COSEWIC
Assessment and Status Report

on the

Striped Whitelip
Webbhelix multilineata

in Canada

ENDANGERED
2018

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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Production note:
COSEWIC would like to acknowledge Annegret Nicolai for writing the status report on the Striped Whitelip. This report was prepared under contract with Environment and Climate Change Canada and was overseen by Dwayne Lepitzki, Co-chair of the COSEWIC Molluscs Specialist Subcommittee.

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Striped Whitelip — Robert Forsyth, August 2016, Pelee Island, Ontario.

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COSEWIC
Assessment Summary

Assessment Summary – April 2018

Common name
Striped Whitelip

Scientific name
Webbhelix multilineata

Status
Endangered

Reason for designation
This large terrestrial snail is present on Pelee Island in Lake Erie and at three sites on the mainland of southwestern Ontario: Point Pelee National Park, Walpole Island, and Bickford Oak Woods Conservation Reserve. The species appears to have been extirpated from four other historically known mainland sites and at least one site on Pelee Island. Human-driven habitat loss and alteration led to decline and population isolation. Threats are extreme weather events (e.g., droughts), prescribed burns, and human disturbance (i.e., trampling as the species forages on trails in moist conditions). Wild Turkeys on Pelee Island and in Point Pelee National Park also might eat this snail.

Occurrence
Ontario

Status history
Designated Endangered in April 2018.

COSEWIC
Executive Summary

Striped Whitelip
Webbhelix multilineata

Wildlife Species Description and Significance

Striped Whitelip is a large land snail (adult shell width 2.0 – 2.5 cm) with a round, but slightly flattened, thin pale-yellow shell that has dark spiral bands. This species is part of the unique fauna of the Carolinian Forest in Canada and has significance for ecosystem function through nutrient cycling. The range-edge population in Canada is important for the global conservation of this species.

Distribution

The distribution of Striped Whitelip extends from southern Ontario southward to Tennessee in the east and Nebraska in the west. In Canada, the species is currently known to occur in the following areas of southwestern Ontario: Pelee Island, Point Pelee National Park, Walpole Island, and Bickford Oak Woods Conservation Reserve. The species appears to have been extirpated in Sarnia, Devonwood Conservation Area, Chatham, and Canard River Scout Camp near Windsor.

Habitat

Striped Whitelip inhabits wet, lowland forest, at the margins of periodically flooded areas (marshland or swamp) or in continuously wet parts. These damp woods are composed of oak, hickory, and maple, with a rich litter layer including logs, bark, leaves, and twigs.

Potential habitats (where the snail has been observed but the entire area not searched) total over 2000 ha and are mainly old-growth forest. Pelee Island is largely developed for agriculture and habitat loss is historical i.e., occurred in the past. Protected areas on the island and mainland are managed with mechanical thinning or prescribed burns to control invasive species and enhance endangered species habitat. The habitat at all sites is surrounded by unsuitable arable land or water.

Biology

Striped Whitelip is an air-breathing (pulmonate) snail that is a simultaneous hermaphrodite (possesses both male and female reproductive organs) and lays eggs. Few details of the life history of the species in Canada are known. Mating probably occurs in

mid-spring and mid-summer, and egg-laying in late spring and late summer. Hibernation extends from early October until April in temperate regions. Striped Whitelip is freeze resistant and can survive harsh winters but its cold hardiness decreases in spring. Dormancy in summer may occur only during prolonged drought, because they are usually active in warm weather. Sexual maturity is probably reached at 2–3 years. The generation time is probably 4 years. The species feeds mainly on fresh plants, such as germinating tree seedlings, and can move across roads and in human-altered habitat to search for food. However, active dispersal for colonization of new areas is in the order of tens of metres over several years, and the species is not found on agricultural land. Passive dispersal by flooding of rivers or transportation by birds is possible but has not been documented. There is no evidence that the species is transported by humans.

Population Sizes and Trends

Striped Whitelip usually occurs locally in large numbers elsewhere, but abundance and distribution in Ontario are extremely heterogeneous and dependent on the density of moist microsites. Population size appeared small and snails were only found in wet areas in 2016, likely due to the drought in August that year. There was a change in the gastropod community composition on higher ground in 2016 compared to 2013–2015 because of Striped Whitelip's absence. Size class distribution was normal and did not differ between Point Pelee National Park and Pelee Island. Recruitment was observed in most sites where the species was found. Nothing is known about the population's genetic structure. Rescue from outside Canada is not possible due to Lake Erie and the St. Clair River acting as barriers.

