

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2012

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Common Name: Massasauga, Eastern Massasauga Rattlesnake

Other Unofficial Names: Missisaug (a/i), Swamp Rattler, Black Snapper

French Name: Massasauga, Serpent à sonnette (rattlesnake),

Anishinaabe/Ojibway:
Name: Wahbunoongn zhenuhwa (Massasauga), zhenuhwa (rattlesnake), kenabig (snake)

Class, Order, Suborder, Family, Subfamily: Reptilia, Squamata, Serpentes, Viperidae, Crotalinae

Species:*Sistrurus catenatus* (Rafinesque 1818)

Subspecies:*S. c. catenatus* (Eastern Massasauga), *S. c. tergeminus* (Western Massasauga), *S. c. edwardsii* (Desert Massasauga)

Subspecies in Canada: *S. c. catenatus* (Eastern Massasauga)

Kubatko *et al.* (2011) have recently suggested that the Eastern Massasauga (*S. c. catenatus*) be elevated to full species status, based on phylogenetic analyses using nuclear and mitochondrial DNA loci. However, Crother *et al.* (2012) suggest that until other difficulties with the taxonomic status of the Massasauga are resolved that the current taxonomy be retained.

Morphological Description

The Massasauga is Ontario's only extant venomous snake. It is a thick-bodied, dorsally blotched snake with a small well-developed rattle at the end of its tail (Figure 1). The Massasauga has elliptical pupils and a pair of heat-sensitive facial pits (loreal pits) situated between the eyes and nostrils. *Sistrurus catenatus* is a relatively small rattlesnake with adults averaging approximately 76 cm in total length (Conant and Collins 1998). Lateral and dorsal scales often have a grey to dark brown background colouration with dark brown dorsal blotches alternating with three rows of smaller lateral blotches. The ventral scales are dark brown or black, often with white mottling. Neonates and yearlings look similar to the adults, except that they have a greyer background colour resulting in a higher contrast between background and blotches, and the rattle is not as developed and is more yellowish. In Ontario, Massasaugas are often confused with several other banded/blotched snake species including the Eastern Hog-nosed Snake (*Heterodon platirhinos*), Eastern Foxsnake (*Pantherophis vulpinus*) (see also Row *et al*. 2011), Eastern Milksnake (*Lampropeltis triangulum triangulum*) and Northern Watersnake (*Nerodia sipedon sipedon*).

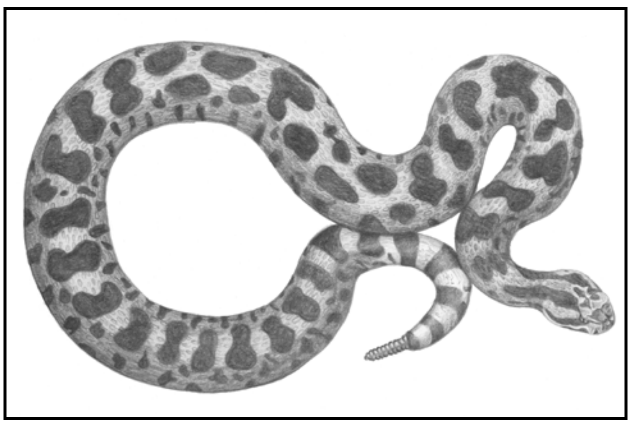

Figure 1. A sketch of an adult Eastern Massasauga, *Sistrurus catenatus catenatus* (Sketch by Sarah Ingwersen 2002).

Population Spatial Structure and Variability

In the last 20 years, multiple studies have investigated the genetics of Massasauga in Canada (Table 1) informing the genetic and population structure of this species, and specifically, of the eastern subspecies.

Table 1. Summary of genetic investigations on Eastern Massasauga (*Sistrurus catenatus catenatus*) relevant to its population spatial structure in Canada.

Author/Date	CDN populations studied (# samples)	DNA methods
Gibbs *et al.* 1994	Bruce Peninsula National Park (24), Georgian Bay Islands National Park (25)	RAPD markers
Gibbs *et al.* 1997	Bruce Peninsula National Park (41), Killbear Provincial Park (80) and Georgian Bay Islands National Park (32)	Nuclear DNA microsatellites (6 loci)
Gibbs *et al.* 1998	Killbear Provincial Park (100)	Nuclear DNA microsatellites (6 loci)
Lougheed *et al.* 2000	Bruce Peninsula (24), Beausoleil Island - Georgian Bay Islands National Park (25)	Nuclear DNA microsatellites (6 loci), RAPD markers (5 primers)
Lougheed 2004	Ojibway (18)	Nuclear DNA microsatellites (10 loci)
Ray 2009	Parry Sound District (3), Bruce County (6), Ojibway (9), Wainfleet (1), unknown (3)	Mitochondrial DNA (ND2 and CytB)
Chiucchi and Gibbs 2010	Ojibway (8), Wainfleet (12), Bruce Peninsula National Park (20), Killbear Provincial Park (20), Georgian Bay Islands National Park (15)	Nuclear DNA microsatellites (19 loci)
Dileo and Lougheed 2011	Eastern shore of Georgian Bay: Byng Inlet to Georgian Bay Islands National Park (139)	Nuclear DNA microsatellites (14 loci)

For the subspecies *S. c. catenatus*, three weakly differentiated geographic subunits based on mitochondrial DNA haplotypes have been described (Eastern, Central and Western: King pers. comm. 2011). Snakes from the Ojibway population were grouped in the Central subunit, whereas snakes from Wainfleet, Bruce County and Parry Sound District were grouped in the Eastern subunit (Figures 2, 3). Sample size for Wainfleet Bog was only a single snake so the inclusion of this site in the Eastern subunit should be viewed with caution. Snakes from all Ontario sites sampled belonged to the same Cytochrome B group (Ray 2009).

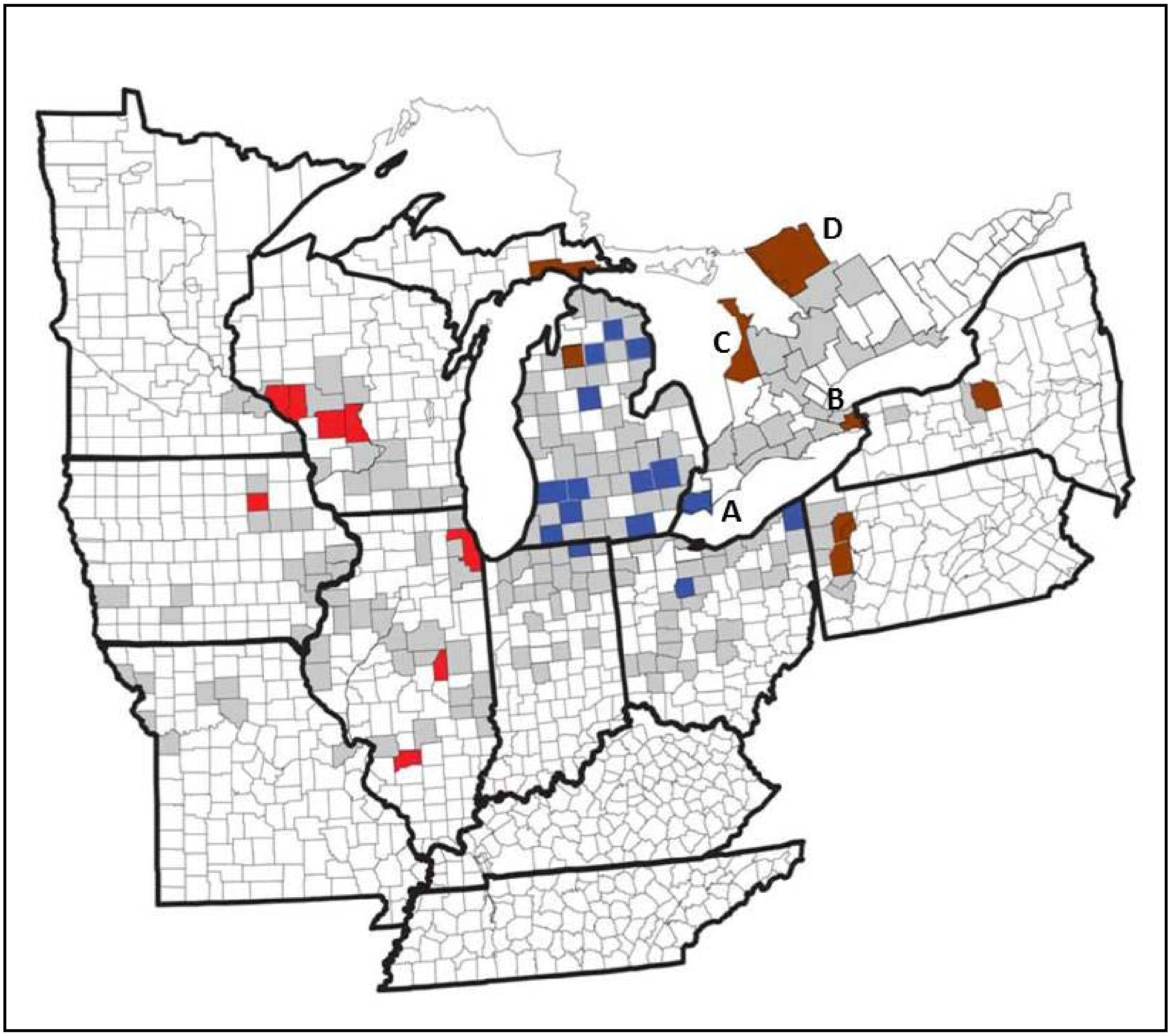

Figure 2. Geographic distribution of haplotype groups for the Eastern Massasauga. Populations are depicted by county and were assigned to a specific haplotype group: western = red, central = blue, eastern = brown. Canadian populations included in the study are labelled on the map as follows: Essex County/Ojibway Prairie= A, Niagara Region/Wainfleet Bog = B, Bruce County (likely Bruce Peninsula National Park) = C, Parry Sound District (likely Killbear Provincial Park) = D. Grey-coloured counties indicate presence of historical populations. Note that recent records on the north shore of Georgian Bay are not included and historical records along the north shore of Lake Ontario have been rejected (see Appendix 2) (figure modified from Ray 2009, used with permission).

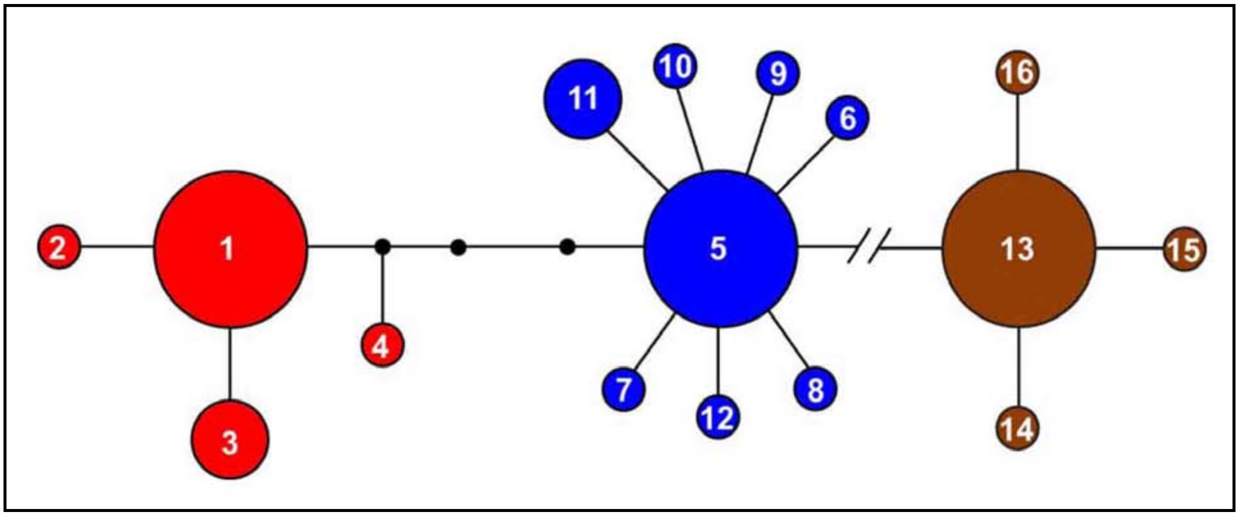

Figure 3. Statistical parsimony network of 16 Massasauga (*Sistrurus catenatus catenatus*) ND2 haplotypes from across its North American range. Each number corresponds to a single haplotype and circle size is proportional to sample size representing each. The parallel bars indicate a codon deletion event. From left to right, these are: western (red), central (blue) and eastern (brown) haplotype groups. Canadian populations correspond to the following haplotypes: Ojibway = 5, Wainfleet = 14, Bruce County = 13, Parry Sound = 13, 15 and 16 (from Ray 2009, used with permission).

Massasauga populations separated by broad geographic expanses (>50 km) exhibit a high degree of genetic structure and a low level of gene flow between populations. Research by Gibbs *et al*. (1997) and Chiucchi and Gibbs (2010) suggests each North American population studied was genetically distinct (overall F_{ST} = 0.21) and each contained population-specific alleles. These samples include five Ontario subpopulations: Ojibway Prairie (OJIB), Wainfleet Bog (WAIN), Bruce Peninsula National Park (BPNP), Killbear Provincial Park (KPP) and Georgian Bay Islands National Park (GBINP). Furthermore, 22.7% (14.8% - 32.7%) of all alleles detected within subpopulation samples were population specific (Gibbs *et al*. 1997). Similar results were reported by Lougheed *et al.* (2000) for subpopulations of the BPNP and GBINP. Genetic work has also revealed low estimates of historical (pre-settlement) and contemporary (within the last 15-30 years) gene flow among these five Ontario subpopulations (Chiucchi and Gibbs 2010). These subpopulations have probably been isolated from each other since before European settlement (Chiucchi and Gibbs 2010).

In addition to population differences at the broad-scale, genetically distinct subpopulations have been identified at scales from < 10 km to < 2 km (Chiucchi and Gibbs 2010). On the eastern shore of Georgian Bay, where Massasaugas are 'continuously distributed', Dileo and Lougheed (2011) found genetic structure at a relatively broad scale (25-30 km; north and south of Parry Sound), and again at the fine scale (< 10 km), indicating four genetic clusters from GBINP to Byng Inlet. At an even finer scale, and within one of the clusters proposed by Dileo and Lougheed (2011), previous field and genetic work indicated at least two distinct subpopulations separated by only 1 – 1.5 km (KPP, Gibbs *et al.* 1997; Rouse 2005). Another example demonstrates fine scale structure on the Northern Bruce Peninsula. Massasaugas from Cyprus Lake (n = 11) and Emmett Lake (n = 7), located approximately 5 km apart, were significantly different in allele frequencies at two out of six loci (P < 0.034), showed a significant overall p value (0.0148) and a nearly significant (P = 0.059) overall FST (0.033) (Gibbs *et al*. 1997). These results were later substantiated by Lougheed (2000). The Bruce Peninsula and eastern Georgian Bay examples demonstrate that even in areas where Massasaugas and habitat appear continuous, population distinction may occur.

Broad scale genetic isolation and low levels of gene flow between populations are assumed to be the natural state for this species and not a result of human-induced habitat fragmentation (Gibbs *et al*. 1997; Chiucchi and Gibbs 2010). Limited dispersal and/or long-term habitat heterogeneity may be responsible (Gibbs *et al.* 1997; Chiucchi and Gibbs 2010). Despite these biological/ecological causes, human-induced habitat fragmentation and disturbance could be contributing to the creation of genetically distinct subpopulations at a fine scale, each with relatively higher risks of extirpation than the population as a whole.

Several anthropogenic barriers to movement, which might create genetic structure or demographic isolation within regional Massasauga populations, have been suggested. These include busy roads/highways (Miller 2005; Rouse 2005; NatureServe 2011; Rouse *et al*. 2011), dense residential/urban development (NatureServe 2011), dams (Andre 2003), and high levels of human disturbance (Parent and Weatherhead 2000). Intensive agriculture is also a likely barrier and has resulted in isolation in other snakes (e.g., Eastern Foxsnakes, Row *et al.* 2010). These activities coupled with existing behavioural barriers (e.g., low dispersal propensity) and ecological barriers (e.g., dense forest) to movement could contribute to further subdivisions and genetic isolation. At Carlyle Lake, Illinois, the creation of a dam and associated lake 40 years ago is presumed to have contributed to the genetic isolation of three Massasauga subpopulations (Andre 2003). At KPP, campgrounds and local roads may have contributed to genetic structure (Rouse 2005).

Populations of Massasauga in Ontario showed moderate to high levels of genetic diversity and allelic richness, on average, relative to all North American populations (Chiucchi and Gibbs 2010). The BPNP subpopulation contains the highest level of genetic variation among Ontario populations and is very important from a conservation standpoint as it contains substantial amounts of the overall adaptive genetic variation for the taxon (Chiucchi and Gibbs 2010). At Ojibway, Lougheed (2004) found genetic diversity (expected heterozygosity and number of alleles) to be lower than in subpopulations from the Georgian Bay region (Gregory 2001; Gibbs *et al.* 1997), including KPP, whose subpopulation occupies a similar total area (Lougheed 2004). Nonetheless, heterozygote deficiencies have also been found at KPP and attributed to inbreeding (Gibbs *et al.* 1998). Inbreeding has been recorded at all Ontario populations studied (Gibbs *et al.* 1997). Investigators suggest that geographically separate populations of Eastern Massasaugas each harbour a unique and substantial portion of the total range-wide genetic variation found in this subspecies (Gibbs *et al.* 1997; Lougheed 2004; Chiucchi and Gibbs 2010).

Designatable Units

Two designatable units (DUs) are proposed for the Massasauga (*Sistrurus catenatus)* in Canada: the Carolinian and Great Lakes/St Lawrence DUs. Both units are discrete and significant based on: genetic distinctiveness, eco-geographic regions, range disjunction, and ecological setting (COSEWIC 2009a). All subpopulations (including historical) in the vicinity of Georgian Bay are included within the Great Lakes/St. Lawrence DU and both Wainfleet Bog and Ojibway Prairie subpopulations are included within the Carolinian DU (see **Canadian Range**).

Genetic Distinctiveness (discreteness and significance)

Analysis of nuclear DNA microsatellites indicates that the following Ontario subpopulations are genetically distinct and currently physically isolated from one another (OJIB, WAIN, BPNP, KPP, and GBINP). These results, coupled with data from U.S. populations strongly suggest that fine-scale genetic structure is the natural state of Massasauga populations. Identification of DUs based on nuclear genetics alone, therefore, would be problematic at the present time due to 1) the need to define and identify each genetically distinct subpopulation in the Great Lakes/St. Lawrence DU, which may amount to dozens (if the number of “locations” provides a reasonable estimate of distinct populations – see Appendix 1), and 2) the lack of genetic data for the majority of subpopulations in the Georgian Bay region.

Analysis of mitochondrial DNA, on the other hand, identified genetic patterns at a broader scale. Results revealed a genetic clustering of Great Lakes/St. Lawrence subpopulations (Parry Sound and Bruce County) as well as a significant divergence between those populations and one of the Carolinian populations (Ojibway Prairie). Although the Wainfleet Bog population was grouped with the Great Lakes/St. Lawrence populations, this grouping was based on a sample from a single snake and should be deemed inconclusive. The data from the other areas sampled directly support the separation of the Great Lakes/St. Lawrence DU from the Carolinian DU (Ojibway population). Additional criteria are used to further support the putative DUs as well as the inclusion of the Wainfleet Bog population within the Carolinian DU

Range Disjunction (discreteness and significance)

Populations in the proposed DUs appear to have been disjunct since before European settlement in Ontario (see **Population Spatial Structure and Variability)**. The Wainfleet Bog and Ojibway Prairie subpopulations are the only two remaining from over a dozen historical subpopulations of Massasauga in the Carolinian Zone (see **Canadian Range)**. When viewed as a cluster, these historical Carolinian populations are geographically disjunct from historical Great Lakes/St. Lawrence populations by a band ~80 km wide within which there is a total absence of records (Figures 4, 5).

