COSEWIC
Assessment and Status Report

on the

Eastern Foxsnake
Pantherophis vulpinus

Carolinian population
Great Lakes / St. Lawrence population

in Canada

THREATENED
2021

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. 2008. COSEWIC assessment and update status report on the Eastern Foxsnake *Elaphe gloydi*, Carolinian population and Great Lakes / St. Lawrence population, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 45 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html).

COSEWIC. 2000. COSEWIC assessment and update status report on the Eastern Foxsnake *Elaphe gloydi* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 31 pp.

Willson, R.J., and K.A. Prior. 1999. COSEWIC status report on Eastern Foxsnake *Elaphe gloydi* in Canada, *in* COSEWIC assessment and status report on the Eastern Foxsnake *Elaphe gloydi* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-31 pp.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la Couleuvre fauve de l'Est (*Pantherophis vulpinus*), population carolinienne et population des Grands Lacs et du Saint-Laurent, au Canada.

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Adult Eastern Foxsnake (*Pantherophis vulpinus*) from Essex County, Ontario. Photo by R. Jones (used with permission).

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COSEWIC
Assessment Summary

Assessment Summary – November 2021

Common name
Eastern Foxsnake - Carolinian population

Scientific name
Pantherophis vulpinus

Status
Threatened

Reason for designation
This large, non-venomous snake is confined to a few small disjunct areas of southwestern Ontario within a landscape subjected to intensive agriculture and urbanization and crisscrossed by a network of roads. New information since the last assessment includes better understanding of population genetic structure, abundance, and habitat use, and clarification of threats. Aggregation of snakes at hibernation sites increases their vulnerability to natural catastrophes and human disturbance. Long seasonal migrations to and from these sites place them at particular risk from road mortality. The number of mature individuals is expected to continue to decline as a result of road mortality and other threats, including storms and flooding associated with climate change. A better understanding of the snake's distribution and re-evaluation of the degree of population fragmentation contributed to the change in status from Endangered to Threatened.

Occurrence
Ontario

Status history
The species was considered a single unit and designated Threatened in April 1999 and May 2000. Split into two populations in April 2008. The Carolinian population was designated Endangered in April 2008. Status re-examined and designated Threatened in December 2021.

Assessment Summary – November 2021

Common name
Eastern Foxsnake - Great Lakes / St. Lawrence population

Scientific name
Pantherophis vulpinus

Status
Threatened

Reason for designation
This large, non-venomous snake is restricted to the eastern shoreline of Georgian Bay, where it reaches the northern limits of its distribution. Population size is small, most likely less than 2000 mature individuals, but further sampling of historical sites is required. Large aggregations of snakes at hibernation sites increase their vulnerability to natural catastrophes and human disturbance. Long seasonal migrations to and from these sites place them at particular risk from road mortality. A better understanding of the snake's distribution and re-evaluation of the degree of population fragmentation contributed to the change in status from Endangered to Threatened.

Occurrence
Ontario

Status history
The species was considered a single unit and designated Threatened in April 1999 and May 2000. Split into two populations in April 2008. The Great Lakes / St. Lawrence population was designated Endangered in April 2008. Status re-examined and designated Threatened in December 2021.

COSEWIC
Executive Summary

Eastern Foxsnake
Pantherophis vulpinus

Population carolinienne
Population des Grands Lacs et du Saint-Laurent

Wildlife Species Description and Significance

Eastern Foxsnake (*Pantherophis vulpinus*) is a North American ratsnake and one of the largest snakes in Canada. Adults are patterned with dark blotches on a yellowish background with alternating smaller dark blotches on the sides. This snake is an important predator of rodents and poses no threat to humans, yet it is often killed out of fear or hatred.

Distribution

Globally, Eastern Foxsnake is limited to the Great Lakes region of North America. In Canada, this species is restricted to Ontario and occurs as two distinct populations: the Carolinian population in southwestern Ontario and the Great Lakes / St. Lawrence population along the eastern shoreline of Georgian Bay. Although the major disjunctions in the Canadian range pre-date European settlement, historical and ongoing habitat loss have further fragmented the Carolinian population. The known range of Eastern Foxsnake in Canada has increased since the previous status assessment due to increased search effort; similarly, the known number of hibernation sites in the Georgian Bay region has increased. Hibernation sites have been lost, however, in the Carolinian region.

Habitat

Eastern Foxsnakes spend most of the active season in open habitats, including wetlands and rocky shorelines. This species requires suitable hibernation sites and egg-laying sites, many of which are used by dozens of snakes year after year. Large-scale habitat loss has occurred within the ranges of both Canadian populations, but disproportionately in the Carolinian region due to historical and ongoing conversion of wetlands and other natural areas to urban and agricultural uses.

Biology

Eastern Foxsnakes mature in about 4 years and may live 11–12 years. The generation time is estimated at 7.5 years. The snakes spend half of the year active above ground and the remainder below ground in hibernation sites. The snakes can swim for kilometres along shorelines and across open water to access island habitat, but expanses of intensive agriculture are a barrier to movement. Foxsnakes are adept at using some human-made structures to meet their needs.

Population Sizes and Trends

The Carolinian population includes about 4,150–7,230 and the Great Lakes / St. Lawrence population about 1,180–2,190 mature individuals. Human-caused threats are contributing to a continuing decline in abundance of this species in both populations.

Threats and Limiting Factors

Foxsnakes have been most severely impacted by the historical loss of wetland habitat in the Carolinian region, resulting from intensive agriculture and, to a lesser extent, from residential, commercial, and highway development. Habitat loss continues to threaten both populations. Road mortality is now the predominant threat to the species, particularly in the Carolinian region, followed by climate change and natural system modifications.

Protection, Status and Ranks

Eastern Foxsnake was previously assessed by COSEWIC as Endangered in both the Carolinian and Great Lakes / St. Lawrence populations. Similarly, it is listed under the federal *Species at Risk Act* as two populations, both Endangered. Provincially, they are listed as Endangered (Carolinian population) and Threatened (Great Lakes / St. Lawrence population) under the Ontario *Endangered Species Act*. This legislation makes it illegal to kill, harm or harass individuals, or damage or destroy their habitat. The majority of parks and protected areas are in the northern portion of the species' Canadian range, leaving the southern population to persist in a few small isolated habitat patches.

TECHNICAL SUMMARY - Carolinian population

Pantherophis Vulpinus

Eastern Foxsnake, Carolinian population

Couleuvre fauve de l'Est - Population carolinienne

Range of occurrence in Canada (province/territory/ocean): Ontario

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2011) is being used)	7.5 yrs.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred and projected decline
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations, whichever is longer up to a maximum of 100 years]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Suspected >30% reduction primarily from road mortality based on population viability modelling on similar species and high road density across the range
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	>30% suspected reduction based on population viability modelling of road mortality impacts on similar species, threats calculator results ("high":10 – 70% decline), and high road density across the range
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any period [10 years, or 3 generations, whichever is longer up to a maximum of 100 years], including both the past and the future.	>30% suspected reduction based on continuing range-wide road mortality
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. No b. Yes c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO) EOO is based on minimum convex polygon within Canada's extent of jurisdiction using current (1999-2018) records	20,165 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value). IAO is based on current (1999-2018) records	1,692 km² based on all records rather than on the smallest area essential to survival (i.e., hibernacula), the locations of which are incompletely known

Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	Unknown, but much greater than 10 based on road mortality as the greatest threat
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes, inferred and projected decline based on climate change vulnerability analysis
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Possibly, projected decline based on climate change vulnerability analysis
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes, inferred decline of at least two subpopulations
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Unknown
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, observed, inferred, and projected decline in area, extent, and quality of habitat
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Total	5,696 (4,147–7,232)

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations whichever is longer up to a maximum of 100 years, or 10% within 100 years]?	Not done

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

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

Was a threats calculator completed for this species? Yes, on 26 May 2020. Overall threat impact "high"

i. Transportation & Service Corridors (medium)
ii. Climate Change & Severe Weather (medium – low)
iii. Natural System Modifications (medium – low)
iv. Biological Resource Use (low)
v. Pollution (low)
vi. Agriculture and Aquaculture (low)

What additional limiting factors are relevant?

i. Large congregations at hibernation sites that place snakes at risk of natural catastrophes and anthropogenic disturbance
ii. Long seasonal migrations that place snakes at risk of road mortality

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Threatened in Michigan, U.S.A.
Is immigration known or possible?	Yes, but limited to the isolated genetic clusters directly adjacent to the U.S.A. border
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Probably not (e.g., Essex and Lambton counties)
Are conditions deteriorating in Canada?[+]	Yes
Are conditions for the source (i.e., outside) population deteriorating?[+]	Unknown
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	No, but possible for subpopulations along the U.S. border
Data Sensitive Species	
Is this a data sensitive species?	No (but considered a "restricted species" by the Ontario NHIC)

Status History

COSEWIC Status History:
The species was considered a single unit and designated Threatened in April 1999 and May 2000. Split into two populations in April 2008. The Carolinian population was designated Endangered in April 2008. Status re-examined and designated Threatened in December 2021.

Status and Reasons for Designation:

Status: Threatened	**Alpha-numeric codes:** A2cd+3cd+4cd

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

Reasons for designation: This large, non-venomous snake is confined to a few small disjunct areas of southwestern Ontario within a landscape subjected to intensive agriculture and urbanization and crisscrossed by a network of roads. New information since the last assessment includes better understanding of population genetic structure, abundance, and habitat use, and clarification of threats. Aggregation of snakes at hibernation sites increases their vulnerability to natural catastrophes and human disturbance. Long seasonal migrations to and from these sites place them at particular risk from road mortality. The number of mature individuals is expected to continue to decline as a result of road mortality and other threats, including storms and flooding associated with climate change. A better understanding of the snake's distribution and re-evaluation of the degree of population fragmentation contributed to the change in status from Endangered to Threatened.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Threatened, A2cd +3cd+4cd. Suspected >30% decline in number of mature individuals over the past three and next three generations (22.5 years) and including a period spanning both past and future, based on c) a decline in extent of occurrence and quality of habitat, and d) actual and potential levels of exploitation (road kill and intentional killing)
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. IAO of 1,692 km^2 is below the threshold for Threatened, but population is not severely fragmented, occurs at >10 locations, and does not experience extreme fluctuations.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Number of mature individuals (4,147–7,232) is below the threshold for Threatened and there is a continuing decline in the number of mature individuals, but at least one subpopulation has more than 1000 mature individuals, no subpopulation has more than 95% of mature individuals, and there are no extreme fluctuations in number of mature individuals.
Criterion D (Very Small or Restricted Population): Not applicable. The population is not very small or restricted.
Criterion E (Quantitative Analysis): Not applicable. Analysis not conducted.

TECHNICAL SUMMARY - Great Lakes / St. Lawrence population

Pantherophis vulpinus

Eastern Foxsnake, Great Lakes / St. Lawrence population

Couleuvre fauve de l'Est - Population des Grands Lacs et du Saint-Laurent

Range of occurrence in Canada (province/territory/ocean): Ontario

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2011) is being used)	7.5 yrs.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred and projected
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations, whichever is longer up to a maximum of 100 years]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Unknown; likely to be towards lower end of threat impact of "high" (10–70% reduction over 3 generations), based on threats calculator results
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any period [10 years, or 3 generations, whichever is longer up to a maximum of 100 years], including both the past and the future.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. No b. Yes c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO) EOO is based on minimum convex polygon within Canada's extent of jurisdiction using current (1999-2018) records and all records (see Distribution)	4,349 - 4,855 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value). IAO is based on current (1999-2018) vs. all records (see Distribution)	684 - 752 km² based on all records rather than on the smallest area essential to survival (i.e., hibernacula), the locations of which are incompletely known

Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	Unknown but much greater than 10
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Unknown; trend confounded by lack of search effort
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Unknown; trend confounded by lack of search effort
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Unknown
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Unknown
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, observed and projected decline in area and quality of habitat
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Poorly known, but unlikely that any will exceed 1000 mature individuals, given the small Canadian population size.	
Total	1,710 (1,180–2,189)

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations whichever is longer up to a maximum of 100 years, or 10% within 100 years]?	Not done

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

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

Was a threats calculator completed for this species? Yes, on 29 May 2020. Overall threat impact "high". i. Transportation & Service Corridors (medium) ii. Climate Change & Severe Weather (medium – low) iii. Residential and Commercial Development (low) iv. Natural System Modifications (low) v. Biological Resource Use (low) What additional limiting factors are relevant? iii. Large congregations at hibernation sites that place snakes at risk of natural catastrophe and anthropogenic disturbance iv. Long seasonal migrations that place snakes at risk of road mortality v. Cold climate limiting range expansion

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Rescue not possible for this DU
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Unknown
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?[+]	Yes
Are conditions for the source (i.e., outside) population deteriorating?[+]	Not applicable
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	No, the population is endemic to Canada

Data Sensitive Species

Is this a data sensitive species?	No (but considered a "restricted species" by the Ontario NHIC)

Status History

COSEWIC Status History: The species was considered a single unit and designated Threatened in April 1999 and May 2000. Split into two populations in April 2008. The Great Lakes / St. Lawrence population was designated Endangered in April 2008. Status re-examined and designated Threatened in December 2021.

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

Status and Reasons for Designation:

Status: Threatened	**Alpha-numeric codes:** C2a(i)
Reasons for designation: This large, non-venomous snake is restricted to the eastern shoreline of Georgian Bay, where it reaches the northern limits of its distribution. Population size is small, most likely less than 2000 mature individuals, but further sampling of historical sites is required. Large aggregations of snakes at hibernation sites increase their vulnerability to natural catastrophes and human disturbance. Long seasonal migrations to and from these sites place them at particular risk from road mortality. A better understanding of the snake's distribution and re-evaluation of the degree of population fragmentation contributed to the change in status from Endangered to Threatened.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Insufficient data to reliably infer, project, or suspect percentage population decline.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. EOO of 4,349 - 4,855 km^2 is below threshold for Endangered and IAO of 684 - 752 km^2 is below threshold for Threatened, but population is not severely fragmented, occurs at >10 locations, and does not experience extreme fluctuations.
Criterion C (Small and Declining Number of Mature Individuals): Meets Threatened, C2a(i). Number of mature individuals is 1,180–2,189, with fewer than 1000 in any one subpopulation, and there is an inferred and projected continuing decline; a(ii) does not apply because more than one subpopulation is expected due to high fidelity of snakes to specific hibernacula.
Criterion D (Very Small or Restricted Population): Not applicable. The population is not very small or restricted.
Criterion E (Quantitative Analysis): Not applicable. Analysis not conducted.

PREFACE

Since the previous status assessment (COSEWIC 2008), a number of studies have been published on the taxonomy, population genetic structure, and habitat use of Eastern Foxsnake in Canada and the USA. Legal protection in Ontario for the species and its habitat has undergone changes and a recovery strategy for both DUs has been published (EFRT 2010; ECCC 2020). Updates to this report include the classification of threats as per IUCN standards, updated estimates of distribution, population size, and number of locations, inclusion of relevant results from recent scientific studies, such as recent research on population genetics of Eastern Foxsnakes in Ontario, and a more detailed assessment of severe fragmentation.

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
(2021)

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

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

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

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

Environment and Climate Change Canada
Canadian Wildlife Service

Environnement et Changement climatique Canada
Service canadien de la faune

Canada

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

COSEWIC Status Report

on the

Eastern Foxsnake
Pantherophis vulpinus

in Canada

2021

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Eastern Foxsnake (*Pantherophis vulpinus*: Baird and Girard 1853) is classified as a North American ratsnake (Family = Colubridae, Order = Squamata, Class = Reptilia). Other English names that are sometimes used locally for this snake include: hardwood rattler, marsh whomper, and copperhead. The French name is couleuvre fauve de l'Est. The scientific name *vulpina* (= fox) is presumed to have been derived from the type specimen's collector, Rev. Charles Fox (Conant 1940; Rivard 1979; Cook pers. comm. 1998).

The scientific name of Eastern Foxsnake (genus and species) has changed since the previous status report (detailed account provided by Crother *et al.* 2011). COSEWIC previously assessed Eastern Foxsnake as *Elaphe gloydi*. The generic name *Elaphe* is no longer applied to New World ratsnakes (Utiger *et al.* 2002; Crother 2017), which are now represented by the genus *Pantherophis* (Crother *et al.* 2011). Eastern Foxsnake was therefore recognized as *P. gloydi* until Crother *et al.* (2011) re-evaluated foxsnake taxonomy using mitochondrial DNA (mtDNA) analysis. The current accepted scientific name for Eastern Foxsnake is *P. vulpinus* (Crother 2017), with *gloydi* now considered a junior synonym of *vulpinus* (Crother *et al.* 2011). Western Foxsnake was previously known as *P. vulpinus* but is now recognized as *P. ramspotti* (Crother 2017).

Morphological Description

Eastern Foxsnakes attain body (snout-vent) lengths of 91–137 cm (record = 179 cm; Conant and Collins 1991). Foxsnakes have weakly keeled scales and a divided anal plate. In older juveniles and adults, head colouration varies from brown to reddish and lacks distinct markings. The dorsum is patterned with dark brown or black blotches on a yellow to tan background that alternate with smaller dark blotches on the sides (see cover photo). The ventral scutes are most often yellow and strongly checkered with black (Conant and Collins 1991). Hypomelanistic and melanistic (black or very dark) individuals have been reported (Kraus and Schuett 1983; Marks pers. comm. 2019). Juveniles have a lighter background colour (often grey or tan), lighter blotches bordered in black, a transverse line anterior to the eyes, and a dark line extending from each eye to the back of the jaw (Conant and Collins 1991). Eastern Foxsnakes of all ages can be distinguished from other blotched or banded snakes, including Eastern Massasauga (*Sistrurus catenatus*), Eastern Milksnake (*Lampropeltis triangulum*), Eastern Hog-nosed Snake (*Heterodon platirhinos*), and Common Watersnake (*Nerodia sipedon*), by head morphology, body length and girth, dorsal blotch pattern, and scale morphology (Rowell 2012).

Population Spatial Structure and Variability

Based on analyses of genetic samples, Corey *et al*. (2005) found that the previous species designations *E. gloydi* and *E. vulpinus*, as distinguished by differences in morphology and geography, did not reflect underlying patterns of genetic differentiation. Later, Crother *et al.* (2011) conducted a phylogenetic analysis of Eastern and Western Foxsnakes (n = 33, including six snakes from Ontario) and identified two distinct mtDNA clades (0.9 - 1.0% divergence; 11 haplotypes; cytochrome *b* region): an eastern clade, including most animals east of the Mississippi River and all Canadian snakes, and a western clade including most animals west of the Mississippi River. These clades were determined to better represent the species boundary between Eastern Foxsnakes (now *P. vulpinus*) and Western Foxsnakes (now *P. ramspotti*) (Crother *et al.* 2011; Crother 2017). Row *et al*. (2011), using a larger sample size (n = 113, including 48 snakes from Ontario), also found two mtDNA foxsnake clades (1.5% divergence; 11 haplotypes, cytochrome *b* region) and also suggested the Mississippi River as a possible boundary between the two genetic lineages. All Ontario foxsnakes arose from a single post-glacial lineage and belong to the eastern mtDNA clade (Dileo *et al.* 2010; Crother *et al.* 2011; Row *et al.* 2011).

Significant population structuring below the species level has been identified in Canadian Eastern Foxsnakes, based on nuclear DNA analysis (Dileo *et al.* 2010; Row *et al.* 2010, 2011; Table 1). Foxsnakes occur in two discrete geographic regions of Ontario (Carolinian and Georgian Bay; see **Distribution**). Dileo *et al.* (2010) conducted a Bayesian spatial assignment test (n = 114 snakes; 11 DNA microsatellite markers: Row *et al*. 2008) and identified five genetically distinct clusters of Eastern Foxsnakes in the Carolinian region (96% of sampled snakes had ≥ 80% probability of belonging to a single genetic cluster). Population structuring was identified at a fine scale, and in one case two distinct clusters were separated by < 5 km. Row *et al.* (2010) expanded on the work by Dileo *et al.* (2010) and conducted a more extensive genetic analysis using two different assignment tests (n = 589 snakes from Ontario, Michigan, and Ohio; 12 DNA microsatellite markers). The authors identified eight genetically distinct clusters of Eastern Foxsnakes in the Carolinian region, including three additional clusters to the five identified by Dileo *et al.* (2010). Differentiation between all eight pair-wise genetic clusters was highly significant ($P < 0.001$), with F_{ST} values ranging from 0.04 to 0.36. Additional work by Row *et al.* (2011) with Eastern and Western Foxsnakes (n = 816 snakes from USA and Ontario; 12 DNA microsatellite markers) using approximate Bayesian computation revealed an additional significant genetic cluster of Eastern Foxsnakes from the Georgian Bay region of Ontario (pairwise F_{ST} values ranged from 0.05 to 0.60 between Canadian genetic clusters; $P < 0.001$). In summary, nine distinct genetic clusters are identified for Eastern Foxsnakes in Canada (Table 1)**Error! Reference source not found.**.

Table 1. Genetically distinct clusters of Eastern Foxsnakes in Canada, including heterozygosity (H/h), degree of population differentiation (F_{ST}), allelic richness, and Euclidean distance between clusters. Euclidean distance was estimated from maps in Dileo *et al.* 2010; Row *et al*. 2010, 2011. F_{ST} values are for mean pair-wise comparisons between Ontario genetic clusters only. The "Holiday Beach/Ojibway Prairie" and "North-East Essex/Chatham-Kent/Lambton" clusters were originally presented as a single genetic cluster by Dileo *et al.* (2010), and later separated by Row *et al.* (2010).