Threats and Limiting Factors

Low dispersal ability, low physiological resistance to fluctuating environmental factors such as temperature and humidity, and predation by Wild Turkeys at Point Pelee National Park are limiting factors. Threats to the species are climate change (droughts, changes in frost regimes), natural system modifications (prescribed burns on Pelee Island), and human intrusions and disturbances (trampling). Other threats include transportation and service corridors, pollution, and invasive species. Depending on the threat or combination of threats, there are 4–6 locations.

Protection, Status and Ranks

Striped Whitelip has no legal designations. It is ranked by Nature Serve as globally secure and nationally secure in the US, but imperilled-vulnerable in Canada and in Ontario. In Ontario, most of the species' range is on protected lands managed by Parks Canada, the Nature Conservancy Canada, or the Ontario Ministry of Natural Resources and Forestry.

TECHNICAL SUMMARY

Webbhelix multilineata

Striped Whitelip

Polyspire rayé

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)	~4 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes. A 42% historical reduction in number of occupied sites and 16% decline in IAO have been observed within at least the last 20 years. Current low abundance in some sites suggests continuing decline.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown. Known declines in number of occupied sites and IAO occurred too far in the past (before the last 3 generation timeframe).
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. Unknown b. Some yes, others no c. Unknown
Are there extreme fluctuations in number of mature individuals?	Unknown

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	887 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	104 km²

Is the population "severely fragmented" i.e., is >50% of its total area of occupancy is in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. Yes
Number of "locations"[1] (use plausible range to reflect uncertainty if appropriate)	4-6 Minimum 4 (3 mainland subpopulations plus Pelee Island) to maximum 6 (2 locations on Pelee Island) depending on combination of various threats
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes. Historical losses (since between 1859 and 1996) observed from four mainland (Chatham, Sarnia, Devonwood Conservation Area, Canard River Scout Camp) sites and at least one Pelee Island (Lighthouse Point, possibly also Middle Point Woods) site
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes. See above.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes. See above.
Is there an [observed, inferred, or projected] decline in number of "locations"[1]?	Yes. See above.
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes. Historical habitat loss/degradation observed; projected: prescribed burn on Pelee Island, thinning of forest vegetation in Point Pelee National Park, and other threats
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
Pelee Island (Fish Point PNR* and Stone Road Alvar could be separate subpopulations; only old shells observed at Middle Point Woods since 2013)	Unknown*
Point Pelee National Park*	Unknown*
Walpole Island	Unknown

[1] See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

Bickford Oak Woods Conservation Reserve	Unknown
* ranges estimated in text but high degree of uncertainty	
Total Canadian population	Unknown

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Unknown, not done

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

Was a threats calculator completed for this species?
Yes.

i. Climate change & severe weather (medium-low impact)
ii. Natural system modifications (low impact)
iii. Human intrusion & disturbance (low impact)
iv. Transportation & service corridors (negligible impact)
v. Pollution (negligible impact)
vi. Invasive & other problematic species & genes (unknown impact)

What additional limiting factors are relevant?
Low dispersal or migration capacity, low resistance to fluctuating environmental conditions, Wild Turkeys in Point Pelee National Park

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Ohio (SNR), Michigan (SNR), New York (SNR)
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?[2]	Habitat quality continues to decline.
Are conditions for the source population (i.e., outside) deteriorating?[+]	NA
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species? Yes, is recommended by the Molluscs SSC due to a "moderate" score for intentional killing of individuals (Data Sensitivity Matrix, O&P F8) but no further withholding of information beyond what is indicated in the report is warranted.	Yes

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

Status History

COSEWIC: Designated Endangered in April 2018.

Status and Reasons for Designation:

Status:	**Alpha-numeric codes:**
Endangered	B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v)
Reasons for designation: This large terrestrial snail is present on Pelee Island in Lake Erie and at three sites on the mainland of southwestern Ontario: Point Pelee National Park, Walpole Island, and Bickford Oak Woods Conservation Reserve. The species appears to have been extirpated from four other historically known mainland sites and at least one site on Pelee Island. Human-driven habitat loss and alteration led to decline and population isolation. Threats are extreme weather events (e.g., droughts), prescribed burns, and human disturbance (i.e., trampling as the species forages on trails in moist conditions). Wild Turkeys on Pelee Island and in Point Pelee National Park also might eat this snail.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Does not meet criteria. The 42% decline in number of occupied sites and 16% decline in IAO within at least the last 20 years are outside the most recent 3 generation time frame. The threats assessment suggests a future decline; however, the magnitude of the decline is uncertain.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v). Both the EOO (887 km^2) and IAO (104 km^2) based on presence of live individuals or fresh shells observed between 2013 and 2016 are well below thresholds for Endangered (< 5000 km^2 and < 500 km^2, respectively). The species is not severely fragmented and does not undergo extreme fluctuation. The lower end of the plausible range in the number of locations falls under the threshold of 5 or fewer. EOO, IAO, area, extent, and quality of habitat, number of locations and subpopulations, and therefore number of mature individuals are projected to continue to decline.
Criterion C (Small and Declining Number of Mature Individuals): Does not meet criteria. The number of mature individuals is unknown. The threats assessment suggests a future decline; however, the magnitude of the decline is uncertain.
Criterion D (Very Small or Restricted Population): D1 is not applicable as the number of mature individuals is unknown. D2 Threatened is not applicable. While the IAO (104 km^2) is above the typical 20 km^2 threshold, the number of locations is below the typical threshold (5 or fewer); however, even though the species is prone to the effects of human activities or stochastic events in an uncertain future, the species will most likely not meet the thresholds for critically endangered within 1 or 2 generations (4–8 years) or become extirpated once the threats occur.
Criterion E (Quantitative Analysis): Not applicable. Analyses have not been done.

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS (2018)

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.

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Webbhelix multilineata

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2018

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Kingdom: Animalia
Phylum: Mollusca
Class: Gastropoda
Order: Pulmonata
Suborder: Stylommatophora
Family: Polygyridae
Genus: *Webbhelix*
Species: *Webbhelix multilineata*
(Say, 1821)

Common English name: Striped Whitelip

Common French name: Polyspire rayé

Originally recognized as *Helix multilineata* by Say in 1821, the species was also called *Mesodon multilineata*, *Polygyra multilineata,* and *Triodopsis multilineata* (Pilsbry 1940). Emberton (1988) placed it in a new monotypic genus, *Webbhelix,* and this is the currently accepted taxonomy (Turgeon *et al.* 1998).

Morphological Description

Striped Whitelip is a relatively large land snail (maximum shell breadth of adults: 2.0–2.5 cm) with a thin, depressed-globose shell (Pilsbry 1940). The shell has oblique striae (shallow grooves on the surface of the shell), and a reflected, white apertural lip in adults. The shell has a few to many russet-coloured spiral bands on a pale yellow background (see figure on cover page) similar to Broad-banded Forestsnail (*Allogona profunda*; COSEWC 2014a); however, the latter species has a denticle (a tooth-like structure) inside the lower lip of the aperture (opening of shell containing the snail's body), and an open umbilicus (hole at the central part of the shell's underside) while Striped Whitelip does not have a denticle and has a closed umbilicus. The animal is light to dark grey, which can give the shell a dark brown appearance (Figure 1).

Figure 1. Striped Whitelip *Webbhelix multilineata* crossing a track (left; photo by A. Nicolai, August 2016) and a trail (right; photo by A. Nicolai, August 2016) in Point Pelee National Park.

Population Spatial Structure and Variability

Within the Canadian range, at least four subpopulations currently exist. The first is on Pelee Island in Lake Erie, separated by approximately 14 km of open water from the closest subpopulation on the mainland in Point Pelee National Park. Lake Erie was formed at the front of the retreating Laurentide ice sheet between 12,500 and 8,000 years ago (Forsyth 1988). The gastropod community presumably colonized the peninsulas and coastal areas of this newly formed lake prior to 4,500 years ago, when rising lake levels isolated the islands from the mainland (Duncan *et al.* 2011). Genetic differences are expected for these subpopulations because there is probably low or close to no gene flow, assuming dispersal over open water is incidental (see **Dispersal and Migration**). Gene flow is probably also absent among other mainland subpopulations: in Bickford Oak Woods Conservation Reserve (south of Sarnia) and on Walpole Island. The mainland sites are separated by a minimum of 10 km. Anthropogenic changes to the landscape have dramatically decreased forested habitat on the intervening mainland, with less than 5% remaining as scattered patches of less than 10 ha (ERCA 2002).