Whereas the current disjunction between the Ojibway Prairie and Wainfleet Bog populations was caused by the extirpation of intermediate subpopulations by people (see **Canadian Range**), there is little evidence to suggest a similar cause for the historical disjunction between the two putative DUs. No documented records exist from this gap in distribution and the species' range is presumed to have already declined in response to climatic shifts long before European settlement (**Canadian Range**). The only reference to historical populations in that zone are from G.C. Toner (undated, *as cited by* Weller and Parsons 1991), who stated that Massasauga records existed along the Lake Huron shoreline from Sarnia to southern Bruce County, but that the species was rare and appeared to have always been so. However, no records or detailed accounts support this claim. Records from Michigan indicate that the Massasauga could have entered the Georgian Bay region either from southern Lake Huron across the St. Clair River or from the extreme northern Upper Peninsula of Michigan in the present-day Sault-Ste Marie area (Holman 2012). There is little evidence that Massasaugas ever occupied the Lake Huron shore south of the Bruce Peninsula (Rowell 2012), but they still occur at the extreme northern edge of the Lower Peninsula of Michigan, and still occupy Bois Blanc Island and formerly occurred on Charity Island (Holman 2012). Regardless, current evidence suggests that populations within the Carolinian DU have been disjunct naturally from populations within the Great Lakes/St. Lawrence DU for an extended period.

The natural disjunction that occurred historically between the proposed DUs was widened within the last two centuries by human activities (and resulting extirpations, Figures 4, 5, 6). Currently, ~200 km of intensively modified southern Ontario landscape separates the two DUs. Considering the dispersal distance of this species is on the order of hundreds of metres to a few kilometres, multiple generations within the land between would be required for individuals of each unit to interact. This restriction, in addition to the lack of available habitat and extensive anthropogenic modifications of the landscape, make it very unlikely that the two DUs will be physically connected in the foreseeable future.

Finally, the Wainfleet Bog and Ojibway Prairie subpopulations are the only known surviving natural occurrences of this species in the Canadian Carolinian region. Loss of these subpopulations would reduce the extent of occurrence of this species in Canada by thousands of square kilometres and create an extensive range gap between Canadian populations in the Great Lakes/St. Lawrence DU and U.S. populations to the south and east.

Eco-Geographic Regions (discreteness)

The Wainfleet and Ojibway subpopulations (and all other historical Carolinian subpopulations) exist within the Carolinian Terrestrial Amphibian and Reptile Faunal Province, whereas all subpopulations in the Georgian Bay region (including historical) exist within the Great Lakes/St Lawrence Terrestrial Amphibian and Reptile Faunal Province (Figure 5).

Ecological Setting (discreteness and significance)

Populations in both DUs persist in unique ecological settings for the species in Canada that are likely to lead to local adaptations. The Carolinian DU supports the only Canadian representatives of a tallgrass prairie-oak-savannah population (Ojibway Prairie) and a peat land-swamp forest-bog population (Wainfleet Bog). The relative uniqueness of the Ojibway Prairie subpopulation raises the possibility of local adaptation to distinctive features (Lougheed 2004), such as using crayfish burrows for hibernation. The temporary nature of these burrows, coupled with rapid rates of vegetation succession at both sites indicates that Carolinian populations are likely adapted to highly dynamic environments. The Great Lakes/St. Lawrence DU supports the only Canadian representatives of alvar and rock barren populations. These ecological settings have given rise to local behavioural adaptations of site fidelity to hibernacula and of long-distance dispersal (see **Habitat Requirements**).

Special Significance

Conserving Massasaugas in Canada also means conserving the natural areas and habitats where they live, including wetlands, alvar, forest, and prairies, some of which are rare in Ontario. Each regional Massasauga population in Canada is genetically distinct and is important for preserving the entirety of the Canadian genetic diversity of this species. This is one of the best studied snakes in Canada, facilitating major contributions to science through numerous studies in ecology, phylogeography, animal behaviour, genetics, human-wildlife conflict, etc.

The Massasauga has been subject to negative public opinion resulting in widespread persecution because these snakes are venomous and can inflict harm or even death upon people and pets. The reality is that Massasaugas pose relatively little threat to public safety. Deaths from Massasauga are virtually unheard of in Canada (Weller and Parsons 1991; Weller 2010) and although snakes are estimated in the thousands in the Georgian Bay region, on average only six bites are reported there each year (WPSHCF 2009). A rattlesnake bite is a medical emergency and treatment is costly (WPSHCF 2009); however, it is easy to avoid harmful encounters when Massasaugas are respected and appropriate precautions are taken.

As one of Canada's three extant rattlesnakes, the Massasauga represents a rare element of our biodiversity. In the Carolinian region, the two remaining subpopulations are important historical symbols that persist in spite of widespread persecution and habitat loss. The upper surface of the Massasauga's head is covered by nine large, symmetrically arranged scales, as are those of all other snake species now found in Ontario. This arrangement differs from almost all other species of rattlesnake which have a multitude of small, irregular scales covering the dorsal surface of the head (Rowell 2012).

In the Georgian Bay region, Massasaugas are a symbol of our ability to co-exist with potentially harmful wildlife. In First Nation tradition, the Massasauga is the medicine keeper of the land (Union of Ontario Indians – Anishinabek Nation 2010). They are protectors of the wildflowers and berries: "When you're out picking blueberries and you hear that rattle, it's a signal for you to stop and think … It's a reminder to take only what you need" (Parks Canada 2009a).

DISTRIBUTION

Global Range

Massasaugas occur in a large but discontinuous range from central Canada to northern Mexico (Figure 7). The subspecies, Eastern Massasauga, occurs in the eastern portion of the species' range, with historical and contemporary occurrences in Ontario, Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, and Wisconsin (USFWS 2010, Figures 2 and 3). The global range of the Eastern Massasauga is estimated at 200 000 – 2 500 000 km^2 (NatureServe 2011).

Although the current estimated global range of the eastern subspecies is similar to the presumed historical range, it has become increasingly fragmented due to economic development (USFWS 1998). Nine of the 11 jurisdictions within the historical range have lost between 30-50% of their populations. Also ~40 % of the counties with historical populations no longer support the subspecies (USFWS 2010). In the U.S.A., more than 65 % of populations are thought to have a low to moderate likelihood of persisting and remaining viable in the long term (USFWS 2010). USFWS (1998, 2010) provide an overview of recently extirpated populations in the U.S.

Canadian Range

The historical and current range of the Massasauga in Canada lies entirely within Ontario (Figures 4, 5). The province hosts approximately 10% of the global distribution of the eastern subspecies (Oldham *et al.* 1999). Only Illinois, Michigan and Ohio have larger proportions of the subspecies' range (Oldham *et al.* 1999). In Ontario, the species occurs in two distinct biogeographic zones, the Carolinian Zone and the Great Lakes/St. Lawrence Zone. These zone boundaries were used to define designatable units (see Appendices 1 and 2 for a list of all accepted historical and contemporary "locations" in both DUs).

The Great Lakes/St. Lawrence DU supports multiple subpopulations of Massasauga surrounding Georgian Bay. These populations are concentrated in relatively undeveloped areas along the eastern shore of Georgian Bay, from Killarney to Port Severn, and the northern Bruce Peninsula, from Tobermory to Oliphant. Outside these areas, recent observations have occurred as far east as Restoule Lake, as far north as Sudbury, as far west as Vidal Island and Blind River, and as far south as the Collingwood area (Figure 4).

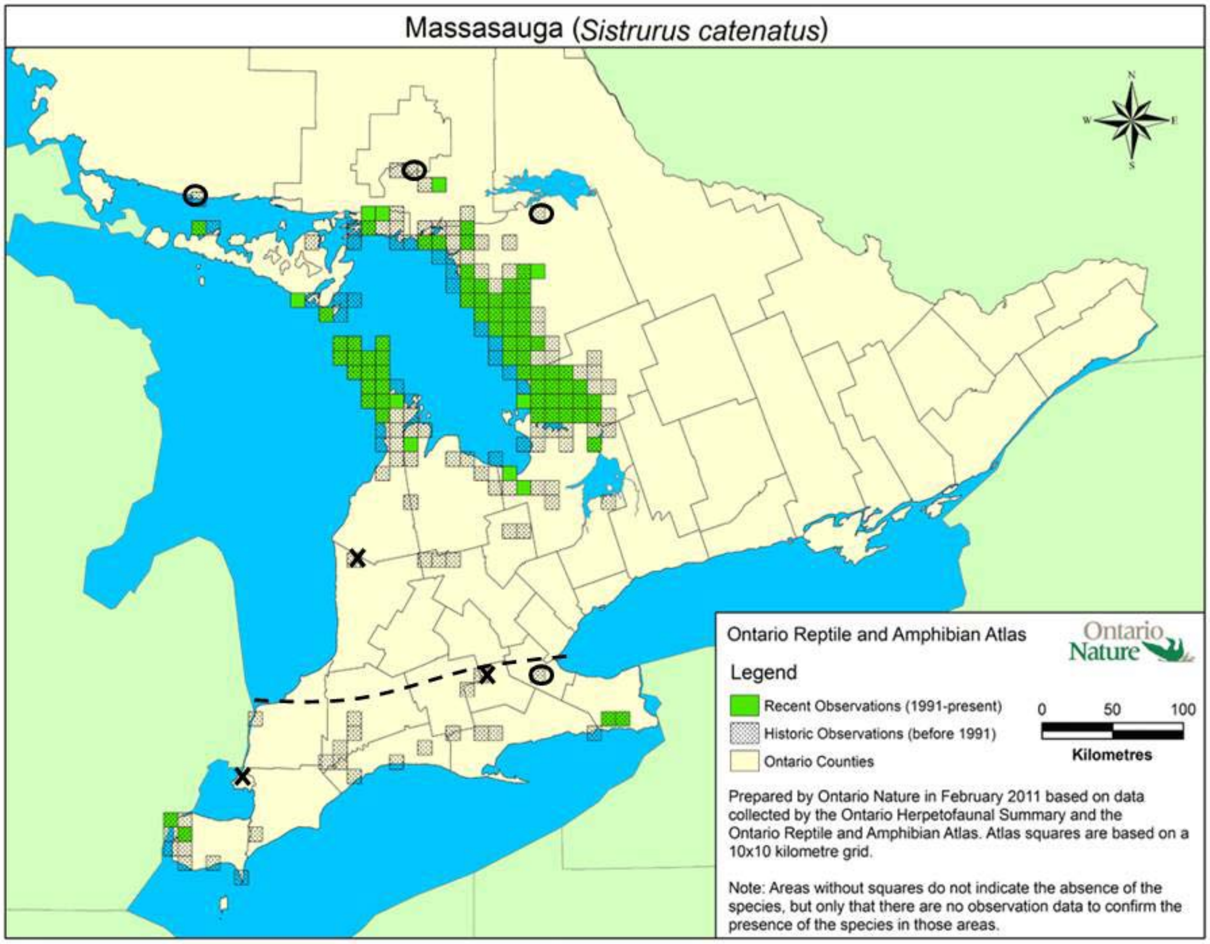

Figure 4. Historical and contemporary occurrence records of Massasauga, *Sistrurus catenatus* (modified from Ontario Nature 2011b, used with permission). Approximate northern boundary of the Carolinian faunal province is depicted by the dashed line (COSEWIC 2009b). Symbols depict historical "locations" that have either been rejected (X) or accepted (O) for the purposes of discussing historical and contemporary "locations" and for estimating range size (see Appendix 1 and 2). Atlas grid squares are 10 x 10 km.

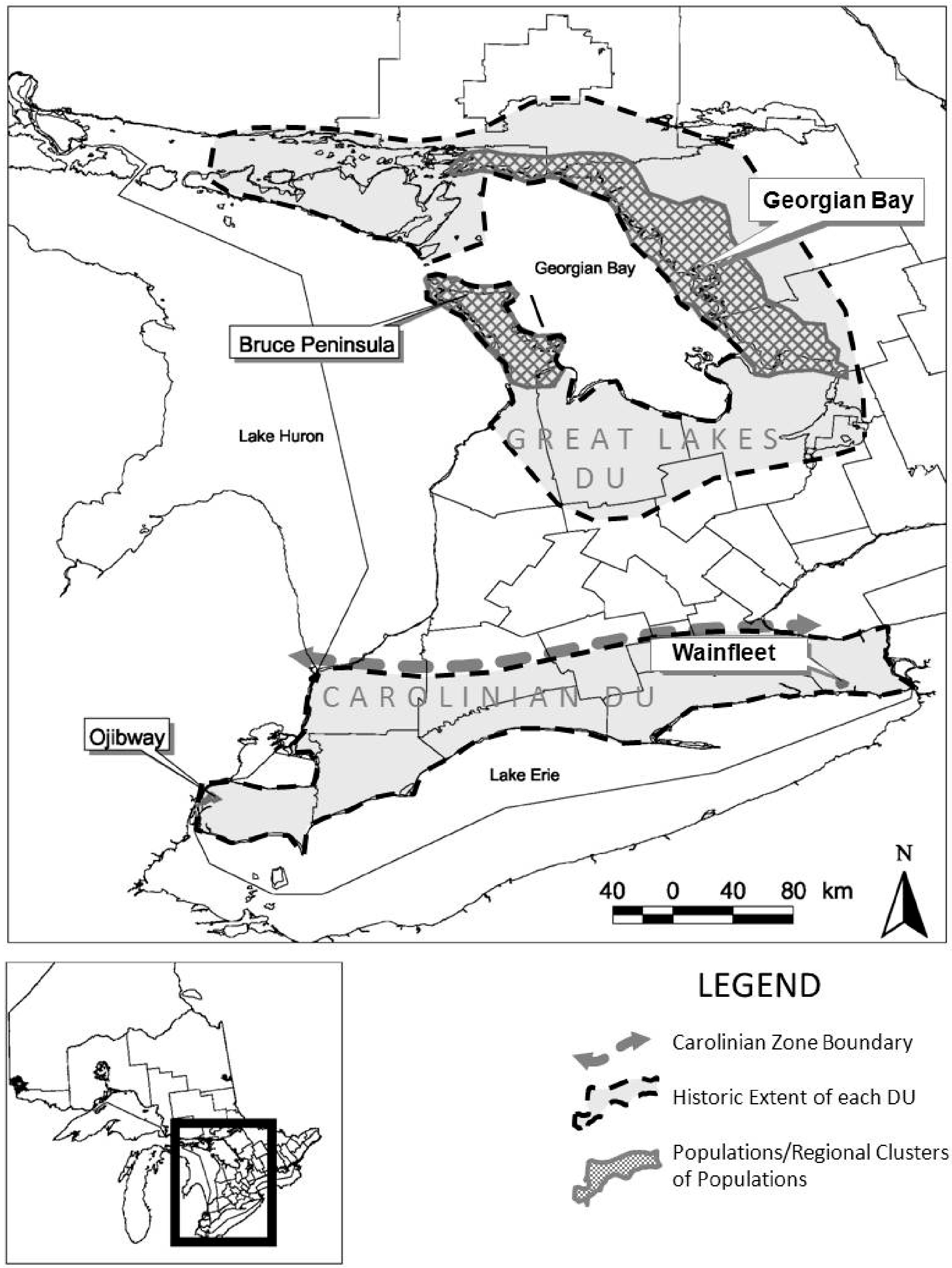

Figure 5. Approximate maximum extent of Massasauga (*Sistrurus catenatus*) designatable units in Canada based on historical and contemporary occurrence records (see Search Effort). Northern boundary of the Carolinian faunal province is approximate (COSEWIC 2009b). Image adapted from Rouse and Willson 2002.

The Carolinian DU supports two isolated subpopulations separated from each other by over 350 km and disjunct from the Great Lakes population by ~200 km. From west to east, these subpopulations are the Ojibway Prairie in Windsor/LaSalle and Wainfleet Bog near Port Colborne (Figure 5).

Extent of occurrence (EOO) and index of area of occupancy (IAO) were estimated following COSEWIC methodology (Appendix 4). Only Massasauga occurrence records from the last 21 years (1991-2011) were used and areas of open water (i.e., Georgian Bay, Lake Huron, Lake Erie and Lake St. Clair) were included in the calculations. The Canadian EOO was estimated by creating a single convex polygon that enclosed all accepted occurrence records in Canada (but see Appendix 2 – Blind River). For the Carolinian DU, EOO was estimated by creating a single convex polygon that enclosed all the occurrence records within the DU. For the GLSL DU, a single EOO polygon was created to enclose all records for the entire DU, including extralimital records (e.g., Collingwood, Pretty River, Long Lake Road, Restoule Provincial Park, see Appendix 1. Blind River was not included, see Appendix 2). The IAO was calculated separately for each DU by adding the sum of all 2 x 2 km grid squares with at least one occurrence record (Table 2).

Table 2. Estimates of extent of occurrence (EOO) and index area of occupancy (IAO) for the Massasauga in Canada. See text (Canadian Range) for a description of methods used for calculations.

Designatable unit (DU)	EOO (km^2)	IAO (km^2)
Entire Canadian population	97,100	2,356
Great Lakes/St. Lawrence DU	37,200	2,316 (conservative estimate, see Technical Summary – GLSL DU)
Carolinian DU	865	40 (Ojibway=16, Wainfleet = 24)

Trends in Canadian Range

The postglacial colonization of Massasauga into Ontario is presumed to have occurred from the southwest during the prairie peninsula expansion of the hypsithermal period, 5000-7000 years ago (Weller and Parsons 1991; Cook 1992). Colonization of the Georgian Bay region by the Massasauga is presumed to have occurred from southern Ontario along the Lake Huron shoreline. Following a period of climatic cooling and a subsequent decline in range (Cook 1992), Massasauga may have only occurred in discrete, isolated populations in southwestern Ontario even before European settlement (Cook 1992; Beltz 1993; Chiucchi and Gibbs 2010). Over the next two centuries, most of the remaining populations between Georgian Bay and Lake Erie were eliminated by widespread wetland drainage and land clearing for agriculture (Weller and Parsons 1991; Weller and Oldham 1992). A severe reduction in the area occupied by this species south of Georgian Bay has occurred (Figure 6).

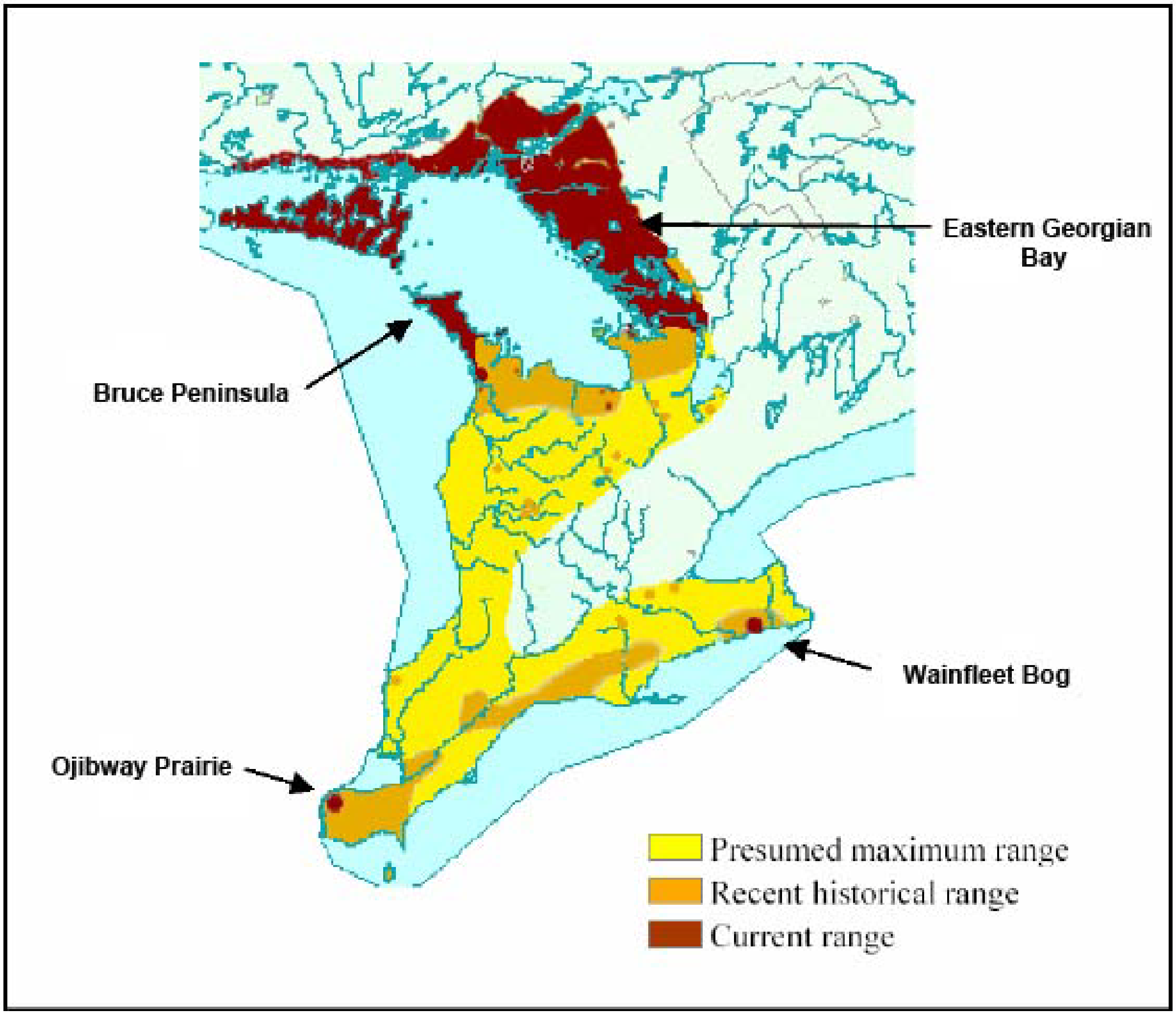

Figure 6. Range-wide decline of the Massasauga (*Sistrurus catenatus*) in Canada (adapted from Rouse and Willson 2002). 'Recent historical range' most likely represents Massasauga range in Ontario at the onset of European colonization. Current range is estimated and is based on most recent observation records (Appendix 2).