Name of Cluster (County)	H/h	F_{ST}	Allelic Richness	Euclidean distance to centre of nearest cluster	Source
Carolinian DU:					
1. Holiday Beach/Ojibway Prairie (Essex)	0.60	0.10	4.06	~ 30 km	Row *et al.* 2010
2. Cedar Creek (Essex)	0.53	0.17	3.99	~ 25 km	Dileo *et al.* 2010; Row *et al.* 2010
3. Lake Erie Islands (Essex)	0.61	0.09	4.55	~ 40 km	Row *et al.* 2010
4. North-East Essex/Chatham-Kent/Lambton	0.63	0.09	4.56	~ 30 km	Row *et al.* 2010
5. Point Pelee/Hillman Marsh (Essex)	0.53	0.10	4.19	< 5 km	Dileo *et al.* 2010; Row *et al.* 2010
6. Talbot (Essex)	0.58	0.12	3.82	< 5 km	Dileo *et al.* 2010; Row *et al.* 2010
7. Rondeau (Chatham-Kent)	0.50	0.12	3.73	~ 40 km	Dileo *et al.* 2010; Row *et al.* 2010
8. Norfolk County area	0.31 - 0.32	0.20 - 0.31	2.51 - 2.88	~ 120 km	Row *et al.* 2010; 2011
GLSL DU:					
9. Georgian Bay region	0.28 - 0.36	0.31 - 0.45	2.05 - 2.40	~ 250 - 300 km	Row *et al.* 2011

Population structuring in Canadian Eastern Foxsnakes appears to be the result of both ancestral (i.e., pre-European settlement) and contemporary drivers. Analyses by Row *et al.* (2011) suggest that ancestral Eastern Foxsnake populations were once larger and more widely distributed across Ontario and that subsequent declines and population fragmentation (occurring ca. 2,340 years ago), probably caused by deciduous forest succession and cooler conditions since the mid-Holocene, have had the largest effect in shaping the major geographical disjunctions and current genetic patterns in this species (e.g., between Georgian Bay and Carolinian regions, and between the Norfolk County area and remainder of Carolinian region**;** Figure 1). At finer geographical scales, however, Row *et al.* (2011) suggest that human-caused habitat loss and fragmentation have accentuated genetic population structure by isolating previously larger and more connected subpopulations (e.g., most Carolinian region genetic clusters). Fragmentation of habitat has been shown to create behavioural barriers to dispersal, and thus limit gene flow (see **Biology**). It appears as though most genetic clusters in the Carolinian region have differentiated due to habitat fragmentation preventing or limiting snake dispersal between clusters (Row *et al.* 2010). The Norfolk County area and Georgian Bay region genetic clusters appear to have been isolated prior to European settlement, yet it is unknown whether or not these clusters represent adaptively distinct lineages (Row pers. comm. 2019).

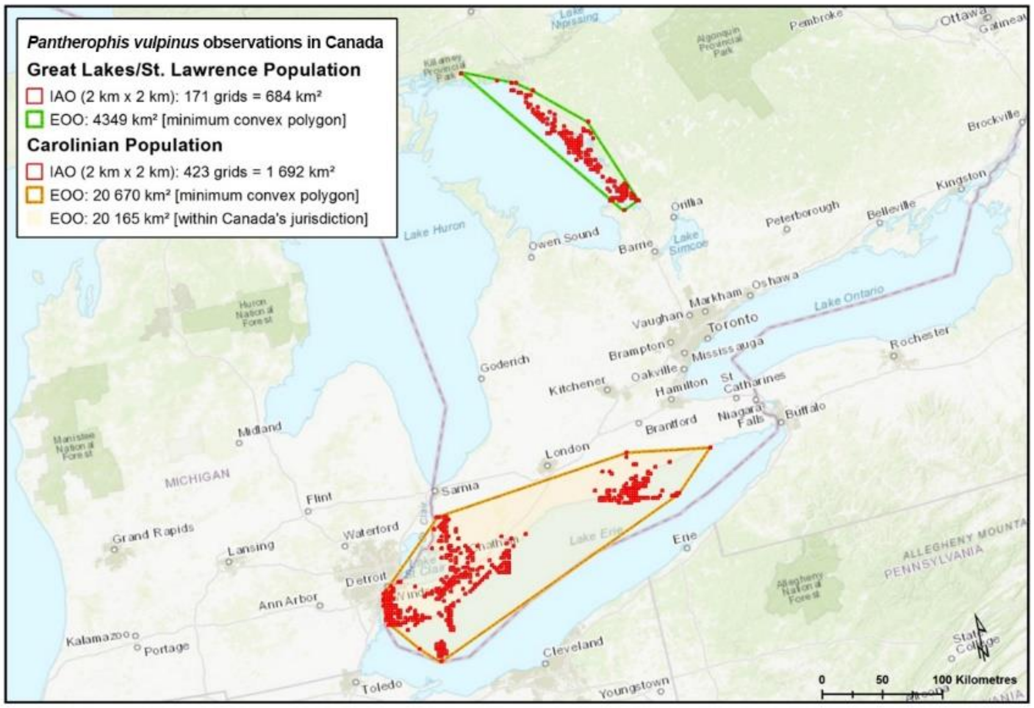

Figure 1. Current (1999–2018) Canadian range of Eastern Foxsnake (*Pantherophis vulpinus*) showing the extent of occurrence (EOO) and index area of occupancy of the two designatable units (DU): Carolinian and Great Lakes / St. Lawrence (GLSL). The Norfolk County area is represented by the cluster in the northeast in the Carolinian DU. All pre-1999 observations fall within, or in very close proximity to, the current EOO of the GLSL DU, whereas some historical observations fall outside the current EOO of the Carolinian DU (see Appendix 1 and 2). Map prepared by Sydney Allen (COSEWIC Secretariat).

Designatable Units

Two designatable units (DU) were identified in 2008 based on discreteness and evolutionary significance: Carolinian population and Great Lakes / St. Lawrence (GLSL) population. These DUs were re-evaluated with a specific focus on whether or not snakes inhabiting the Norfolk County area (part of the Carolinian DU – but geographically isolated) should be recognized as a separate DU. Although there is some evidence for the discreteness of snakes from the Norfolk County area, it is not considered evolutionarily significant, and they are not separated from the Carolinian DU in this report. The Carolinian DU (i.e., Carolinian population) includes all snakes in the Carolinian region of Ontario, while the GLSL DU (i.e., GLSL population) includes all snakes in the Georgian Bay region (see **Distribution**). Evidence for discreteness (D1, D2) and significance (S1, S2) is discussed below in relation to COSEWIC criteria for DUs.

Discreteness

D1. Evidence of heritable traits or markers that clearly distinguish the putative DU from other DUs (e.g., evidence from genetic markers or heritable morphology, behaviour, life history, phenology, migration routes, vocal dialects, etc.), indicating limited transmission of this heritable information with other DUs.

There are significant genetic differences between Eastern Foxsnakes in the Georgian Bay region, Norfolk County area (on the north shore of Lake Erie), and the rest of the Carolinian region (i.e., Essex/Chatham-Kent/Lambton counties) based on DNA microsatellites, allelic richness, and heterozygosity (Table 1). These differences provide evidence for a long-term lack of gene flow between the three areas originating prior to European settlement and land conversion. Foxsnakes in the Norfolk County area are genetically distinct from snakes elsewhere in the Carolinian region.

D2. Natural (i.e., not the product of human disturbance) geographic disjunction between putative DUs such that transmission of information (e.g., individuals, seeds, gametes) between these “range portions” has been severely limited for an extended time and is not likely in the foreseeable future. “Extended time” is intended to mean that sufficient time has passed that either natural selection or genetic drift are likely to have produced discrete units, given the specific biology of the taxon.

There is a clear natural disjunction separating foxsnakes in the Georgian Bay region from those in the Carolinian region (~250–300 km). A disjunction also exists within the Carolinian region, between those in the Norfolk County area and other Carolinian region foxsnakes (separation distance of 120 km). Genetic analyses (Row *et al.* 2011) and historical assessment of habitat distribution (wetlands: see Figure 3 in DUC 2010) both suggest these disjunctions predate European settlement. Although genetic analysis found little genetic admixture in the Georgian Bay region, some admixture was found between snakes in the Norfolk County area and snakes from elsewhere in the Carolinian region (Row *et al.* 2011). Some degree of dispersal between the Norfolk County area and Essex/Chatham-Kent/Lambton counties along the Lake Erie shoreline would have been possible in the past due to the shorter distance between suitable habitat patches, coupled with the propensity of foxsnakes to use shoreline habitats and swim long distances. Although foxsnakes from the Norfolk County area are naturally disjunct from the remainder of snakes in the Carolinian region, this disjunction is not as discrete as the disjunction between snakes in the Georgian Bay region and Carolinian region as a whole.

Significance

S1. Direct evidence or strong inference that the putative DU has been on an independent evolutionary trajectory for an evolutionarily significant period, usually intraspecific phylogenetic divergence indicating origins in separate Pleistocene refugia.

Not applicable. There is no genetic evidence to suggest significance.

S2. Direct evidence or strong inference that can be used to infer that the putative DU possesses adaptive, heritable traits, that cannot be practically reconstituted if lost. For example, persistence of the discrete, putative DU in an ecological setting where a selective regime is likely to have given rise to DU-wide local adaptations that could not be reconstituted.

The Georgian Bay region is an ecological setting unique to foxsnakes in Canada (i.e., freshwater island archipelago with mosaic of coastal rock barrens and sparse boreal forest), and this habitat together with climate may have given rise to potentially heritable life history, behavioural, and ecological traits. In the Canadian context, these include unique hibernation habitat, extremely dense hibernation congregations, and large home range sizes (see **Habitat)**, as well as unique parasite ecology, stress levels, and long-distance swimming behaviour (see **Biology**) (note that some differences [e.g., home range size: Mitrovich *et al.* 2009] may be attributed to phenotypic plasticity as opposed to local adaptation). Measurable differences in these or other traits between snakes in the Norfolk County area and those in the Carolinian region as a whole, however, have not been documented or searched for despite genetic differences.

Foxsnakes of the Georgian Bay region occupy a separate Amphibian and Reptile Faunal Province (Great Lakes / St. Lawrence) and national ecological area (Boreal) from all foxsnakes in the Carolinian region (Carolinian and Great Lakes Plains, respectively). This separation has occurred prior to European settlement, and natural movement of snakes between the two faunal provinces will not occur in the foreseeable future. Foxsnakes from the Norfolk County area occupy the same eco-geographic region as the remainder of snakes in the Carolinian region. The occurrence of foxsnakes in two distinct faunal provinces provides strong inference that each forms a distinct “ecological setting where a selective regime is likely to have given rise to DU-wide local adaptations that could not be reconstituted”. The Great Lakes / St. Lawrence population is endemic to Canada, whereas the Carolinian population could conceivably extend to the USA.

Special Significance

Eastern Foxsnakes are predators of rodents, and thus can be beneficial in agricultural systems with elevated rodent populations. This species is also prey for a wide variety of native birds and mammals, and is readily killed by people out of fear/hatred of snakes or because it is mistaken for a venomous species. Eastern Foxsnakes are regularly featured in education and awareness programs to encourage greater acceptance of native snakes. Foxsnakes’ docile demeanour and tolerance of handling despite its large size make them effective native snake ambassadors.

DISTRIBUTION

Global Range

The global range of Eastern Foxsnake is limited to the Great Lakes region of North America east of the Mississippi River (Figure 2). It is found mainly in Ontario and the states of Illinois, Indiana, Michigan, Missouri, Ohio, and Wisconsin (Crother *et al.* 2011; NatureServe 2019). Observations outside of the core global range are discussed by Crother *et al.* (2011) and NatureServe (2019). Using a GIS and range map by Crother *et al.* (2011), global range is estimated to be ~334,450 km^2 (excluding zone of overlap between Eastern and Western foxsnakes).

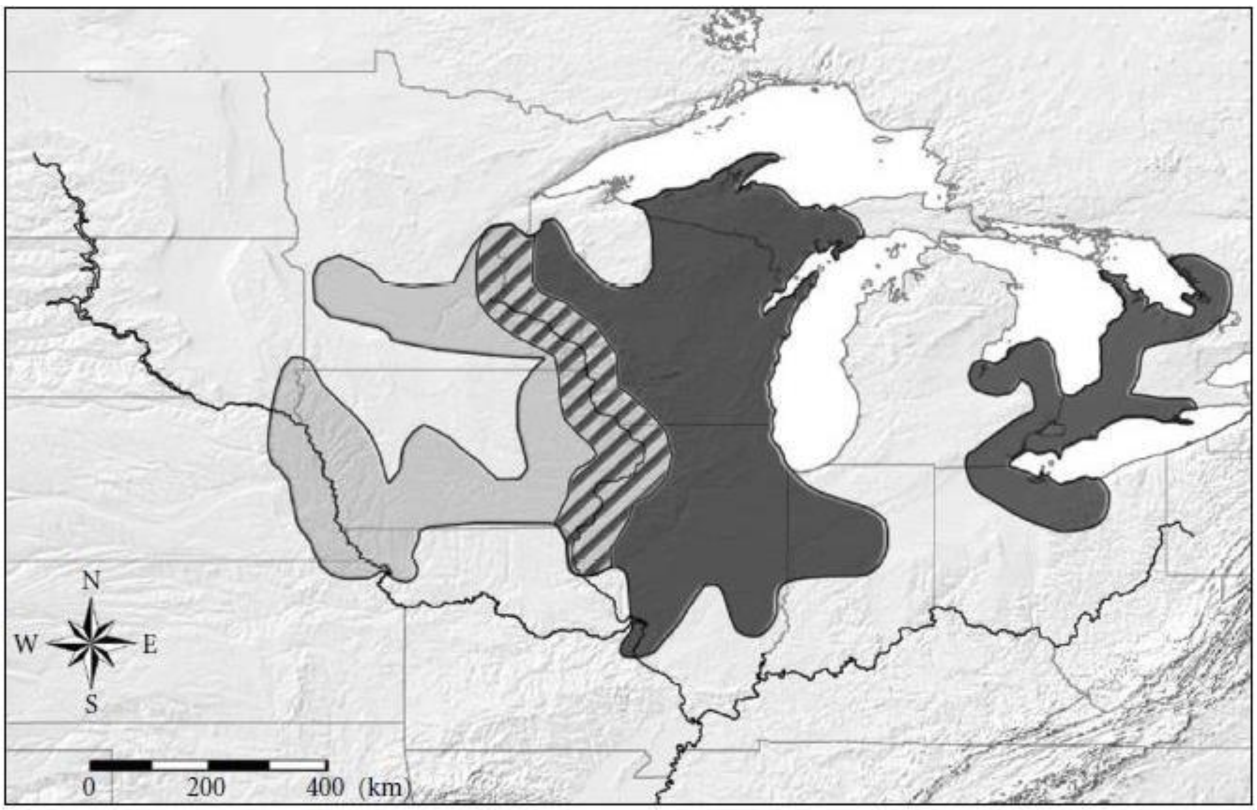

Figure 2. Map of the Great Lakes region of North America, depicting the global range of Eastern Foxsnake (*Pantherophis vulpinus*), represented by the dark shaded area (~334,450 km^2, excluding hatched area). The range of the Western Foxsnake (*Pantherophis ramspotti*) is represented by the light shaded area. The hatched area includes the historical barrier between the two species (the Mississippi River), and the region where both species have been recorded based on mtDNA (Copyright © 2011 Brian I. Crother *et al.*; used with permission under Creative Commons Attribution License).

Canadian Range

The Canadian range of Eastern Foxsnake is limited to southwestern and central Ontario and spans two Amphibian and Reptile faunal provinces (Carolinian and Great Lakes / St. Lawrence) (Figure 1). Foxsnakes occur in two discrete areas of Ontario, Carolinian and Georgian Bay regions. In the Carolinian region, Foxsnakes are found in Essex, Chatham-Kent, and Lambton counties, and in the Norfolk County area (Port Burwell to Port Maitland, including Long Point). In the Georgian Bay region, foxsnake distribution is restricted to the eastern shoreline of Georgian Bay, mainly from Port Severn to Key Harbour. Two UNESCO Biosphere Reserves occur within the Canadian range of Eastern Foxsnakes: Georgian Bay Biosphere Reserve in the Georgian Bay region (347,269 ha; GBBR 2004) and Long Point Biosphere Reserve in the Carolinian region (26,250 ha; LPWBRF 2018). Using a GIS and adapting the global range map by Crother *et al.* (2011), it is estimated that approximately 13% of the global distribution of Eastern Foxsnake lies within Canada (excludes zone of intergradation; Figure 2). This is much lower than the estimate produced using this species' global range based on the previous taxonomy (~54% within Canada).

Extent of Occurrence and Area of Occupancy

Observation records from the Ontario Natural Heritage Information Centre (NHIC) were used to calculate the extent of occurrence (EOO) and index of area of occupancy (IAO). NHIC observation records, as opposed to the element occurrence (EO) data, were used because this data set was presumed to be more up-to-date and complete, as not all observations are linked to EOs. This approach required a detailed review and scrutiny of observation records to remove historical (pre-1999) and ambiguous observations. Relatively greater scrutiny was directed toward observations on the periphery of the range, as these have the greatest impact on EOO estimation (details of records omitted due to ambiguity are documented in Supplementary Information 1, which can be obtained from COSEWIC Secretariat upon request).

EOO estimates are based on a minimum convex polygon within Canada's jurisdiction encompassing the NHIC records from the previous 20 years (n = 13,871; 1999–2018). Index of area of occupancy (IAO) estimates are based on the sum of all 4 km^2 grid squares with at least one NHIC record from the previous 20 years (1999–2018). A 20-year timeframe approximates three Eastern Foxsnake generations (7.5 years per generation: Row *et al.* 2011). Ideally, IAO should be calculated based on areas during the smallest essential habitat at any life stage, which would be hibernation sites for this species. However, incomplete information on the location of hibernacula precludes the use of this method, and the values based on records during all life history functions are most likely overestimates, especially for the GLSL DU, where snakes congregate in large numbers for hibernation.

For the Carolinian DU, the current EOO and IAO were calculated as 20,165 km^2 and 1,692 km^2, respectively (Figure 1). Eastern Foxsnake no longer appears to occupy a portion of its former range in the Carolinian region, based on an absence of recent (1999-

2018) confirmed observations from a heavily modified landscape, despite recent search effort at historical sites (note that verified observation records from outside the current range are represented by only four IAO squares; Appendix 1). As a result, the current EOO of the Carolinian DU may have contracted by ~17% when compared to the EOO derived using all current and pre-1999 records (i.e., 20,165 km^2 vs. 24,178 km^2, respectively). The presumed decline in the IAO of the Carolinian DU, however, is small (~1%; 1,692 km^2 vs 1,708 km^2). Foxsnake range and/or abundance in the Carolinian region are likely to decrease by 2050 due to the effects of climate change (see **Threats and Limiting Factors**).

For the GLSL DU, current EOO and IAO were calculated as 4,349 km^2 and 684 km^2, respectively (Figure 1). The current EOO and IAO estimates (using records from 1999-2018) are ~10% and ~9% smaller, respectively, than estimates using combined recent and historical (pre-1999) observations (EOO = 4,855 km^2 for all records; IAO = 752 km^2 for all records: Appendix 2). Recent search effort has been less extensive for the GLSL DU than for the Carolinian DU, and it is uncertain whether sites with historical records only have been adequately surveyed. Therefore, it is appropriate to include a range of values for both EOO (4,349-4,855 km^2) and IAO (684-752 km^2) for this DU, based on recent (minimum) and all records (maximum).

The current estimated EOO and IAO for both DUs are larger than reported in the previous COSEWIC (2008) status report (based on applying a similar 10-year time frame). The increase in the known distribution of Eastern Foxsnake is higher in the Carolinian DU and presumed to be attributed to differences in methodology or data availability at that time, as well as to an increase in search effort in the past decade. For example, in the Carolinian region, there were 2.4 times the number of observation records submitted to the NHIC in the last decade (n = 3,132) than in the decade prior (n = 1,320). The increases are not considered to reflect a range expansion or fluctuations.

Search Effort

The Canadian range of Eastern Foxsnakes is estimated based on results of targeted field studies by academic researchers and environmental practitioners (primarily in parks and protected areas: Dileo *et al*. 2010; Row *et al*. 2011), and observation data submitted to provincial databases (Ontario Reptile and Amphibian Atlas and Ontario NHIC). In the Carolinian region, recent survey work is presumed to have sampled much of this species' disjunct distribution (Dileo *et al*. 2010; Row *et al*. 2010), providing confidence in the accuracy of IAO estimates there. Observation frequency is often related to site accessibility rather than patterns of occupancy (Lindermeyer and Burgman 2005), suggesting that the IAO may be underestimated in remote areas, including parts of the Georgian Bay region.

Sampling methods for Eastern Foxsnake generally provide an accurate basis for the estimation of EOO (Gaston and Fuller 2009); however, recent occupancy modelling incorporating search effort has provided a means to further evaluate these estimates. Eastern Foxsnake occupancy probability in Ontario was modelled at the scale of 10 km x 10 km grid squares using Ontario Reptile and Amphibian Atlas data from 2009 to 2018, and accounting for search effort, habitat loss, road density, and climate (Paterson pers. comm. 2020). Predictions were conditional, meaning that probability of occupancy declined as more search effort occurred in a particular square without finding an Eastern Foxsnake. The exercise was conducted to identify squares where the species has a high probability of occurring but was unreported, and to estimate how road density and habitat loss affect occupancy probability (see **Threats**). In the Georgian Bay region, aside from the 27 occupied squares, no additional squares had a high (>75%) probability of occupancy. In the Carolinian region, however, in addition to the 69 occupied squares, the model predicted multiple squares with a high probability of occupancy (mostly along the north shore of Lake Erie). More specifically, the EOO of the Carolinian DU is possibly underestimated based on occupancy predictions in the Niagara Peninsula. These results suggest that at the scale of 10 x 10 km squares, and using data from the past 10 years, range estimates for the Carolinian DU are more likely to be underestimated than for the GLSL DU.

HABITAT

Habitat Requirements

General Habitat

Eastern Foxsnakes are closely associated with wetland, shoreline, and riparian ecosystems of the Lake Erie and Huron watersheds. In the Carolinian region, foxsnakes use sparsely forested, or unforested, early successional vegetation communities (e.g., old field, prairie, marsh wetland, coastal marsh, creek floodplain, forests edge, hedgerows, dune-shoreline) during the active season (Rivard 1976; Freedman and Catling 1978; Watson 1994; M'Closkey *et al.*1995; Brooks *et al.* 2000; Willson 2000; DeGregorio *et al.* 2011). Radiotelemetry in Essex County indicated that individuals spend most of their active season in marsh and open, early successional habitats and strongly avoid agricultural fields (Row *et al.* 2012). Hedgerows bordering farm fields and riparian zones along drainage canals are also used in areas of intensive farming (Row *et al.* 2012). At one site in the Carolinian region, mean home range length along the greatest dimension was 1,186 m (± 131 m SE, n = 5 females: R. Willson unpubl. data cited in COSEWIC 2008). Mean home range size (minimum convex polygon method) was 34–53 ha at two sites (range of 5–164 ha; n = 27: Row *et al.* 2012) and 67 ha at a third site (range of 2–441 ha; n = 27: Davy pers. comm. 2020).