A genetic study of barcodes by A. Nicolai and R. Forsyth is in progress at the Biodiversity Institute of Ontario (BIO, Guelph, Ontario). DNA barcoding employs sequence diversity in a 648 base pair region of the cytochrome c oxidase subunit I (COI) gene to distinguish species (Hebert *et al.* 2003). In order to evaluate similarity of the COI gene within the Canadian range, live individuals were collected from Fish Point on Pelee Island (in 2013, 2014, and 2015) and Point Pelee National Park (in 2016). Five to seven specimens per site were sent to BIO for extraction, amplification, and sequencing of the COI gene using a standardized method for molluscs (Layton *et al.* 2014). Non-lethal DNA sampling with swabs has been tested in slugs (Morinha *et al.* 2014) and could be used for future sampling, especially for genetic analyses needing large numbers of individuals, along with photography. The Barcode Index Number (BIN) algorithm was applied to delineate clusters corresponding to operational taxonomic units at the species level

(Ratnasingham and Hebert 2013). Results from preliminary barcoding show that COI gene sequences from three specimens from Pelee Island are assigned to the same BIN in the Barcode of Life Database (BOLD, Ratnasingham and Hebert 2007): ACP9473. The specimens from Point Pelee National Park have not yet been processed due to insufficient funding.

Small-scale genetic population structure has not been studied in the Canadian population and there are no observable morphological differences in the snails among subpopulations. Some genetic exchange among individuals on Pelee Island is possible if habitat patches are currently connected. Historically, habitat on Pelee Island consisted of four forested bedrock islands, separated from each other by swamps, through which Striped Whitelip could likely disperse. Subpopulations are now sufficiently separated by unsuitable habitat to limit current gene flow to within Fish Point Provincial Nature Reserve (Fish Point PNR), Stone Road Alvar, and Middle Point Woods. The likelihood of genetic exchange among individuals within Point Pelee National Park, Bickford Oak Woods Conservation Reserve, and Walpole Island is higher than that on Pelee Island because the remaining habitat in these areas is less patchy.

Designatable Units

All Canadian subpopulations are within the Great Lakes Plains ecological area. Genetic data and evidence of local adaptations (e.g., morphological differences) are unavailable. However, Grimm (1996) identified specimens from Pelee Island as a new species, separate from *W. multilineata*. While some material in the Canadian Museum of Nature (CMN) has his manuscript name on the label, this purported taxon was never formally described, and it is not clear on what basis Grimm distinguished these from *W. multilineata* (Forsyth pers. comm. 2017). Therefore, all Canadian occurrences are considered to be a single designatable unit.

Special Significance

Striped Whitelip in Canada only occurs in the Carolinian Forest Region, at the northern limit of the species' global range. As shown by Fraser (2000), range-edge populations can have significance for genetic diversity, long-term survival and evolution of the species, and provide opportunities for human recreation activities (e.g., recreational wildlife observations, in this case, snail watching).

Snails and slugs represent 2.5 to 6% (assuming densities of 2 - 38 snails/m^2) of the total animal biomass of boreal forest ecosystems (Hawkins *et al.* 1997b). Snails and slugs generally play important roles in forest ecosystem functioning, specifically by (i) aiding in decomposition, nutrient cycling, and soil building processes (Mason 1970a,b; Jennings and Barkham 1979); (ii) providing food and essential nutrients to wildlife (South 1980; Churchfield 1984; Frest and Johannes 1995; Martin 2000; Nyffeler and Symondson 2001); and (iii) serving as hosts for parasitic worms (e.g., Rowley *et al.* 1987). Graveland *et al.* (1994) have shown that gastropod declines can have an important impact on population dynamics of forest passerines. Gastropod diversity can also indicate the degree of anthropogenic disturbance (Douglas *et al.* 2013).

This species is unknown to most Canadians. It has no commercial value and is not an agricultural or garden pest. Aboriginal Traditional Knowledge is not available.

DISTRIBUTION

Global Range

Striped Whitelip is “in the loess, generally distributed from Indiana to Kansas” (Pilsbry 1940) in eastern North America. The northern limit is the province of Ontario and the US states of New York in the east and Minnesota in the west; the southern limit is Arkansas/Tennessee in the west and Maryland in the east (Figure 2). Current east-west distribution extends from West Virginia to Kansas/Nebraska (Figure 2). See **Non-Legal Status and Ranks** for the detailed list of US states where the species currently occurs.