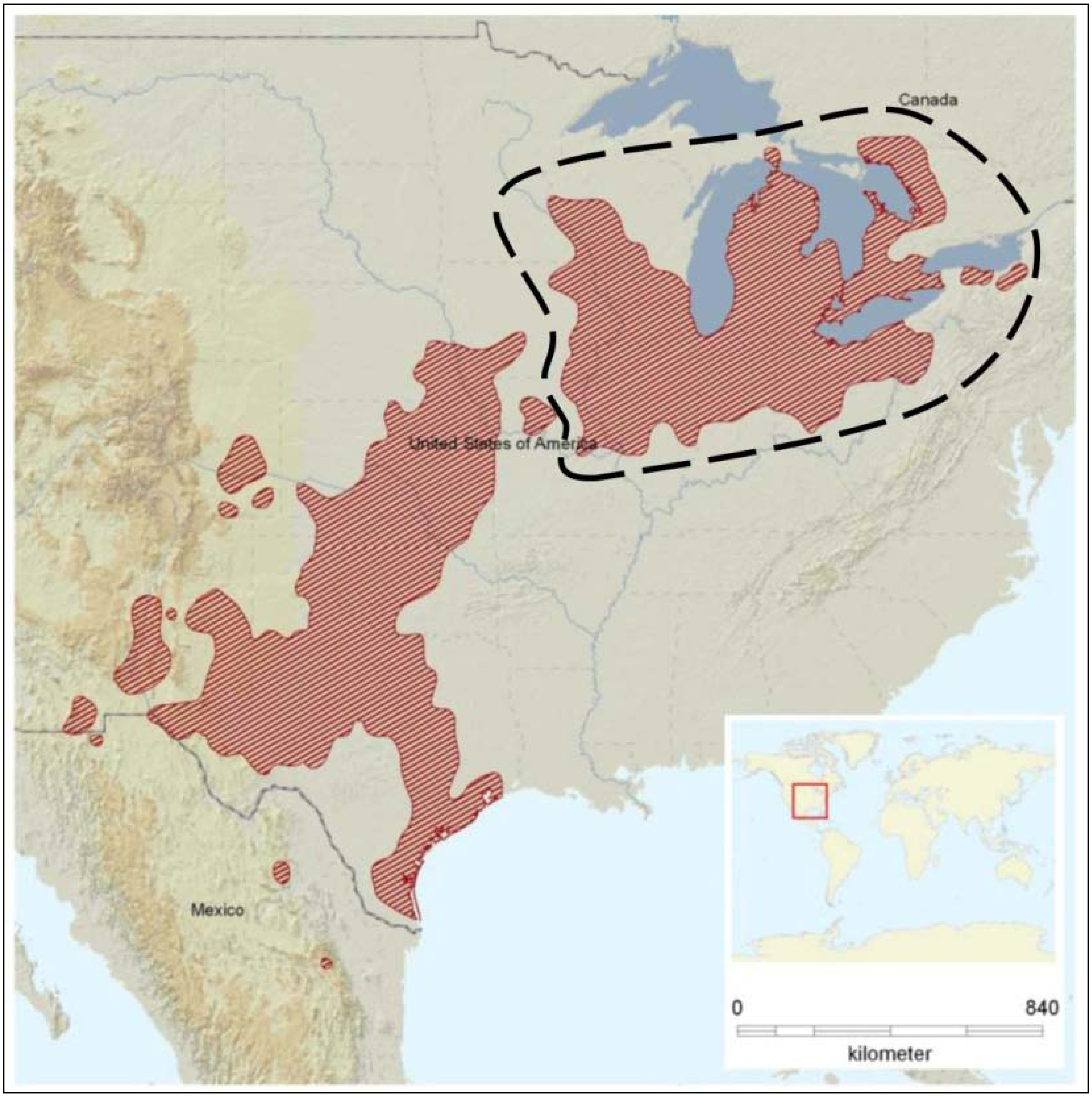

Figure 7. Approximate global range of the Massasauga (*Sistrurus catenatus*), represented by the hatched area. The range of Eastern subspecies (*S. c. catenatus*) is represented by the dashed polygon (Modified from Frost *et al*. 2007, used with permission).

At least 17 subpopulations of Massasauga are recognized from the Carolinian DU (subpopulation = “location”, Appendix 1). These have been recorded along the north shore of Lake Erie and as far north as Sarnia and Hamilton (Figures 4, 5). By the late 1800s and early 1900s, Massasaugas were exceedingly scarce in the Carolinian DU (Garnier 1881; Nash 1905; Miner 1928) and by the late 1970s the species is presumed to have been extirpated from its entire historical Carolinian range except for the Windsor/LaSalle and Wainfleet areas (Weller and Parsons 1991). An estimated 85 - 90% decline in the IAO of this DU has occurred post-settlement.[1] For the last 25 years (3 generations), all verified records were from the Ojibway Prairie or Wainfleet Bog (Figure 6). A decline is projected in the number of “locations” in this DU as well as in its IAO and EOO due to the likely extinction of the Ojibway population (see POPULATION SIZES AND TRENDS).

In the Great Lakes/St. Lawrence DU, out of 65 historical and contemporary “locations”, 10 (15%) are considered extirpated (Appendix 1, but see Appendix 2) and all of these are from the geographic south of the DU. As a result, Massasauga range in the Great Lakes/St. Lawrence DU has contracted northward to the point where Massasaugas either no longer persist along the southern shore of Georgian Bay or do so in a few, small, localized sites (see **Search Effort;** Appendix 2). Massasauga subpopulations appear to have been distributed continuously along the southern shore of Georgian Bay up until the 1960s (Weller and Oldham 1992). Despite an historical range contraction, the number of Massasauga subpopulations in the Great Lakes/St. Lawrence DU has remained relatively stable in the last 25 years (3 generations). There has been a trend toward increased knowledge of the species’ distribution since the previous report. For example, three new “locations” were accepted and seven historical “locations” were recently substantiated (Table 4; Appendix 1**;** Appendix 2). Furthermore, the estimated EOO of the Great Lakes/St. Lawrence DU has increased in size by ~ 40 to ~ 500% (7013 km^2, Rouse and Willson 2002; 10 007 km^2, Parks Canada unpub. data from 2011; 37 200 km^2, this report), likely as a result of increasing knowledge of Massasauga distribution in combination with more liberal range estimates.

Despite an increase in the estimated range of the Great Lakes/St. Lawrence DU, an overall decline in the Canada-wide EOO of the Massasauga is projected based on the likely extinction of the Ojibway population (see POPULATION SIZES AND TRENDS). The loss of this population will result in an estimated 50% decrease in the size of the Canadian distribution of the Massasauga (Appendix 6).

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[1] 17 historical subpopulations multiplied by an estimated IAO of 16 - 24 km^2 each (based on IAO of Ojibway Prairie and Wainfleet Bog populations) = a pre-settlement IAO in the range of 272 km^2 – 408 km^2. The current estimated IAO of 40 km^2 is 10 - 15 % of the estimated historical IAO.

Search Effort

Historical range, contemporary range and range trends of the Massasauga in Canada are based on information and data provided by the Natural Heritage Information Centre (NHIC), Ontario Herpetofaunal Summary (OHS), Canadian Museum of Nature (CMN), Royal Ontario Museum (ROM), Parks Canada, Ontario Reptile and Amphibian Atlas (ORAA) and other experts (Appendix 1).

In the Carolinian DU, targeted searches have occurred almost yearly at both confirmed “locations” since the last status assessment. Herpetofaunal inventories have occurred recently and periodically at some historical “locations” (e.g., Skunk’s Misery, Sarnia area, Walpole Island, Point Pelee, Tilbury and Hamilton).

In the Great Lakes/St. Lawrence DU, targeted search efforts are concentrated in the vicinity of BPNP (Miller 2005; Truscott pers. comm. 2011; Crowley pers. comm. 2011), in the vicinity of Georgian Bay Islands National Park and within several Provincial Parks. The majority of incidental observations are in areas that receive high human traffic such as on the northern Bruce Peninsula (including adjacent islands) and eastern shore of Georgian Bay from campgrounds and cottage areas (Promaine pers. comm. 2011; Truscott pers. comm. 2011). Targeted searches and incidental encounters are less frequent in the southern portion of Bruce Peninsula (Truscott pers. comm. 2011; Crowley pers. comm. 2011), Manitoulin Island (Tonge 2006), and on the northern and eastern range extremities (CAGB 2003). The lack of sightings in the latter areas may be due to lack of search effort (much of the area is difficult to access) and/or relatively low Massasauga abundance.

Within the southern portion of the Great Lakes/St. Lawrence DU, targeted searches and sightings are rare yet human density is relatively high. Staff from both Conservation Authorities in the area, Nottawasaga and Grey Sauble, are unaware of any recent sightings; however, searches have not been conducted on their properties (I. Ockendon and C. Hachey pers. comms. 2011), except for general searches in the Minesing Swamp (Bowles *et al*. 2007). No confirmed sightings have occurred on either of the defence establishments in the area: Base Borden or Meaford, despite targeted searches at the latter (Nernberg pers. comm. 2011) and general searches at the former (Sandilands pers. comm. 2011). The most recent encounters on the southern shore are from two “locations” in the Collingwood and Pretty River areas in the 1990s (Appendix 1). Recent unconfirmed reports have been made from other southern “locations” and these should be further investigated (Appendix 2). If remnant populations still occur in the southern extent of this DU, they do so in relatively remote or inaccessible areas and are most likely small and isolated from the rest of the DU.

HABITAT

Habitat Requirements

Massasaugas have three essential habitat requirements: gestation sites, hibernation sites, and foraging habitat, the first two being more specialized (Johnson *et al*. 2000).

General Habitat Use/Foraging Habitat

Massasaugas utilize strikingly different macrohabitats across their range (Reinert and Kodrich 1982; Seigel 1986; Weatherhead and Prior 1992; Johnson 1995; Kingsbury 1996, 1999; Johnson and Leopold 1998; Rouse 2005, Sage 2006; Bissell 2006). Preference for suitable microhabitats appears to drive habitat selection in Massasaugas (Harvey and Weatherhead 2006a). During the active season, this species prefers microhabitats with relatively low canopy cover (including gaps in forest), large rocks and dense ground cover or shrubbery (retreat sites) (Harvey and Weatherhead 2006a; Sage 2006). Massasaugas will disperse through less desirable habitats to reach preferred habitat (Rouse 2005; Durbian *et al*. 2008).

In both DUs, the Massasauga occurs in habitats considered rare ecological communities. The Ojibway subpopulation is the only Canadian representative in a tallgrass prairie-oak-savannah (Pither 2003). The Wainfleet subpopulation is the only remaining representative of a peatland-swamp forest-bog population in Canada. In the Bruce Peninsula and Manitoulin regions, Massasauga use Great Lakes Alvar among a diversity of other habitats.

Great Lakes/St. Lawrence DU: Radio telemetry data have shown Georgian Bay Massasaugas to use a mosaic of bedrock barrens, conifer swamps, beaver meadows, fens, bogs, and shoreline habitats (Beausoleil Island, Villeneuve unpub. data; Killbear Provincial Park, Parent unpub. data; Hwy 69 corridor; Rouse *et al.* 2001). On the upper Bruce Peninsula, radio telemetry data have demonstrated that Massasaugas are habitat generalists and the use of habitat varies seasonally from forested habitats (dense deciduous, dense coniferous and sparse forest) during hibernation to open, wetland, and edge habitat with canopy closure < 50% in mid-late summer (Harvey and Weatherhead 2006a; Harvey pers. comm. 2011).

Carolinian DU: Radio telemetry data have shown Massasaugas use tall grass prairies composed of dry, sandy, low forb prairie and old field habitats at Ojibway Prairie (Pratt *et al.* 2000; Pither 2003). Recorded habitat also includes wet sedge meadows, wet to wet-mesic prairie and early successional fields (Pratt *et al.* 1993). Pratt *et al*. (2000) provide details of 19 species of plants which occurred at over half of Masassauga encounter "locations". At Wainfleet Bog radio telemetry has shown snakes use bog habitat, wet woods, meadow/old fields, and hedgerows (Pratt *et al.* 2000). Furthermore, snakes use adjacent agricultural areas within 500 m of the wetland boundary (Yagi pers. comm. 2012).

Hibernation Habitat

Successful hibernacula for the Massasauga includes some or all of the following necessary features: structural stability, access to the water table/moist substrate, access to sufficient depth below the frost line, protection from extreme temperature fluctuations (e.g., presence of vegetative cover or large rocks) and space to adjust to changing conditions (Maple 1968; Reinert 1978; Johnson 1995; Johnson *et al*. 2000; Harvey and Weatherhead 2006b). Hibernation habitat varies across the Ontario range of Massasauga. Hibernation is unlikely to be successful in flood prone areas (Yagi pers. comm. 2012; Preney unpub. data).

Great Lakes/St. Lawrence DU: In Bruce Peninsula National Park, Massasaugas hibernate singly or in small groups in old root systems, rodent burrows, and rock crevices, typically within forested habitats, and the majority do not exhibit fidelity to a hibernaculum, but do hibernate within 100 m of previously used hibernacula (Weatherhead and Prior 1992; Harvey and Weatherhead 2006a,b; Harvey pers. comm. 2011). At KPP, Massasaugas demonstrate strong hibernacula fidelity and hibernate in treed depressions in rock-outcrops and areas of wet conifer forest (Rouse 2005). Hibernacula fidelity is assumed to be low-moderate for Bruce Peninsula populations and high for populations on the eastern shore of Georgian Bay. Massasaugas often hibernate in large groups (> 20) in the latter region (Crowley pers. comm. 2011).

Carolinian DU: At Wainfleet Bog, Massasaugas hibernate in upland areas (not flood-prone) dominated by tall shrubs (Yagi pers. comm. 2012). Snakes access subterranean hollows via mammal burrows and tree root systems (Yagi pers. comm. 2012). Snakes demonstrate hibernation 'area' fidelity and radio telemetry has shown that most hibernated within 40 - 100 m of their previous burrow (Yagi pers. comm. 2011). Limited radio-telemetry data exist for the Ojibway population; however, cases of fidelity and non-fidelity of hibernacula have been recorded (Preney unpub. data). Snakes have been found hibernating in a forested area under an abandoned sidewalk and in wet meadows in Meadow Crayfish (*Cambarus diogenes)* burrows, the preferred hibernation structure (Preney unpub. data). Given the ephemeral nature of these burrows, it's probable that hibernacula fidelity is low.

Gestation Sites

The most important aspects of gestation sites are favourable thermal conditions for embryonic development (i.e., open canopy) and available refuge that provides protection from predators and warmth during cool weather (Harvey and Weatherhead 2006a).

Great Lakes/St. Lawrence DU:

Gestation sites at KPP are usually located on the rock-barren habitats and consist of large perched table rocks, with sufficient cover habitat (small bushes, grasses), and easily accessible protective retreat sites (Rouse 2005). Females demonstrate gestation site fidelity and a number of sites in KPP are used yearly by multiple females (Rouse 2005). Gravid females at BPNP had relatively more rock cover and less canopy closure than sites used by males and non-gravid females (Harvey and Weatherhead 2006a) and gravid females may use 2-3 different sites in a given summer (Harvey pers. comm. 2011).

Carolinian DU:

At Wainfleet Bog, Massasaugas use open areas in low or tall shrub vegetation communities as well as anthropogenic woody debris piles (soil, brush and timber) for gestation (Yagi and Tervo 2005). In the Ojibway subpopulation, female Massasaugas will use low forb prairie openings surrounded by shrubs and anthropogenic structures/debris for gestation sites (T. Preney pers. obs. 2011).

Home Range Size

Massasauga home range size varies between subspecies and between “locations” for a particular subspecies. Average home range size of the Eastern Massasauga has been observed from 1-135 ha (Table 3). In the Great Lakes/St. Lawrence DU, average home range size was 25 ha at BPNP (Weatherhead and Prior 1992). Data on home range size are unavailable for both Carolinian subpopulations, but it is likely these are at the smaller end of the scale.

Table 3. Average home range (activity range) size for male Massasaugas and size of study areas in U.S. and Canada. Home range sizes were estimated as Minimum Convex Polygons and reported in hectares (adapted from Choquette 2011a).

Location of Study Site	Size of Study Area (ha)	Mean Home Range (ha)	Source
Pennsylvania	8-36 (two sites)	1.0	Reinert and Kodrich 1982
Michigan (southeast)	815	1.6	Moore and Gillingham 2006
Wisconsin	69	2.4	Durbian *et al*. 2008
Indiana	<100	8.6	Marshall *et al.* 2006
Missouri	100-478 (three sites)	13.5	Durbian *et al*. 2008
Bruce Peninsula, Ontario	15 000 (max)	25.0	Weatherhead and Prior 1992
Cicero Swamp, New York	2 204	27.8	Johnson 2000
Wisconsin	669	135.8	Durbian *et al.* 2008

Table 4. Estimates of total number, number of extant, number of historical/unknown and number of extirpated "locations" of Massasauga (*Sistrurus catenatus*) in the Great Lakes/St. Lawrence DU for three different time periods.

Source	# Locations/ populations	# Extant	# Historical/ Unknown	# Extirpated
USFWS1998 (based on NHIC)	59	24 (41%)	16 (27%)	18 (31%)
NHIC 2011	63	28 (44%)	25 (40%)	10 (16%)
COSEWIC 2011 (Appendix 1)	65	37 (57%)	18 (28%)	10 (15%)

Variation in home range size appears to be affected by habitat quality and availability). Marshall *et al*. (2006) suggested small home range sizes at a fen "location" in Indiana might be the result of all life history needs being fulfilled in a relatively small, centrally located area (<100 ha) with no need for snakes to disperse across expanses of inhospitable habitat. Durbian *et al*. (2008) suggested small home range size at their Missouri site to be a factor of extremely limited open canopy habitat. At their site with largest home ranges, the authors believed this was due to limited and widely dispersed open canopy habitat (Durbian *et al*. 2008). It has been suggested that approximately 40 ha of suitable habitat is large enough for the average Massasauga and 100 ha is the minimum amount of habitat needed for sustaining a Massasauga population (Durbian *et al.* 2008).

Habitat Trends

Great Lakes/St. Lawrence DU

Massasauga habitat is widespread in the Great Lakes/St. Lawrence DU (except in the southern portion, see **Search Effort)**. Habitat in this DU is subject to low-moderate levels of habitat loss and fragmentation. Habitat loss is expected to continue in the short term mostly due to road and residential development in the upper Bruce Peninsula and along the eastern shore of Georgian Bay, although this is expected to occur at relatively low to moderate levels (Truscott pers. comm. 2011; Rouse pers. comm. 2011; Crowley pers. comm. 2012). For example, human population growth projections for the Bruce Peninsula are minimal, with very little growth (~ 400 people/~ 300 households) expected between 2011 and 2016 with no population growth expected during 2016 to 2021 (Bruce County 2010). Population growth projections for eastern Georgian Bay and other "locations" in the DU are unknown.