Eastern Foxsnakes in the Georgian Bay region use open habitats along shorelines and on islands during the active season (e.g., coastal rock barrens and meadow marshes with intermittent trees and shrubs), as well as forest clearings and edges (Lawson 2005; MacKinnon 2005). Snakes in this region show a high affinity for habitats that are in close proximity to the Georgian Bay shoreline. For example, 95% of all telemetry locations from individuals at Killbear Provincial Park and Honey Harbour-Port Severn study sites were within 94 to 149 m of the shorelines of Georgian Bay (MacKinnon 2005), and most individuals used water for dispersal between sites and to access rocky offshore islands (Lawson 2005; MacKinnon 2005). At least one occupied site in the Georgian Bay region, centred on a locally rare limestone formation at the southern extent of the GLSL DU, is characterized by similar habitats to those in the Carolinian region and includes old field and anthropogenic microhabitats in an agricultural landscape (MacKinnon 2005). In the Georgian Bay region, mean home range length was 3,593 m (± 618.5 m SE, n = 9 females: Lawson 2005; MacKinnon 2005). Home range sizes (minimum convex polygon method) ranged from 132 to 1,951 ha at two sites (Brooks *et al.* 2003). The difference in average home range size between Georgian Bay and Carolinian regions is likely attributed to differences in habitat patch size (see **Habitat Trends**) and resource distribution as opposed to local adaptations (Mackinnon 2005; Row *et al*. 2012).

Eastern Foxsnakes use discrete microhabitat features for thermoregulation, shelter from predators, digestion, and ecdysis (shedding), with some individuals showing annual fidelity to these features (Paleczny *et al.* 2005; Willson and Brooks 2006). In the Carolinian region, brush piles, table rocks, tree stumps, root systems of downed trees, and driftwood are used, in addition to anthropogenic features such as wood and metal debris, abandoned vehicles, buildings, plumbing, asphalt, and masonry (Rivard 1976, 1979; Catling and Freedman 1980; Watson 1994; M'Closkey *et al.* 1995). Juniper shrubs are also often used as shelter in Norfolk County (Gillingwater pers. comm. 2008). In the Georgian Bay region, microhabitat features used are predominantly rock-based (e.g., table rocks with suitable rock-substrate gaps, or fissures in the bedrock); however, brush piles, root systems of living and downed trees, and junipers are sometimes used.

Hibernation Sites

Eastern Foxsnakes' hibernation sites include bedrock fissures, rotted tree root systems, animal burrows, and anthropogenic features such as old wells and building foundations (Watson 1994; M'Closkey *et al.* 1995; Lawson 2005; MacKinnon 2005; Gartshore pers. comm. 2008; Gillingwater pers. comm. 2019; Marks pers. comm. 2019). Hibernation sites may consist of a distinct subterranean feature with one or more entrances, or may be part of a complex of clustered and/or interconnected features with several entrances (Porchuk 1996). They provide suitable subterranean configurations that extend below the frost line, contain sufficient moisture to prevent dehydration, and are not prone to flooding or easily accessible to predators.

In some cases, a large proportion of snakes occupying a distinct area may rely on a small number of hibernation sites. In the Carolinian region, hibernacula are typically occupied by fewer than 20 snakes (Watson 1994; M'Closkey *et al.* 1995; Brooks *et al.* 2000; Xuereb *et al.* 2012; Marks pers. comm. 2019), whereas 150 to 264 individuals were documented using single hibernation sites in the Georgian Bay region (MacKinnon 2005; Xuereb *et al.* 2012). A large proportion of foxsnakes will return to previously used hibernation sites annually (Watson 1994; Marks pers. comm. 2019), with some sites used by foxsnakes for at least 15 years (GBBR 2019).

Oviposition Sites

Eastern Foxsnakes' oviposition sites include rock crevices, interior cavities within decaying tree trunks, logs and stumps, under rotting driftwood, natural and piles of decaying vegetation (leaves, woodchips, sawdust, herbaceous vegetation, and/or hay), root systems along exposed edges of dunes and wetlands, and rodent burrows along roadside edges (Porchuk and Brooks 1995; Brooks *et al.* 2000, 2003; Willson 2000; Lawson 2005; MacKinnon 2005; Willson and Brooks 2006). Oviposition sites need to maintain sufficient humidity to prevent egg desiccation, provide suitable thermal conditions for egg incubation (embryogenesis), and protect eggs from predation (Willson 2000). Clutches of eggs may be deposited singly or communally (Brooks *et al.* 2003; Lawson 2005; Marks pers. comm. 2019) and communal sites can contain dozens of eggs (e.g., 84 eggs laid by four females: Willson 2000; 10 females using one site: Lawson pers. comm. 2005). Female foxsnakes may show strong annual fidelity to specific oviposition sites for at least two consecutive years (Willson 2000; Paleczny *et al.* 2005; Lawson pers. comm. 2005; Marks pers. comm. 2019).

Habitat Trends

Availability and trends in Eastern Foxsnake habitat are discussed at the local level (county, watershed, and/or ecodistrict), with a focus on wetlands. The vast majority of Eastern Foxsnake observations in the Carolinian region are from Windsor-Essex, Chatham-Kent, Lambton, and Norfolk counties. These four counties lie within four local watersheds (Essex, Lower Thames Valley, St. Clair, and Long Point) and within two ecodistricts (7E-1 and 7E-2). The vast majority of Eastern Foxsnake observations in the Georgian Bay region are from within the Georgian Bay Biosphere Reserve, within a single ecodistrict (5E-7).

From ca. 1800 to 1982, an estimated 4,699.3 km^2 (87.2%) of pre-settlement wetlands in the Carolinian region counties of Essex, Kent (now Chatham-Kent), Lambton and Haldimand-Norfolk (now separated into Haldimand and Norfolk), combined, were converted to human uses, predominantly to intensive agriculture (Snell 1987). Total losses were the most pronounced in Essex (95.8%) and Kent (94.2%) counties (Snell 1987). In all four counties net wetland losses continued to occur even during the 16 years prior to 1982, at an average rate of 145.6 ha/year/county (Snell 1987). From 1982 to 2002, although wetlands were gained in Essex County, there was an estimated net loss of 10,302 ha across the four counties (DUC 2010; Table 2), amounting to an average loss of 122.6 ha/year/county. In the Carolinian region wetland losses have continued over the past three foxsnake generations (~22.5 years); however, the rate of loss appears to have slowed. For example, from 2000 to 2011, 0.81–1.20% of wetlands (101–500 ha) were lost in ecodistrict 7E-1 and 0.01–0.40% of wetlands were lost (101–500 ha) in ecodistrict 7E-2 (OBC 2015). This equates to a wetland loss of 8.4–41.7 ha/year/ecodistrict during that period. Also, during the previous decade, conservation authorities in the Carolinian region have not reported significant declines in wetland or natural area cover within the Eastern Foxsnake's range (Table 3). Excluding forests, current habitat availability in both ecodistricts is limited to ~2–3% of the land area (Table 4), with remnant natural areas in the Essex, Lower Thames, and St. Clair watersheds being mostly small, isolated, and highly fragmented relative to central Ontario watersheds (ERCA 2012; SCRCA 2018; LTVCA 2018).

Table 2. Trend in area of wetland cover in four counties within the Carolinian region of the Canadian range of Eastern Foxsnake (DUC 2010). "+" = positive trend, "-" = negative trend.

County	Area (ha) and % wetland coverage (1982)	Area (ha) and % wetland coverage (2002)	Trend (ha; 1982-2002)
Essex	2,394 (1.3%)	3,068 (1.6%)	+ 674 (+ 28.2%)
Haldimand-Norfolk	17,838 (6.1%)	15,572 (5.4%)	- 2,266 (- 12.7%)
Chatham-Kent	3,007 (1.2%)	2,123 (0.8%)	- 884 (- 29.4%)
Lambton	12,918 (4.5%)	5,092 (1.8%)	- 7,826 (- 60.6%)
TOTAL	**36,157**	**25,855**	**- 10,302** **(- 28.5%)**

Table 3. Trends in forest cover, wetland cover, and natural area cover in four watersheds within the Carolinian region of the Canadian distribution of Eastern Foxsnake. For Essex Region, "% wetland cover" actually reflects "% natural area cover". DU = Designatable Unit; ↔ = no change; ↓ = declining trend; ↑ = increasing trend; ? = percentage not reported by source(s).

Watershed	% Forest Cover	% Wetland Cover	Source
Essex	2006–2018: ↔ (5.7%)	2006–2018: ↑ (7.5% to 8.5%)	ERCA 2006; 2012; 2018
Lower Thames Valley	2013 –2018: ↔ (10%)	2013–18: ↔ (? %)	LTVCA 2013; 2018
St. Clair	2008–2018: ↓ (11.5 to 11.3%)	2008–2018: ↑ (0.8% to 1.1%)	SCRCA 2008; 2013; 2018
Long Point	2012–2018: ↔ (20%)	2013–2018: ↔ (4.5%)	LPRCA 2013; 2018

Table 4. Total area and current percent coverage of different land cover types in each ecodistrict within the Canadian range of Eastern Foxsnake (Wester *et al.* 2018). DU = Designatable Unit; GLSL = Great Lakes / St. Lawrence.

Ecodistrict	Area covered	Land area (ha)	% Settlement and associated infrastructure	% Pasture/ cropland	% Deciduous & mixed forest	% Other natural
7E-1: Essex (Carolinian DU)	Essex County and portions of Lambton and Chatham-Kent counties	379,328	3	90	4 (15,173 ha)	3 (11,380 ha)
7E-2: St. Thomas (Carolinian DU)	Includes Norfolk County, in addition to several others	944,493	1	82	15 (141,674 ha)	2 (18,890 ha)

Ecodistrict	Area covered	Land area (ha)	% Settlement and associated infrastructure	% Pasture/ cropland	% Deciduous & mixed forest	% Other natural
5E-7: Parry Sound (GLSL DU)	Eastern shoreline of Georgian Bay – majority of observations in GLSL DU	625,998	<1	<1?	52 (325,519 ha)	48 (300,479 ha) 30% sparse forest, 8% bedrock, 9% other natural

Most habitat loss in the Carolinian region is historical, but small-scale losses continue due to expanding urban development around population centres, such as Windsor, road improvements and infrastructure development, and intensification of agriculture associated with soybean and grain corn production (see **Threats**). Loss of habitat features important for the snakes have been documented over the past 20 years, including loss of 13 hibernacula from development (Gillingwater pers. comm. 2020). The invasive European Common Reed (*Phragmites australis*) also continues to expand and degrade habitats.

New habitats may become available for Eastern Foxsnakes in the Carolinian region due to ongoing reforestation, restoration, and wetland creation projects by conservation authorities and other habitat stewards (e.g., LTVCA 2013, 2019; SCRCA 2013; ERCA 2018). Some habitat creation projects (e.g., wetlands, prairie) are expected to provide greater benefits to foxsnakes than others (e.g., reforestation) due to lower canopy cover. With the slowing rate of wetland loss in the Carolinian region, ongoing wetland creation may contribute toward a future reduction in the rate of habitat decline. However, the large interconnected wetlands that would most benefit this species are difficult to restore in this agriculturally dominated landscape. Increased human recreational use, expansion of residential development, and improvements to roadways will further complicate restoration efforts.

Settlement and land clearing in the Georgian Bay region has been slower than in the Carolinian region due to low agricultural potential. The Parry Sound ecodistrict is currently dominated by natural cover types, including ~48% of the land area presumed to be suitable for Eastern Foxsnakes (Table 4). By the early 1850s there were only a few thousand people living in the Georgian Bay region (GBBR 2004). Human population growth occurred from 1872 to 1880 due to the lumber industry, with deforestation and land clearing peaking in 1905 (GBBR 2004). In recent decades, cottage development has been a main driver of development within the species' range, but overall development rates have been relatively low. Within the Georgian Bay Biosphere Reserve, urban development rates were 3 to 6% from 2004 to 2014 with no significant changes in the main habitat types or ecosystems GBBR (2014). There was a 10.8% loss of coastal wetland cover in the southern portion of the Georgian Bay region from 1987 to 2013, largely due to decreasing water levels (GBBR 2019). However, because foxsnakes are largely confined to habitats within ca.100 m from the Georgian Bay shoreline, its habitat throughout the region is succumbing to cottage and other recreational developments (see Figure 7 in COSEWIC 2008 for an example). This region continues to experience development pressure due to its proximity to the Greater Toronto Area and its appeal as prime cottage country, resulting in ongoing habitat loss.

BIOLOGY

Life Cycle and Reproduction

In general, foxsnakes enter hibernation in September and October, emerge in mid-April to mid-May, and breed from late May to mid-June. Foxsnakes become reproductively active, and are therefore considered mature, at snout-vent lengths of 93–100 cm (Lawson 2005), and after four to five years of age (Willson 2000; ECCC 2020). Mature snakes typically account for ~46% of individuals in a subpopulation (range of 29–67%), based on average capture rates from four Ontario studies (Appendix 3). Longevity is estimated at 12–15 years in the wild (ECCC 2020). Most of the adult females in an area are gravid annually (Mackinnon 2005). The generation time is estimated at 7.5 years (half-way between age at maturity and longevity, averaged from available data for GLSL and Carolinian populations; Row *et al.* 2011).

In Ontario, females lay eggs from early to mid-July (Willson 2000; Brooks *et al*. 2003), after 30–50 days of gestation (Willson and Brooks 2006). Females lay 6–29 eggs per clutch (Ernst and Barbour 1989; Willson 2000) and will only spend 1–4 days at their oviposition site before leaving the eggs to incubate on their own (COSEWIC 2008; MacKinnon pers. comm. 2008). Eggs require 50 to 65 days to incubate (Harding 1997; Tennant 2003). In the Carolinian region, hatchlings emerge from late August to mid-September (Willson 2000), whereas hatching may occur later in the Georgian Bay region. Hatchlings may remain at the oviposition site for up to a week before dispersing. Females are highly selective of oviposition sites and will make long-distance movements to and from these sites each year (Watson 1994; Row *et al*. 2012).

Physiology and Adaptability

As ectotherms, Eastern Foxsnakes are constrained by the thermal characteristics of their local environment. Three temperature-dependent processes that have been studied include thermoregulation by gravid females (Willson and Brooks 2006), cold water swimming, and environmentally induced stress. MacKinnon *et al.* (2006) documented 49 radio-tagged foxsnakes swimming 313 times in water as cold as 11°C in the Georgian Bay region, and observed a maximum body temperature decrease of 22.6°C over 11 minutes (35.6°C to 13°C). Xuereb *et al. (*2012) found that stress levels were significantly greater in foxsnakes from the Georgian Bay region than in those from the Carolinian region, and a negative relationship was found between stress and residual growth rate in the Georgian Bay snakes, possibly due to lower average temperatures in the Georgian Bay region.

The use of anthropogenic structures suggests that Eastern Foxsnakes are able to tolerate some level of human disturbance. They have also been observed using hibernation and egg-laying sites artificially created for research or conservation purposes (e.g., Willson 2000; Smith 2019) and have used hibernacula created out of the basements of demolished homes in Windsor (OMECP 2016).

Dispersal and Migration

Each year individual Eastern Foxsnakes make long-distance movements to and from hibernation sites (Row *et al.* 2012), which are typically located outside of the active season portion of their home range (Watson 1994). During the active season, females in the Carolinian region have been detected a mean maximum distance of 930 m (± 81 SE, n = 5: R. Willson unpubl. data cited in COSEWIC 2008) to ~ 2,000 m (Row *et al.* 2012) from hibernacula. In the Georgian Bay region, females have been found at a mean maximum distance of 3,229 m (± 568 SE, n = 9) from hibernacula (Lawson 2005; MacKinnon 2005).

Eastern Foxsnakes are proficient swimmers and will take to the water and swim long distances across bays and between islands. Swimming can create links across large expanses of open water. For example, open water swims of 6–12 km to access rocky offshore islands were recorded by radio-tracking of foxsnakes in the Georgian Bay region (Brooks *et al.* 2003; Lawson 2005; MacKinnon 2005). Analysis by Row *et al.* (2010) suggests that open water separating the Lake Erie Islands (~4–9 km) presents less of a dispersal barrier for Eastern Foxsnakes in the Carolinian region than does unsuitable terrestrial habitat.

Intensive agricultural landscapes and high-traffic roads create dispersal barriers between suitable habitat patches and contribute to population fragmentation and, in the case of roads, mortality of individuals. Dileo *et al.* (2010) overlaid five genetic clusters in the Carolinian region onto a habitat map and found that the clusters corresponded roughly with patches of suitable marshland and prairie habitat isolated by intensive agriculture. Row *et al.* (2010) expanded on the previous study by combining habitat suitability modelling and population genetic analysis, and found that boundary regions between most of the genetic clusters in the Carolinian region were dominated by low suitability habitat (Table 1; e.g., agricultural fields). These authors concluded that habitat degradation limits dispersal of Eastern Foxsnakes, which resulted in a genetically fragmented Carolinian population. Results by Dileo *et al.* (2010) and Row *et al.* (2010) are further substantiated by movement behaviour observed by Row *et al.* (2012). The study found that radio-tracked foxsnakes at two sites in the Carolinian region spent most of their active season in marshes and natural meadows and avoided agricultural fields.

Although roads were shown to contribute to Eastern Foxsnake population fragmentation, their effect was variable and only partially explained the genetic structure of the Carolinian population. For two genetic Eastern Foxsnake clusters separated by less than 5 km, the most likely barrier to gene flow was a two-lane provincial highway (Highway 3, along which a high number of road kills was found) (Dileo *et al*. 2010). In contrast, a major four-lane provincial highway (Highway 401) did not appear to restrict gene flow within a different genetic cluster, perhaps due to the maintenance of connectivity along riparian corridors under the highway (Dileo *et al*. 2010). The significant genetic fragmentation observed within the Carolinian population (Row *et al.* 2010) arises because dispersal is limited by the snakes' avoidance of vast areas of intensive agricultural lands (Row *et al.* 2012), coupled with an inability to successfully cross some high-traffic roads (Dileo *et al.* 2010).

Interspecific Interactions

Natural predators of Eastern Foxsnakes include raptors (e.g., Red-tailed Hawk [*Buteo jamaicensis*], Great Horned Owl [*Bubo virginianus*]), gulls (family Laridae), herons and egrets (family Ardeidae), and mammals (e.g., Fisher [*Martes pennant*], Mink [*Mustela vison*], Northern Raccoon [*Procyon lotor*], Red and Gray Fox [*Vulpes vulpes*; *Urocyon cinereoargenteus*], and Striped Skunk [*Mephitis mephitis*]) (Kraus 1991; Porchuk pers. comm. 1998; Lawson 2004). Nest predators include various mammals (e.g., Racoons, Coyotes [*Canis latrans*]), and burying beetles (*Nicrophorus pustulatus*) (Porchuk and Brooks 1995; Willson 2000; Gillingwater pers. comm. 2008). Foxsnakes are prone to ejecting a foul-smelling glandular secretion from the cloacal scent glands when threatened.

Small mammals (voles, mice, chipmunks, rabbits) and birds (adults, nestlings, and eggs) make up the bulk of Eastern Foxsnakes' diet, with amphibians and invertebrates rarely taken (reviewed in COSEWIC 2008).

Xuereb *et al.* (2012) investigated parasite loads in Eastern Foxsnakes from the Georgian Bay region (n = 354) and the Carolinian region (n = 240). A relatively higher proportion of the Georgian Bay snakes (50%) were infected with blood parasites (hemogregarines) when compared to the Carolinian snakes (5%). The authors speculated that the relatively low heterozygosity of Georgian Bay snakes compared to Carolinian snakes (see **Population Spatial Structure and Variability**) may be responsible for lowered immunological response, and hence higher hemoparasite intensities. Nonetheless, blood parasite infection intensity was not related to residual growth rate or body condition, which suggests a stable interaction has evolved between the parasites and Georgian Bay region Foxsnakes (Xuereb *et al*. 2012).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Eastern Foxsnake densities were calculated using census estimates derived from mark-recapture data collected at three study sites in the Carolinian region and one site in the Georgian Bay region (Appendix 4). The densities were then extrapolated to the entire ranges of the two DUs (IAO grid cells), assuming that these densities are representative across the range. This method has biases, but no robust estimates are available. The calculations would result in an underestimate of true population size if there are large gaps in the IAO data or an overestimate if density is much greater at the study sites than in the remainder of the landscape. Effective population size is presented for comparisons, as reported by Row *et al.* (2011) based on fieldwork from 2006 to 2009. Effective population size (N_e) represents the approximate number of breeding individuals in an idealized population based on genetic characteristics and is presumed to be lower than the actual number of mature individuals (Frankham 1995; Frankham *et al.* 2004). No abundance estimates were provided in the previous (COSEWIC 2008) status report.

Abundance

<u>Carolinian DU</u>

The number of mature individuals was estimated from mark-recapture data as 148 (95% CI, 122–173) at the Ojibway Prairie Complex and as 45 (95% CI, 20-70) at Rondeau Provincial Park (Appendix 4). Foxsnake densities were calculated using data from these two sites and from historical census data from a third site in the Amherstburg area. Densities were then multiplied by the total area of IAO squares in the Carolinian DU (Appendix 5). This method resulted in a population estimate of 5,696 (4,147–7,232) adults. Combining the estimates presented by Row *et al.* (2011) for Norfolk County and southwestern Ontario, the effective population size N_e is 1,268–3,302 in the Carolinian DU (Table 5). The values for mature individuals in Appendix 5 can be viewed as rough estimates of subpopulation sizes, assuming that the identified genetic clusters are an appropriate proxy for subpopulations. Most subpopulations are small, but estimates for three genetic clusters (1, 4, and 8) exceed 1000 mature individuals (Appendix 5). These values should be interpreted with caution because they are based on densities derived from a small number of study sites and extrapolated to the spatial scale of IAO squares. Given the fragmented nature of foxsnake habitat, actual current subpopulation sizes may be much smaller.