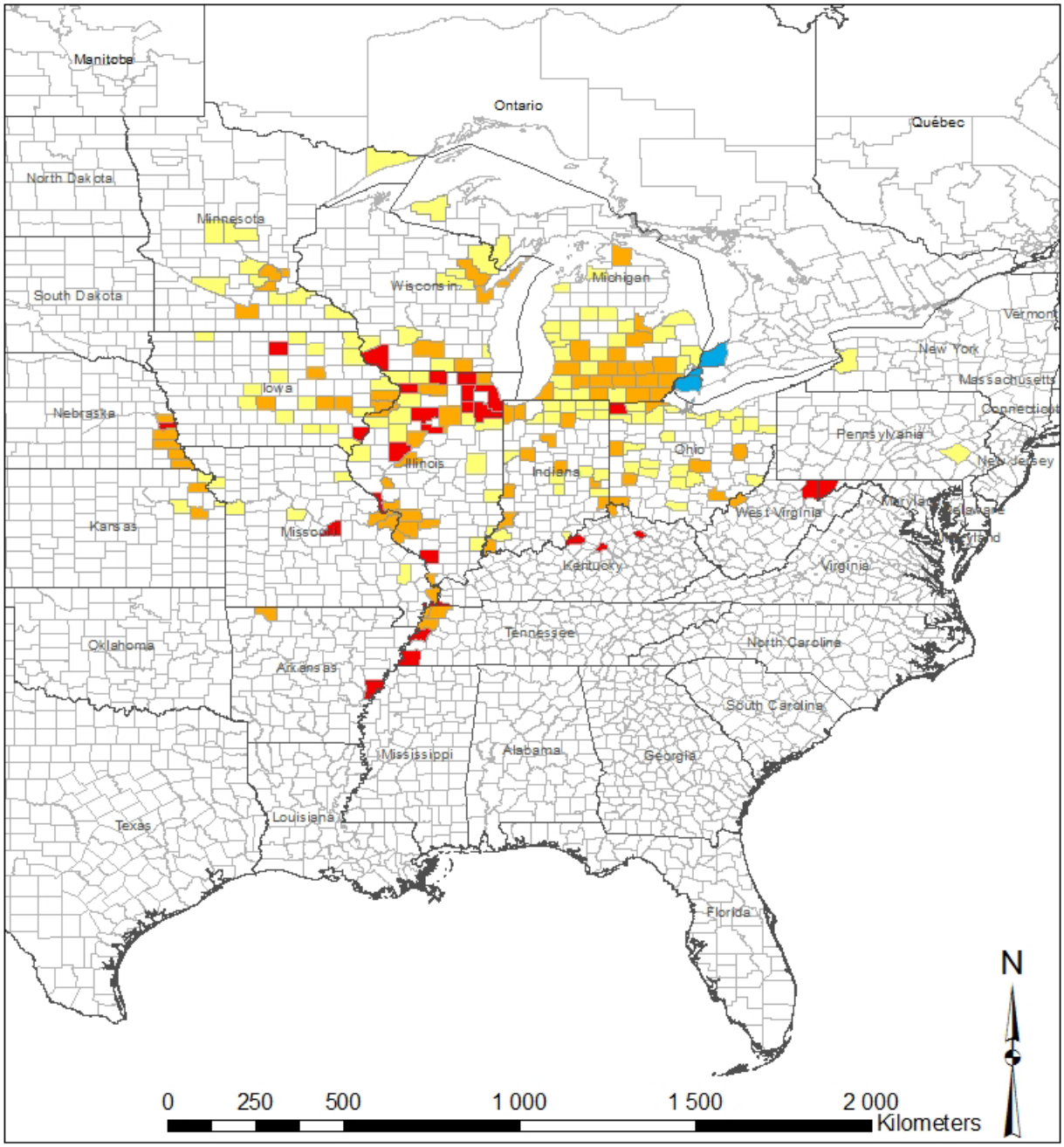

Figure 2. Global distribution of Striped Whitelip *Webbhelix multilineata*. Canadian counties in Ontario (blue: field verification from 2013–2016, for exact distribution refer to Figure 3) and US counties (yellow: records without date, orange: old records from 1821–1990, red: recent records from 1991–2015). Note that the species does not occur in the entire county. Occurrences per county are based on records in collections (see **Collections Examined**) and literature (Say 1821; Robertson and Blakeslee 1948; Cadwell 1971; Grimm 1971; Rudolph 1975; Taylor and Counts 1976; Hubricht 1985; Freeman and Perkins 1992; Hotopp and Pearce 2007). Number of occurrences per county range from 1 to 33. (Map prepared by Muriel Guérnion, UMR 6553 EcoBio, University Rennes 1.)