Habitat quality varies in protected areas. At GBINP, the number of campsites has decreased over the last 20 years which has likely resulted in lower levels of human disturbance (Promaine pers. comm. 2011). At KPP, a number of gestation sites have been used yearly by multiple females (Rouse 2005). Habitat quality there, however, may be in decline due human disturbance and fragmentation by roads (Parent and Weatherhead 2000; Rouse 2005). In BPNP, over 4 years of study, no decline in quality of hibernacula or gestation sites was witnessed and abundance of suitable gestation and hibernation sites does not appear to be limiting for Massasaugas (Harvey pers. comm. 2011).

Ecological niche modelling by Ray (2009) suggests that climate change might increase the range of suitable habitat in Ontario by 2050 (based on climate). Although Massasauga distribution (and by extension habitat availability) is likely limited in parts of this DU by climatic variables (Harvey and Weatherhead 2010), the potential effect of climate change on future habitat trends is unknown.

Carolinian DU

Massasauga habitat in the Carolinian DU has drastically declined since European settlement. For example, over 97% of southern Ontario's original prairie and savanna, and 83% of wetlands have been lost (Reid *et al*. 1996; Rodger 1998). At Wainfleet Bog, centuries of agricultural, peat extraction (including drainage) and transportation activities have contributed to a drastic reduction in the size of the wetland from ~204 km^2 to an area approximately 14 times smaller than it was historically (Yagi and Frohlich 1999; NPCA 2010). At Ojibway, an estimated 50 km^2 of tallgrass prairie and oak savannah existed in the Windsor/LaSalle area at the time of European settlement (late 1700s - 1800s, Pratt *et al*. 1993; Pither 2003), but this has been reduced by approximately 90% of its historical extent. Habitat is limiting for both Carolinian subpopulations although the problem is probably more severe in Windsor/LaSalle. Persistence of both Carolinian subpopulations will likely depend on the artificial maintenance of open areas (Brennan 2004; Yagi pers. comm. 2012).

At Ojibway Prairie, Massasauga habitat remains within the Ojibway Prairie Complex in the City of Windsor (~450 ha, Pratt *et al*. 2000) and within protected and unprotected parcels in the Town of LaSalle (~ 100 - 150 ha) (Figure 8). Habitat fragmentation is particularly severe, with roads and/or residential subdivisions bisecting remaining habitat and protected areas (Figure 8, Pratt *et al*. 1993). There is an ongoing trend toward habitat loss, fragmentation and degradation due to residential development, road construction and natural succession (see Pither 2003). In the Town of LaSalle between 1986 and 1996, 78 ha of natural area were destroyed for development and an estimated 4500-8500 dwelling units were expected between 1997 and 2016 (Town of LaSalle 2003). Furthermore, natural succession and lack of management (e.g., controlled burns or manual shrub removal) have resulted in reduction of habitat quality within the last decade (T. Preney pers. obs. 2010). The entire Ojibway Prairie population is now believed to be confined to one subpopulation with an extremely limited availability (~ 9 ha) of suitable open habitat (see **POPULATION SIZES AND TRENDS**). Despite some minor increases in habitat quality (Marks pers. comm. 2011; Child pers. comm. 2011; Choquette pers. obs. 2012), residential development is projected to increase resulting in the removal of remaining unprotected habitat and further isolation of protected areas.

Figure 8. Approximate maximum extent of available Massasauga (*Sistrurus catenatus*) habitat at the Wainfleet Bog (top) and the Ojibway Prairie (bottom) enclosed in dashed lines. At Ojibway, the interior ovals depict relatively large areas with remaining habitat. At Wainfleet, Massasaugas are also recorded using adjacent agricultural areas. Permission to reproduce granted by J. Choquette and T. Preney.

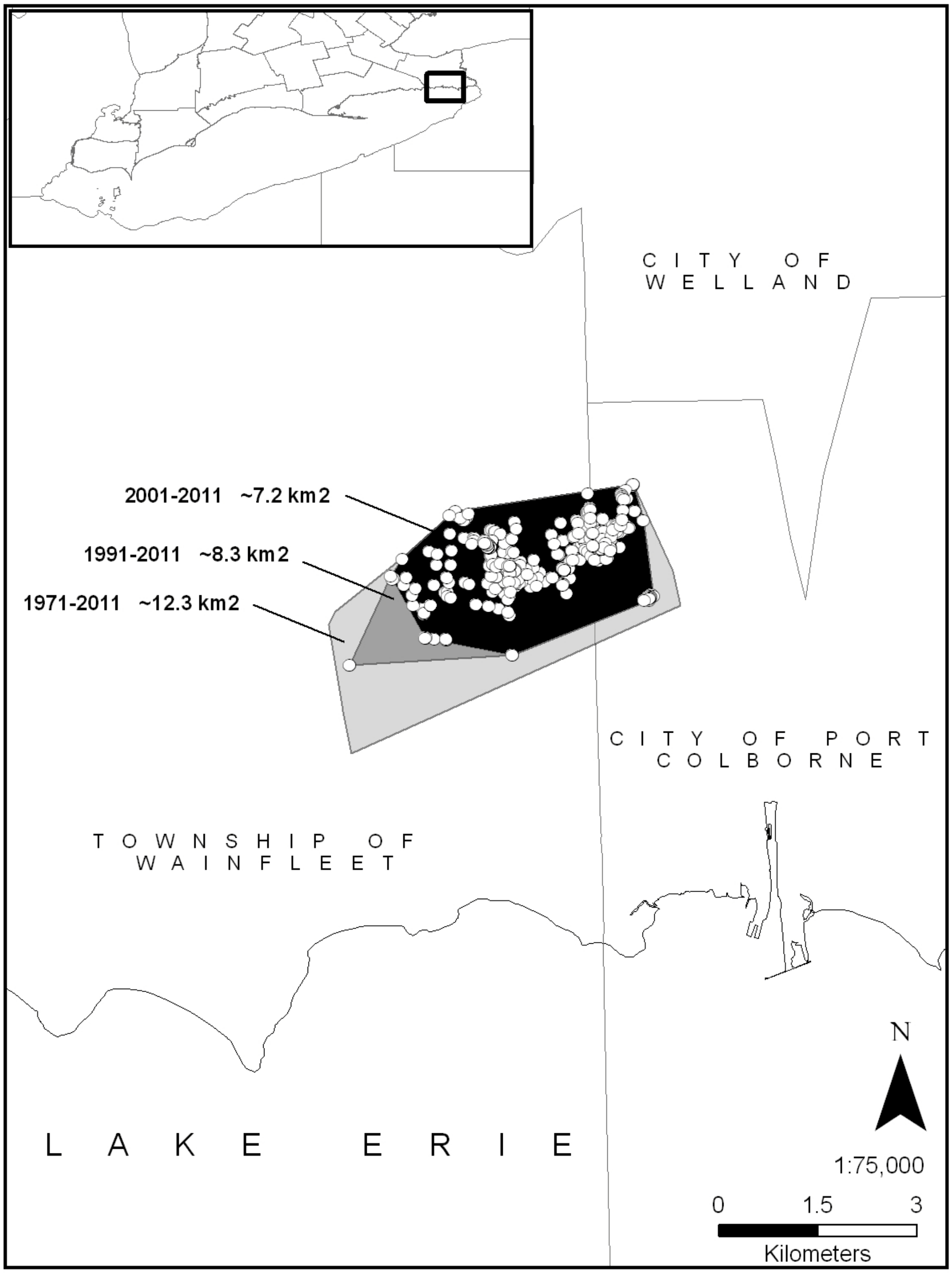

Figure 9. Geographic extent of the Wainfleet Bog population of Massasauga in three time periods, 1971-2011, 1991-2011, and 2001-2011. A convex polygon was drawn to include all occurrence records within each respective time period. Point data are only shown for the last 20 years (1991-2011 period). Data were received by the CMN, ROM, NHIC and Parks Canada. Area of each polygon was measured in ArcGIS using 'measure polygon feature' tool. Permission to reproduce granted by J. Choquette and T. Preney.

At Wainfleet Bog, habitat occupied by Massasaugas consists of a contiguous, road-less, natural area (~ 1650 ha, Figure 8). The level of anthropogenic disturbance is relatively low at one quarter of the site (given ANSI designation) and moderate to severe in the remainder, primarily due to past peat mining (NPCA 2009). Also, suitable hibernacula are limited to areas where peat extraction has not occurred (N.E. and S.W. corners, A. Yagi pers. comm. 2012). An additional ~580 ha of marsh, swamp and alvar habitat exists to the south of the bog but the area is currently unoccupied by Massasaugas (Middleton 1993; NPCA 2009; Yagi pers. comm. 2012).

Recent trends in habitat quality at Wainfleet are not immediately apparent, as examples of both declines and gains have been found. Habitat declines have occurred due to clearing of land for agriculture in the western portion of the bog, ongoing peat extraction, succession from invasive species (i.e. European Birch (*Betula pendula*) and flooding from Beavers (*Castor canadensis*) (Yagi and Frohlich 1999; Yagi and Frohlich pers. comms. 2011). Examples of habitat gains include a slight northern expansion of the wetland, habitat rehabilitation of 57 ha of previously mined peat land and restoration/naturalization projects on three adjacent rural properties (Frohlich 2004; NPCA 2006; NPCA 2010; Frohlich and Yagi pers. comms. 2011). Much of the open extracted peat barrens are now re-vegetated with bog species (Yagi pers comm. 2012).

BIOLOGY

Life Cycle and Reproduction

In Ontario, Massasaugas are active from approximately May to October, and hibernate for the rest of the year (C. Parent unpublished data; Rouse *et al.* 2001). Spring emergence coincides with ground temperatures of 10°C or more (Wainfleet Bog, Pratt *et al*. 2000). Mating occurs during late summer (late July to early September) and females store sperm until ovulation the following spring. The Massasauga is live-bearing and requires approximately 3 months of gestation prior to giving birth. In KPP, gravid Massasaugas spend 2-3 weeks in foraging habitat before making predictable movements to distinctive microhabitats (gestation sites or rookeries), where they will remain until parturition in late summer (mid-July to mid-September; Rouse and Willson unpub. data). In some areas, limited availability of optimal gestation sites may contribute to their use by several females. Furthermore, post-partum females experience significant weight loss and must feed and rehydrate adequately before hibernation to survive winter (Yagi pers. comm. 2012). Adult females rarely give birth more than once at Wainfleet Bog due to post-partum, over-winter mortality (Yagi pers. comm. 2012).

In Ontario, age at sexual maturity varies between 3-6 years (Middleton and Chu 2004; Rouse 2005; Miller 2005). Climatic conditions, local site characteristics (e.g., prey density) and within population variation can influence age of maturation (Parent *et al.* unpub. data). The estimated maximum breeding age in the wild is 12 years (Miller 2005), although individuals from Ontario have been observed surviving to 14-17 years of age (Crowley pers. comm. 2012). Most females are believed to reproduce only once every 2-3 years and an estimated 50% of adult females will successfully breed in a given year (Miller 2005). Litter sizes range from 3 to 20 at Bruce Peninsula (mean = 13, Parent and Weatherhead 2000) and 2 to 19 at Wainfleet Bog (mean = 10, Yagi pers. comm. 2012). The ratio of breeding males to breeding females is generally 1.75:1 (Harvey 2008).

Estimates of annual mortality rates for adult Massasaugas range from 39% (Bruce Peninsula, Miller 2005; Harvey and Weatherhead 2006b) to 67% (Wisconsin, King 1999 *as cited by* Bailey *et al.* 2011). Similarly, King *et al*. (2004) recorded a 47% mortality rate in adult repatriated Massasaugas and annual adult mortality rates were estimated at 35% - 76% during a mark - recapture and telemetry study at Wainfleet Bog (Yagi unpub. data). In contrast, research in Michigan suggests natural mortality may be much lower (5% during the active season but undocumented overwinter, Bailey *et al.* 2011). At that rate, and with a similar overwinter mortality as in Bruce Peninsula (21%, Harvey and Weatherhead 2006b), annual mortality rate could be as low as 25% (using the formula in Miller 2005). Persecution and road mortality are likely to lead to higher mortality rate estimates (Bailey *et al.* 2011). Neonate mortality rates have been estimated at 33 % (King *et al*. 2004).

Generation time, the average age of parents of the current cohort, is estimated in two ways: 1) Generation Time = age at maturity + [1/annual adult mortality rate]. Using 3-6 for age of maturity and 25% - 40% annual adult mortality rate, generation time equals 7.8 years (5.5 – 10), 2) Generation Time = age at which 50% of total reproduction is achieved. If we assume female reproduction is every other year, age of maturity at 3-6 years and maximum age of breeding at 12 years, then any given female might reproduce, at most, 4-5 times in her life. Each female would achieve 50% of her reproductive output after birthing 2-3 litters, or at 7-8 years of age. Generation time equals 7.5 years (7-8).

Physiology and Adaptability

Massasauga populations may persist in areas with low-moderate levels of human disturbance. For example, gravid females continue to use gestation sites immediately adjacent to well-used human trails in KPP (Parent and Weatherhead 2000). Also, human created or abandoned features such as old boats, boat docks, railways, organic debris piles and junk piles have been used for gestation and refuge (Pratt *et al*. 2000; Marshal *et al*. 2006; Yagi pers. comm. 2012). Furthermore, Massasaugas will use artificially maintained open habitat, which may be particularly important where habitat is limiting (e.g., hydro right-of-ways, rail corridors, municipal drains, active agricultural areas, feeder canals and grassy roadsides: Weller and Parsons 1991; Glowacki and Grundel 2005; Durbian *et al*. 2008; Harvey 2008; Yagi pers. comm. 2012; Preney unpub. data). Massasaugas may decrease their frequency of movement and travel distances in response to human disturbance and limited habitat availability (Parent and Weatherhead 2000).

Ultimately, where disturbance and habitat fragmentation are high, Massasauga populations will disappear; a fact attested to by the ongoing decline in size and number of subpopulations at Ojibway (see **POPULATION SIZES AND TRENDS**). Where roads and development sever subpopulations from one another, Massasaugas are not well adapted to local extirpations due to their biology (Rouse *et al.* 2011), behaviour (Weatherhead and Prior 1992) and dispersal barriers that prevent them from re-colonizing vacant habitat patches. For example, fire has been used at a site in Windsor for decades to maintain tallgrass prairie and savannah, suitable Massasauga habitat, but roads and development have prevented recolonization from nearby occupied sites.

When strong dispersal barriers are absent, Massasaugas re-colonize newly created, restored or burned habitat adjacent to currently occupied sites. At Wainfleet Bog, the highest concentration of rattlesnakes was recorded in an area previously burned by a natural fire (Yagi pers. comm. 2012). Massasaugas have also been observed using previously unoccupied sites that have undergone habitat restoration in Wainfleet Bog (Frohlich pers. comm. 2011) and in Indian Springs Metropark in southeastern Michigan (Sage 2006).

In the Ojibway subpopulation, Massasaugas will likely need to be repatriated to remaining protected areas, and additional subpopulations established, if extinction of the entire subpopulation is to be thwarted. Despite a failed repatriation attempt at the Ojibway Prairie Provincial Nature Reserve (Preney unpub. data), Massasaugas have been successfully bred in captivity and individuals are likely to survive in the wild if they are released at the appropriate age and time of year (King *et al*. 2004).

Dispersal and Migration

Dispersal distances vary substantially between Massasauga populations (Reinert and Kodrich 1982; Weatherhead and Prior 1992) and are likely influenced by the proximity of important habitat features. Relatively long distance, straight-line, movements occur seasonally when Massasaugas shift their centres of activity: fall and spring are spent in wet, heavily vegetated habitats near their hibernacula and summer is spent in upland, drier foraging habitats (Reinert and Kodrich 1982; Seigel 1986; Weatherhead and Prior 1992; Johnson 2000; Parent and Weatherhead 2000; Pratt *et al*. 2000; Rouse *et al*. 2001; Yagi pers. comm. 2012). These shifts may require migrations as great as 1 – 4 km (Rouse *et al*. 2001; Durbian *et al*. 2008; Rouse *et al.* 2011; Yagi pers. comm. 2012). Similarly, relatively long-distance dispersal movements are exhibited by mate-seeking males (Rouse 2005; Yagi pers. comm. 2012). In absolute terms, dispersal distances are much smaller where habitat is restricted (Durbian *et al*. 2008; Preney unpub. data). Massasaugas are susceptible to high levels of mortality during these dispersal events (e.g., predation and roadkill) and several authors stress the need to identify and protect dispersal/habitat corridors (Rouse 2005; Elgie *et al*. 2010; Choquette 2011a; Rouse *et al*. 2011) and/or provide suitable habitat within a threshold distance of hibernacula (e.g., 400m, Durbian *et al*. 2008).

In Ontario, limited data exist on juvenile dispersal. In the Great Lakes/St. Lawrence DU, marked neonate Massasaugas were recorded moving at least 400 m from their birth site to a suitable hibernaculum (Rouse *et al.* unpub. data). A radio telemetry study in Illinois indicated that dispersal distance of neonates was 100-300 m (Wylie pers. comm. 2011). Another study in Wisconsin indicated neonate range length was 20-80 m (Durbian *et al*. 2008).

Interspecific Interactions

Massasaugas are both diurnal (Rouse and Willson 2002) and crepuscular/nocturnal predators (Yagi pers. comm. 2012). They ambush their prey and are adapted to terrestrial foraging. In Ontario, adult Massasaugas feed almost exclusively on small mammals (BPNP, Weatherhead *et al*. 2009), but songbirds (e.g., *Melospiza melodia*) and Snowshoe Hares (*Lepus americanus)* are also taken (Weatherhead and Prior 1992). Neonate and juvenile snakes eat a wider range of prey including snakes, amphibians (especially frogs), and invertebrates (Seigel 1986; Rouse and Willson pers. obs.). Feeding rates are likely dependent on a number of factors including life stage and habitat quality (Yagi pers. comm. 2012); however, Massasaugas probably exert minor pressure on vertebrate populations due to their overall low rate of feeding (Keenlyne and Beer 1973; Seigel 1986; Hallock 1991).

Massasaugas rely on passive defence and shrub cover to avoid confrontation with predators (Parent and Weatherhead 2000) and tend to remain close to retreat sites at all times (e.g., within 0.5 m: Harvey and Weatherhead 2006a). Documented predators include Great Horned Owl (*Bubo virginianus*), Northern Harrier (*Circus cyaneus)*, Coyote (*Canis latrans*), and Mink (*Mustela vison*) (Durbian *et al*. 2008; Yagi pers. comm. 2012; Preney unpub. data). Predation by Coyotes at Wainfleet Bog and Ojibway Prairie was high on transmittered snakes (Yagi pers. comm. 2012; Preney unpub. data). Other potential predators include various birds of prey and mammals such as Red Fox (*Vulpes vulpes*), Fisher (*Martes pennanti*), Short-tailed Weasel (*Mustela erminea*), Opossum (*Didelphis virginiana)*, Bobcat (*Lynx rufus)* and Raccoon (*Procyon lotor*). Domestic or feral cats and dogs may also prey upon or kill Massasaugas. Young snakes are likely to be preyed upon by a wider variety of predators.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Population sizes and trends for Massasauga in Canada are extremely difficult to estimate due to the snakes' cryptic nature (Harvey 2008). Capture rates range from 0.01 – 0.40 snakes per person-hour of searching (Black and Parent 1999; Parker and Prior 1999; Pratt *et al*. 2000; Harvey 2005; Choquette unpub. data). Accuracy of estimates is further reduced by the expansiveness of Massasauga range in the Georgian Bay region and small sample sizes and low search effort in the Carolinian region.