Table 5. Effective population sizes (Ne) of Eastern Foxsnake genetic clusters in Canada based on two scales of analysis (adapted from tables 3 and 5 in Row *et al.* 2011). Note: Estimates for the Georgian Bay Islands National Park (GBINP) cluster may be underestimates due to very low genetic diversity (Row pers. comm. 2019).

Regional Genetic Cluster	Ne - Population-scale analysis (mode and 90% highest subpopulation density)	Ne - Range-wide analysis (mode and 90% highest subpopulation density)
Georgian Bay (GBINP)	392 (100 – 978)	642 (400 – 1,046)
Norfolk County	n/a	1,450 (868 – 1,918)
Southwestern Ontario (includes 7 genetic clusters: Table 1)	n/a	772 (400 – 1384)

<u>GLSL DU</u>

Subpopulation size in Georgian Bay Islands National Park (GBINP) was estimated as 180 (SE 124–230) mature individuals by Lawson (2005), who used two simple Peterson's mark-recapture estimates and intensive hibernacula capture data from 2003 to 2005. More recent abundance estimates at GBINP or elsewhere within the range of this DU are not available (Promaine pers. comm. 2020). Assuming the GBINP study area represents 18 IAO squares (arrived at by cross-referencing the study area map in Lawson 2005 with the

IAO map in Appendix 2 using GIS), then the approximate density of mature Eastern Foxsnakes at the GBINP study area is 10 (6.9–12.8) per IAO square, consistent with, although slightly lower than, average density estimated for the Carolinian DU (Appendix 4). Assuming an equal density of mature snakes across the DU, and a total of 171 IAO squares (20-year timeframe; Appendix 2) then there are an estimated 1,710 (1,180–2,189) mature Eastern Foxsnakes in this DU. Effective population size N_e was estimated by Row *et al.* (2011) for only one site (GBINP) as 400 –1,046 (Table 5). Although no data on subpopulation structure for the GLSL DU is available, more than one subpopulation is expected due to high fidelity of snakes to specific hibernacula. If we assume a similar structure to the sympatric Eastern Massasauga rattlesnake (four genetic clusters along eastern shoreline of Georgian Bay: Dileo *et al.* 2013), and an even distribution of snakes across clusters, then subpopulations are most likely to consist of <1000 mature individuals.

Fluctuations and Trends

The current population size of both Eastern Foxsnake populations in Canada is likely much smaller than it was historically. The majority of declines occurred perhaps hundreds of years prior to extensive European settlement (i.e., ancestral declines: Row *et al.* 2011). Human-caused habitat loss and fragmentation is continuing to affect populations today, as evidenced by the pattern of genetic fragmentation within the Carolinian population (Row e*t al*. 2011). A continuing decline in the number of mature foxsnakes is inferred for both the Carolinian and GLSL populations based on ongoing road mortality and other threats, including projected future declines based on threats over the next three generations, unless significant remedial actions are taken (see **Threats and Limiting Factors**).

Carolinian DU

Little empirical data is available on decline rates over the past three-generation period, but shorter-term data exists for four sites. However, the results from these case studies must be interpreted with extreme caution because extensive threat mitigation was in place at one of the sites, the Ojibway Prairie Complex (OPC), and the others were in protected areas. Of the subpopulations at the four sites, two were stable while two appeared to be in decline. A mark-recapture study of the Eastern Foxsnake was undertaken at the Ojibway Prairie Complex (OPC) from 2011 to 2018 as part of the Herb Gray Parkway Project. Although abundance estimates significantly declined and then increased over a period of two years (2014, 2015), total subpopulation size appears to have stabilized, and was similar in the 2016–2018 period as in the 2011–2013 period (Hazell pers. comm. 2020). The OPC subpopulation was heavily impacted and intensively managed over this time and the results may not be representative of longer-term trends at this site. At Rondeau Provincial Park, a mark-recapture study of Eastern Foxsnake was undertaken from 2013 to 2019. The trendline suggests a decline in abundance from ~100 to ~50 mature snakes, but the decline was not statistically significant and may be explained by a reduction in survey area in later years (Davy and Patterson unpubl. data). At Long Point, a decline in observations between the 1990s and 2000s suggests a potential subpopulation decline; however, surveys were not standardized, and it is unknown if the trend represents a true decline or a reduction in detectability due to the expansion of European Common Reed

(*Phragmites australis*) (Gillingwater pers. comm. 2019). At Middle Island (PPNP), foxsnake abundance seems to have declined over time, possibly due to significant habitat changes caused by an increased number of Double-crested Cormorants (*Phalacrocorax auratus*) nesting there (Dobbie pers. comm. 2020), coupled with the small size of the island (18.5 ha) precluding establishment of a resident, self-sustaining subpopulation.

The loss of hibernation sites is expected to be particularly detrimental and likely to lead to local declines. Over the past three foxsnake generations, a number of hibernation sites have been destroyed in the Carolinian DU. Nine hibernation areas were in the construction footprint of the completed Herb Gray Parkway in Windsor (LGL and URS 2010), four hibernacula were lost in the Long Point region (Gillingwater pers. comm. 2020), and seven hibernacula identified in the 1990s at Point Pelee National Park (PPNP) are presumed no longer in use (McKay pers. comm. 2006). Although new artificial hibernacula have been created, it is unknown if they compensate for losses of natural sites. For example, four artificial hibernacula were created at PPNP since 2014, two of which have been used to overwinter by multiple Eastern Foxsnakes (all ages) as well as other snake species (Degazio pers. comm. 2020).

Population modelling conducted for two similar species in Canada, Great Basin Gophersnake (*Pituophis catenifer deserticola;* COSEWIC 2013) and Gray Ratsnake (*Pantherophis spiloides*; COSEWIC 2018a), suggests a suspected population decline of 30% or more over the past two decades for the Carolinian DU, based on observed road mortality and high density of roads, although no empirical data are available over the DU's range specifically for that period. In the case of both species, these models predicted declines of greater than 30% over three generations as a result of increases in annual mortality due to roadkill (see **Threats and Limiting Factors**). Given that road densities and traffic volumes in southwestern Ontario are among the highest in Canada, it is likely that Eastern Foxsnake subpopulations in the Carolinian region are experiencing similar, if not higher, rates of decline. Threats assessment conducted for this status report indicates an overall projected threat impact of "high" with road mortality as the greatest threat, suggesting a 10–70% decline over the next three generations (see **Threats and Limiting Factors**).

GLSL DU

No information on subpopulation trends is available for this DU. Over the past three generations, there has been an increase in the discovery of previously undocumented hibernation sites in the GLSL DU (from 8 to 13; see Lawson 2005); there is no documentation of losses. Similar to the Carolinian DU, the overall threat impact from all threats was assessed as "high", implying a projected decline of 10%-70%, although the rate of decline for this DU is presumed to be closer to the lower end of this range. Although declines are suspected to be less severe than in the Carolinian region, the long-term impacts of road mortality are nonetheless concerning (See **Threats and Limiting Factors**). The southernmost portion of eastern Georgian Bay is prime "cottage country" for the Greater Toronto Area and much of southwestern Ontario (MacKinnon *et al*. 2005). Consequently, this region experiences a significant spike in human use during the summer months, resulting in greatly increased seasonal traffic volumes on many of the major roads, which coincides with the active season for foxsnakes. Habitat loss from ongoing cottage development also contributes locally to an ongoing decline for this population.

Severe Fragmentation

Previously, both Eastern Foxsnake DUs were considered “severely fragmented” due to habitat fragmentation caused primarily by recreational shoreline development and roads (COSEWIC 2008). However, severe fragmentation no longer applies to either DU under the current interpretation of the concept (i.e., more than 50% of the population in habitat fragments smaller than expected to support a viable subpopulation; IUCN SPC 2019). While the habitat is fragmented, information on abundance and viability of genetic clusters is largely unknown. Furthermore, the species is relatively vagile and not closely tied to specific habitats. For the Carolinian DU, less than 25% of its area of occupancy is represented by small isolated genetic clusters; therefore, this DU is not considered severely fragmented. For the GLSL DU, less than 5% of occupied habitat patches were separated by a distance greater than the maximum range length for this species; therefore, this DU is also not considered severely fragmented (Appendix 6).

Rescue Effect

Eastern Foxsnakes on the Canadian Lake Erie islands are within dispersal distance of foxsnakes on U.S. islands. Foxsnakes may also be able to cross from the U.S. to Ontario at the Detroit River and the north end of Lake St. Clair (to Walpole Island). Eastern Foxsnakes show the capacity to disperse long distances over water (see **Dispersal and Migration**); however, potential rescue from the U.S. would be limited to the isolated genetic clusters directly adjacent to the U.S. border, given the fragmented nature of the Carolinian population. The GLSL population is endemic to Canada, and therefore rescue from the U.S. is not possible.

THREATS AND LIMITING FACTORS

Threats to Eastern Foxsnakes in Canada were assessed using the IUCN threats calculator and are presented in the approximate order of highest to lowest impact (for all scores see Appendices 7 and 8 for the Carolinian and GLSL DUs, respectively). Although discussed separately, it is important to recognize the cumulative impacts of multiple threats across a landscape. For example, in the Georgian Bay region, cumulative effects of multiple threats in specific areas (e.g., Port Severn and Parry Sound areas: Figure 3; GBBR 2019) have been shown to result in such high levels of foxsnake mortality that they are likely acting as ecological sinks for this species (Mackinnon 2005). Also, despite extensive habitat protection in some areas (see **Protection, Status and Ranks**), a number of anthropogenic threats remain therein and can impact this species (e.g., road mortality). Foxsnakes are subject to a greater number of threats in the Carolinian DU than in the GLSL DU. For both DUs, and due to cumulative impacts of combined threats, the overall threat impact was rated as “high” (implying 10–70% decline over the next three generation period from threats operating over the next 10 years).

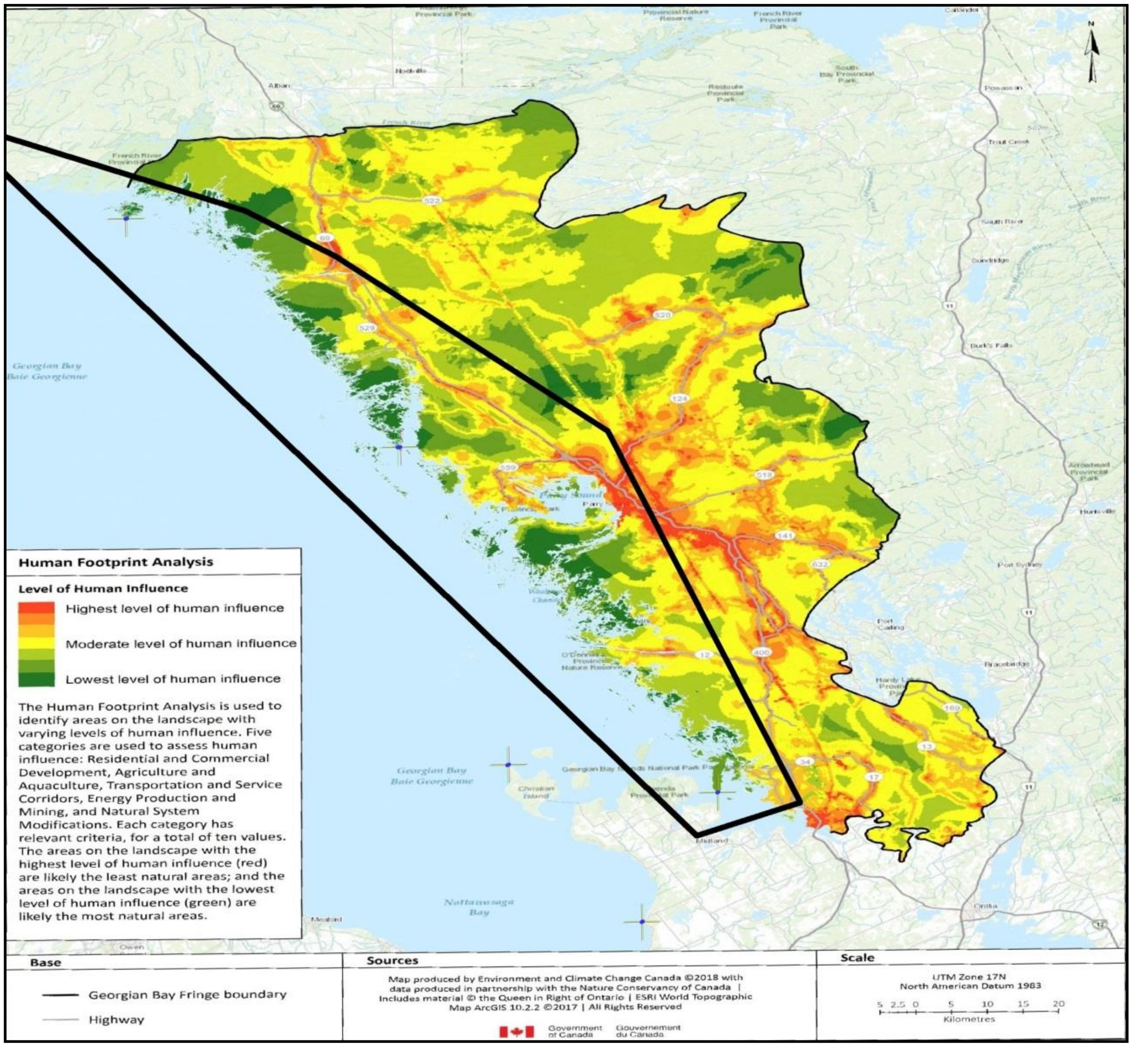

Figure 3. Human footprint analysis of the Georgian Bay region showing the cumulative impacts of human influence (i.e., threats) on the landscape. Extent of occurrence of the Great Lakes / St. Lawrence population based on data from 1999 to 2018 depicted by the bold black polygon. (Adapted from ECCC 2017; permission granted to reproduce).

Transportation & Service Corridors (IUCN threat 4.0; overall impact for Carolinian DU: medium; for GLSL DU: medium)

Foxsnakes are threatened by road mortality and degradation and fragmentation of habitats associated with new and existing roads (4.1: Roads & railroads). The Herb Gray Parkway project in Windsor (IO 2015) and the HWY 69/400 expansion south of Parry Sound (GBBR 2014; OMT 2016) are two examples of recent large-scale highway developments having direct impacts on Eastern Foxsnakes and resulting in the loss and fragmentation of habitat from the widening of existing highway rights-of-way. However, comprehensive mitigation and offsetting strategies are becoming standard for large transportation infrastructure projects in Ontario (e.g., wildlife crossings, barrier fencing, habitat acquisition and enhancement; Baxter-Gilbert *et al.* 2015; OMECP 2016). Highway improvement projects are expected to continue within the ranges of both DUs over the next 10-year period (e.g., Carolinian: Hwy 40, Chatham to Sarnia, proposed: OMT 2017; Irwin 2020); GLSL: HWY 69/400 from Nobel to French River, proposed; OMNDM 2017; Erskine 2019). Regardless, the greatest future impact from roads on foxsnakes will most likely accrue from road mortality on existing and improved roads, rather than from habitat loss due to construction of new roads; an extensive road network overlaps a substantial portion of the GLSL DU (37% of IAO squares have roads; total length of 307 km), and almost completely covers the species' Carolinian range (94% of IAO squares have roads; total length of 3,354 km) (Figure 4). Traffic volumes are also expected to increase due to expanding human population.

Road mortality is one of the most conspicuous and commonly reported sources of foxsnake mortality in Canada. Foxsnakes will readily cross or bask near roads (Rivard 1976), placing them at risk. Outside of settled areas, road mortality and the isolating effect of roads (including genetic fragmentation) have been best documented on county roads and provincial highways (Row *et al*. 2010). Many protected areas still have high road densities and/or traffic volumes within or adjacent to their boundaries (Crowley 2006; Farmer and Brooks 2012; Choquette and Valliant 2016). Due to Ontario's extensive road network and the number of studies that have documented substantial Eastern Foxsnake mortality along relatively small stretches of road (Ashley and Robinson 1996; Brooks *et al*. 2000; MacKinnon *et al*. 2005; Farmer and Brooks 2012), the number of foxsnakes regularly killed on roads across their range is presumed to be considerable and potentially unsustainable. For example, a road mortality study of a 10 km section of road in the Georgian Bay region in 2003–2004 documented 16 dead foxsnakes (Brooks *et al*. 2003; Mackinnon 2005). A study of 13 km of arterial and collector roads at the Ojibway Prairie Complex in the Carolinian region documented 50 dead foxsnakes over two field seasons (Choquette and Valliant 2016). Ashley *et al.* (2007) demonstrated that 3% of motorists in one study intentionally ran over turtle and snake decoys placed on the road. Rudolph *et al.* (1999) documented abundances of large-bodied snakes in Texas that were ~50% lower within 450 m of moderately used roads when compared to abundances 850 m from roads. Even where road mortality mitigation measures have been installed, snake mortality may continue (e.g., snakes breaching barrier fences: Baxter-Gilbert *et al.* 2015; Gillingwater pers. comm. 2019).

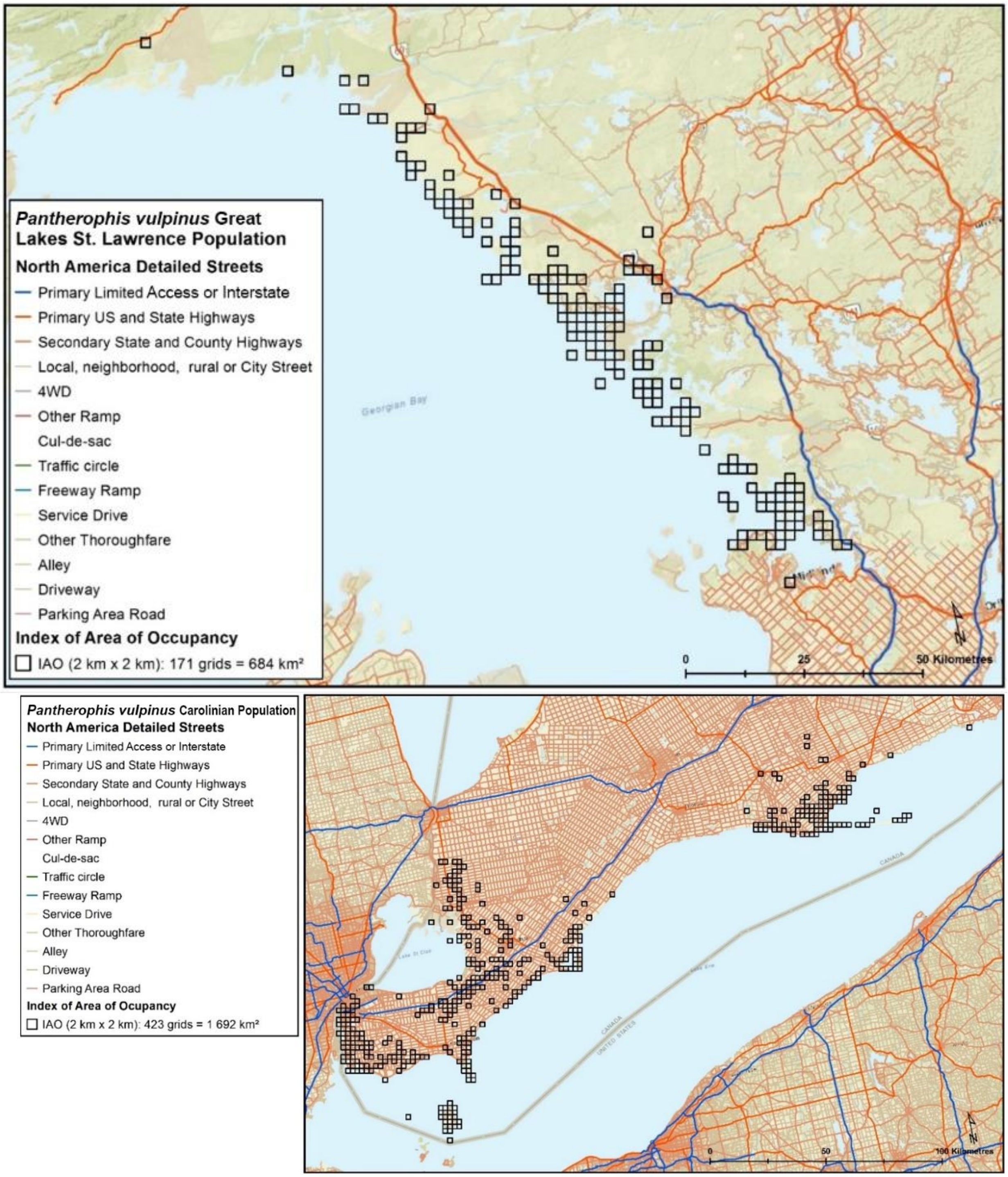

Figure 4. Current (1999–2018) occurrence records of Eastern Foxsnake, as represented by the open black squares (i.e., occupied IAO squares), plotted on a map of roads for the two designatable units: Great Lakes / St. Lawrence (GLSL; upper) and Carolinian (lower). Roads occur within 63/171 IAO squares in the GLSL DU, and 399/423 IAO squares in the Carolinian DU. Map prepared by Sydney Allen (COSEWIC Secretariat).

Population-level effects of road mortality have not been studied in foxsnakes. However, population models for several other large-bodied snakes have predicted road mortality will result in declines and increased local extinction risk. Middleton and Chu (2004) demonstrated that even one adult Eastern Massasauga rattlesnake killed per year on roads can increase the risk of extinction in a subpopulation of 100 snakes from zero to over 20% in 100 years. Row *et al*. (2007) demonstrated that estimated rates of Gray Ratsnake road mortality (9 adults per year) increased the probability of extinction of the local population (~400 adults) from 7.3% to 99% over 500 years. A population viability model developed by Winton *et al*. (2020) for a Western Rattlesnake (*Crotalus oreganus*) population of 2,131 individuals predicted a 97% decline over 100 years based on estimated rates of road mortality (141 snakes per year), despite this population occurring in a protected area with low road density. A stage-based population model of the Great Basin Gophersnake predicted that excess mortality from roadkill would result in a 40–50% reduction in population size over 3 generations (COSEWIC 2013). Similarly, a stage-based population model for the Gray Ratsnake in Canada predicted that 1% – 3% additional mortality would result in declines of 34% (CI 18-50%) and 57.5% (CI 38-77%), respectively, over the next 3 generations (COSEWIC 2018a). Based on observed rates of road mortality and road density across the range of the Gray Ratsnake, COSEWIC (2018a) inferred that additional mortality due to roads would likely fall within the range of these thresholds. Although there are some differences between the biology of these species and Eastern Foxsnake (e.g., Great Basin Gophersnake has similar generation time and age of maturity, but lower reproductive output of 2–8 eggs per clutch), and the scope and severity of local threats, the results of these models suggest that even small increases in annual mortality can result in significant declines in large-bodied snake populations.