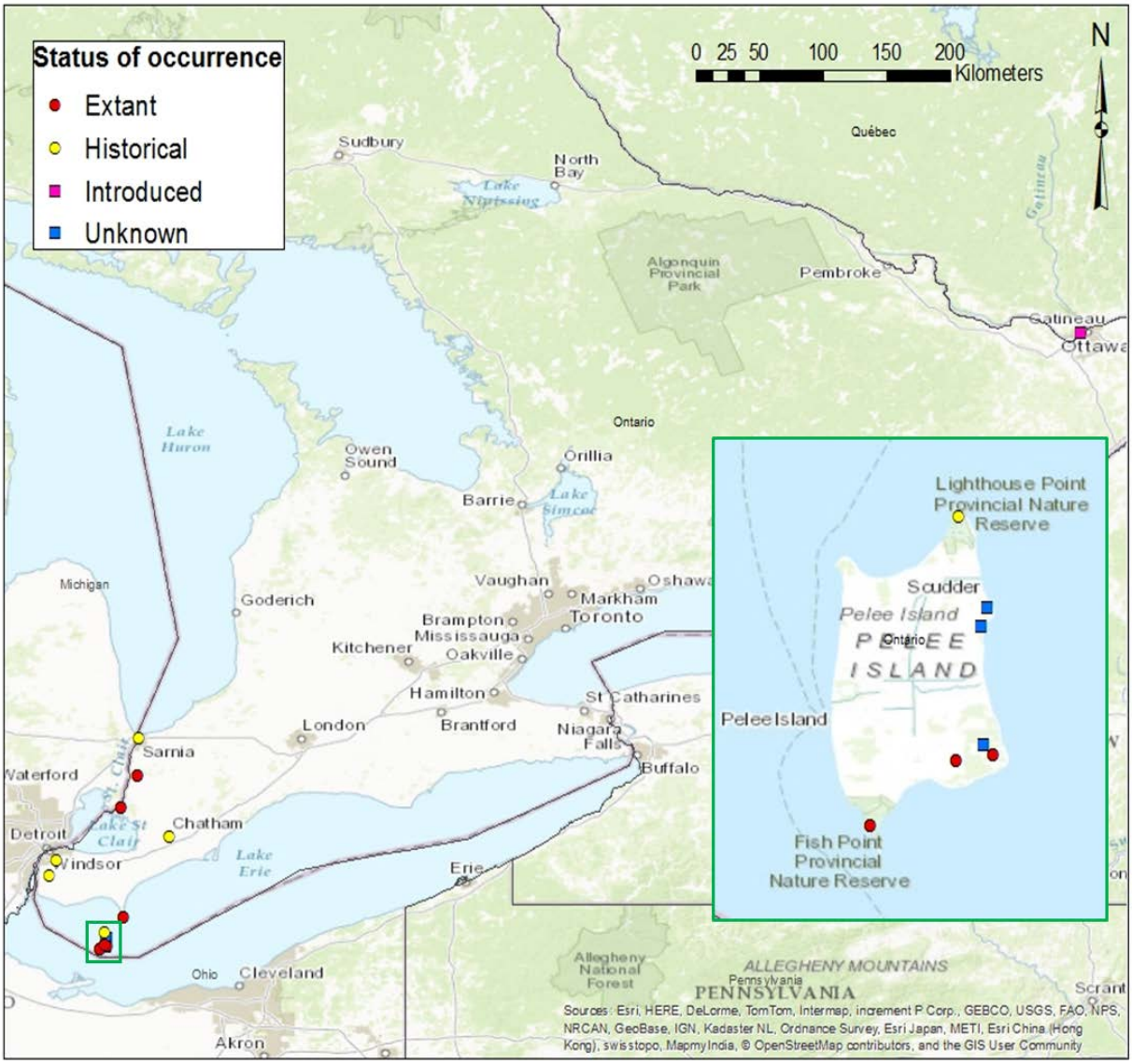

Figure 3. Distribution of Striped Whitelip *Webbhelix multilineata* in Ontario. Map prepared by Muriel Guernion (Université Rennes 1) based on records from 2013–2017 compiled for this report. “Unknown” means the presence of the species is unknown, because only shells have been found.