A number of abundance estimates have been conducted for subpopulations within the Great Lakes/St. Lawrence DU. Population sizes and trends were conducted for GBINP using data from 1978-2002 (almost 900 capture records) and three methods: number of captures, Minimum Number Known Alive, and a Mark-Recapture estimate (Middleton and Chu 2004). Population size estimates were calculated for KPP males and females separately using data from four years of capture-mark-recapture data, radio telemetry, and the Jolly-Seber Model for open populations (Rouse 2005). Intensive mark-recapture studies during 2000-2001 were used to estimate preliminary population size at a study site north of Moon River and west of Mactier (Rouse *et al*. unpub. data). At BPNP, monitoring research and monitoring has occurred since 1989 (Tonge 2006) and Miller (2005) estimated population size based on snake density (0.5-2 snakes/ha, Harvey 2008). Abundance was also estimated for the entire Bruce Peninsula and eastern Georgian Bay regions by Rouse and Willson (2002) but estimation methods are unknown. Population Viability Analyses (PVA) were conducted for the upper Bruce Peninsula and GBINP (Middleton and Chu 2004; Miller 2005).

Limited research activities on both Carolinian subpopulations since the late 1990s (Pratt *et al*. 2000; Middleton and Chu 2004) have led to crude population size estimates. For example, Massasauga abundance at Wainfleet Bog was recently estimated through extrapolation (Yagi pers. comm. 2012). Abundance at a discrete study site (~10% of the entire bog) was calculated based upon the average number of unique adult snakes encountered there per year (+/- 95% CL) during an 8-year mark-recapture study (2000 – 2008). This site-level estimate was then extrapolated to the remaining 90% of Wainfleet Bog assuming equal density of snakes across the area. At the Ojibway Prairie, Massasauga abundance was estimated based on both the number of adult snakes captured since 1999 and presence/absence of subpopulations (Cedar pers. comm. 2011; Pratt pers. comm. 2011). A carrying capacity estimate was also conducted for the lone confirmed subpopulation based on a density of 1.3 – 5.0 adult snakes per ha (Brennan 2004; Cedar pers. comm. 2011) and an estimated 8.7 ha of open habitat remaining.

Abundance

The total adult global population size for the eastern subspecies across Ontario and the U.S. (~236 "locations", USFWS 1998) is estimated at 11 800 adults (using an average of 50 adults per "location", NatureServe 2011). The uncertainty surrounding this estimate, however, is quite large (2500 – 100 000 adults, NatureServe 2011). This "method" may reflect the increasing decline of most US populations of Massasauga into small isolated fragments, but it would give a total estimate of 1600 adults in Canada (Appendix 7), which is certainly an underestimate. Total population size as approximated from Rouse and Willson (2002) is 9400 (6800 – 12 000) mature individuals (17 000 – 30 000 x 40% mature, Seigel *et al.* 1998). This estimate may be reasonable, but it was not accompanied by any explanation of how it was derived. Based on genetic data provided by Chiucchi and Gibbs (2010), and assuming 40% of individuals in each population are adults (Seigel *et al.* 1998), population sizes range from 73 (64 -84) to 1020 (880 – 1160) mature individuals across the five Canadian subpopulations studied (Wainfleet Bog, Ojibway Prairie, GBINP, KPP and BPNP). When there is a fairly accurate estimate of subpopulation size (i.e., Ojibway Prairie, Wainfleet Bog, GBINP, KPP) these indirect estimates from genetic data tend to inflate abundance.

<u>Great Lakes/St. Lawrence DU</u>

The Great Lakes/St. Lawrence DU supports multiple subpopulations of Massasauga and 99 % of Massasaugas in Canada. There are an estimated 37 extant "locations" in this DU (Appendix 1), and they vary in status from a few verified records to hundreds of records spanning hundreds of hectares. Massasauga subpopulations in the northern Bruce Peninsula and, in particular, the eastern Georgian Bay region are believed to be the largest, most dense, and most secure in the global range of the eastern subspecies (Rouse and Willson 2002; Harvey 2008).

On the upper Bruce Peninsula and adjacent islands (GL/SL DU "locations" # 2, 3 and 4, Appendix 1) abundance has been estimated from two separate sources:

1. Rouse and Willson (2002) estimated 4000 – 8000 individuals (detailed estimation methods were not provided). Assuming that 40% of individuals are adults (Missouri, Seigel *et al*. 1998) there would be an estimated 2400 (1600-3200) mature individuals.
2. Miller (2005) estimated 6650 individuals (based on distribution and density data, but did not provide confidence intervals). Assuming that 40% of individuals are adults (Missouri, Seigel *et al*. 1998) there would be an estimated 2660 mature individuals.

When Rouse and Willson's (2002) and Miller's (2005) estimates are averaged and the confidence intervals suggested by the former are included, there are an estimated 2500 (1600-3200) mature individuals on the upper Bruce Peninsula. This estimate seems reasonable considering the population estimate derived from genetic data in Chiucchi and Gibbs (2010) for a subset of the upper Bruce Peninsula was 1020 (880-1160) mature individuals (2550 [2200 – 2900] individuals multiplied by 40%, Seigel *et al*. 1998).

On the eastern shore of Georgian Bay, abundance has been estimated at two "locations", for a combined population size of 94 (67 – 120) mature individuals:

1. GBINP (GL/SL "location" #27, Appendix 1) abundance is estimated at 50 (40-60) adults based on a long-term mark-recapture dataset presented in Middleton and Chu (2004). Conversely, a total of 390 (336 – 444) mature individuals is estimated using genetic data presented in Chiucchi and Gibbs (2010). In this case, the estimate using data from the long-term study (Middleton and Chu 2004) was chosen as most valid as it is based on long-term field data.
2. KPP (GL/SL "location" #38, Appendix 1) abundance is estimated at 458 (396 – 520) based on genetic data in Chiucchi and Gibbs (2010). Alternatively, 109 (67-150) adults/juveniles were estimated by Rouse (2005) using capture-recapture methods. Assuming 40% of snakes are adults (Missouri, Seigel et al. 1998), KPP contains 44 (27 – 60) adult snakes. Again, the estimate based on mark-recapture field data was chosen.

For the remaining 32 "locations" in the Great Lakes/St. Lawrence DU for which detailed demographic data are lacking, two crude estimates of abundance were derived: a) 15 300 (10 260 – 19 220) mature individuals, and b) 11 580 (4 632 – 18 528) mature individuals (see Appendix 7). When results from both methods are added and averaged, the result is a total of 13 440 (7 446 – 18 874) mature individuals

In summary, the abundance estimates described above are as follows:

1. Upper Bruce Peninsula = 2500 (1600-3200)
2. KPP and GBINP = 94 (67 – 120)
3. 32 GLSL "locations" = 13440 (7446 – 18874)

Total abundance in the Great Lakes/St. Lawrence DU is derived by adding the latter estimates and equates to 16 034 (9 113 – 22 194) mature individuals. Clearly, this estimate is unusually crude and involves many untested assumptions. These include the use of the NatureServe "estimate" of 50 adults per "location" as well as the assumption that the densities from the upper Bruce Peninsula are similar across the DU. It is likely that densities in the forests inland from the Georgian Bay shoreline and especially in the northern half of the range are lower than on the Bruce peninsula, because of temperature constraints and decreased open canopy. Ultimately, invoking the precautionary principle and the COSEWIC/IUCN guidelines, we must heed the lower value of the range of estimates in assessing risk.

Carolinian DU

At Wainfleet Bog, over 80 adults and juveniles have been captured in 12 years of study (Yagi pers. comm. 2012). Population size (all age classes) has been estimated at 200 individuals (Chiucchi and Gibbs 2010) and 200-400 individuals (Pratt *et al*. 2000). Abundance of mature individuals is estimated at 40-70 snakes (Rouse and Willson 2002; Yagi unpub. data).

At Ojibway Prairie, 14 adults were recorded between 1999 and 2002 (Pratt *et al*. 2000; Pither 2003) and 8 adults/juveniles were recorded between 2009 and 2011 with limited search effort (Choquette and Preney, unpub. data). Brennan (2004) estimated the maximum potential number of adult snakes based on carrying capacity and presence within four historical subpopulations to be between 77 - 308 adults. At the writing of the previous status report, with two confirmed subpopulations, abundance was estimated at 30-60 adults (Rouse and Willson 2002). Currently, with one confirmed subpopulation, abundance may be as low as 10 - 40 adults (Pratt pers. comm. 2011; Choquette, unpub. data).

Combining abundance estimates for the Wainfleet Bog and Ojibway Prairie subpopulations, abundance of the Carolinian DU is estimated at 80 (+/- 30) mature individuals.

Fluctuations and Trends

The global short-term trend for the subspecies (over last 15 years, or 2 generations) is estimated to be a decline of 10-50% and the global long-term trend is estimated at a decline of 25-75 % (NatureServe 2011). Contemporary trends in the Canadian population size are unknown, but suspected to be experiencing a slight decline on the basis of inferred population trends in the Great Lakes/St. Lawrence DU (see **Canadian Range** for historical trend).

Great Lakes/St. Lawrence DU

A continuing decline in abundance on the upper Bruce Peninsula is inferred. For example, Miller (2005) suggests there is ‘reasonable circumstantial evidence’ that Massasaugas on the upper Bruce Peninsula have been numerically stable at best, and probably slightly declining, over the past few decades. In the long term, abundance is projected to decline slightly due to habitat loss (Miller 2005, see **THREATS AND LIMITING FACTORS**). Furthermore, the current rates of road mortality are suspected to be unsustainable, therefore contributing to an even greater loss in abundance and increased extinction risk (see **THREATS AND LIMITING FACTORS**). The combination of projected and suspected declines due to ongoing habitat loss and road mortality, respectively, allows us to infer that the population size in the upper Bruce Peninsula will continue to decline into the future.

Population level trends in other Great Lakes/St. Lawrence subpopulations are more difficult to assess. At GBINP, despite having over two decades of data, population trends could not be identified with any level of certainty (Middleton and Chu 2004). Elsewhere along the eastern shore of Georgian Bay, human density is relatively high, development pressure is increasing and anthropogenic mortality is ongoing (see **THREATS AND LIMITING FACTORS, Habitat Trends**). As a result, it would be prudent to suspect declines in abundance on a similar scale to those projected for the upper Bruce Peninsula (i.e., numerically stable at best, probably slightly declining with further declines projected). These inferences are much more optimistic than NatureServe’s projections for the global population.

Carolinian DU

At Wainfleet Bog, the geographic extent occupied by Massasaugas is presumed to have declined in recent decades (Yagi and Tervo 2005; Yagi pers. comm. 2011). In addition, a comparison between historical and contemporary occurrence records suggests a 13 - 42% contraction in the geographic extent of this population has occurred within the last 20 - 40 years, respectively (3 – 5 generations, Figure 9). Chiucchi and Gibbs (2010) suggest this population might not have enough genetic variability to adapt to future environmental changes, placing it at a high level of extinction risk.

The Ojibway population has experienced a drastic decline in historical range and the extirpation of most subpopulations (Weller and Parsons 1991; Pratt *et al*. 1993). A comparison between historical and contemporary occurrence records suggests a 60 - 82% contraction in the geographic extent of this population within the last 20 – 40 years (3 – 5 generations, Figure 10). If presence/absence at historical subpopulations provides an additional indication of trends, a severe decline in abundance has occurred in the last 40 years. Three of four distinct subpopulations are presumed extirpated as the most recent records for each are from the late 1970s (Pratt *et al*. 1993; Pither 2003), late 1980s (Town of LaSalle 1996) and mid-1990s (Pratt unpub. data), respectively. Massasaugas are now only encountered by researchers and residents within one subpopulation (Pratt *et al*. 1993; Pratt pers. comm. 2009; Choquette and Preney pers. obs. 2011). Abundance there is known to have declined by at least 4 adults in 2003 due to a residential development which removed ~3ha of habitat (Austin 2004; Cedar pers. comm. 2011; Preney pers. obs.).

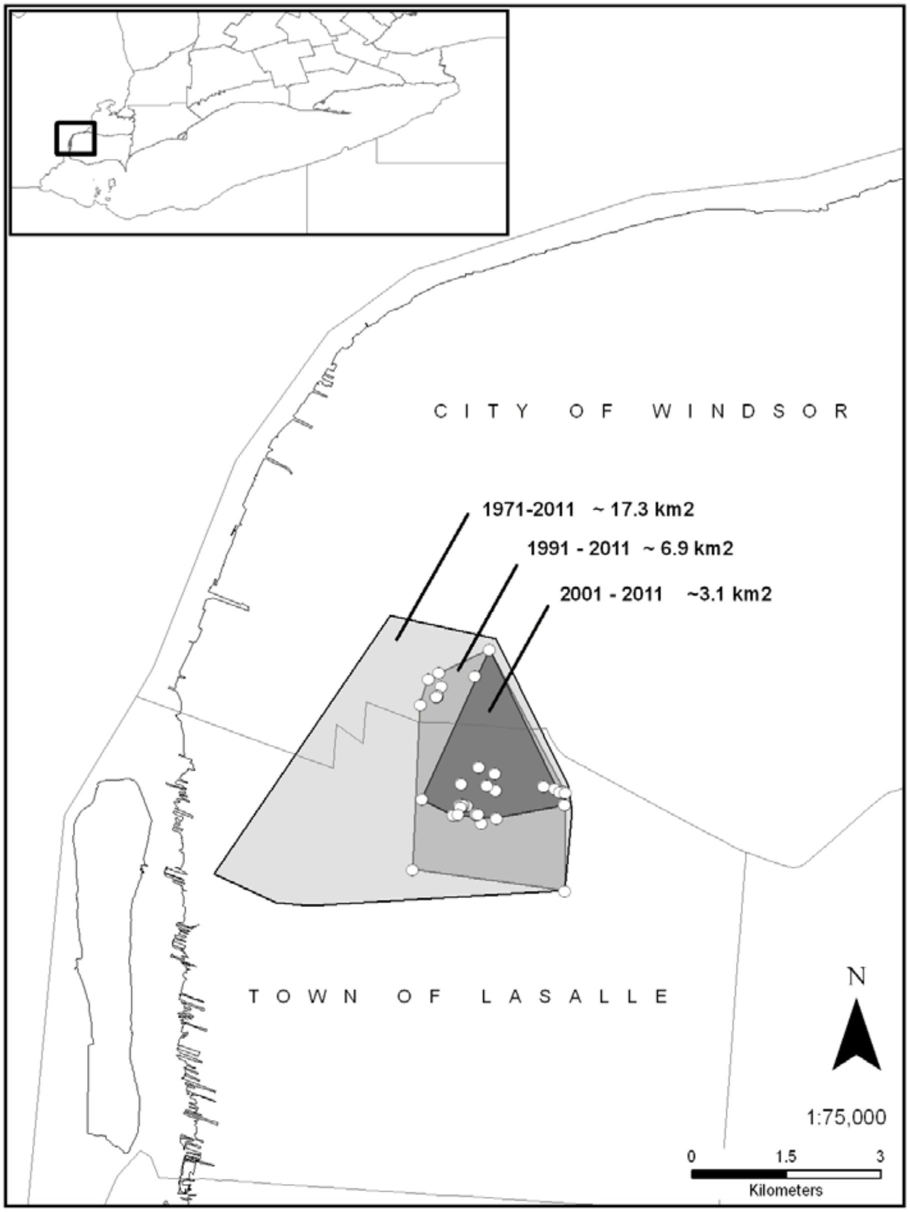

Figure 10. Geographic extent of the Ojibway Prairie population of Massasauga in three time periods, 1971-2011, 1991-2011, and 2001-2011. A convex polygon was drawn to include all occurrence records within each respective time period. Point data are only shown for the last 20 years (1991-2011 period). Data were received by ROM, Parks Canada, P. Pratt and J. Choquette. Area of each polygon was measured in ArcGIS using 'measure polygon feature' tool. Permission to reproduce granted by J. Choquette and T. Preney.

Although the Ojibway Prairie population is still extant, the fact that it is represented by a single declining subpopulation now poses a severe threat to its persistence (Brennan 2004). A PVA by Middleton and Chu (2004) suggests extinction risk is on average 25% (range of 5 – 55%), based on demographic variables alone, when population size is as low as 25 adults. Also, a PVA by Brennan (2004) suggests that the Ojibway Prairie population is not viable in the long term. The combination of stochastic events, habitat loss, habitat fragmentation, decline in habitat quality and human-induced mortality poses an immediate and severe threat to the persistence of this population. The extinction of the Ojibway Prairie population is imminent, perhaps within the next decade or two, without intensive active management and repatriations (Pither 2003, Brennan 2004; Middleton and Chu 2004).

Rescue Effect

Both Carolinian subpopulations are isolated geographically and genetically (Chiucchi and Gibbs 2010) from the Great Lakes/St. Lawrence populations (**Population Spatial Structure and Variability**) and the closest U.S. populations. Natural dispersal into these small populations is extremely unlikely. At Wainfleet Bog, the next closest verified population in the U.S. occurs ~100 km to the west in Bergen Swamp near Byron, New York. At Ojibway, at least four verified populations occur within 55-65 km in Michigan, including University of Michigan Matthaei Botanical Gardens in Ann Arbor Michigan, Proud Lake State Recreation Area, Indiana Springs Metropark and Independence Oaks County Park (Prior and Weatherhead 1995; USFWS 1998).

Although potential immigrants from Michigan or New York would likely be adapted to survive in Canada, rescue from U.S. populations is prevented by geographic barriers such as the Detroit and Niagara Rivers and the Great Lakes. In addition, Canadian populations are isolated from US populations by heavily altered human landscapes (urbanization and intensive agriculture). Although the Detroit River may/may not act as a dispersal barrier to reptiles, the Niagara River is recognized as a natural dispersal barrier preventing recolonization of reptiles from western New York (Yagi *et al*. 2009). In summary, natural dispersal-based rescue in the short-term is highly unlikely and any rescue that occurs for the Carolinian DU would have to occur artificially through translocations.

In the Great Lakes/St. Lawrence DU, despite the relatively high number of populations and apparent connectivity of Massasauga habitat, short-term rescue of currently extirpated populations (and potential future extirpations) from within the DU or adjacent Michigan populations from natural dispersal is unlikely (see **Population Spatial Structure and Variability**). Short-term rescue is extremely unlikely for populations isolated by natural or human-created barriers.

THREATS AND LIMITING FACTORS

In both DUs, the viability of Massasauga populations is threatened by a number of anthropogenic pressures. In addition, limiting factors such as biennial reproduction, cool temperatures, and a long generation time decrease the ability of this species to recover from the impacts of those pressures. In the Great Lakes/St. Lawrence DU, Massasaugas are at the northern extent of their North American range, and their distribution in this region is limited by climate (Harvey and Weatherhead 2010). The threat to persistence of Carolinian populations (particularly Ojibway Prairie) is immediate and severe (Pither 2003).

Unnaturally high neonate or adult mortality can pose significant constraints on population persistence (Middleton and Chu 2004). Miller's (2005) PVA results suggest that high levels of adult mortality (relative to population size) can eliminate Massasauga populations and Harvey (2008) adds that loss of adult females is a relatively greater threat to population persistence than the loss of adult males. The best documented threats are habitat loss and direct mortality from roads, persecution and collecting. Alone, none of these may pose a significant threat to population persistence, but when combined, these threats have the potential to create a synergistic effect that may significantly heighten long-term population declines and extinction risk, especially in geographically restricted subpopulations.

<u>Habitat loss</u>

The predominant cause of the historical decline of Massasaugas in Ontario was the extensive drainage of wetlands for agricultural production (Weller and Oldham 1993; Oldham *et al*. 1999; Pither 2003, see **Canadian Range**). Many other types of development (e.g., housing, golf courses, resource extraction, shoreline development for recreation, and road construction) continue to remove habitat and threaten remaining Massasauga subpopulations.

Massasauga habitat in the Great Lakes/St. Lawrence DU has undergone historical (see **Canadian Range**) and contemporary declines. Of greatest concern has been the ongoing loss, degradation and fragmentation of habitat in the upper Bruce Peninsula and southern Georgian Bay from expansion and improvement of road systems (Fenech *et al.* 2000; Watters 2003; Figure 11), cottage and residential developments and intensification of developed areas (Miller 2005, Crowley pers. comm. 2011; Truscott pers. comm. 2011; Harvey pers. comm. 2011; Rhodes-Munk pers. comm. 2011; Rouse pers. comm. 2011). On the southern Georgian Bay coast, low intensity agriculture and low density residences are being replaced with high density developments (MacKinnon *et al.* 2005), and the human population in this area is growing faster than any other in Ontario (Watters, 2003). On the eastern shore of Georgian Bay as a whole, loss of habitat is presumed to be less relative to total amount of protected area as one goes north (Rouse pers. comm. 2011). Crown land is being severed and sold for cottage shoreline development, but less than 1% has the potential to be severed in this way (Rouse pers. comm. 2011).