Climate Change & Severe Weather (IUCN threat 11.0; overall impact for both DUs: medium-low)

Climate change may threaten Eastern Foxsnakes due to lake level fluctuations and increased frequency of severe storms (11.4: Storms & flooding), which in turn could impact groundwater levels and flood hibernation sites. Foxsnakes are concentrated during hibernation (see **Habitat**); therefore, high mortality rates during hibernation due to drowning places them at greater risk of local extinction. Brinker *et al.* (2018) used NatureServe's Climate Change Vulnerability Index to assess the relative vulnerability of Eastern Foxsnakes (among 280 other Great Lakes species) to climate change based on projected changes in temperature and moisture from both recent historical (1960–1990) records and near-future projections (2041–2071). Vulnerability was defined as "the degree to which a species is susceptible to and unable to cope with the adverse effects of climate change" (Brinker *et al.* 2018). Eastern Foxsnakes (Carolinian population) were considered to be "moderately vulnerable" (with 60–80% confidence), with primary risk factors being natural and anthropogenic barriers impeding recolonization after local extinction. Results suggest that foxsnake abundance and/or range extent within the Carolinian region are likely to decrease by 2050. The Great Lakes / St. Lawrence population, however, was considered "less vulnerable" (with <60% confidence), and although abundance and/or range extent are projected to change substantially by 2050, they could either increase or decrease.

Natural System Modifications (IUCN threat 7.0; overall impact for Carolinian DU: medium-low; for GLSL DU: low)

Foxsnakes are threatened by wild and prescribed fires (7.1: Fire and fire suppression), maintenance of drains/swales and berms (7.2: Dams & water management/use), and control of invasive European Common Reed (7.3: Other ecosystem modifications). Overall, the calculated threat impact is higher for the Carolinian DU (low-medium) than for the GLSL DU (low).

Wild and prescribed fires can result in direct mortality, sometimes of multiple individuals in a short time period. For example, at Rondeau Provincial Park in 2000, 18 adult Eastern Foxsnakes were found killed by an unplanned spring fire in the south end of the park (Gillingwater 2001). A wildfire spread across an 11,000-ha area within land adjacent to the GLSL DU in the summer of 2018 (caused by a wind energy development; White 2019). Despite no documentation of foxsnake mortality in the latter incident, wildfires can be a major threat to subpopulation viability of large snakes (e.g., Eastern Massasauga; Miller 2005). Even when fires are prescribed and well planned, snakes can be killed (Russell *et al.*1999; Cross *et al.* 2015). In the Carolinian DU, this threat is presumed to be limited to protected areas that continue to be managed for grasslands and savannah using prescribed fire, whereas in the GLSL DU wildfires may occur across vast undeveloped areas.

The maintenance of drains/swales and berms may cause foxsnake mortality and destruction of hibernation sites. For example, the maintenance of berms bordering wetlands at Long Point (i.e., dredging new material from the wetland and reforming eroding berms) resulted in the loss of at least one foxsnake hibernaculum (a Muskrat, *Ondatra zibethicus*, burrow; Gillingwater pers. comm. 2019). Drain maintenance includes roadside swales and municipal drains and occurs during active and hibernation seasons. Impacts are presumed greatest during the hibernation season, but vegetation removal could cause mortality/injury in the active season. This threat is concentrated within and across the Carolinian DU where there is a predominance of managed wetlands and municipal drains and roadside swales (380 drains in the Town of Essex alone: Town of Essex 2017). Since 2013, for example, 19 activities affecting Eastern Foxsnake or its habitat have been ‘registered’ under the Ontario ESA (mostly health and safety projects, or drainage works), and 68% of these were for projects in the Carolinian region (OMECP 2016).

Foxsnakes and their habitat may be impacted by the invasive European Common Reed, in addition to the intensive methods used to control large stands of the plant. This plant is incredibly widespread across the Carolinian region, particularly across the north shore of Lake Erie, and is present at many, if not most, wetland sites occupied by foxsnakes (Gillingwater pers. comm. 2020). Large monocultures of the plant do not appear to degrade Foxsnake habitat. Results from a radio-telemetry study at Rondeau Provincial Park from 2013-2018 suggest that foxsnakes do not avoid European Common Reed stands and are able to move through and use even dense stands (Davy pers. comm. 2020). Rather, negative impacts are presumed to be from control efforts during the active season (rolling, cutting, burning), potentially resulting in injury or death of snakes, followed by a short-term reduction in natural cover resulting in greater exposure to predators (Gillingwater pers. comm. 2020). Protected areas are heavily impacted by European Common Reed, and many parks are planning future removals including Point Pelee National Park (Government of Canada 2021).

Biological Resource Use (IUCN threat 5.0; overall impact for both DUs: low)

Foxsnakes are deliberately killed out of dislike or fear of snakes (5.1: Hunting and collecting of terrestrial animals) and because they are sometimes mistaken for venomous species (e.g., Eastern Massasauga, or the non-native Eastern Copperhead [*Agkistrodon contortix*]) due to their large size, reddish head, bold markings, and habit of vibrating their tail when alarmed (Rivard 1976). Human encounters with foxsnakes are common because much of the species' Canadian range occurs within a heavily populated area, and because the snakes inhabit sites that experience high levels of human use (e.g., shoreline, provincial parks). The number of permanent residents in the Georgian Bay Biosphere Reserve (GBBR) is ca. 20,000, with a seasonal population of ca. 1,000,000 people concentrated in readily accessible areas and along shorelines (GBBR 2014). Also, the number of permanent residents in the Carolinian region is ca. 617,000 (combined population of Windsor-Essex, Chatham-Kent, Norfolk, and Lambton counties, excluding Sarnia: Statistics Canada 2019a), with protected habitats welcoming ca. 714,000 visitors annually (combined visitors at Long Point, Rondeau and Wheatley provincial parks, and PPNP: Ontario Parks 2012; PCA 2019).

Eastern Foxsnakes are sometimes collected as pets (5.1: Hunting and collecting of terrestrial animals). Although foxsnakes do fairly well in captivity, few captive-bred individuals are available (Staszko and Walls 1994), creating a demand for wild snakes. The collection of wild foxsnakes as pets was previously discussed by Rivard (1976) and has been recently documented at the Ojibway Prairie Complex (Marks pers. comm. 2019) and at Long Point (SNN 2014). Foxsnakes have also been found in/near urban areas outside of their natural range and are presumed to have been illegally collected elsewhere and released (City of London: Gillingwater pers. comm. 2019; Town of Dundas: Yagi pers. comm. 2019).

Foxsnakes are adept at using human-made features and tend to end up in boat houses, sheds, basements, campsites, and on roads, placing them at an elevated risk of intentional killing or illegal collection, regardless of whether they are on private land in rural areas or on public land in protected areas (Rivard 1976; Gillingwater pers. comm. 2019). Even though some property owners no longer intentionally kill Eastern Foxsnakes on their land, persecution of the snakes by neighbours, workers (e.g., construction, landscaping, crop harvesting), or visitors (e.g., campers and hikers) still occurs on a regular basis (Gillingwater pers. comm. 2019). This threat is continuing in both DUs, occurring primarily in readily accessible protected areas and settlement areas, but also to a lesser extent across the rural landscape.

Pollution (9.0; overall impact for Carolinian DU: low; for GLSL DU: unknown)

Foxsnakes are threatened by entanglement in plastic mesh netting (9.4: Garbage and solid waste) and may also be threatened by agricultural chemical runoff (9.3: Agricultural and forestry effluents). The impact of plastic mesh netting has been demonstrated by the multitude of cases of snakes, including foxsnakes, becoming lethally entangled in the material, which is used for gardening, erosion control, and vegetation establishment (Kapfer and Paloski 2011). A 5-m section of nylon erosion fencing entangled and killed three Foxsnakes in Amherstburg (Kamstra pers. comm. 2008), M. Gartshore (pers. comm. 2008) observed three foxsnakes trapped in garden netting, Long Point cottagers have found dead and injured foxsnakes in garden netting (Gillingwater pers. comm. 2019), and T. Preney (pers. comm. 2019) rescued six entangled foxsnakes from suburban residences in Windsor and LaSalle. These incidental observations of dead or injured adults raise concern, but subpopulation-level impacts are unknown.

Foxsnakes may be threatened by herbicide and pesticide runoff from agricultural crops (Carolinian DU only). The potential for negative impacts from pesticide runoff (e.g., DDT) was discussed by Rivard (1976) and is based on pesticide residues found in Eastern Foxsnakes in the USA and Canada even decades after application had ceased (Meeks 1968; Russell *et al.* 1995). Ongoing studies provide more evidence of DDT residues in foxsnakes at PPNP (Dobbie pers. comm. 2020); however, direct evidence of short-term negative impacts is lacking.

Agriculture and Aquaculture (IUCN threat 2.0; overall impact for Carolinian DU: low; not scored as a threat for GLSL DU)

The expansion and intensification of agriculture (2.1: Annual & perennial non-timber crops) has resulted in permanent loss and degradation of foxsnake habitat and isolation of habitat patches, including the removal of hedgerows and riparian habitat. The types of agriculture involved are generally intensive crops like corn and soybean, and development of greenhouses, which provide little to no habitat. Although hay fields may provide relatively more suitable habitat based on vegetation cover, these crops are frequently harvested (2–3 times per season), exposing snakes to increased risk of mortality. In Essex County, for example, foxsnakes have been observed killed by hay mowers (e.g., Dobbie pers. comm. 2020). Using OMAFRA (2020) data, it is estimated that ~ 2% (48,484 acres / 196 km^2) of the combined land base in Essex, Chatham-Kent, Lambton and Haldimand-Norfolk counties were seeded in hay annually (on average) from 2004 - 2019. In contrast, ~ 55% (1,399,000 acres / 5,662 km^2) of the combined land base in Essex, Chatham-Kent, Lambton and Haldimand-Norfolk counties were seeded in soybean or grain corn annually (on average) from 2004 to 2019 (estimated using OMAFRA 2020 data).

Intensive agriculture has resulted in extreme levels of habitat loss in the Carolinian region (e.g., Essex County and Chatham-Kent; see **Habitat Trends**) and has fragmented foxsnakes into a number of isolated genetic clusters (see **Population Spatial Structure and Variability**). Also, Kerr and Cihlar (2004) show a strong link between agriculture and species endangerment. The current rate of habitat loss from agricultural activities, however, is much less than it was historically (see **Habitat Trends**). Using OMAFRA (2020) data, an increasing trend is observed in the number of acres of soybean and grain corn seeded in Essex, Chatham-Kent, Lambton, and Haldimand-Norfolk counties (combined) from the period 2009-2018, at a rate of ~ 1% per year (12,861 acres / 52 km^2).

<u>Residential and Commercial Development (IUCN threat 1.0; overall impact for Carolinian DU: negligible; for GLSL DU: low)</u>

The expansion of human settlements results in permanent loss and fragmentation of Foxsnake habitat, and the death of individuals during construction and operation. Human settlements may also act as population sinks due to the combined effects of many associated threats (Lawson 2004). In the Carolinian region, the Windsor Census Metropolitan Area (CMA) is the fourth fastest growing community in Canada (Statistics Canada 2019b), resulting in the destruction of natural areas for housing development (Town of LaSalle 2003). However, within the range of the Carolinian DU, most development has already taken place, and little additional habitat loss is expected over the next 10 years. From 2008 to 2015, 91% of the 23 'agreements' and 'overall benefit permits' issued under the Ontario *ESA Act* to mitigate and offset development activities impacting Eastern Foxsnake or their habitat (see **Protection, Status and Ranks**) were in the Carolinian region (OMECP 2016).

In the Georgian Bay region, settlement and associated infrastructure occupy less than 1% of the area (ecodistrict 5E-7: Wester *et al*. 2018). However, cottage development, which comprises a high proportion of the infrastructure in this region, is largely concentrated along the Eastern Georgian Bay Shoreline (including the islands). This results in a disproportionally high impact to the narrow band of Eastern Foxsnake habitat within the GLSL DU (COSEWIC 2008). The Eastern Georgian Bay region is continuing to experience high development pressure due to its proximity to the Greater Toronto Area and its appeal as "cottage country". In addition to increasing cottage development, recreational use, and associated changes to and pressures on habitat, a growing human population has resulted in further destruction of natural areas for commercial development in small urban centres to accommodate the influx of visitors and residents (GBBR 2014). Cottage development remains of continuing concern for the GLSL DU.

<u>Invasive & Other Problematic Species & Genes (IUCN threat 8.0; overall impact for both DUs: unknown)</u>

This threat was suspected to be of importance but there are many uncertainties about the severity of the threat at the population level. Foxsnakes are threatened by predation by cats and dogs (8.1: Invasive non-native/alien species), and may be threatened by the fungus causing Snake Fungal Disease (8.2: Problematic native species). Cats (*Felis cattus)* and Dogs (*Canis lupus familiaris*) are known to capture and kill many types of snakes (Whitaker and Shine 2000; Shine and Koenig 2001), including Eastern Foxsnakes (Gillingwater pers. comm. 2019; Paleczny *et al.* 2005). Juvenile snakes in general are disproportionately killed or injured compared to adults (Shine and Koenig 2001), somewhat mitigating threat severity.

The fungus *Ophidiomyces ophiodiicola* is the causal agent of the potentially lethal fungal skin infection “Snake Fungal Disease” (SFD) (Allender *et al.* 2015). SFD symptoms have been observed in Ontario Foxsnakes, including snakes from Long Point (Gillingwater pers. comm. 2019), Rondeau Provincial Park, and PPNP (Dobbie pers. comm. 2020). Preliminary data indicate that SFD did not reduce survivorship, body condition, or fitness in Eastern Foxsnakes from Rondeau Provincial Park; however, it may have slightly increased Foxsnake vulnerability to predation (Davy pers. comm. 2020). From 2015 to 2017 at PPNP, five Eastern Foxsnakes showing severe symptoms of SFD were monitored using radiotelemetry or mark-recapture, and two died within 2-4 months of release (one predated, one dead on road; remaining snakes survived at least one year after release; Dobbie pers. comm. 2020). SFD has been confirmed via PCR from across the GLSL DU and within the western half of the Carolinian DU (CWHC 2017). A review by Davy *et al*. (2021) concluded that the fungus is widespread and probably endemic in Ontario snakes, including Eastern Foxsnakes, and although incidents of disease leading to morbidity have been documented, there is no evidence of population impacts at this time.

Limiting Factors

Limiting factors that contribute to the vulnerability of the Eastern Foxsnake include seasonal migrations (see **Biology**) that expose the snakes to road mortality and other threats, living in a cold climate at the northern extremity of their range, and their propensity to concentrate at hibernacula. The numbers of Foxsnakes using a single hibernation site are higher in the Georgian Bay region than in the Carolinian region, which is consistent with the predicted pattern of increasing communal hibernacula use in temperate zone snakes with increasing latitude (Gregory 1982). Climate may also play a role in limiting the abundance or distribution of this species in the Georgian Bay region. For example, results from an occupancy modeling study suggest that Foxsnakes are much more likely to occur in warmer portions of their Canadian range, regardless of habitat loss and road density, which may explain why foxsnakes are not more widespread in the GLSL DU (Paterson pers. comm. 2020; see **Search Effort**).

When concentrated at hibernation sites, Eastern Foxsnakes are vulnerable to natural disturbance and stochastic events (i.e., rising water table, flooding, collapse, temperature extremes, and predation), which can result in mortality and on occasion catastrophic loss of individuals (e.g., Shine and Mason 2004). For example, the cave in/flooding of a hibernation area resulted in the death of six Eastern Foxsnakes at PPNP (Watson 1994). Three of 23 radio-tracked foxsnakes died overwinter at Georgian Bay Islands National Park when they were excavated from one of the few soil-based hibernacula by a mammal (Lawson 2004). Also, collapse of access points resulted in the trapping of hibernating Eastern Foxsnake in limestone substrates on Pelee Island (Porchuk 1996). One communal hibernaculum at Killbear Provincial Park was depredated over winter causing the demise of dozens of adults (Paleczny *et al.* 2005). Unpredictable mortality events due to environmental stochasticity are an important limitation threatening already small and isolated local populations with extirpation.

Number of Threat-based Locations

A location is a geographically distinct area in which a single threatening event can rapidly affect all individuals of the species that are present within a short period (COSEWIC 2018b). For the purpose of defining threat locations, the most serious plausible threats to the species (in terms of impact) are those brought about by transportation corridors, climate change, and natural systems modifications. The effects of these threats are cumulative and not necessarily due to single events, such as individual developments or roads, resulting in some uncertainty regarding adequate characterization of locations. The number of threat-based locations for both DUs of Eastern Foxsnake is unknown, but it is likely large, greatly exceeding ten.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

In Canada, Eastern Foxsnake is afforded protection in National Parks through the Canada *National Parks Act*, in National Wildlife Areas through the *Canada Wildlife Act* (R.S. 1985, c. W-9), and on all federal lands since 2003 via the *Species at Risk Act* (listed as "*Pantherophis gloydi"*; Carolinian and GLSL populations both listed as Endangered on Schedule 1). A recovery strategy for Eastern Foxsnake in Canada was published in 2020, wherein designated critical habitat is described (ECCC 2020). This species is not protected under the CITES convention (CITES 2019) or the U.S. *Endangered Species Act* (USFWS 2019), but is listed as threatened in the state of Michigan (MSU 2021).

Ontario's *Endangered Species Act* (ESA) came into force in 2008 and makes it illegal to kill, harm, harass, capture, or take an Eastern Foxsnake in the province, or damage or destroy its habitat (listed as "*Pantherophis gloydi"*; Carolinian population is listed as Threatened and GLSL population is listed as Endangered; OMECP 2016). A recovery strategy for Eastern Foxsnake in Ontario was published in 2010, followed by a government response statement in 2011, and a specific habitat regulation for each DU in 2012 (EFRT 2010; OMECP 2016). Between 2008 and 2015, three convictions (fines from $12,000 to $20,000) were obtained for contraventions of the ESA related to Eastern Foxsnake (OMECP 2016). See Plotkin *et al.* (2017) and Curran (2018) for a critique of the effectiveness of current legal protection for endangered species (including Eastern Foxsnake) in Ontario. Eastern Foxsnake is also listed as a "specially protected reptile" under the Ontario *Fish and Wildlife Conservation Act,* which makes it illegal to harass, possess (without a permit), or kill the species.

Non-Legal Status and Ranks

Eastern Foxsnake (*Pantherophis vulpinus*) has a global rank of G5 (Secure) and national ranks of N5 (Secure: USA) and N3 (Vulnerable: Canada). The sub-national ranks are as follows: S5 (Secure: Illinois), S4S5 (Secure/Apparently Secure: Wisconsin), S4 (Apparently Secure: Indiana), S3 (Vulnerable: Ohio, Ontario), S1 (Critically Imperilled:

Missouri), and SNR (Status Not Ranked: Michigan) (NatureServe 2020). The IUCN lists the species as Least Concern (Hammerson 2019).

Habitat Protection and Ownership

The eastern Georgian Bay coastline is considered “one of the longest and largest corridors of almost continuous protected landscape/waterscape in south-central Ontario” (GBBR 2004), whereas the Mixed Woods Plains Ecozone of southwestern Ontario and Quebec (which the Carolinian region is a part of) is considered “…at best, nearly devoid of protected areas” (Kerr and Cihlar 2004). There are ~140,789 ha (1,407.89 km^2) of national parks, national wildlife areas, provincial parks, and provincial conservation reserves entirely or partially within the Canadian distribution of Eastern Foxsnake. The overwhelming majority (91%) of this publicly owned land is located within the GLSL DU, which contains over ten times the amount of protected land than the Carolinian DU (128,240 ha versus 12,548 ha). At the landscape scale, this equates to a negligible proportion of the Carolinian DU in protected areas, compared to about one third in the GLSL DU. For example, protected areas represent less than 1% of ecodistricts 7E-1 and 7E-2 combined (Carolinian DU included within), while ~27% of ecodistrict 5E-7 (includes entire GLSL DU) contains protected areas (Wester *et al.* 2018). Also, 44% of the Georgian Bay Biosphere Reserve land base (which closely approximates the GLSL DU boundary) is made up of provincial and federal protected areas (GBBR 2004).

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INFORMATION SOURCES

Allender, M.C., D.B. Raudabaugh, F.H. Gleason, and A.N. Miller. 2015. The natural history, ecology, and epidemiology of *Ophidiomyces ophiodiicola* and its potential impact on free-ranging snake populations. Fungal Ecology 17:187-196.

Ashley, E.P., A. Kosloski, and S.A. Petrie. 2007. Incidence of intentional vehicle–reptile collisions. Human Dimensions of Wildlife 12:137-143.

Ashley, E.P., and J.T. Robinson. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie, Ontario. Canadian Field- Naturalist 110:403-412.

Baird, S.F., and C. Girard. 1853. Catalogue of North American reptiles in the museum of the Smithsonian Institution; part I: serpents. Smithsonian Misc. Coll. 2. xvi+172 pp.

Baxter-Gilbert, J.H., J.L. Riley, D. Lesbarrères, and J.D. Litzgus. 2015. Mitigating reptile road mortality: fence failures compromise ecopassage effectiveness. PLos one 10(3):p.e0120537.

Beck, G., pers. comm. 2019. *Personal Communication to J. Choquette*. Senior Conservation Advisor, Bird Studies Canada, Port Rowan, Ontario.

Blott, C., pers. comm. 2019. *Personal communication to J. Choquette*. Biotechnical Services, Haldimand Stewardship Council, Cayuga, Ontario.

Brinker, S.R., M. Garvey, and C.D. Jones. 2018. Climate change vulnerability assessment of species in the Ontario Great Lakes Basin. Ontario Ministry of Natural Resources and Forestry, Science and Research Branch, Peterborough, Ontario. Climate Change Research Report CCRR-48. 85 p. + appendices.