Canadian Range

Striped Whitelip is historically known in the southwestern Ontario counties of Essex and Lambton, and the municipality of Chatham-Kent (Table 1). Of the islands in Lake Erie, it was only recorded from Pelee Island (Table 1). A subpopulation in Hull, Gatineau, Quebec was introduced by Latchford (1887; LaRocque 1938) and described as extant in 1937 by Fairbairn (1937), but no specimens were found in Grimm’s 1970s to mid-1990s Gatineau collection at the CMN (Forsyth pers. comm. 2017), and the species could not be found during searches around Gatineau in 2016 (14 sites, 40 person-hours). A 1958 record in the

University of Michigan Museum of Zoology (UMMZ 249523) from Hall Creek near Bethany in Peterborough Co. was misidentified and thus not valid. Oughton (1948) also mentioned a doubtful record from Welland. If the Bethany (spurious) and Hull (introduced) records are excluded, the historical range extends north to Sarnia, south to Pelee Island, west to the St. Clair River, and east to Chatham (Figure 3). Except for one record in Hamilton (exact site is unknown, Table 1), all historical records fall within this range. Some sites in and around Hamilton, specifically lowland forests, and elsewhere on the Niagara Escarpment were searched in 2013–2017 (Table 2). Time for field verification was insufficient to visit multiple areas on the Niagara Escarpment, which seemed to be outside of the historical range and may not be the correct habitat for this species. During other recent gastropod surveys in southern Ontario by Nekola (2003a, 2005, 2010), the species was not found on the Niagara Escarpment. Moreover, the putative record from Hamilton, Ontario, comes from A.J. Brown who collected mainly in the USA and occasionally in Hamilton, Illinois, with the exception of this one specimen from Hamilton, Ontario (Gerber pers. comm. 2017).

Table 1. Collections of *Webbhelix multilineata* from Ontario and verification of all sites during fieldwork in 2013-2017, except Hamilton, where the exact site is unknown. For a complete list of survey dates and years see Table 2. Collections are curated by Royal Ontario Museum (ROM), by the Canadian Museum of Nature (CMN), by the Field Museum of Natural History (FMNH), and by R.G. Forsyth. The F.W. Grimm collection has not completely been examined yet. Population studies were implemented in the densest subpopulations.

County	Site	Most recent records	Collectors	Population Status (2013-2017)
Essex Co.	Pelee Island - Fish Point PNR	Aug 2, 2017	A Nicolai	extant (population study in 2016)
	Pelee Island - Stone Road Alvar - ERCA	Aug 14, 2017	A Nicolai	extant (found alive)
	Pelee Island - Stone Road Alvar - NCC (Porchuck)	Sep 1, 2016	A Nicolai, RG Forsyth	extant (found alive)
	Pelee Island - Middle Point Woods – NCC (east part)	Sep 3, 2016	A Nicolai, RG Forsyth	unknown (old shells)
	Pelee Island - Middle Point Woods – NCC (Novatney)	Sep 3, 2016	A Nicolai, RG Forsyth	unknown (old shells)
	Pelee Island - Stone Road Alvar - ON Nature	Nov 21, 2012	A Nicolai (AN43.1112)	unknown (old shells)
	Pelee Island - Lighthouse Point PNR	May 15, 1984	R MacCulloch (ROMIZ M9163)	historical
	Point Pelee NP - mainland	Aug 11, 2017	A Nicolai, T. Degazzio	extant (population study in 2016)
	Canard River Scout Camp (south of Windsor)	Apr 19, 1996	MJ Oldham (CMNML 098114)	historical

County	Site	Most recent records	Collectors	Population Status (2013-2017)
	Devonwood CA	Apr 3, 1995	MJ Oldham (16901a)	historical (juvenile in Grimm collection)
Lambton Co.	Bickford Oak Woods CR (south of Sarnia)	Sep 22, 2013	A Nicolai, L Coello (ANi D038)	extant (fresh shells)
	Sarnia	1859-60	R Bell (1861)	historical
	Walpole Island FN, Snye Prairie	May 2, 2013	J Bowles (AN320.0513)	extant (fresh shells)
Chatham-Kent	Chatham	1937	Oughton (1948)	historical
Hamilton		1970	AJ Brown (FMNH172367)	probably error on label in Burch collection, suitable habitat searched
Gatineau	Hull, Valtétreau, east escarpment	May 25, 1937	GE Fairbairn (1937, LaRocque 1938)	introduced by Latchford (1887), unknown existence, but site is now urbanized

Table 2. Summary of general gastropod survey sites in southwestern Ontario for *Webbhelix multilineata* in 2013-2017; if *W. multilineata* had been present, it would have been detected. Observers were Jane Bowles (JMB), Tammy Dobbie (TD1), Tarra Degazzio (TD2), Robert Foster (RFF), Allan Harris (AGH), Annegret Nicolai (AN), Michael Oldham (MJO), Robert Forsyth (RGF), Hiroko Udaka (HU), Litza Coello (LC), Dwayne Lepitzki (DL), Suzanne Dufour (SD), Ron Gould (RG), Kara Layton (KL), Mykola Mykow (MM), Paul Catling (PC). CA – Conservation Area, NCC – Nature Conservancy of Canada, TTLT – Thames Talbot Land Trust. (NAD83, 17T or 18T/N UTM).