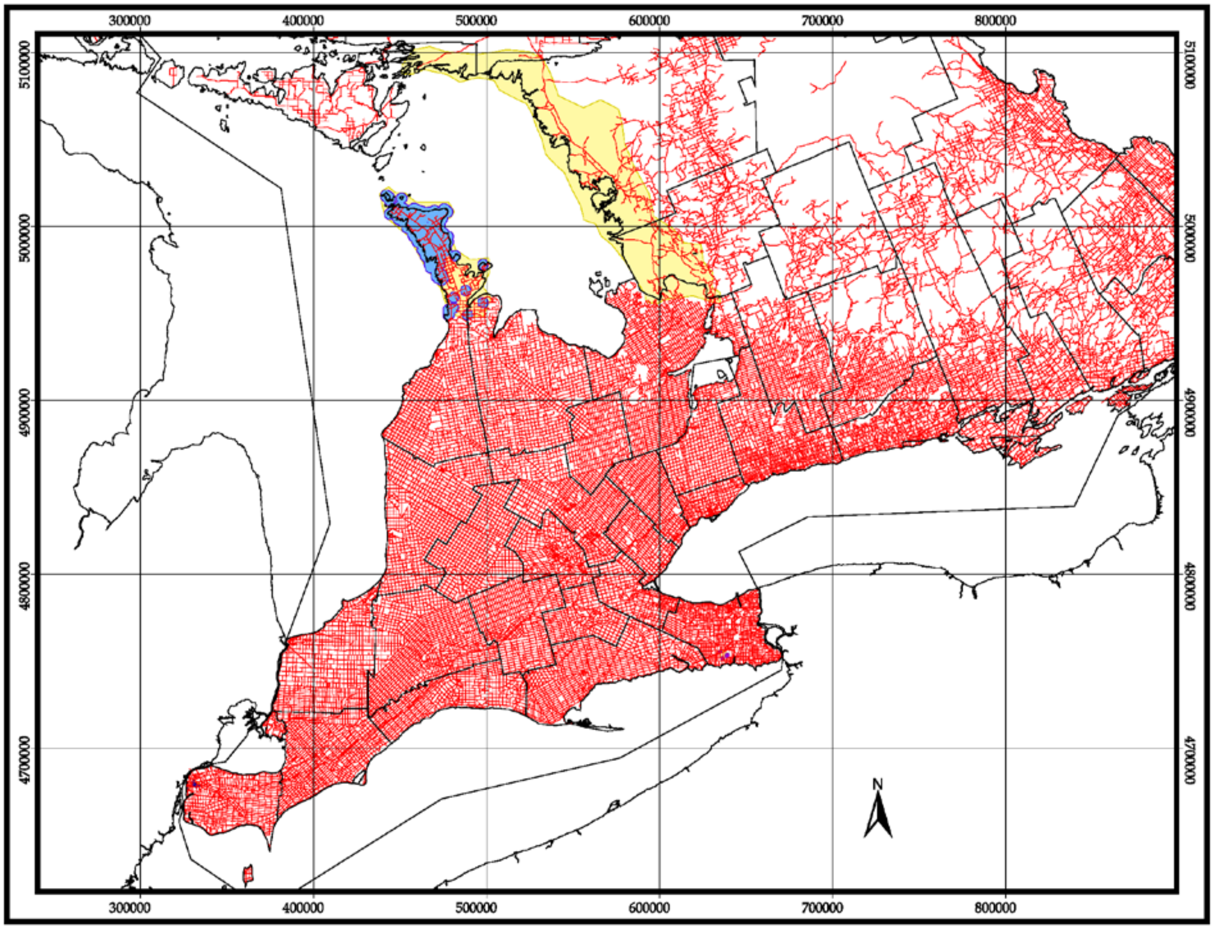

Figure 11. Relative road density in Southern Ontario (Fenech *et al*. 2000) and distribution of Massasauga in the Northern Bruce Peninsula (shaded in blue) and Eastern shore of Georgian Bay (shaded in yellow) in the Great Lakes/St. Lawrence DU. Note the absence of recently verified “locations” (e.g., Manitoulin Island). Ojibway and Wainfleet subpopulations are barely noticeable at this scale. Image from Rouse and Willson 2002.

On the upper Bruce Peninsula, a PVA model by Miller (2005) suggests that fire is a more important threat to the viability of subpopulations than current and projected rates of development (but see **Habitat Trends** and **BIOLOGY)** for reference to benefits of fire disturbance for Carolinian populations). Furthermore, 80% of new developments are projected to take place in existing settlement areas (Bruce County 2010). At the current estimated rate of habitat loss, a slight decrease in population size is estimated in the next 100 years and four out of seven subpopulations in the upper Bruce Peninsula are expected to experience declines (Miller 2005). Nonetheless, the relative quasi-extinction risk for each subpopulation is low, and the projected declines are not predicted to have a measurable impact on quasi-extinction risk of the entire upper Bruce Peninsula population over the next 100 years (Miller 2005). Overall, the metapopulation is highly buffered against total extinction in most cases (Miller 2005).

Within the Carolinian DU, habitat loss through natural succession is resulting in an ongoing decline in availability and quality of open foraging and gestating habitat (Yagi pers. comm. 2012, Preney pers. obs.). Where overall habitat is limiting, natural succession can contribute to population declines (Johnson and Breisch 1993; Reinert and Buskar 1993). Furthermore, hibernacula quality at Wainfleet Bog has been reduced by historical peat extraction and ongoing wetland drainage, which have lowered the water table (Yagi pers. comm. 2012). At Ojibway Prairie, the additional threat of habitat loss from residential development is particularly severe. In 2003, a residential development in LaSalle was directly responsible for the removal of a significant number of adult snakes from the population (see **POPULATION SIZES AND TRENDS**). Ongoing and projected development adjacent to the Ojibway Prairie Complex and the LaSalle Woodlot Environmentally Significant Area (Town of LaSalle 2003; City of Windsor 2007) will continue to destroy habitat, kill individuals and isolate protected areas.

<u>Road mortality</u>

Traffic on roads, and even off roads, is a significant anthropogenic source of mortality for snakes as these reptiles are generally small, not readily visible to drivers, and slow moving. Evidence of the impact of road mortality on Massasauga is suggested in the species' current and historical distribution in Figure 11. This figure shows road density in southern Ontario in 1995, but as the source document points out (Fenech *et al.* 2000), the number (density) of roads and their traffic volume and speed continue to increase inexorably. All these metrics increase mortality rates of Massasaugas in occupied habitat (e.g., Row *et al.* 2010, 2011; Rouse *et al.* 2011; Farmer and Brooks 2012; Rowell 2012), but the full impact goes well beyond direct mortality from vehicles to all anthropogenic threats contingent upon increasing road network densities. Although, road networks are still more sparse in the Bruce Peninsula and Georgian Bay region these areas are under pressures from ever-expanding recreational and urban development, all dependent on more and bigger roads. A move to provide "ecopassages" under or over a major highway may reduce mortality but this reduction is undoubtedly minor in the overall context of mortality from vehicles.

Massasaugas are particularly susceptible to mortality while crossing or basking on roads because they are slow moving, even for snakes. Rates of road mortality are high in areas with high snake abundance and where roadways bisect snake dispersal paths (Weatherhead and Prior 1992; Rouse *et al*. 2011, Farmer and Brooks 2012; Rowell 2012). Road-killed Massasaugas have been observed across the species' range in Canada (Pratt *et al*. 1993; Oldham *et al*. 1999; Rouse 2005; NatureServe 2011; Rowell 2012) and Massasauga road mortality has been investigated in detail at a few "locations" (Bruce Peninsula, Tonge 2006; Reed and McKenzie unpub. data 2010; Stinnissen unpub. data 2012; Ojibway Prairie, Choquette 2011b; eastern Georgian Bay, MacKinnon *et al*. 2005; Rouse 2005). Some studies have found relatively low rates of Massasauga road mortality (MacKinnon *et al*. 2005; Reed and McKenzie unpub. data 2010; Choquette 2011b) probably because of low population densities or limited survey methodologies (Choquette 2011b). For example, no recent incidents of road mortality have been recorded at Wainfleet Bog (Yagi pers. comm. 2012), because the subpopulation's IAO is not severed by roads.

Relatively high rates of road mortality have been witnessed at other sites. For example, one investigator estimated that at a particular site in the Great Lakes/St. Lawrence DU, roughly 50% of Massasaugas attempting to cross roads are killed (R. Willson *in* Johnson and Wright 1999). At KPP, the known (minimum) number of Massasaugas killed on roads in and adjacent to the park ranges from 2-8 per year (Rouse 2005) from a population of only about 100 individuals (see **Abundance**). Two road mortality surveys in and around BPNP detected at least 20 dead Massasaugas along 1100 km of road (0.02 snakes/km) (Tonge 2006) and a minimum of 31 dead Massasaugas from five roads, including a portion of Highway 6 (Stinnissen unpub. data 2012). When these values are extrapolated to all roads with similar traffic and speed in the upper Bruce Peninsula, it is assumed that annual mortality rates may be in the hundreds (Crowley pers. comm. 2012) from a population of just over two thousand individuals (see **Abundance**).

Two additional impacts of roads are: 1) Massasauga road mortality is male-biased (Shepard *et al.* 2008a; Harvey 2008; Crowley pers. comm. 2012), which may contribute to female-skewed sex ratios (KPP, Rouse 2005), and 2) Roads may serve as an impermeable or semi-permeable barrier to snake movement (Shepard *et al*. 2008b), effectively isolating populations from one another and resulting in genetic isolation and a reduced probability that vacant habitat is recolonized (Rouse *et al.* 2011). For example, genetic substructure in Eastern Foxsnake populations in southwestern Ontario severed by a busy road indicated extremely limited to non-existent dispersal and breeding between subpopulations (Row *et al*. 2010, 2011).

Several investigators assert that road mortality is a severe threat to Massasauga populations in the U.S. and Canada (Rouse and Willson 2002; Seigel and Pilgrim 2002; Rouse 2005; Harvey pers. comm. 2011; Crowley pers. comm. 2012) and that it is contributing to regional and local population declines (Middleton and Chu 2004; Miller 2005; Rowell 2012). Massasaugas have become almost completely extirpated from areas in Ontario that now have high road densities, but persist where road densities are low (Crowley unpub. data, Figure 11; Rowell 2012). Unfortunately, no studies have specifically addressed the relative importance of road mortality on Massasauga population persistence (Middleton and Chu 2004). Row *et al. (*2007), however, used data on road mortality rates and abundance for a large snake species (*Elaphe obsoleta)* to show that even relatively low rates of roadkill (~2% of adults killed annually, similar to those witnessed with Massasauga at BPNP and KPP) increased extinction risk to 99% over 500 years. Although these results are not directly transferrable to Massasaugas, they suggest the long-term threat of road mortality on population persistence is severe.

Road mortality and loss of connectivity may be reversible, in a small, local context, through mitigation efforts. At KPP, recent installation of culverts/fencing along roads in the park has reduced the rate of road mortality (Otterbein pers. comm. 2011). On HWY 69, on the eastern shore of Georgian Bay, barrier fencing and ecopassage culverts are being installed to reduce road mortality and allow for safe dispersal across the highway (Crowley pers. comm. 2011). The effectiveness of this project has not yet been measured. Although a few new roadways may be held to higher standards in terms of mitigating road mortality and loss of connectivity, effective mitigation for existing roads is likely to continue at a very slow pace, if at all.

Discriminate killing

Discriminate killing is a direct threat faced by most Ontario snakes, and in particular rattlesnakes (Rowell 2012). Intentional persecution of Massasaugas is well documented in Ontario and was commonplace historically on both private and public land (Weller and Parsons 1991; Pratt *et al*. 1993; Pither 2003; Rouse 2005; Weller 2010). Interestingly, persecution may have been commonplace historically even within parks and protected areas (e.g., Bruce Peninsula National Park, Crowley pers. comm. 2012; KPP, Rouse 2005; Rowell 2012).

Along with habitat loss, direct killing by rural landowners contributed to the historical decline of Massasaugas in the southern portion of their range (Pither 2003; Rowell 2012). A small, localized population can easily be functionally exterminated or severely reduced in size by a single intent individual such as Miner (1928). For example, Weller (2010) reported on a case in which nine Massasaugas were killed by one person in one day. The most conspicuous and vulnerable members of a Massasauga population are gravid females basking in exposed gestation sites, (Parent and Weatherhead 2000), and these losses have a larger impact on population persistence than losses of other demographic groups

Some investigators suggest mortality from persecution is in decline due to changing attitudes and education/outreach efforts (Weller and Parsons 1991; Rouse 2005; Truscott pers. comm. 2011; Rowell 2012). Nonetheless, negative attitudes toward rattlesnakes persist and many are still intentionally killed across Ontario (Preney pers. obs.; Smith pers. comm. 2011; Rowell 2012).

Collection

Massasaugas are collected in the wild predominantly by herpetoculturalists for personal collections and for trading with other hobbyists (Miller pers. comm. 2011). The market value of a Massasauga ranges from $50 - $500 (Marks pers. comm. 2011; Miller pers. comm. 2011). Although Massasaugas do not appear to be as popular in the pet trade as some other species (Miller pers. comm. 2011; Marks pers. comm. 2011), there is evidence that collection has occurred or has been attempted across the species' range in Ontario (Marks pers. comm. 2011; Yagi pers. comm. 2011; Miller pers. comm. 2011; Rowell 2012). Recently, a poacher was prosecuted for collecting 33 Massasaugas from an eastern Georgian Bay "location" (Miller pers. comm. 2011). The threat to Ontario Massasauga populations from collection may increase in the future as interest in herpetoculture increases (Miller pers. comm. 2011).

Small population size

Carolinian populations are at an increased risk of extinction due to their small size and geographic extent. Small populations generally have little to no resilience to certain environmental fluctuations (short and long term). For example, an unusually warm winter with high rainfall followed by a flash freeze is believed to have contributed to a failed repatriation attempt at the Ojibway Prairie Provincial Nature Reserve (Pratt, Cedar and Preney unpub. data). Also, there are subpopulations in the Great Lakes/ St. Lawrence DU that could be considered 'small' based on behavioural, genetic or anthropogenic isolation and, therefore, would be highly vulnerable to extirpation (Miller 2005; Harvey 2008).

Inbreeding depression has not been detected in Carolinian populations (Lougheed 2004) and is probably not an important threat (Chiucchi and Gibbs 2010). The reduced genetic variation of these populations, however, may impede them from successfully adapting in the long term to a changing environment through natural selection (Lougheed 2004; Chiucchi and Gibbs 2010).

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

The Massasauga is currently listed as Threatened under the *Ontario Endangered Species Act,* 2007 and Threatened (Schedule 1) under the federal *Species at Risk Act*, 2002 (Parks Canada 2009b). This species is also a "specially protected reptile" under Ontario's *Fish and Wildlife Conservation Act* (January 1999). It is illegal to harm, harass, possess, or kill a Massasauga in Ontario.

The habitat of this species is minimally protected legally in Ontario through the Provincial Policy Statement under the *Planning Act*. Massasaugas and their habitat are protected within the boundaries of two national parks (Georgian Bay Islands and Bruce Peninsula) through the *Canada National Parks Act* (EC 2010). Additional habitat protection may be offered on the eastern Bruce Peninsula through the *Niagara Escarpment Planning and Development Act* (Niagara Escarpment Commission 2011). A draft federal recovery strategy has been developed for this species.

At the international level, as of 1997, a framework exists between the U.S. and Canadian governments to cooperate in identifying and recovering shared species at risk (Framework for Cooperation between the U.S. Department of the Interior and Environment Canada in the Protection and Recovery of Wild Species at Risk). Currently, the Eastern Massasauga is a candidate subspecies for listing under the U.S. *Endangered Species Act* (USFWS 2011, USFWS 1998). If this species becomes listed, coordinated bi-national recovery efforts will likely be triggered (EC and USDI 2001). Massasauga is not listed by the Convention on International Trade in Endangered Species (CITES 2011).

Non-Legal Status and Ranks

Massasauga was designated a 'threatened' species in Canada by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1991 and again in 2002. Massasauga was designated a 'threatened' species by the Committee on the Status of Species at Risk in Ontario (COSSARO) in 1998. Massasauga is listed as 'Least Concern' on the IUCN Red List (Frost *et al.* 2007). Conservation ranks in each range jurisdiction of the species are listed in Table 5. All states with the Eastern Massasauga except Michigan designate it as S1 or S2 in apparent contrast to the IUCN global designation. In summary, nine of the 11 states/provinces that historically supported Massasauga populations have lost more than 50 percent of their historical populations, while the remaining two have lost more than 30 percent of their occurrences (USFWS 1998). In all states, less than 45 percent of their extant populations are considered secure.

Table 5. Conservation Status of the Massasauga (*Sistrurus catenatus*) throughout its North American range (NatureServe 2011). An asterisk (*) indicates jurisdictions for which only the subspecies *S. catenatus catenatus* was ranked.

Rank, *S. catenatus*	**Location (State or Province)**
S1 (Critically Imperiled)	Iowa, Minnesota, Missouri*, Nebraska, New York, Wisconsin, Pennsylvania*
S2 (Imperiled)	Arizona, Colorado , Illinois*, Indiana*, Ohio
S3 (Vulnerable)	Ontario
S3S4	Kansas, Michigan, New Mexico, Texas
S4 (Apparently Secure)	Oklahoma
N3 (Vulnerable)	Canada (last assessed in 2011)
N3N4 (Vulnerable/Apparently Secure)	United States (last assessed in 2010)
G3G4 (Vulnerable)	Globally (last assessed in 2010)

Habitat Protection and Ownership

Great Lakes/St. Lawrence DU

Habitat currently used by Massasaugas is protected within the boundaries of several national parks, provincial parks, provincial nature reserves, and nature reserves owned by environmental non-government organizations (ENGOs, e.g., Ontario Nature and the Nature Conservancy of Canada) (**Appendix 5**). Two extensive regions within the Great Lakes/St. Lawrence DU are designated as world biosphere reserves: the Georgian Bay Littoral Biosphere Reserve (3470 km^2 of shoreline in the eastern Georgian Bay region) and the Niagara Escarpment Biosphere Reserve (a significant portion of which is on the Bruce Peninsula) (UNESCO 2010). Massasaugas also occur on multiple First Nations reserves, vast areas of Crown land and other federal lands (Public Works Canada, Department of Fisheries and Oceans, Department of National

Defence) which may offer some protection due to relatively low levels of development (Appendix 5; AANDC 2010; Rouse pers. comm. 2011; Truscott pers. comm. 2011).

Within the last two decades, numerous new protected areas have been created along the Georgian Bay coast as part of Ontario's Living Legacy program and in the Bruce Peninsula through purchase by environmental non-governmental organizations (Truscott pers. comm. 2011). On the Bruce Peninsula, conservation land ownership in 2011 (federal, provincial and county/municipal-owned) was estimated at 235 km^2, an increase in several square kilometres over the past 3 years (Truscott pers. comm. 2011). In a subset of the eastern Georgian Bay region 2306km^2 (64%) of land was estimated under public ownership (provincial parks, conservation reserves, Crown land and other federal lands: Rouse pers. comm. 2011). In the entire Great Lakes/St. Lawrence DU, at least 2541 km^2 of land is under public or ENGO ownership. This amounts to 25% of the EOO (based on total area) and an area equivalent in size to 1.0 - 1.5 times the area of the current IAO estimate.

On the upper Bruce Peninsula, Miller (2005) estimates that roughly 37% of the Massasauga population resides within protected area boundaries and is therefore protected from the effects of habitat loss from development. Furthermore, additional habitat protection is projected through future purchase of private lands (40 km^2) within the boundaries of the BPNP (Truscott pers. comm. 2011).