Brooks, R.J., A. Lawson, C.A. MacKinnon, and R.J. Willson. 2003. Ecology of Eastern Foxsnake populations in Georgian Bay. Unpubl. report for the Endangered Species Recovery Fund, WWF-Canada and Environment Canada, Toronto and Ottawa, Ontario.

Brooks, R.J., R.J. Willson, and J.D. Rouse. 2000. Conservation and ecology of three rare snake species on Pelee Island. Report for the Endangered Species Recovery Fund, WWF-Canada and Environment Canada, Toronto and Ottawa, Ontario.

Canadian Wildlife Health Cooperative (CWHC). 2017. Snake Fungal Disease in Canada Rapid Threat Assessment. Canadian Wildlife Health Cooperative, Guelph, Ontario. 45 pp.

Carroll, E., pers. comm. 2019. *Personal communication to J. Choquette.* Director of Biology, St. Clair Region Conservation Authority.

Catling, P.M., and B. Freedman. 1980. Variation in distribution and abundance of four sympatric species of snakes at Amherstburg, Ontario. Canadian Field-Naturalist 94:19-27.

Choquette, J.D., and L. Valliant. 2016. Road mortality of reptiles and other wildlife at the Ojibway Prairie Complex and Greater Park Ecosystem in southern Ontario. The Canadian Field-Naturalist 130:64-75.

Conant, R. 1940. A new subspecies of the foxsnake, *Elaphe vulpina* Baird and Girard. Herpetologica 2:1-14.

Conant, R., and J. T. Collins. 1991. A Field Guide to Reptiles and Amphibians of Eastern and Central North America. 3rd edition. Houghton Mifflin Co., Boston, Massachusetts. 450 pp.

Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES). 2019. CITES Appendices I, II and III. CITES Secretariat, Geneva, Switzerland. Website: https://www.cites.org/eng/app/appendices.php [accessed 6 Dec. 2019].

Cook, F.R., pers. comm. 1998. *Personal communication to R. Willson.* Researcher Emeritus, Research Associate, Canadian Museum of Nature, Ottawa, Ontario.

Corey, S.J., H.L. Gibbs, F. Mohammed, and K.A. Prior. 2005. Genetic analysis of Eastern and Western Foxsnakes. Unpubl. manuscript. 23 pp. Cited in COSEWIC (2008).

COSEWIC. 2008. COSEWIC assessment and status report on the Eastern Foxsnake *Elaphe gloydi* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ontario. viii + 45 pp.

COSEWIC. 2013. COSEWIC assessment and status report on the Great Basin Gophersnake *Pituophis catenifer deserticola* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ontario. xi + 53 pp.

COSEWIC. 2018a. COSEWIC assessment and status report on the Gray Ratsnake *Pantherophis spiloides*, Great Lakes / St. Lawrence population and Carolinian population in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. Xvi + 44 pp.

COSEWIC. 2018b. Instructions for preparing COSEWIC status reports. Committee on the Status of Endangered Wildlife in Canada. Ottawa. Website: http://cosewic.ca/index.php/en-ca/reports/preparing-status-reports/instructions-preparing-status-reports [accessed 6 Dec. 2019].

Cross, M.D., K.V. Root, C.J. Mehne, J. McGowan-Stinski, D. Pearsall, and J.C. Gillingham. 2015. Multi-scale responses of Eastern Massasauga Rattlesnakes (*Sistrurus catenatus*) to prescribed fire. The American Midland Naturalist 2015:346-362.

Crother, B.I. (ed.). 2017. Scientific and Standard English Names of Amphibians and Reptiles of North America North of Mexico, with Comments Regarding Confidence in our Understanding. Eighth Edition. Society for the Study of Amphibians and Reptiles Herpetological Circular 43.

Crother, B.I., M.E. White, J.M. Savage, M.E. Eckstut, M.R. Graham, and D.W. Gardner. 2011. A reevaluation of the status of the Foxsnakes *Pantherophis gloydi* Conant and *P. vulpinus* Baird and Girard (Lepidosauria). ISRN Zoology 2011:436049.

Crowley, J.F. 2006. Are Ontario reptiles on the road to extinction? Anthropogenic disturbances and reptile distributions within Ontario. MSc. Thesis, University of Guelph, Guelph, Ontario. 67 pp.

Curran, A. 2018. Assessing the implementation of Ontario's overall benefit permit application: A case study approach. MES dissertation, Nipissing University, North Bay, Ontario. 77 pp.

Davy, C., pers. comm. 2020. *Personal communication with J. Choquette.* Wildlife Research Scientist (Species at Risk), Ontario Ministry of Natural Resources and Forestry, Trent University, Peterborough, Ontario.

Davy, C. M., L. Shirose, D. Campbell, R. Dillon, C. McKenzie, N. Nemeth, T. Braithwaite, H. Cai, T. Degazio, T. Dobbie, S. Egan, H. Fotherby, J. Litzgus, P. Manorome, S. Marks, J.E. Paterson, L. Sigler, D. Slavic, E. Slavik, J. Urquhart, and C. Jardine. 2021. Revisiting Ophidiomycosis (Snake Fungal Disease) after a decade of targeted research. Frontiers in Veterinary Science 8:1-10. DOI=10.3389/fvets.2021.665805

Degazio, T., pers. comm. 2020. *Personal communication with J. Choquette.* Point Pelee National Park, Parks Canada Agency, Leamington, Ontario.

DeGregorio, B.A., B.J. Putman, and B.A. Kingsbury. 2011. Which habitat selection method is most applicable to snakes? Case studies of the Eastern Massasauga (*Sistrurus catenatus*) and Eastern Foxsnake (*Pantherophis gloydi*). Herpetological Conservation and Biology 6:372-382.

Dileo, M.F., J.D. Rouse, J.A. Dávila, and S.C. Lougheed. 2013. The influence of landscape on gene flow in the Eastern Massasauga rattlesnake (*Sistrurus c. catenatus*): insight from computer simulations. Molecular Ecolology 22:4483-4498.

DiLeo, M.F., J.R. Row, and S.C. Lougheed. 2010. Discordant patterns of population structure for two co-distributed snake species across a fragmented Ontario landscape. Diversity and Distributions 16:571-581.

Dobbie, T., pers. comm, 2020. *Personal communication to J. Choquette.* Park Ecologist - Species at Risk and Greater Park Ecosystem, Point Pelee National Park, Parks Canada Agency, Leamington, Ontario.

Ducks Unlimited Canada (DUC). 2010. Southern Ontario Wetland Conversion Analysis. Ducks Unlimited Canada, Barrie, Ontario. 23 pp + appendices.

Eastern Foxsnake Recovery Team (EFRT). 2010. Recovery strategy for the Eastern Foxsnake (Pantherophis gloydi) – Carolinian and Georgian Bay populations in Ontario. Ontario Recovery Strategy Series. Prepared for the Ontario Ministry of Natural Resources, Peterborough, Ontario. vi + 39 pp.

Environment and Climate Change Canada (ECCC). 2017. The Canadian Wildlife Service Biodiversity Atlas: Southern and Central Ontario. Environment and Climate Change Canada, Toronto, Ontario.

Environment and Climate Change Canada (ECCC). 2020. Recovery Strategy for the Eastern Foxsnake (*Pantherophis gloydi*), Carolinian and Great Lakes / St. Lawrence populations, in Canada. Species at Risk Act Recovery Strategy Series. Environment and Climate Change Canada, Ottawa, Ontario. 3 parts, 38 pp. + vi + 39 pp. + 5 pp.

Erskine, M. 2019. Feds commit $169.2 million to four laning Hwy 69. Manitoulin Exposition, 29 May 2019. Website: https://www.manitoulin.ca/feds-commit-169-2-million-to-four-laning-hwy-69/ [accessed 29 July 2020].

Essex Region Conservation Authority (ERCA). 2006. Essex Region Watershed Report Card 2006. Essex Region Conservation Authority, Essex, Ontario. 4 pp.

Essex Region Conservation Authority (ERCA). 2012. Essex Region Watershed Report Card 2012. Essex Region Conservation Authority, Essex, Ontario. 8 pp.

Essex Region Conservation Authority (ERCA). 2018. Essex Region Watershed Report Card 2018. Essex Region Conservation Authority, Essex, Ontario. 8 pp.

Farmer, R.G., and R.J. Brooks. 2012. Integrated risk factors for vertebrate roadkill in southern Ontario. The Journal of Wildlife Management 76:1215-1224.

Frankham, R. 1995. Effective population size/adult population size ratios in wildlife: a review. Genetics Research 66: 95-107.

Frankham, R., J.D. Ballou, and D.A. Briscoe. 2004. A Primer of Conservation Genetics. Cambridge University Press, Cambridge, United Kingdom. 220 pp.

Freedman, W., and P.M. Catling. 1978. Population size and structure of four sympatric species of snakes at Amherstburg, Ontario. Canadian Field-Naturalist 92:167-173.

Gartshore, M.E., pers. comm. 2008. *Personal communication with R. Willson.* Owner, Pterophylla Native Plants and Seeds, Walsingham, Ontario.

Gaston, K.J., and R.A. Fuller. 2009. The sizes of species' geographic ranges. Journal of Applied Ecology 46:1-9.

Georgian Bay Biosphere Reserve Inc. (GBBR). 2004. Nomination Submission from Canada for the Georgian Bay Littoral Biosphere Reserve. Georgian Bay Biosphere Reserve Inc., Parry Sound, Ontario. 186 pp.

Georgian Bay Biosphere Reserve Inc. (GBBR). 2014. Georgian Bay Biosphere Reserve Self Study Document in Preparation for the 2014 Periodic Review. Georgian Bay Biosphere Reserve Inc., Parry Sound, Ontario. 89 pp. + appendices.

Georgian Bay Biosphere Reserve Inc. (GBBR). 2019. State of the Bay. Georgian Bay Biosphere Reserve, Parry Sound, Ontario. Website: https://www.stateofthebay.ca/our-species-at-risk/ [accessed 9 Nov. 2019].

Gillingwater, S.D. 2001. A selective herpetofaunal survey, inventory and biological research study of Rondeau Provincial Park. Upper Thames River Conservation Authority, London, Ontario. 94 pp. + appendices.

Gillingwater, S.D., pers. comm. 2008. *Personal communication to R. Willson.* Species at Risk Biologist, Upper Thames Region Conservation Authority, London, Ontario.

Gillingwater, S.D., pers. comm. 2019 and 2020. *Personal communication to J. Choquette.* Species at Risk Biologist, Upper Thames Region Conservation Authority, London, Ontario.

Government of Canada. 2021. Point Pelee marsh restoration project. Website: https://aeic-iaac.gc.ca/050/evaluations/proj/80420?culture=en-CA [accessed September 2021].

Gregory, P. T. 1982. Reptilian hibernation. pp. 53-154 *in* C. Gans and F. H. Pough. (eds.), Biology of the Reptilia, Academic Press, London.

Hammerson, G.A. 2019. *Pantherophis vulpinus*. The IUCN Red List of Threatened Species 2019: e.T90069683A90069697. Website: https://www.iucnredlist.org/species/90069683/90069697 [accessed 6 Dec. 2019].

Harding, J.H. 1997. Amphibians and Reptiles of the Great Lakes Region. University of Michigan Press, Ann Arbor, Michigan. 378 pp.

Hazell, M., pers. comm. 2020. *Personal communication to J. Choquette.* Senior Biologist, WoodPLC, Toronto, Ontario.

Infrastructure Ontario (IO). 2015. Rt. Hon. Herb Gray Parkway. Infrastructure Ontario, Toronto, ON. Website https://www.infrastructureontario.ca/Rt-Hon-Herb-Gray-Parkway/ [accessed 3 Dec 2019].

Irwin, M. 2020. Highway 40 widening raised at Ontario budget consultation. Blackburn News, 29 January, 2020. Website: https://blackburnnews.com/sarnia/sarnia-news/2020/01/29/highway-40-widening-raised-ontario-budget-consultation/. [accessed 29 July 2020].

IUCN. 2012. IUCN - CMP Unified Classification of Direct Threats. International Union for the Conservation of Nature, Cambridge, UK. 20pp. Website: https://nc.iucnredlist.org/redlist/content/attachment_files/dec_2012_guidance_threats_classification_scheme.pdf [accessed 30 Nov. 2019].

IUCN Standards and Petitions Committee (IUCN SPC). 2019. Guidelines for Using the IUCN Red List Categories and Criteria. Version 14. Prepared by the Standards and Petitions Committee. Website: http://www.iucnredlist.org/documents/RedListGuidelines.pdf. [accessed 8 July 2020].

Kamstra, J., pers. comm. 2008. *Personal communication to R. Willson.* Author of Eastern Foxsnake recovery plan.

Kapfer, J.M., and R.A. Paloski. 2011. On the threat to snakes of mesh deployed for erosion control and wildlife exclusion. Herpetological Conservation and Biology 6:1-9.

Kerr, J.T., and J. Cihlar. 2004. Patterns and causes of species endangerment in Canada. Ecological Applications 14:743-753.

Kraus, D T. 1991. Herptile records of Point Pelee National Park and the surrounding region. Unpublished report for Point Pelee National Park, Leamington, Ontario.

Kraus, F., and G.W. Schuett. 1983. A melanistic *Elaphe vulpina* from Ohio Herpetological Review 14:10-11.

Lawson, A. 2004. Update on assessment of eastern foxsnake (*Elaphe gloydi*) movement patterns and habitat use in Killbear Provincial Park: Year-end report. Unpublished report, Ontario Parks, Killbear Provincial Park.

Lawson, A., pers. comm. 2005. *Personal communication with J. Kamstra*. October, 2005. M.Sc. student, University of Guelph, Ontario.

Lawson, A. 2005. Potential for gene flow among foxsnake (*Elaphe gloydi*) hibernacula of Georgian Bay, Canada. M.Sc. dissertation, University of Guelph, Ontario, Canada. 52pp.

LGL Ltd. (LGL) and URS. 2010. Eastern Foxsnake (*Elaphe gloydi*) management, monitoring and habitat restoration plan prepared in accordance with Permit No. AY-D-001-09 Issued Under the Authority of Clause 17(2)(d) of the *Endangered Species Act*, 2007. Prepared for Ontario Ministry of Transportation, Toronto, Ontario. 76 pp. + appendices.

Lindermeyer, D., and M. Burgman. 2005. Practical Conservation Biology. CSIRO Publishing, Collingwood, Victoria, Australia. 609 pp.

Long Point Region Conservation Authority (LPRCA). 2013. Long Point Region Watershed Report Card 2013. Long Point Region Conservation Authority, Tillsonburg, Ontario. 8 pp.

Long Point Region Conservation Authority (LPRCA). 2018. Long Point Region Watershed Report Card 2018. Long Point Region Conservation Authority, Tillsonburg, Ontario. 2 pp.

Long Point World Biosphere Reserve Foundation (LPWBRF). 2018. Long Point Biosphere: Ontario's first priority place for conservation investment. Website: https://longpointbiosphere.com/ [accessed 30 July 2020].

Lower Thames Valley Conservation Authority (LTVCA). 2013. Lower Thames Valley Watershed Report Card 2013. Lower Thames Valley Conservation Authority, Chatham, Ontario. 8 pp.

Lower Thames Valley Conservation Authority (LTVCA). 2018. Lower Thames Valley Watershed Report Card 2018. Lower Thames Valley Conservation Authority, Chatham, Ontario. 2 pp.

Lower Thames Valley Conservation Authority (LTVCA). 2019. 2018 Annual Report. Lower Thames Valley Conservation Authority, Chatham, Ontario. 26 pp.

MacKenzie, A., pers. comm. 2019. *Personal communication with J. Choquette.* Resource Management & Natural Heritage Education Supervisor, Pinery Provincial Park, Ontario Parks, Grand Bend, Ontario.

MacKinnon, C.A. 2005. Spatial ecology, habitat use and mortality of the Eastern Foxsnake (*Elaphe gloydi*) in the Georgian Bay area. MSc dissertation, University of Guelph, Ontario. 66 pp.

MacKinnon, C.A., L.A. Moore, and R.J. Brooks. 2005. Why did the reptile cross the road? Landscape factors associated with road mortality of snakes and turtles in the south eastern Georgian Bay area. Proceedings from the 2005 Parks Research Forum of Ontario (PRFO):153-166.

MacKinnon, C.A., pers. comm. 2008. *Personal communication with R. Willson*. University of Guelph M.Sc. student, Guelph, Ontario.

MacKinnon, C.A., A. Lawson, E.D. Stevens, and R.J. Brooks. 2006. Body temperature fluctuations in free-ranging eastern foxsnakes (*Elaphe gloydi*) during cold-water swimming. Canadian Journal of Zoology 84:9-19.

Marks, S., pers. comm. 2019. *Personal communication to J. Choquette.* Species at Risk Snake Specialist - Herb Gray Parkway project, John Wood Group PLC Inc., Windsor, Ontario.

McKay, V., pers. comm. 2006. *Personal communication with J. Kamstra.* Species at Risk Biologist, Point Pelee National Park, Ontario.

M'Closkey, R.T., C. Watson, and J. Barten. 1995. Eastern Fox Snake status investigation, Point Pelee National Park. Unpubl. report for Parks Canada, Gatineau, Québec. 69 pp.

Meeks, R.L. 1968. The accumulation of 36th ring-labelled DDT in a fresh water marsh. J. Wildlife Management 32:376-398.

Michigan State University (MSU). 2021. Michigan's Rare Animals. Michigan Natural Features Inventory, MSU Extension. Michigan State University, East Lansing, Michigan. Website: https://mnfi.anr.msu.edu/species/animals [accessed 18 February 2021].

Middleton, J., and J.Y. Chu. 2004. Population Viability Analysis (PVA) of the Eastern Massasauga rattlesnake, *Sistrurus catenatus catenatus*, in Georgian Bay Islands National Park and Elsewhere in Canada. Centre for the Environment, Brock University, St. Catharines, Ontario. 52 pp.

Miller, P. 2005. Population viability assessment for the Eastern Massasauga Rattlesnake (*Sistrurus catenatus catenatus*) on the Bruce Peninsula, Ontario, Canada. Prepared with IUCN/SSC Conservation Breeding Specialist Group and in collaboration with participants of the Third International Eastern Massasauga Symposium, October 2005, Toronto Zoo, Toronto, Ontario. 39 pp.

Mitrovich, M., J. Diffendorfer, and R. Fisher. 2009. Behavioral response of the Coachwhip (*Masticophis flagellum*) to habitat fragment size and isolation in an urban landscape. Journal of Herpetology 34:646-656.

NatureServe. 2019. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Website: http://explorer.natureserve.org [accessed 6 Dec. 2019].

NatureServe. 2020. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Website: http://explorer.natureserve.org [accessed 18 February 2021].

Ontario Biodiversity Council (OBC). 2015. State of Ontario's Biodiversity [web application]. Ontario Biodiversity Council, Peterborough, Ontario. Website: http://ontariobiodiversitycouncil.ca/sobr [accessed 11 Nov. 2019].

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). 2020. Statistics: Field Crops, Area and Production Estimates by County (2004 -2019). Website: http://www.omafra.gov.on.ca/english/stats/crops/index.html [accessed 29 July 2020].

Ontario Ministry of the Environment, Conservation and Parks (OMECP). 2016. Five-year review of progress towards the protection and recovery of Ontario's species at risk – 2016. Ministry of the Environment, Conservation and Parks, Toronto, Ontario. Website: https://www.ontario.ca/document/five-year-review-progress-towards-protection-and-recovery-ontarios-species-risk-2016 [accessed 4 Dec. 2019].

Ontario Ministry of Environment, Conservation and Parks (OMECP). 2019. Round Lake Provincial Park Management Statement. Website: https://www.ontario.ca/page/round-lake-provincial-park-management-statement [accessed 30 July 2020].

Ontario Ministry of Northern Development and Mines (OMNDM). 2017. Ontario Northern Highways Program 2017-2021. Ontario Ministry of Northern Development and Mines, Sudbury, Ontario. 36 pp.

Ontario Ministry of Transportation (OMT). 2016. Highway 69 Four-Laning. Ministry of Transportation of Ontario, Northeastern Region, North Bay, Ontario. Website: http://files.news.ontario.ca.s3-website-us-east-1.amazonaws.com/mndmf/en/learnmore/ontario_upgrading_northern_highways_and_bridges/Highway%2069%20Four-laning%20Map%20%28English%29.pdf [accessed 3 Dec. 2019].

Ontario Ministry of Transportation (OMT). 2017. Ontario Southern Highways Program 2017-2021. Ontario Ministry of Transportation, Toronto, Ontario. 51 pp.

Ontario Nature. 2019. Ontario Reptile and Amphibian Atlas: Eastern Foxsnake. Online mapping tool. Website: https://ontarionature.org/oraa/maps/ [accessed 13 Sept 2019].

Ontario Parks. 2012. Park Statistics 2011. Ontario Parks, Ministry of Natural Resources - Operations & Development Section, Peterborough, Ontario. Website:

Ontario Parks. 2019. Park Locator. Website: https://www.ontarioparks.com/park-locator [accessed 30 July 2020].

Paleczny, D., A. Lawson, K. Otterbein, P. Walsh, and L. Chora. 2005. Species at risk and park development: The eastern foxsnake and the Killbear Provincial Park visitor centre. Pp. 167-180 in G. Nelson, T. Nudds, M. Beveridge, and B. Dempster (eds.). Protected Areas and Species and Ecosystems at Risk: Research and Planning Challenges. Proceedings of the Parks Research Forum of Ontario (PRFO) and Carolinian Canada Coalition (CCC) Annual General Meeting, University of Guelph, Guelph, Ontario.

Parks Canada Agency (PCA). 2010. Point Pelee National Park of Canada Management Plan. Parks Canada Agency, Leamington, ON. 81 pp.

Parks Canada Agency (PCA). 2019. Parks Canada Attendance 2018-19. Parks Canada Agency, Gaineau, QC. Website: https://www.pc.gc.ca/en/docs/pc/attend [accessed 3 Dec. 2019].

Paterson, J., pers. comm. 2020. *Personal Communication to J. Choquette.* Liber Ero Fellow, Environmental and Life Sciences Program, Trent University, Peterborough, Ontario.

Plotkin, R., L. Podolsky, A. Bell, J. Boan, and S. McDonald. 2017. Without a Trace? Reflecting on the 10th anniversary of Ontario's Endangered Species Act, 2007. David Suzuki Foundation, Ontario Nature and Ecojustice, Toronto, Ontario. 19 pp.

Porchuk, B.D. 1996. Ecology and conservation of the endangered blue racer snake (*Coluber constrictor foxii*) on Pelee Island, Canada. MSc dissertation, University of Guelph, Ontario. 162 pp.

Porchuk, B.D., pers. comm. 1998. *Personal Communication to R. Willson and K. Prior.* Blue Racer researcher, Wilds of Pelee Island, Pelee Island, Ontario.

Porchuk, B.D. and R.J. Brooks. 1995. Natural history: *Coluber constrictor*, *Elaphe vulpina* and *Chelydra* reproduction. Herpetological Review 26:148.

Preney, T., pers. comm. 2019. *Personal communication to J. Choquette.* Biodiversity Coordinator, Ojibway Nature Centre, City of Windsor, Ontario.

Promaine, A., pers. comm. 2020. *Personal communication to J. Choquette.* Resource Conservation Manager ll, Georgian Bay Islands National Park, Parks Canada Organization, Honey Harbour, Ontario.

Rivard, D.H. 1976. The biology and conservation of Eastern Foxsnakes (*Elaphe vulpina gloydi* Conant). MSc. Dissertation, Carleton University, Ottawa, Ontario. 64 pp.

Rivard, D.H. 1979. The status of the Eastern Foxsnake (*Elaphe vulpina gloydi*), in Canada. Report to Parks Canada, Gaineau, Quebec. 33 pp.

Row. J., pers. comm. 2019. *Personal communication to J. Choquette.* Biostatistician, Minnow Environmental Inc., Georgetown, Ontario.

Row, J.R., G. Blouin-Demers, and S.C. Lougheed. 2010. Habitat distribution influences dispersal and fine-scale genetic population structure of Eastern Foxsnakes (*Mintonius gloydi*) across a fragmented landscape. Molecular Ecology 19:5157-5171.

Row, J.R., G. Blouin-Demers, and S.C. Lougheed. 2012. Movements and habitat use of Eastern Foxsnakes (*Pantherophis gloydi*) in two areas varying in size and fragmentation. Journal of herpetology 46:94-100.

Row, J.R., G. Blouin-Demers, and P.J. Weatherhead. 2007. Demographic effects of road mortality in black ratsnakes (*Elaphe obsoleta*). Biological Conservation 137:117-124.

Row, J.R., R.J. Brooks, C.A. Mackinnon, A. Lawson, B.I. Crother, M. White, and S.C. Lougheed. 2011. Approximate Bayesian computation reveals the factors that influence genetic diversity and population structure of Foxsnakes. Journal of Evolutionary Biology 24:2364-2377.

Row, J.R., Z. Sun, C. Cliffe, and S.C. Lougheed. 2008. Isolation and characterization of microsatellite loci for Eastern Foxsnakes (*Elaphe gloydi*). Molecular ecology resources 8:965-967.

Rowell, J.C. 2012. The Snakes of Ontario: Natural History, Distribution and Status. Art Bookbindery, Winnipeg, Manitoba. 411pp.

Rudolph, D.C., S.J. Burgdort, R.N. Conner, and R.R. Schaefer. 1999. Preliminary evaluation of the impact of roads and associated vehicular traffic on snake populations in eastern Texas. Pp. 129–136, in G. L. Evink, P. Garrett, D. Zeigler, and J. Berry (eds.). Proceedings of the International Conference on Wildlife Ecology and Transportation. Florida Department of Transportation, Tallahassee, Florida.

Russell, R.W., S.J. Hecnar, G.D., Haffner and R.T. M'Closkey. 1995. Organochlorine contaminants in Point Pelee National Park marsh fauna (1994). Report to Parks Canada, Leamington, Ontario. 150 pp.

Russell, K.R., D.H. Van Lear, and D.C. Guynn. 1999. Prescribed fire effects on herpetofauna: review and management implications. Wildlife Society Bulletin 27:374-384.

Shine, R., and J. Koenig. 2001. Snakes in the garden: an analysis of reptiles "rescued" by community-based wildlife carers. Biological Conservation 102:271-283.

Shine, R., and R.T Mason. 2004. Patterns of mortality in a cold-climate population of garter snakes (*Thamnophis sirtalis parietalis*). Biological Conservation 120:201-210.

Smith, K. 2019. Eastern Foxsnake use of artificial nesting boxes: A literature review. St. Clair Region Conservation Authority, Strathroy, Ontario. 16pp + appendices.

Snell, E.A. 1987. Wetland distribution and conversion in southern Ontario. Inland waters and lands directorate working paper No. 48. Inland Waters and Lands Directorate, Environment Canada, Ottawa, Ontario. 53 pp.

St. Clair Region Conservation Authority (SCRCA). 2008. St. Clair Region Watershed Report Card 2008. St. Clair Region Conservation Authority, Strathroy, Ontario. 39 pp.

St. Clair Region Conservation Authority (SCRCA). 2013. St. Clair Region Watershed Report Card 2013. St. Clair Region Conservation Authority, Strathroy, Ontario. 4 pp.

St. Clair Region Conservation Authority (SCRCA). 2018. St. Clair Region Watershed Report Card 2018. St. Clair Region Conservation Authority, Strathroy, Ontario. 91 pp.

Staszko, R., and J.G. Walls. 1994. Rat Snakes: a Hobbyist's Guide to Elaphe and Kin. T.F.H. Publications, New Jersey. 208 pp.

Statistics Canada. 2019a. Census Profile, 2016 Census. Statistics Canada, Ottawa, Ontario. Website: https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E [accessed 4 Dec. 2019].

Statistics Canada. 2019b. Canada's population estimates: Subprovincial areas, July 1, 2018. Statistics Canada, Ottawa, Ontario. Website: https://www150.statcan.gc.ca/n1/daily-quotidien/190328/dq190328b-eng.htm?hootPostID=59750e8c3a56c9c8effa888158c0d935%20%20Friday,%20March%2029,%202018 [accessed 4 Dec. 2019].

Sun News Network (SNN). 2014. Collecting endangered animals nets Toronto man a $3,125 fine. Website: http://www.noanimalpoaching.org/animal-poaching-news-2014-2015/collecting-endangered-animals-nets-toronto-man-a-3125-fine [accessed 3 Dec. 2019].

Town of Essex. 2017. Drainage. Website: https://www.essex.ca/en/live/drainage.aspx [accessed 31 July 2020].

Town of LaSalle. 2003. Official Plan. Town of Lasalle, Department of Planning, LaSalle, Ontario. 58 pp.

Treasury Board of Canada Secretariat (TBCS). 2019. Directory of Federal Real Property. Treasury Board of Canada Secretariat, Ottawa, Ontario. Website: https://www.tbs-sct.gc.ca/dfrp-rbif/home-accueil-eng.aspx [accessed 6 Dec. 2019].

United States Fish and Wildlife Service (USFWS). 2019. Threatened & Endangered Species, Listed Animals. ECOS Environmental Conservation Online System. U.S. Fish and Wildlife Service, Washington, DC, USA. Website: https://ecos.fws.gov/ecp0/reports/ad-hoc-species-report?kingdom=V&kingdom=I&status=E&status=T&status=EmE&status=EmT&status=EXPE&status=EXPN&status=SAE&status=SAT&fcrithab=on&fstatus=on&fspecrule=on&finvpop=on&fgroup=on&header=Listed+Animals [accessed 6 Dec. 2019].

Utiger, U., N. Helfenberger, B. Schatti, C. Schmidt, M. Ruf, and V. Ziswiler. 2002. Molecular systematics and phylogeny of Old and New World ratsnakes, Elaphe auct., and related genera (Reptilia, Squamata, Colubridae). Russian Journal of Herpetology 9:105-124.

Watson, C. 1994. Habitat use and movement patterns of the Eastern Fox Snake (*Elaphe vulpina gloydi*) at Point Pelee National Park, Ontario. MA Dissertation, University of Windsor, Windsor, Ontario. 141 pp.

Wester, M.C., B.L. Henson, W.J. Crins, P.W.C. Uhlig, and P.A. Gray. 2018. The Ecosystems of Ontario, Part 2: Ecodistricts. Science and Research Technical Report TR-26. Ontario Ministry of Natural Resources and Forestry, Science and Research Branch, Peterborough, Ontario. 474p. + appendices.

Whitaker, P.B., and R. Shine. 2000. Sources of mortality of large elapid snakes in an agricultural landscape. Journal of Herpetology 34:121-128.

White, E. 2019. Key River cottagers concerned by results of investigation into Parry Sound 33 forest fire. 28 February 2019, Sudbury region, Canadian Broadcasting Corporation. Website: https://www.cbc.ca/news/canada/sudbury/parry-sound-33-forest-fire-investigation-1.5035252 [accessed 2 Dec. 2019].

Willson, R.J. 2000. The thermal ecology of gravidity in Eastern Foxsnakes (*Elaphe gloydi*). MSc dissertation, University of Guelph, Ontario. 60 pp.

Willson, R.J., and R.J. Brooks. 2006. Thermal biology of reproduction in female Eastern Foxsnakes (*Elaphe gloydi*). Journal of Herpetology 40:285-289.

Winton, S.A., Bishop, C.A., and K.W. Larsen. 2020. When protected areas are not enough: low-traffic roads projected to cause a decline in a northern viper population. Endangered Species Research 41:131-139.

Xuereb, A., J.R. Row, R.J. Brooks, C. MacKinnon, and S.C. Lougheed. 2012. Relation between parasitism, stress, and fitness correlates of the Eastern Foxsnake (*Pantherophis gloydi*) in Ontario. Journal of Herpetology 46:555-562.

Yagi, A., pers. comm. 2019. *Personal communication to J. Choquette.* President, 8 Trees Inc., Fonthill, Ontario.

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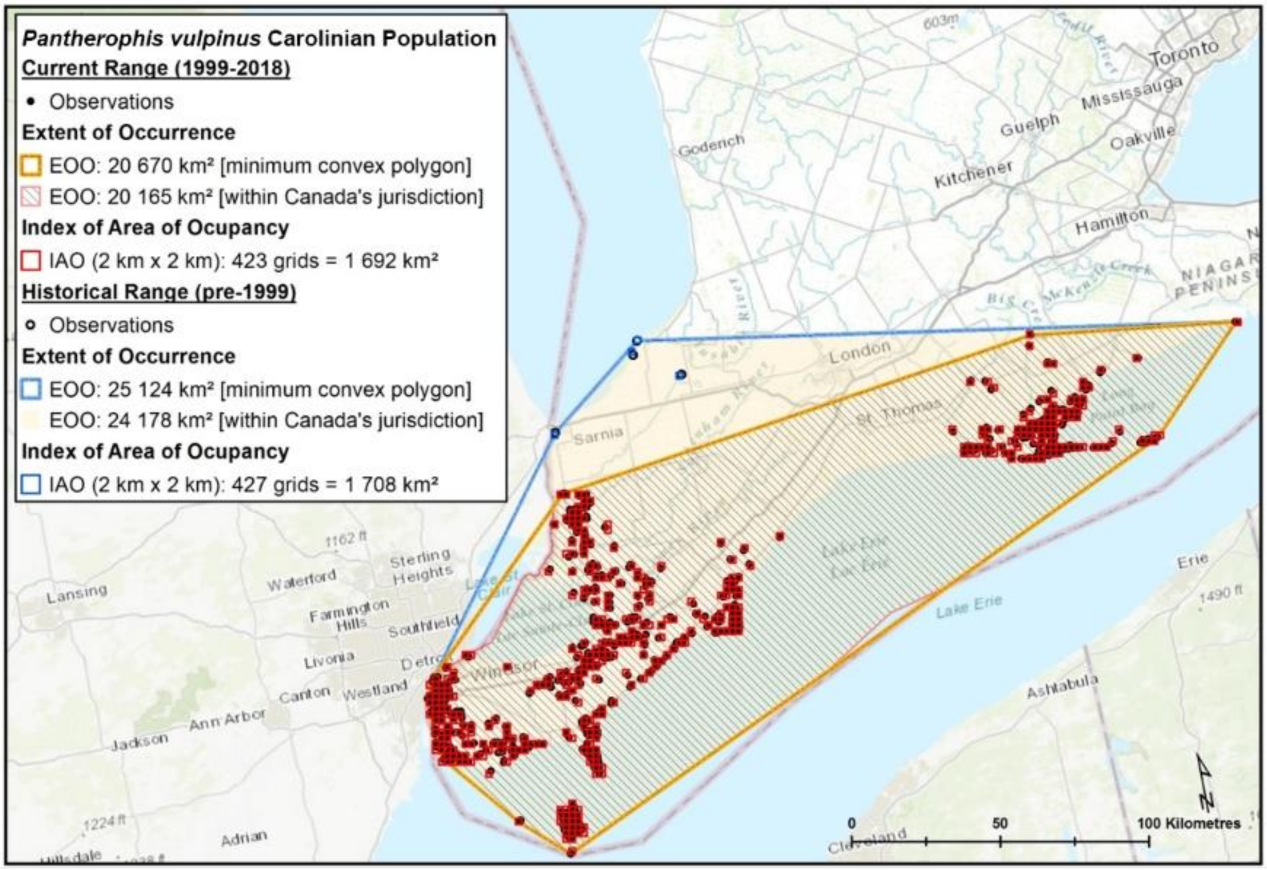
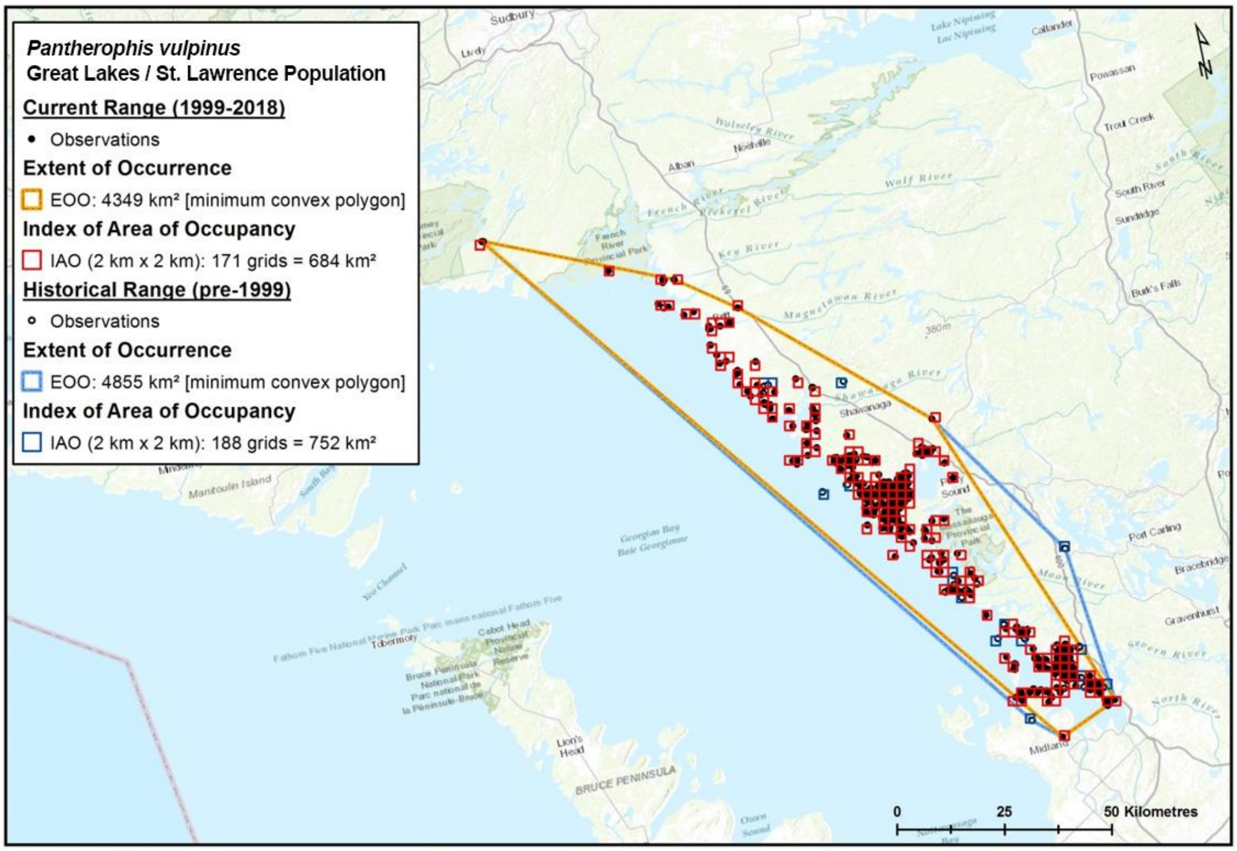
COLLECTIONS EXAMINED

No collections were examined. Observation data on Eastern Foxsnake held by the Ontario Natural Heritage Information Centre (Ontario Ministry of Natural Resources) was consulted.

Appendix 1. Eastern Foxsnake range in the Carolinian DU based on current (1999-2018) and historical (pre-1999) observation records. The Norfolk County area is represented by the cluster in the northeast. Only historical observations outside of the current EOO are displayed (within the current EOO historical observation sites are generally consistent with current observation sites). Map prepared by COSEWIC Secretariat (Sydney Allen).



Appendix 2. Eastern Foxsnake range in the Great Lakes / St. Lawrence DU based on current (1999-2018) and historical (pre-1999) observation records. Historical observations within and outside of the current EOO are displayed (within the current EOO some historical observation sites are outside current observation sites). Map prepared by COSEWIC Secretariat (Sydney Allen).



Appendix 3. Average Eastern Foxsnake age structure based on results of targeted surveys at four provincial and national parks across its Canadian range. GLSL = Great Lakes / St. Lawrence, NP = National park, PP = Provincial park.

Study Site, DU and Size	Sampling Method and Years	# Individuals Captured (all ages; mature)	Proportion Mature	Reference(s)
Rondeau PP (Carolinian) ~1600 ha excluding open water	Targeted visual encounter, artificial cover object, and drift fence surveys (2000-01)	120; 35	0.29	Gillingwater 2001; Ontario Parks 2019
Georgian Bay Islands NP (GLSL) 1,312 ha	Opportunistic visual encounter, targeted hibernacula, and radio-telemetry surveys (2003-05)	307; 112	0.36	Lawson 2005
Killbear PP (GLSL) 1,760 ha	Opportunistic visual encounter, targeted hibernacula, and radio-telemetry surveys (2003-05)	177; 66	0.37	Lawson 2005; Ontario Parks 2019
Point Pelee NP (Carolinian) 1,550 ha	Targeted visual encounter and artificial cover object surveys (1972-73)	137; 92	0.67	Rivard 1976; PCA 2010
Point Pelee NP (Carolinian) 1,550 ha	Targeted visual encounter, hibernacula, and radio-telemetry surveys (1993-94)	107; 65	0.61	Watson 1994; PCA 2010
Proportion Mature (Average) = 0.46 (0.29 – 0.67)				

Appendix 4. Eastern Foxsnake density per index of area of occupancy grid cell based on results of mark-recapture estimates at four study sites from across its Canadian range. GLSL = Great Lakes / St. Lawrence, NP = National park, PP = Provincial park. For Rondeau Provincial Park and Ojibway Prairie Complex, abundance estimates are from the most recent year of study (i.e., 2019 and 2018, respectively). "# of IAO Squares" was estimated in a GIS and is the approximate number of 2 x 2 km IAO grid squares represented by each specific study site (suitable Foxsnake habitat not surveyed as part of a particular study may be included in some squares). "[ ]" denote abundance estimates produced for this status report using published abundance estimates and proportion of mature individuals estimated from nearest study site (see Appendix 3).

Study Site and DU	Study Period	# IAO Squares	Abundance (total)	Abundance (mature)	Density/ IAO square (total)	Density/ IAO square (mature)	Reference
Rondeau PP (Carolinian)	2013 - 2019	11	[155 (69 - 241)] Assumes 29% mature	45 (20 - 70)	14.1 (6.3 – 21.9)	4.1 (1.8 – 6.4)	Davy and Paterson unpubl. data 2020; Davy pers. comm. 2020
Georgian Bay Islands NP (GLSL)	2003 - 2005	18	[500 (344 - 639)] Assumes 36% mature	180 (124 - 230)	27.8 (19.1 – 35.5)	10.0 (6.9 – 12.8)	Lawson 2005
Amherstburg Quarry (Carolinian)	1976 - 1977	4	90 (52 - 128)	[58 (33 - 82)] Assumes 64% mature	22.5 (13.0 – 32.0)	14.5 (8.3 – 20.5)	Freedman and Catling 1978
Ojibway Prairie Complex, Herb-Gray Parkway site (Carolinian)	2011 - 2018	5	231 (191 - 271)	[148 (122 - 173)] Assumes 64% mature	46.2 (38.2 – 54.2)	29.6 (24.4 – 34.6)	Hazell unpub. data. 2020; Hazell pers. comm. 2020
Average density (Carolinian sites only) =					27.6 (19.2 – 36.0)	16.1 (11.5 – 20.5)	

Appendix 5. Eastern Foxsnake abundance in the Carolinian region extrapolated from density estimates derived from three study sites. "[ ]" denote abundance estimates produced for this status report using density estimates from either nearest study site or average for Carolinian region (see Appendix 4). Genetic cluster numbers are described in Table 1. # IAO squares for each site/area were estimated by cross referencing IAO map with map of genetic clusters.