Carolinian DU

Massasauga populations in the Carolinian DU are confined to the Wainfleet Bog Provincially Significant Wetland near Port Colborne and the Ojibway Prairie Remnants ANSI and LaSalle Prairie Remnants in the City of Windsor and Town of LaSalle. The Wainfleet Bog (1656 ha) is designated a Class 1 provincially significant wetland and the least disturbed portions (207 ha of the northeastern corner) are designated as an ANSI (Macdonald 1992; Middleton 1993). Currently 68% (1117 ha) of the evaluated bog wetland is in quasi-public ownership: 801 ha are owned by the Niagara Peninsula Conservation Authority and 316 ha are owned by the Ontario Ministry of Natural Resources (Yagi pers. comm. 2012). The majority of land acquisition - 887 ha - occurred between 1994 and 2000 (EC 2005) and no change in the protected area boundary has occurred in the last 10 years (Yagi pers. comm. 2011). It is unknown if the current area of protected land is sufficient to ensure long-term survival of this population. For example, detailed population and radio telemetry studies completed in the last 10 years have demonstrated that this species uses agricultural land outside of the bog during the active season, resulting in human-caused mortalities (Yagi and Tervo 2005).

At Ojibway, ~260 ha of Massasauga habitat is protected within three distinct, fragmented parcels: 1) the Ojibway Prairie Provincial Nature Reserve and adjacent Tallgrass Prairie Heritage Park (81 ha combined), owned by the Ontario Ministry of Natural Resources and the City of Windsor, respectively, 2) the Spring Garden ANSI (~93 ha or 2/3 of the 140ha ANSI purchased), owned by the City of Windsor, and 3) the

LaSalle Woodlot ESA (~89 ha), owned by the Town of LaSalle (Pratt *et al*. 1993; Windsor Star 2004). As of 2011, the Spring Garden ANSI, and the LaSalle Woodlot ESA are not entirely under public ownership (Pratt pers. comm. 2011; ERCA 2011) but are offered additional protection through land use planning regulations (City of Windsor 2007; Burgess pers. comm. 2011). It is unknown if the current area of protected land is sufficient to ensure long-term survival of this population, especially considering its fragmented state. For example, suitable habitat with historical and recent sightings remains outside of protected area boundaries (Town of LaSalle 2003; Pither 2003; Choquette pers. obs. 2011). Within the next 10 years the City of Windsor has plans to purchase additional lands (Pratt pers. comm. 2011).

It is important to note that protected areas alone cannot ensure the persistence of the species that reside within. Internal threats, including road mortality, may still contribute to population declines and extirpations. For example, a recent study found that two Species at Risk turtles are likely extirpated from Point Pelee National Park (Browne and Hecnar 2002).

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Jonathan Choquette graduated with a B.Sc. in Biology (2007) and a Masters in Landscape Architecture (2011) both from the University of Guelph. His MLA thesis was focused on identifying habitat corridors for Massasaugas in a fragmented landscape and he has assisted with surveys for this species across Ontario. Jonathan co-authored the COSEWIC Status Report Update on the Butler’s Gartersnake in 2009 and is authoring the Status Report Update on the Milksnake. His interests include urban herpetology, landscape ecology and conservation biology. His overarching goal is to combine his training in landscape architecture and biology to design landscapes where our herpetofauna populations are restored and reconnected. First stop: Ojibway Massasauga.

Thomas Preney graduated from Sir Sanford Fleming with a Fish and Wildlife Technician diploma (2005). Since 2001 he has conducted radio telemetry, mark-recapture, and standardized surveys on the Windsor/LaSalle population of Massasauga and Eastern Foxsnake with the Ojibway Nature Centre in Windsor, Ontario. In 2006, he was part of a repatriation attempt of the Massasauga in the Ojibway Prairie Provincial Nature Reserve. Thomas has been an advisor for the Eastern Massasauga Recovery Team since 2004. He also conducts Massasauga outreach and education programs for the City of Windsor and Town of LaSalle where he has developed numerous resources and presentations. Thomas works as a Naturalist at Ojibway Nature Centre where he is very passionate about educating people to conserve Ontario’s biodiversity.

Appendix 1. Table of distinct Massasauga "locations" in Canada.

The majority of "locations" are based on 'element occurrences' as identified by the Ontario Ministry of Natural Resources Natural Heritage Information Centre. Additional "locations" were identified by the authors of this status report update on the basis of new occurrence records from outside of previously identified "locations". All "locations" are identified on the basis of one of more observations of this species separated from other occurrence records by a biologically relevant separation distance. A separation distance of 5 km is used to define unique "locations" for the Massasauga (NatureServe 2011). This distance is roughly three times the maximum diameter of an elongate 40-ha activity range and is greater than the maximum known migration distance (NatureServe 2011). Occurrence records (or clusters of occurrence records) geographically separated from other occurrences by a distance greater than the 5 km threshold are identified as a unique "location". Ranks follow NatureServe definitions (Hammerson *et al.* 2008): A = Excellent viability, B = Good Viability, C = Fair Viability, E = Verified extant, H = Historical, X = Extirpated. All ranks were assigned by the NHIC, except where otherwise noted.

In general, each "location" can be considered synonymous with a population or a cluster of subpopulations. COSEWIC defines a population as "…the individuals of a species or subspecies that interact with each other and are potentially interbreeding". Tabulation and evaluation of "locations" is a valuable means to assist in the assessment of extent of occurrence, area of occupancy and trends in these values over time. Caution must be exercised, however, when assessing abundance or trends in the number of populations from the "location" data. Each "location" may differ greatly in geographic extent and/or in the number of distinct Massasauga occurrences for which it represents. For example, one "location" might be represented by a single occurrence record from a small island while another might be represented by hundreds of records spanning many square kilometres. In addition, the number of "locations" may change over time as they are re-evaluated. For example, one large, single, "location" could be divided into two "locations" after a review indicates extensive habitat fragmentation has separated occurrences beyond the separation threshold. Furthermore, two "locations" could be merged into a single, geographically larger, "location" after increased search effort identifies multiple occurrences of the species in the landscape in between. This becomes particularly problematic where habitat is widespread and search effort is minimal (e.g., GLSL DU). See Appendix 3 for a map of counties/districts.

#	"Location" Name	County/District	Year of Last Observation	Rank	Notes	Source
CAROLINIAN DU						
1	Dunwich Marsh	Elgin	1930	X		NHIC
2	Dexter Area	Elgin	1930	X		NHIC
3	Aylmer	Elgin	1962	X		NHIC
4	Amherstburg - Canard Valley	Essex	1814	X	There is a 1988 Massasauga record from the Canard Valley in the NHIC which is also listed in the NHIC Milksnake database. It is assumed this was originally entered as a Massasauga and then decided it was an erroneous report and most likely a Milksnake (and forgotten to be removed from the Massasauga database).	NHIC
5	Harrow Area	Essex	1960	X		NHIC
6	Kingsville Area	Essex	pre-1930	X		NHIC
7	Point Pelee	Essex	1893	X		NHIC
8	Ojibway Prairie and Vicinity	Essex	2011	C	Update of last observed date (1994)	Pratt *et al.* 1993; J. Choquette pers. obs. 2011; NHIC; ONC; ROM;
9	Tilbury	Essex/Kent	pre- 1881	X		NHIC
11	Simcoe Area	Haldimond-Norfolk	pre-1969	X		NHIC
12	Hamilton	Hamilton	1950	X	Not assessed by NHIC but status assumed to be 'X' due to limited habitat and lack of sightings in this heavily populated area (Appendix 2)	Weller and Parsons 1991; Weller and Oldham 1993; Lamond 1994; Oldham *et al*. 1999; USFWS 1998; ORAA
13	Sarnia Area	Lambton	1962	X		NHIC
14	Mount Brydges Area	Middlesex	1895	X		NHIC
15	Glencoe	Middlesex	1851	X		Weller and Parsons 1991; NHIC
16	Skunk's Misery	Middlesex	1965	H		NHIC
17	Wainfleet Bog	Niagara	2011	C	Update of last observed date (2000)	J. Choquette pers. obs. 2011; NHIC; ROM; CMN;
18	Tillsonburg	Oxford	1962	X		NHIC

#	"Location" Name	County/District	Year of Last Observation	Rank	Notes	Source
GREAT LAKES/ST. LAWRENCE DU						
1	Oliphant	Bruce	2009	E	Update of last observed date (1986). Status updated from 'H' to 'E' (Appendix 2)	Jones 2009; NHIC; NHIC unprocessed observations
2	Lyal Island	Bruce	2008	E		NHIC
3	Cove Island	Bruce	2006	B	Update of last observed date (1996)	Tonge 2006; NHIC
4	Upper Bruce Peninsula	Bruce	2009	A	Update of last observed date (2008)	NHIC; NHIC unprocessed observations
5	Mar Area	Bruce	1983	H		NHIC
6	Lions Head	Bruce	2009	E	Update of last observed date (1984). Status updated from 'H' to 'E' (Appendix 2)	NHIC; NHIC unprocessed observations
7	Cape Croker Ir #27	Bruce	1984	H		NHIC
8	Sauble Beach	Bruce	pre-1962	X	But see Appendix 2	NHIC
9	Gould Lake	Bruce	1962	H		NHIC
10	Chesley	Bruce/Grey	1962	X		NHIC
11	Clavering	Bruce/Grey	1981	H		NHIC
12	Shelburne Area	Dufferin	1962	X		NHIC
13	Mulmer Mills Area	Dufferin	1963	X		NHIC
14	Mud Lake	Grey	2003	E		NHIC
15	Charles Lake	Grey	1980	H		NHIC
16	Big Bay	Grey	1977	H		NHIC
17	Meaford Area	Grey	1975	X	But see Appendix 2	NHIC
18	Lowbanks	Haliburton	Pre -1955	X		NHIC
19	Manitoulin Island - Sucker Creek	Manitoulin	1985	H		NHIC
20	Manitoulin Island - Pool Lake	Manitoulin	2002	E		NHIC
21	Fitzwilliam Island - Rattlesnake Harbour	Manitoulin	2008	E	Update of last observed date (1984). Status updated from 'H' to 'E' (Appendix 2)	J. Jones pers. comm. 2011; NHIC
22	Lonely Island	Manitoulin	2006	E	New location, not in NHIC (Appendix 2)	F. Burrows pers. comm. 2011; J. Jones pers. comm. 2011
23	Griffith Island	Manitoulin	1968	H		NHIC
24	Club Island	Manitoulin	1963	H		NHIC
25	Fitzwilliam Island - South end	Manitoulin	2008	C		NHIC

#	"Location" Name	County/District	Year of Last Observation	Rank	Notes	Source
26	Vidal Island	Manitoulin	2002	E		J. Jones pers. comm. 2011; NHIC
27	Beausoleil Island, GBINP	Muskoka	2009	E	Update of last observed date (2007)	NHIC; NHIC unprocessed observations
28	Go Home Lake/McCrae Lake Area	Muskoka	2008	E		NHIC
29	Walker's Bay (Lake Muskoka)	Muskoka	1984	H		NHIC
30	Muskoka Falls	Muskoka	1979	H		NHIC
31	Six Mile Lake to Morriston Lake Area (within Trent-Severn Waterway)	Muskoka/Simcoe	2009	E		NHIC
32	12 Mile Bay to Oastler Lake PP	Parry Sound/ Muskoka/	2009	E	Update of last observed date (2004).	NHIC; NHIC unprocessed observations
33	Magnetawan River - HWY 520	Parry Sound	2002	E		NHIC
34	Magnetawan River Area	Parry Sound	2005	E	Update of last observed date (1987). Status updated from 'H' to 'E' (Appendix 2).	NHIC; NHIC unprocessed observations
35	Little Whitefish Lake	Parry Sound	1984	E		NHIC
36	Parry Island - N Side	Parry Sound	1983	H		NHIC
37	Ardbeg/Wahwashkeh Area	Parry Sound	2003	E		NHIC
38	Killbear Provincial Park and Area	Parry Sound	2009	A		NHIC
39	Hurdville Area	Parry Sound	1984	H		NHIC
40	Shawanaga Area	Parry Sound	2008	E	Update of last observed date (2007)	NHIC; NHIC unprocessed observations
41	Restoule Lake	Parry Sound	2006	E	Update of last observed date (1978). Status updated from 'H' to 'E' (Appendix 2)	D. Noble pers. comm. 2011; NHIC
42	French River to Grundy Lake	Parry Sound/ Manitoulin	2005	C	Update of last observed date (pre-2004)	NHIC; NHIC unprocessed observations
43	Coldwater/Carley	Simcoe	1983	H	But see Appendix 2	NHIC
44	Sawlog Point	Simcoe	2001	E		NHIC
45	Collingwood	Simcoe	1994	E		NHIC
46	Giants Tomb Island	Simcoe	2002	E		NHIC

#	"Location" Name	County/District	Year of Last Observation	Rank	Notes	Source
47	Balm Beach Area	Simcoe	1967	X		NHIC
48	Angus Area	Simcoe	1963	X		NHIC
49	Pretty River	Simcoe	1994	C		NHIC
50	Coldwater Area	Simcoe	1971	H		NHIC
51	Midland Area	Simcoe	1969	X	But see Appendix 2	NHIC
52	Long Lake	Sudbury (Greater)	2009	E	Update of last observed date (1987). Status updated from 'H' to 'E'. (Appendix 2)	D. Jacobs pers. comm. 2011; E. Cobb pers. comm. 2012; NHIC
53	McVitties Area	Sudbury	2003	E	Update of last observed date (pre-2003)	D. Jacobs pers. comm. 2011; NHIC
54	Alban Area	Sudbury	1985	H		NHIC
55	Millerd Lake	Sudbury	1985	H		NHIC
56	Crooked Lake	Sudbury	2008	E	New location, not in NHIC (Appendix 2)	E. Cobb pers. comm. 2012
57	Beaverstone Bay	Sudbury	2005	E	Update of last observed date (1984). Status updated from 'H' to 'E' (Appendix 2)	NHIC; NHIC unprocessed observations
58	Key Harbour and Area	Sudbury	2004	E		NHIC
59	George Island	Sudbury	1972	H		NHIC
60	KILLARNEY PP	Sudbury	2003	E		NHIC
61	Killarny PP - west side	Sudbury	2003	E		NHIC
62	Killarny PP - Little Mountain Lake	Sudbury	2001	E		NHIC
63	Killarny PP - Johnnie Lake	Sudbury	2002	E		NHIC
64	French River Delta	Sudbury	2003	E		NHIC
65	Jacksons Point	York	1962	X		NHIC

Appendix 2. Detailed explanations for accepting or rejecting historical and contemporary Massasauga "locations". Only accepted "locations" are included in the extent of occurrence and index area of occupancy calculations.

Carolinian DU

- Paris, Brant County: An historical record from Paris, Ontario was rejected as it was considered of 'uncertain validity' by Oldham *et al*. (1999) despite being included on the ORAA distribution map and in the NHIC.
- Pelee Island, Essex County: Although some investigators suggested that the Massasauga was present historically on the island (Campbell 1971, 1976, as cited by King *et al.* 1997; Kamstra *et al.* 1995), King *et al.* (1997) add that no records were based on specimens or direct observations and that Massasaugas have not been reported from other Lake Erie islands. As a result, Pelee Island was not accepted as a historical location.
- Hamilton, Regional Municipality of Hamilton-Wentworth: This historical location was accepted as it was identified by a number of sources (see Appendix 1) despite being absent from the NHIC database.
- Walpole Island, Lambton County: Massasaugas are considered extirpated from Walpole Island by Bowles (2005) and J. Hathaway (pers. comm. 2011). Nonetheless, this location was not mentioned in a review by Weller and Oldham (1992) or Oldham *et al*. (1999) and is absent from the NHIC database, as a result it was not accepted.

Great Lakes/St. Lawrence DU

- Blind River, Algoma District: A Massasauga was confirmed in 2012 by an MNR Biologist and conservation officer near the Mississagi River Delta at Blind River (J. Trottier pers. comm. 2012). This occurrence is ~ 120 km west of locations in the Greater Sudbury Area and ~25 km north of the Vidal Island location. The ORAA map indicates an historical record of Massasauga exists for the same atlas square (a record was submitted in 2010 of multiple Massasaugas being observed in that area in the 1970s). The 2012 Blind River observation also led to several unconfirmed reports of Massasaugas at various locations along the north channel of Lake Huron. This location was not included in the calculation of IAO or EOO nor was it included in any discussion of locations or population size as it was received after the calculations had been completed.
- Lion's Head, Bruce County: This location was confirmed as extant based on the observation of a Massasauga in 2009 by a reliable source (John Urquhart). The record was submitted to the NHIC.
- Lucknow, Bruce County: A historical record from the Lucknow area was rejected due to its absence in the NHIC, its being considered of 'uncertain validity' in a review by Oldham *et al*. (1999) (and see Weller and Parsons 1991), despite its presence on the ORAA map.

- Oliphant, Bruce County: This location was confirmed as extant based on the observation of a Massasauga in 2009 by a reliable source (Jones 2009). Records were submitted to the NHIC.
- Sauble Beach/Chief's Point, Bruce County: An MNR biologist commented on the draft of this report indicating that a Massasauga was confirmed by MNR staff in Sauble Beach in the summer of 2011 (S. Robinson pers. comm. 2012). The biologist added that regular reports of Massasaugas are submitted for the north end of Sauble Beach (area adjacent to Chief's Point). Due to the late acquisition of this record in the status report update process, after data analysis and calculations, this location was left as 'Extirpated' in Appendix 1.
- Long Lake, Greater Sudbury District: This historical location was confirmed extant on the basis of 3 recent records in the vicinity of Long Lake (All were along Tilton Lake Road). The first was a specimen found DOR in 2008 and held by MNR staff and the second was observed prior to the first on an adjacent property by a conservation officer (D. Jacobs pers. comm. 2012). A third specimen was found DOR in 2009 and confirmed with photographs (J. Choquette pers. obs.) on the same road and just over 5 km east of the first 2 records (coordinate accuracy is unknown, E. Cobb pers. comm. 2012). The historical record is ~6km east of the 2009 record (1km greater than the separation distance used), but due to limited coordinate accuracy and relative proximity of recent and historic records, these were all considered part of the same location.
- Meaford Area, Grey County: An MNR biologist commented on the draft of this report indicating that a Massasauga was confirmed near Meaford in 2006 with a photo and that this record was sent to the Eastern Massasauga Recovery Team via the Midhurst District MNR office in 2006 (S. Robinson pers. comm. 2012). Due to the late acquisition of this record in the status report update process, after data analysis and calculations, this location was left as 'Extirpated' in Appendix 1.
- Fitzwilliam Island – Rattlesnake Harbour, Manitoulin District: This location was updated to 'Extant' based on the 2008-2009 sightings from a reliable source (Judith Jones).
- Beaverstone Bay, Manitoulin District: This location was accepted as 'Extant' based on 3 records from 2005 in the NHIC unprocessed observations database.
- Flowerpot Island, Manitoulin District: Despite 2 confirmed sightings of Massasauga on this island (2001 and 2008), it was rejected as a location on the recommendation of Harvey (2008) who suggested the snakes found there were vagrants and not part of an established population.
- Lonely Island, Manitoulin District: This new location was accepted on the basis of multiple records from 2006 (adults and neonates) by reliable observers (J. Jones pers. comm. 2011 and F. Burrows pers. comm. 2011).

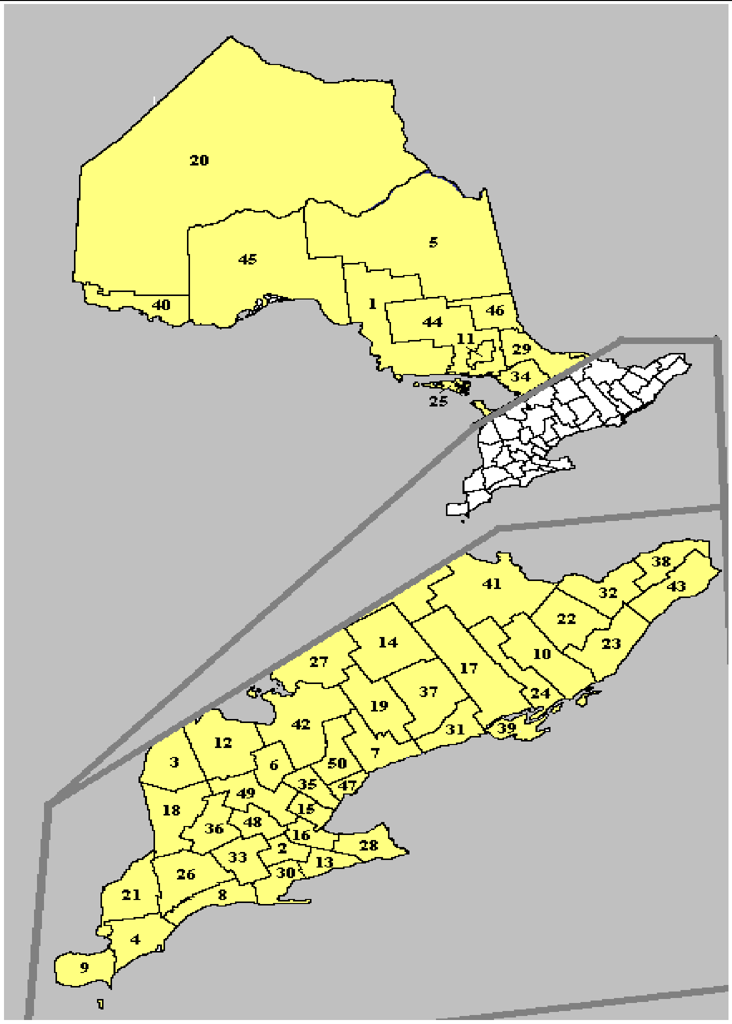
- Manitoulin Island – Wikwemikong, Manitoulin District: A 2006 sighting from a reliable source (Judith Jones pers. comm. 2011) in Wikwemikong was not accompanied by detailed location data. It is unknown if this is a separate location or part of the Poole Lake location. As a result the record was rejected until further information can establish whether or not is in a new location.
- Magnetawan River Area, Parry Sound: This location was accepted as 'Extant' based on a 2005 record from the Magnetawan First Nation in the NHIC unprocessed records database.
- Restoule Lake, Parry Sound: A Massasauga was recorded in Restoule Provincial Park in 2006 (D. Noble pers. comm. 2012) and confirmed with photographs (W. Murrant pers. comm. 2012). The record is ~ 7km from the historical record in the area, but due to low accuracy of the latter, the recent record was assumed to be part of the same location. As a result the location was accepted as 'Extant'.
- Coldwater/Carley, Simcoe County: An MNR biologist (name unknown) commented on the draft of this report indicating that Massasaugas were confirmed in Severn Township and last observed by MNR staff in 2008. The biologist indicated additional recent records from non-MNR have also been reported. These sightings may be from the Coldwater/Carley location, but due to a lack of detailed information, these locations remains 'Historical' until further confirmation.
- Midland Area, Simcoe County: An MNR biologist commented on the draft of this report indicating that a confirmed sighting of a Massasauga with a photo had been observed at Midland Point (Little Sandy Bay Lane) in August 2011 in addition to other recent observations in the area (J. Benvenuti pers. comm. 2012). Due to the late acquisition of this record in the status report update process, after data analysis and calculations, this location was left as 'Extirpated' in Appendix 1.
- Crooked Lake, Sudbury District: This location is accepted based upon two confirmed sightings from 2007 and 2008 (E. Cobb pers. comm. 2012). This location is ~7km distant from the closest records from the 'Alban Area' Location.
- Trout Lake - Cherriman Twp., Sudbury District: Preliminary NRVIS data (J. Truscott pers. comm. 2011) indicate a record for the area which would be a new location. Nevertheless, it was not accepted based on a lack of detailed information.

<u>Other unconfirmed records</u>

- Unconfirmed/historical/unverified reports prior to1999 from other locations (e.g., northern shore of Lake Ontario) are discussed and mapped by Weller and Parsons (1991) and Oldham *et al*. (1999) and are maintained in a database at NHIC.

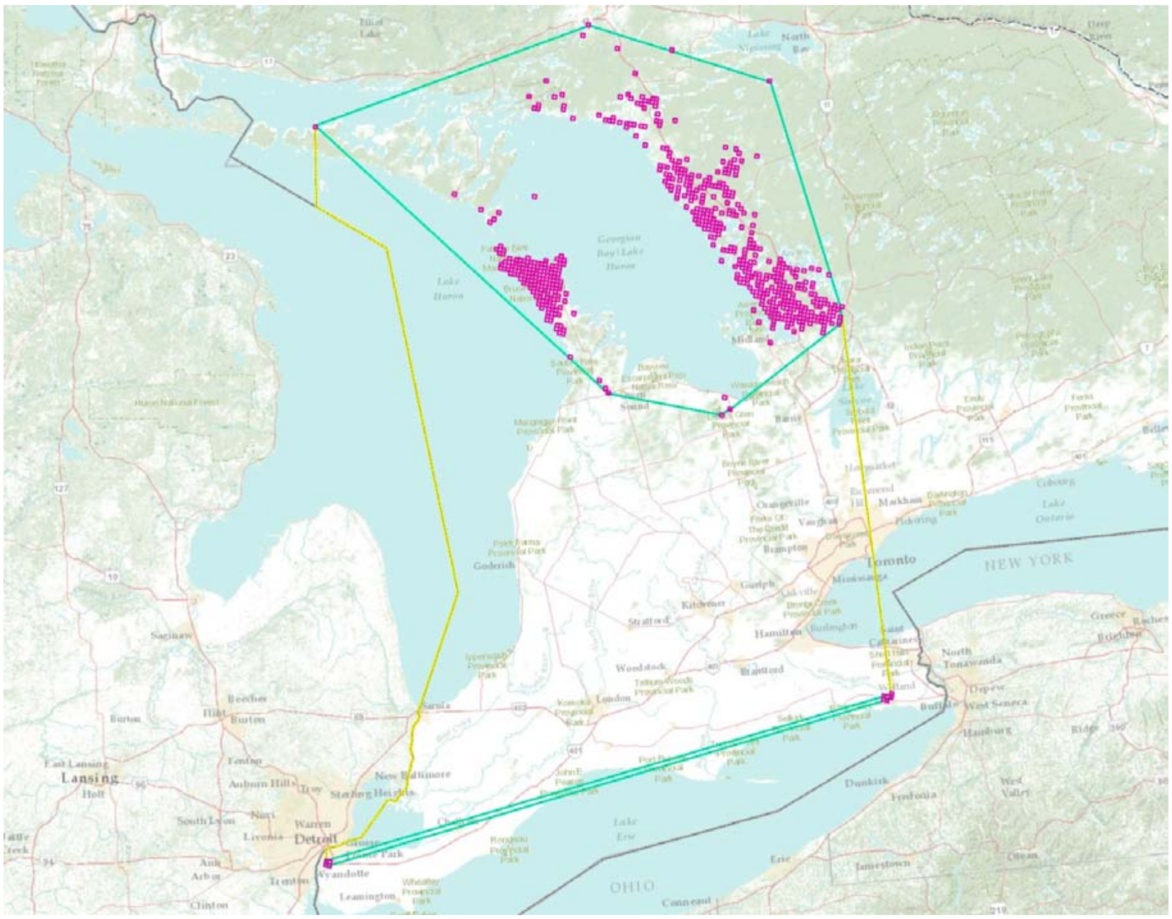
- Kingston, Frontenac County: A Massasauga was reported in 2006 but unconfirmed on a residential property near Kingston (Kingston Whig - Standard. Sep 12, 1996.: *http://www.brocku.ca/massasauga/bibliography/newspaper%20articles/12Sep96.htm, http://www.brocku.ca/massasauga/bibliography/newspaper%20articles/17Sep96.htm)*
- Goderich, Huron County: An adult Massasauga was reported on the Maitland Trail in 2007 by an animal control officer. (The Goderich Signal Star. 2007. “Animal control officer reports rattlesnake was sighted in Goderich”. Web Site: *http://www.goderichsignalstar.com/ArticleDisplay.aspx?archive=true&e=1939739)*
- Wiarton, Bruce County: Massasauga was unconfirmed on a residential property in the town in 2009. (Wiarton Echo. 2009. “Rattlesnake spotted in town”. *http://www.wiartonecho.com/ArticleDisplay.aspx?e=1553773&archive=true)*

Appendix 3. Map of Ontario counties and districts. To be used as a reference for Appendix 1 (from Wikipedia 2011).



1. Algoma	14. Haliburton	26. Middlesex	39. Prince Edward
2. Brant	15. Halton	27. Muskoka	40. Rainy River
3. Bruce	16. Hamilton	28. Niagara	41. Renfrew
4. Chatham-Kent	17. Hastings	29. Nipissing	42. Simcoe
5. Cochrane	18. Huron	30. Norfolk	43. Stormont, Dundas and Glengarry
6. Dufferin	19. Kawartha Lakes	31. Northumberland	44. Sudbury
7. Durham	20. Kenora	32. Ottawa	45. Thunder Bay
8. Elgin	21. Lambton	33. Oxford	46. Timiskaming
9. Essex	22. Lanark	34. Parry Sound	47. Toronto
10. Frontenac	23. Leeds and Grenville	35. Peel	48. Waterloo
11. Greater Sudbury	24. Lennox and Addington	36. Perth	49. Wellington
12. Grey	25. Manitoulin	37. Peterborough	50. York
13. Haldimand		38. Prescott and Russell	

Appendix 4. Map showing grid squares (in pink) and polygons (yellow and teal) used to calculate the IAO and the EOO, respectively, of the Massasauga in Canada. The yellow polygon represents the entire Canadian EOO of this species, while the upper teal polygon represents the GLSL DU and the lower teal polygon represents the Carolinian DU.

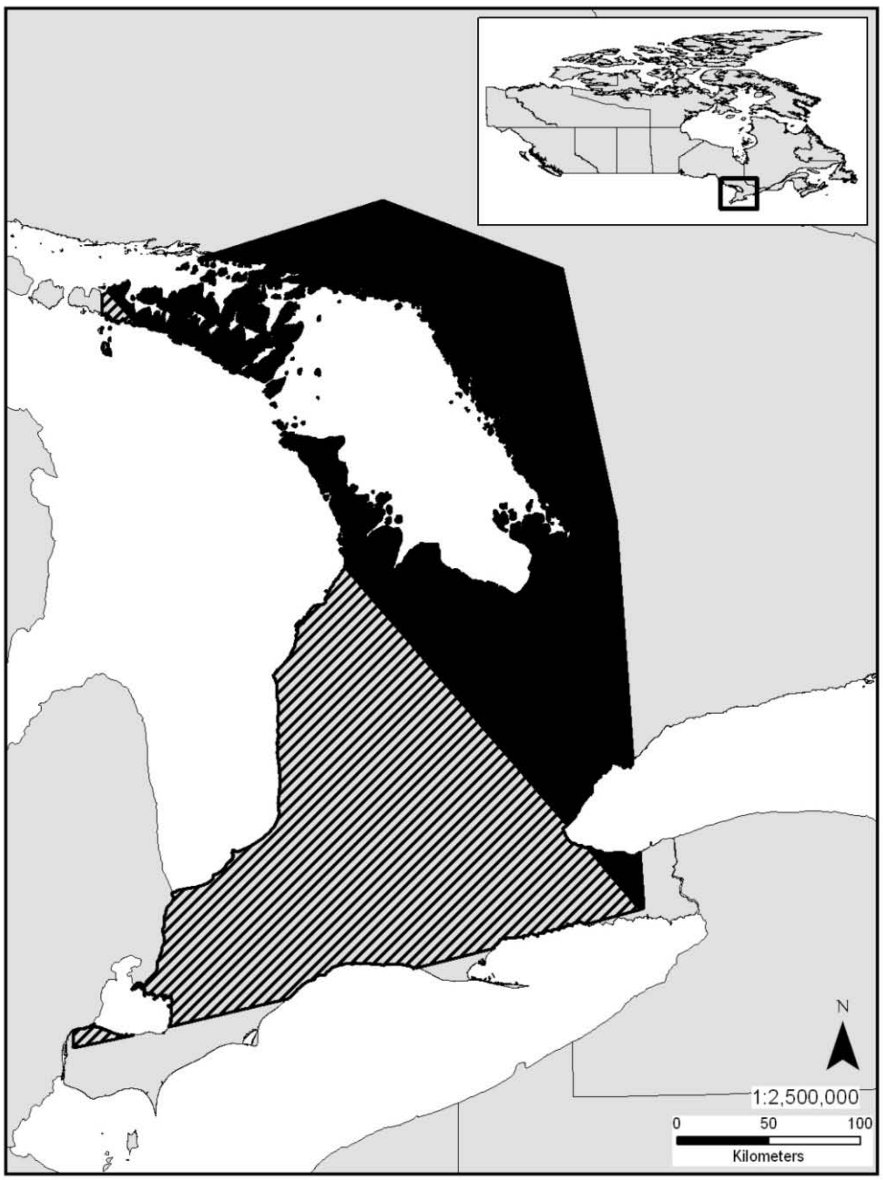


Appendix 5. Federal lands, protected areas and First Nations in the Great Lakes/St. Lawrence designatable unit with suspected or confirmed presence of Massasauga.

Federal lands, protected area or First Nation	Size (ha)	Massasauga Present	Source
Bruce Peninsula National Park	12200	YES	Parks Canada 2009c; Natural Resources Canada 2009; M. Patrikeev pers. comm. 2012
Fathom Five National Marine Park	2560	YES	Parks Canada 2009c; Natural Resources Canada 2009; P. Nantel pers. comm. 2012
Georgian Bay Islands National Park		YES	
Trent-Severn Waterway National Historical Site	1567	YES	Parks Canada 2009c; J. Rouse pers. comm. 2011
Awenda Provincial Park	2915	?	Ontario Parks 2006
Killarney Provincial Park	49 325	YES	Weller and Oldham 1993; Ontario Parks 2006; NHIC
Grundy Lake Provincial Park	2554	?	Weller and Oldham 1993; Ontario Parks 2006
Killbear Provincial Park	1133	YES	Weller and Oldham 1993; Rouse 2005; NHIC
Restoule Provincial Park	2800	YES	Ontario Parks 2006; Darin Noble pers. comm. 2011; NHIC
French River Provincial Park	73 530	YES	Ontario Parks 2006; D. Jacobs pers. comm. 2011
Oastler Lake Provincial Park	32	YES	Ontario Parks 2006; NHIC
Six Mile Lake Provincial Park	94	?	Weller and Oldham 1993; Ontario Parks 2006
The Massasauga Provincial Park	13 105	YES	Weller and Oldham 1993; Ontario Parks 2006
Gibson River Provincial Nature Reserve	168	?	Weller and Oldham 1993; Ontario Parks 2006
Sturgeon Bay Provincial Park	14	?	Ontario Parks 2006
O'Donnel Point Provincial Nature Reserve	875	YES	Ontario Parks 2006; OMNR 2007
Cognashene Point Conservation Reserve	42	?	OMNR 2001
Beaton Nature Reserve (NCC)	23	YES	J. McCarter pers. comm. 2011
Davis Nature Reserve (NCC)	40	YES	J. McCarter pers. comm. 2011
Gunn Nature Reserve (NCC)	8.78	?	J. McCarter pers. comm. 2011
Rovers Nature Reserve (NCC)	366	?	J. McCarter pers. comm. 2011
H.N. Crossley, Bruce Peninsula (Ontario Nature)	17	?	Ontario Nature 2011a
Quarry Bay Nature Reserve, Manitoulin Island (Ontario Nature, NCC, Ontario Parks)	391	?	Ontario Nature 2011a
Bruce Alvar, Bruce Peninsula (Ontario Nature)	67	YES	Ontario Nature 2011a
Lyle Island, Bruce Peninsula (Ontario Nature)	305	YES	Ontario Nature 2011a; J. Crowley pers. comm. 2011
Saugeen Ojibway First Nation	Unk	YES	NHIC
Shawanaga First Nation	Unk	YES	NHIC
Magnetawan First Nation	Unk	YES	NHIC
Dokis First Nation	Unk	YES	NHIC

Federal lands, protected area or First Nation	Size (ha)	Massasauga Present	Source
Whitefish River/Point Grondin First Nation/Wikwemikong (Mainland)	Unk	YES	D. Jacobs pers. comm. 2011; NHIC
Chippewas of Nawash Unceeded First Nation (Cape Croker Indian Reserve no. 27)	6 381	YES	NHIC; CNUFN 2011
M'Nidoo M'nissing First Nation (Vidal Island)	Unk	YES	J. Jones pers. comm. 2011
Wikwemikong Unceeded First Nation (Manitoulin Island)	Unk	YES	J. Jones pers. comm. 2011

Appendix 6. Projected decline in the Canadian extent of occurrence of the Massasauga resulting from the extinction of the Ojibway Population (see Population Sizes and Trends). The Canadian EOO was estimated at 61 694 km^2 (solid and hatched area combined, not including large bodies of water) whereas the Canadian EOO minus the Ojibway population is estimated at 31 920 km^2 (solid area only). As a result, the Canadian EOO is projected to decline by ~30000 km^2, or 50% (Choquette unpub. data).



Appendix 7. Estimation of Massasauga abundance for 32 extant "locations" in the Great Lakes/St. Lawrence DU which are lacking detailed abundance data.

Crude estimates were obtained in three ways, two of which were used to develop the final estimate (see Abundance):

1) Simplified Method: The remaining number of extant "locations" (32) x 50 adults per "location" (NatureServe 2011) = 1600 mature individuals. Applying the NatureServe (2011) criteria evenly across the GL/SL DU is most probably inappropriate and gives a significant underestimate as it was likely developed to reflect the small size of most subpopulations across the species' North American range. As a result, this estimate will not be used.

2) Large vs. Small "Locations" Method: The preceding method ignores the relative large expanse of a few "locations" and the following method attempts to reflect this difference:

   a. Geographically large "locations": Following recent genetic work by Dileo and Lougheed (2011, **Population Spatial Structure and Variability)**, two distinct genetic subpopulations were identified on a broad scale 1: Parry Sound District (Parry Sound north to Byng Inlet) and 2: Muskoka District (Parry Sound south to Big Chute). These genetic subpopulations, when compared to a GIS map of "locations", each correspond geographically to three large "locations": Parry Sound District ("locations" # 34, 37 and 40), and Muskoka District ("locations" # 28, 31, and 32). When a polygon is drawn to include all three "locations" in each of the Parry Sound and Muskoka genetic subpopulations, each produces an area of ~ 1700 km^2. This is ~ 2.8 times larger in area than a polygon drawn around the upper Bruce Peninsula "locations" (~600 km^2: GL/SL "locations" # 2, 3 and 4). Assuming a similar population density to the upper Bruce Peninsula (abundance = 2500 [1600-3200]), and using a multiplier of 2.8, each genetic subpopulation has an abundance of 7000 (4480 - 8960) mature individuals. The combined abundance of both genetic subpopulations is therefore 14 000 (8960 – 17 920) adults.
   b. Geographically small "locations": Assuming the NatureServe (2011) estimate of 50 adults per "location" is valid for the remaining 26 geographically small "locations" in this DU, an estimated 1300 mature individuals are present across these "locations" (26 x 50 adults).
   c. When a. and b. are added, this method produces an estimate of 15300 (10 260 – 19 220) mature individuals..

3) IAO Method:

   a. Multiplying the IAO of the GLSL DU (2316 km2/231600 ha) by the density of snakes estimated in the upper Bruce Peninsula (0.5 -2.0 snakes per hectare) = 115 800 – 463 200 snakes.
   b. Multiplying the result (115 800 – 463 200 snakes) by 40% to reflect the number of mature individuals = 46 320 - 185 280 adults
   c. Dividing the result (46 320 - 185 280 adults) by a correction factor (10*) to reflect the appropriate order of magnitude = 11 580 (4 632 – 18 528) mature individuals

*The correction factor was determined by conducting a similar calculation for the upper Bruce Peninsula alone and 'calibrating' the result so that it was within the same order of magnitude as the known abundance estimate of 2500 (1600-3200) adults:

   a. ~140 grid squares x 4 km^2/square = 560 km^2/56 000 ha
   b. 56 000 ha x 0.5-2.0 snakes/ha = 28000 – 112000 snakes
   c. 28000 – 112000 snakes x 40% mature = 28000 (11200 – 44800) adults
   d. 28000 (11200 – 44800) adults /10 = 2800 (1120 – 4480) adults