Site/area Name and Genetic Cluster #	# IAO Squares	Abundance (total)	Abundance (mature)
Ojibway Prairie, Herb-Gray Parkway (1)	5	231 (191 - 271)	148 (122 - 173)
Holiday Beach / Ojibway Prairie (excludes Herb-Gray Parkway) (1)	60	[2772 (2292 - 3252)] Assumes avg. density of 46.2	[1740 (1452 – 2076)] Assumes avg. density of 29.6
Cedar Creek (2)	18	[405 (234 - 576)] Assumes avg. density of 22.5	[261 (149 - 365)] Assumes avg. density of 14.5
Lake Erie Islands (3)	18	[405 (234 - 576)] Assumes avg. density of 22.5	[261 (149 - 365)] Assumes avg. density of 14.5
North-East Essex/Chatham-Kent/Lambton (4)	86	[2374 (1651 - 3096)] Assumes avg. density of 27.6	[1385 (989 - 1763)] Assumes avg. density of 16.1
Point Pelee / Hillman Marsh & Talbot (5 & 6)	18	[405 (234 - 576)] Assumes avg. density of 22.5	[261 (149 - 365)] Assumes avg. density of 14.5
Rondeau Provincial Park (7)	11	155 (69 - 241)	45 (20 - 70)
Greater Rondeau Area (excludes Rondeau PP) (7)	20	[282 (126 - 438)] Assumes avg. density of 14.1	[82 (36 - 128)] Assumes avg. density of 4.1
Norfolk County (8)	94	[2594 (1805 - 3384)] Assumes avg. density of 27.6	[1513 (1081 - 1927)] Assumes avg. density of 16.1
TOTAL	**330**	**9623 (6836 - 12410)**	**5696 (4147 - 7232)**

Appendix 6. Methods used to assess severe fragmentation.

Within the Carolinian designatable unit (DU), the NHIC lists 16 extant element occurrences (excludes four historical and three of uncertain validity), while eight distinct genetic clusters have been identified (Table 1). For the purpose of assessing severe fragmentation, the genetic clusters were used as these were considered to be biologically isolated from each other (see definition of "severe fragmentation" in IUCN SPC 2019). Due to genetic connectivity, all individuals within each cluster were then considered to inhabit the same habitat "patch" (despite functionally residing perhaps across a number of actual habitat patches on the landscape). The smallest five clusters based on geographical area were identified visually using the map by Row *et al.* (2010). The approximate index of area of occupancy (IAO) of each of the latter clusters was then estimated by referring to a map of Eastern Foxsnake IAO (similar to Appendix 1, but using a 10-year timeframe to account for potential recent local extirpations). In total, 77 IAO squares are represented by the combined IAO distribution of the five smallest clusters (Talbot = 2; Point Pelee/Hillman Marsh = 17; Cedar Creek = 17; Lake Erie Islands = 18; Rondeau = 23). Based on a total distribution of 330 IAO squares (i.e., 1,320 km^2: Appendix 1), the five smallest clusters in the Carolinian DU account for ~23% of the total IAO in the DU, whereas a threshold of >50% must be attained to consider a taxon as severely fragmented. Due to the 50% threshold not being met, an additional analysis was not conducted to determine if the smallest clusters are in fact too small to be considered viable.

Within the Great Lakes / St. Lawrence (GLSL) DU, the NHIC lists 12 extant element occurrences (excludes six historical), while the number of genetic clusters has not been determined. The NHIC element occurrences (EO) are based on a separation distance of 5 km, yet the maximum Eastern Foxsnake range length in the GLSL is ~7 km (see **Habitat**); therefore, EOs were not used. For the purpose of assessing severe fragmentation, occupied IAO squares were assumed to represent occupied habitat patches. Due to the continuous nature of Foxsnake habitat in the GLSL DU (see **Habitat**), isolated habitat patches (i.e., IAO squares) were assumed to be those separated from an adjacent patch by a distance greater than 7 km. The measure tool in a GIS was used to measure separation distance between IAO squares in the GLSL DU (similar to Appendix 2, using a 10-year timeframe to account for potential recent local extirpations). Using this method, three large clusters of IAO squares were identified (24 – 28 squares each) in addition to a single small isolated cluster (7 squares). The smallest cluster represents only 8% of the total number of IAO squares in the DU (7 divided by 86), whereas a threshold of >50% must be attained to consider a taxon as severely fragmented. Furthermore, when examining the larger 20-year dataset, the vast majority of IAO squares cluster together with only ~3 squares (2%) isolated by a distance greater than 7 km.

Appendix 7. Threats calculator for Eastern Foxsnake, Carolinian population.

THREATS ASSESSMENT WORKSHEET				
Species or Ecosystem Scientific Name	*Pantherophis vulpinus* - Carolinian population			
Element ID			**Elcode**	
Date:	5/26/2020			
Assessor(s):	Kristiina Ovaska (facilitator/A&R Co-Chair), Tom Herman (A&R Co-chair), Rosana Soares (Secretariat), Sydney Allen (Secretariat), Alain Filion (Secretariat), Jonathan Choquette (SRW), Colin Jones (Ontario Gov), Syd Cannings (CWS), Chris Edge (A&R SSC), Connie Browne (A&R SSC), Scott Gillingwater (A&R SSC), Joe Crowley (A&R SSC), Lea Randall (A&R SSC), Njal Rollinson (A&R SSC), Karolyn Pickett (CWS), Tammy Dobbie (PCA), Megan Hazell (PCA), Tarra Degazio (PCA), Jeff Row, Rachel Windsor (PCA), Steve Lough (Queen's University)			
References:	COSEWIC draft status report, Jan 2020			
		Overall Threat Impact Calculation Help:	**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	0	0
	C	Medium	3	1
	D	Low	3	5
		Calculated Overall Threat Impact:	High	High
		Assigned Overall Threat Impact:	**B = High**	
		Impact Adjustment Reasons:		
		Overall Threat Comments	***Generation time: 7.5 yrs; IAO 1,692 km² (1999-2018 records)***	

Threat			**Impact (calculated)**	**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development		Negligible	Negligible (<1%)	Extreme - Serious (31-100%)	High (Continuing)	
1.1	Housing & urban areas		Negligible	Negligible (<1%)	Extreme - Serious (31-100%)	High (Continuing)	Causes permanent loss and fragmentation of habitat and the death of individuals during construction and operation. Scope: Expansion of residential development into the species' habitat is projected in Windsor/LaSalle area and Norfolk region near Port Rowan; in Chatham-Kent, near Wheatley Provincial Park, suitable farmland is subdivided and turned into houses. However, the area affected by new developments comprises only a portion of the species' range. If current settlement area is 1-3% of IAO, then development is unlikely to grow beyond 1%. Severity is extreme to serious because housing developments result in permanent habitat loss and reduce connectivity; however, there is some uncertainty, depending on the type of development and whether habitat is retained.
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Commercial development is probably mostly limited to Windsor/LaSalle area. The nature of the threat is similar to residential development, but the severity is extreme due complete loss of habitat within the development footprint.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1.3	Tourism & recreation areas						
2	Agriculture & aquaculture	D	Low	Restricted - Small (1-30%)	Slight (1-10%)	High (Continuing)	
2.1	Annual & perennial non-timber crops	D	Low	Restricted - Small (1-30%)	Slight (1-10%)	High (Continuing)	This threat includes both habitat loss from land conversion and intensification of use of existing agricultural lands and mortality from farm machinery, such as observed during haying. Scope: Current rate of habitat loss from agricultural activities is much less than it was historically; intensification occurs in some areas with cropland converted to greenhouses. There is an apparent overall ongoing decline in natural habitat due to existing farms in Essex region and intensification in general due to high land prices in SW Ontario. Near Point Pelee National Park farmers are removing hedgerows. Scope reflects proportion of land in hay (variable across counties) and also projected habitat loss. Severity rating reflects mostly ongoing mortality from farm machinery on active agricultural lands.
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture						
3	Energy production & mining		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
3.1	Oil & gas drilling						
3.2	Mining & quarrying						
3.3	Renewable energy		Negligible	Negligible (<1%)	Negligible (<1%)	High - Moderate	Renewable energy activities causing direct and permanent loss of habitat, and possibly death of individuals during construction and operation. Scope is limited to small area of the DU. Wind turbines are still being installed in the Wheatley area, but on smaller scale relative to past projects. There may be some short-term impacts from construction.
4	Transportation & service corridors	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
4.1	Roads & railroads	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	Includes improvements and widening of roads, and increasing road traffic, in addition to new road construction. By far the greatest impacts are due to ongoing mortality from vehicle collisions on existing and improved roads, rather than from habitat loss. Some roads also act as strong barriers (e.g., HWY 3, Essex Co.; underpasses of HWY 401, however, appear to allow movements of snakes, mitigating threats). Scope is wider in Carolinian versus GLSL DU due to extensive network of roads; 94% of occupied IAO squares (399/423) have roads, for a total length of 3,354 km. Severity can be considerable due to mortality of adults from the population during critical life stages, including gravid females (many examples of roadkill).
4.2	Utility & service lines						
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Deliberate killing or illegal collection causing the permanent removal of individuals from population. Threat of killing is ongoing and occurring in portions of the species' range primarily overlapping settlement areas and also scattered across agricultural landscape but in presumed lower intensity. There are also cases of killing of snakes around parks. Threat of collection for pets is limited in scope to readily accessible areas, e.g., parks and protected areas. Severity at the population level is deemed Slight.
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting						
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Recreational activities (e.g., off-road vehicles, mountain bikes, and motorboats) can cause injury or death of individuals. For this DU, accidental mortality on land is likely greater than in water. Scope: Threat is mostly within parks and protected areas, which receive intensive human use and make up ~6% of the IAO of this DU. However, off-road vehicles are a threat also on non-protected lands. Severity: Presumed negligible at the population level. Boating may be more of a threat than terrestrial recreational activities, but no data are available for this DU.
6.2	War, civil unrest & military exercises						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.3	Work & other activities						Work related to recovery actions or scientific research (e.g., radio-telemetry) may cause injury or death of a small number of individuals, but population level impacts are not expected. Scope limited to small number of sites, such as parks and recreational areas. Conservation related research on this species is expected to be beneficial and facilitate mitigation. The group discussed whether research can be considered a threat at all and left blank or whether it should be scoped as negligible in scope and severity.
7	Natural system modifications	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	Scope of two Restricted sub-categories at the high end of the range pushed the scope to Large
7.1	Fire & fire suppression		Negligible	Negligible (<1%)	Moderate - Slight (1-30%)	High (Continuing)	Wild and controlled fires can cause mortality, sometimes of multiple individuals, in a short time period. Scope: Controlled burning occurs within subset of parks and protected areas; NCC and ERCA lands may also be burned. Burns at Point Pelee NP occur in a very small area, but there are plans to expand this activity. Severity: Prescribed burns are timed to occur early in the season, mitigating impacts to snakes (e.g., Point Pelee NP, NCC lands). However, accidents/lack of oversight occur, and severity score reflects significant mortality risk to snakes in such cases.
7.2	Dams & water management/use	CD	Medium - Low	Restricted (11-30%)	Moderate - Slight (1-30%)	High (Continuing)	Included are maintenance of drains/swales and berms, which may cause mortality and destruction of hibernation sites. Drain maintenance occurs both in active and hibernation season of the species, but not all drains are cleared on a regular basis. Roadside ditches are cleaned frequently but agricultural drains only infrequently (e.g., every ~5-20 years). Impacts are probably greatest during the hibernation season (when scooping out sediment/soil), but heavy machinery cutting/chopping/grinding vegetation could also cause mortality/injury in the active season. While the threat occurs across the DU's range in agricultural and settled landscape, the scope is reduced based on habitat use by snakes and expected frequency of drain maintenance over the next 10 years. Therefore, the scope was considered restricted rather than large. Severity has a range, reflecting uncertainties in the responses of the snakes at the population level.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.3	Other ecosystem modifications	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	Both the indirect impacts of invasive phragmites on habitat and the efforts to control/remove it are included here. Most impacts appear to be from control efforts (spraying, rolling, cutting, burning). The snakes are able to use phragmites stands at least to some degree, based on radio-telemetry studies (Christina Davies unpubl. data). Scope: Much of the north shore of Lake Erie has been overtaken by invasive phragmites. Once controlled, hundreds of acres of “barren” landscapes remain, with little or no natural cover for the snakes. Protected areas are heavily impacted by phragmites, and many parks are planning future removals. Severity is deemed moderate because control efforts make habitat unsuitable for long periods.
8	Invasive & other problematic species & genes		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
8.1	Invasive non-native/alien species		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Cats and dogs are known to capture and kill many types of snakes (Whitaker and Shine 2000; Shine and Koenig 2001), and there are anecdotal records of juvenile Eastern Foxsnakes caught by cats (Gillingwater pers. comm. 2019). Predation by domestic cats and dogs causes removal of individuals from a population. Scope covers majority of urban, rural, and agricultural landscape within the species' range. Severity at population level is unknown. Juveniles are killed more often than adults, somewhat mitigating effects.
8.2	Problematic native species		Unknown	Pervasive - Large (31-100%)	Unknown	High (Continuing)	Threat of Snake Fungal Disease (SFD) in Canada appears to be of low severity (possibly increasing predation risk). Scope is pervasive-large over the next 10 years, although to date SFD has been reported only in the western half of the Carolinian DU. Severity at the population level is unknown.
8.3	Introduced genetic material						
9	Pollution	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	
9.1	Household sewage & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Direct evidence is lacking for negative short-term impacts of herbicide and pesticide runoff from agricultural crops. Scope includes most of the Carolinian DU. There is recent evidence of DDT residues in E. Foxsnake individuals at Point Pelee NP (Russel *et al*. 1995). Severity is unknown.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.4	Garbage & solid waste	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Snakes can be injured or killed by plastic mesh netting erected for gardening, erosion control, and vegetation establishment purposes. Scope limited to settlement areas. There is uncertainty about significance at the population level, but relatively 13 anecdotally reported cases raise concerns; severity is scored as slight.
9.5	Air-borne pollutants						
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs)	Ontario CCVI score indicates that this DU is "moderately vulnerable" (moderate confidence) to climate change. The score is higher than for GLSL DU (low vulnerability, low confidence) because of barriers to movement, which affect vulnerability.
11.1	Habitat shifting & alteration						
11.2	Droughts						
11.3	Temperature extremes						
11.4	Storms & flooding	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs)	Water levels in the Great Lakes have been high in recent years associated with an overall decline in amount of suitable habitat along shorelines. There is much uncertainty about future predictions, and most models predict lower Great Lakes water levels due to climate change. Terrestrial habitat along north shore of Lake Erie has decreased because of storms and flooding. Storms and flooding could affect nesting success, and overwinter survival.
Classification of Threats adopted from IUCN-CMP, Salafsky *et al*. (2008).							

Appendix 8. Threats calculator for Eastern Foxsnake, Great Lakes / St. Lawrence population.

THREATS ASSESSMENT WORKSHEET				
Species or Ecosystem Scientific Name	*Pantherophis vulpinus* - Great Lakes / St. Lawrence DU			
Element ID			**Elcode**	
Date:	5/29/2020			
Assessor(s):	Kristiina Ovaska (facilitator/A&R Co-Chair), Tom Herman (A&R Co-chair), Rosana Soares (Secretariat), Jonathan Choquette (SRW), Christina Davy (Ontario Gov), Gina Schalk (CWS), Chris Edge (A&R SSC), Joe Crowley (A&R SSC), Njal Rollinson (A&R SSC), Karolyn Pickett (CWS), Tammy Dobbie (PCA), Tarra Degazio (PCA)			
References:	COSEWIC draft status report, Jan 2020			
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	0	0
	C	Medium	2	1
	D	Low	3	4
Calculated Overall Threat Impact:			High	High
Assigned Overall Threat Impact:			**B = High**	
Impact Adjustment Reasons:				
Overall Threat Comments			***Generation time: 7.5 yrs; IAO: 684 km² (1999-2018 records). Score in red text changed after conference call following review***	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	
1.1	Housing & urban areas		Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	Settled area in GLSL area is less than 1%. Most development is cottages and most land around remains in natural state, but cottage development is expected to continue. Severity is moderate (lower than for Carolinian DU), because footprint of construction for cottages is less in GLSL.
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	The nature of the threat is similar to residential development, but the severity is extreme due complete loss of habitat within the development footprint. The group was not aware of specific examples, but some development is likely to occur.
1.3	Tourism & recreation areas						
2	Agriculture & aquaculture						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual & perennial non-timber crops						Very small area of cropland in GLSL in contrast to Carolinian; presumed not a threat
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture						
3	Energy production & mining		Negligible	Negligible (<1%)	Unknown	High (Continuing)	
3.1	Oil & gas drilling						
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Unknown	High (Continuing)	Mining and quarrying activities causing direct and permanent loss of habitat, and possibly death of individuals during construction and operation. Some ongoing and planned activity is likely. Scope is presumed limited to very small portion of range. Footprint of project is equal to loss of habitat, but there could be ongoing mortality of snakes accessing quarry. Rehabilitation of quarries might improve habitat. Long-term are impacts are less than from urban development, which removes habitat permanently. Severity may be negligible but left as unknown as the group couldn't come to a decision.
3.3	Renewable energy		Negligible	Negligible (<1%)	Serious (31-70%)	High - Moderate	Renewable energy activities causing direct and permanent loss of habitat, and possibly death of individuals during construction and operation. Wind farms result in much greater habitat loss in GLSL DU compared to Carolinian DU, due to large areas of relatively pristine habitat that will be affected, but scope remains negligible. No new solar energy operations are planned for next three years, but there is much uncertainty beyond this period. Severity was scored serious within the small scope because of potential loss of previously undisturbed habitat.
4	Transportation & service corridors	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
4.1	Roads & railroads	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	Mortality on existing roads is the biggest issue for this mobile species. Scope is based on estimated percentage of IAO squares with roads (37% of IAO squares (63/171); total length of roads = 307 km). Roads in GLSL DU overall are a lower class of roads than in CARO DU; many are smaller cottage roads. During summer, however, many roads experience greatly increased traffic. Severity is moderate, presuming a similar decline rate as in Carolinian DU.
4.2	Utility & service lines						
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Included are deliberate killing and illegal collection causing the permanent removal of individuals from a population. Threat of killing is ongoing and occurring in portions of the species' range overlapping areas dominated by settlement areas, including cottage country. Threat of collection is ongoing but limited in scope to readily accessible areas, such as parks and protected areas. Scope based % settlement areas and % parks with high access (~4%): Restricted scope covers high (red) and moderate (orange) areas of the human footprint map (ECCC 2017b) (note that EOO is actually smaller than the area depicted on this map and to the west of the HWY). Severity (slight) was set to be the same as for the Carolinian DU.
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting						
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Large (31-70%)	Negligible (<1%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.1	Recreational activities		Negligible	Large (31-70%)	Negligible (<1%)	High (Continuing)	Recreational activities (e.g., off-road vehicles, mountain bikes, and motorboats) can cause injury or death of individuals. Scope includes all areas of open water in the archipelago and focus is mainly on potential for boat collisions in the southern half of DU, where appr. 2/3 of IAO squares are located. While collision mortality may occur, impacts on population level are probably negligible.
6.2	War, civil unrest & military exercises						
6.3	Work & other activities						Work related to recovery actions or scientific research (e.g., radio-telemetry) may cause injury or death of a small number of individuals, but population level impacts are not expected. Scope limited to small number of parks and recreational areas. Conservation related research on this species is expected to be beneficial and facilitate mitigation. The group discussed whether research can be considered a threat at all and left blank or whether it should be scoped as negligible in scope and severity.
7	Natural system modifications	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs)	
7.1	Fire & fire suppression	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs)	Wild and controlled fires cause direct mortality, sometimes of multiple individuals, in a short time. Scope is much larger than for Carolinian DU due to greater extent of forested areas and increased probability of wildfires. Remnant prairie patches, which may be subject to prescribed fire, overlap with this DU's range only around Port Severn. A large wildfire (11,000 ha fire at Hervey Inlet First Nation) occurred recently, but fire frequency is unknown. At 110 km^2, this equates to 3 – 16% of EOO and IAO. Severity has a high degree of uncertainty, depending on the intensity and size of fires.
7.2	Dams & water management/use						Not an issue for this DU, in contrast to Carolinian DU, due to limited agriculture and fewer drains in this area.
7.3	Other ecosystem modifications		Negligible	Negligible (<1%)	Moderate (11-30%)	High (Continuing)	Phragmites control occurs but is very limited. Extensive stands of phragmites comparable to those in the Carolinian DU have not been established. The species will likely expand but probably not significantly within the next 10 years.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8	Invasive & other problematic species & genes		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
8.1	Invasive non-native/alien species		Unknown	Small (1-10%)	Unknown	High (Continuing)	Cats and dogs are known to capture and kill many types of snakes (Whitaker and Shine 2000; Shine and Koenig 2001), and there are anecdotal records of juvenile Eastern Foxsnakes caught by cats (Gillingwater pers. comm. 2019). Juveniles are killed more often than adults, somewhat mitigating effects. Scope is limited to settlements and campgrounds (<1% (EOO) to 6% (IAO). The group discussed whether severity could be assigned a score (the effects are negative) but it was left as unknown.
8.2	Problematic native species		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Threat of Snake Fungal Disease (SFD) in Canada appears to be of low in severity (possibly increasing predation risk). Scope is entire range of the species (SFD reported in both DUS). Population effects are unknown.
8.3	Introduced genetic material						
9	Pollution		Unknown	Unknown	Unknown	High (Continuing)	
9.1	Household sewage & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents		Unknown	Unknown	Unknown	High (Continuing)	Agricultural effluents are probably not a threat for this DU. While pesticides and herbicides are widely used in central Ontario (e.g., glyphosate) in forestry operations, forestry is probably not occurring close to the shoreline where most records of the species are from. Therefore, scope of this threat may be limited.
9.4	Garbage & solid waste		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Snakes can be injured or killed by plastic mesh netting erected for gardening, erosion control, and vegetation establishment purposes. Scope limited to a portion of the settlement areas, and is lower that for Carolinian DU due to less development. Severity is kept the same as for Carolinian DU.
9.5	Air-borne pollutants						
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11	Climate change & severe weather	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs)	Ontario CCVI score indicates that this DU has low vulnerability (with low confidence) to climate change. The score is lower than for the Carolinian DU (moderately vulnerable, moderate confidence) because there are fewer barriers to movement, which affect vulnerability.
11.1	Habitat shifting & alteration						
11.2	Droughts						
11.3	Temperature extremes						
11.4	Storms & flooding	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs)	Main impact would be from flooding of hibernacula near lake shores. Scope is likely similar to Carolinian DU due to population being tied to lake shoreline and experiencing lake level fluctuations. Concentrations of snakes at hibernacula are usually larger in this than the Carolinian DU, and more snakes would be affected, but there is much uncertainty in severity, captured with a range in scoring. There is uncertainty about predictions of lake level changes in Great Lakes, but extreme events may be more likely.