Site	Effort (personhours)	Observers	Date(s) 2013	Date(s) 2014	Date(s) 2015	Date(s) 2016	Date(s) 2017	*W. m.* records
Black Oak Heritage Forest, south part, Windsor	14	AN, JMB, MJO	May 3, July 28, Aug 27-28, Sep 5					No
Former industrial area south of Black Oak Heritage Forest, Windsor	3	MJO	Sep 5					No
Black Oak Heritage Forest, north part, Windsor	4	AN, MJO,	Apr 29					No
Devonwood Conservation Area, Windsor	6	AN, MJO, DL, SD, RGF	April 29		Aug 22			No
Springgarden Road Park, Windsor	2	AN, MJO	April 29					No
Ojibway Park, Windsor	5	AN, MJO, JMB	Apr 29, May 3					No
Malden Park, Windsor	2	AN, JMB	May 3					No

Site	Effort (personhours)	Observers	Date(s) 2013	Date(s) 2014	Date(s) 2015	Date(s) 2016	Date(s) 2017	*W. m.* records
Oakwood, Windsor	2	AN, MM	Aug 27					No
Brunet Park, La Salle	1	AN	Aug 28					No
South Cameron Woodlot, Windsor	1	AN, MM	Aug 28					No
Peche Island, Windsor	2	AN, HU	May 19					No
Middle Island, Point Pelee National Park, Lake Erie	36	RFF, AN, MJO; AN, TD1, RG, RGF, 1 park staff, TD2	May 1; Aug 29		Aug 13			No
East Sister Island Provincial Park, Lake Erie	16.5	TD1, RFF, AGH, AN, MJO, RGF, RG, 1 park staff, TD2	Apr 30		Aug 13			No
Middle Sister Island, Lake Erie	3.5	TD1, RFF, AGH, AN, MJO	Apr 30					No
Lighthouse Point Provincial Nature Reserve, Pelee Island (2 sites)	9	RFF, AN, MJO; AN, RGF	May 1; Aug 25		Aug 12	01 Sep	14 Aug	No
Erie Sand and Gravel NCC parcel, Pelee Island	4.5	AN, MJO, AGH, RGF	May 2		Aug 12			No
Middle Point Woods – north part, NCC, Pelee Island	5	AGH, RFF, MJO, AN, RGF	May 2; Aug 25		Aug 14	03 Sep	17 Aug	Shells
Middle Point Woods – south part, NCC, Pelee Island	7.5	RFF, AGH, AN, RGF	May 1, 2; Aug 26	Aug 3		03 Sep	17 Aug	Shells
Middle Point Woods – Novatney, NCC, Pelee Island	2	AN, MJO, RGF	May 2			03 Sep		Shells
Gibwood Property, NCC, Pelee Island	3	AN, MJO	May 2				14 Aug	No
Richard and Beryl Ivey Nature Reserve, NCC, Pelee Island	8	RFF, AGH, AN, RGF	May 1	Aug 2	Aug 12	02 Sep	16 Aug	No
Winery property, Pelee Island	6	RFF, AGH, AN, MJO, RGF	May 2	Aug 2		31 Aug	16 Aug	No
Porchuk Property, NCC, Pelee Island	9	AN, MJO, RGF, AN	May 2			01 Sep	15 Aug	Alive
Fish Point Provincial Nature Reserve, Pelee Island	20	RFF, AGH, AN, RGF	May 1	Aug 3	Aug 11	02 Sep	16 Aug	Alive
Fleck Property, Pelee Island	1	RFF	May 2					No
Essex Region Conservation Authority Stone Road Alvar, Pelee Island	4	AGH, AN	May 2		Aug 11		16 Aug	Alive
Ontario Nature Stone Road Alvar, Pelee Island	7.5	AGH; AN, MM, RGF	May 2; Aug 27		Aug 11		16 Aug	No
NCC Stone Road Alvar, Pelee Island	2	RGF, AN			Aug 11			No
Cohen Shaughnessy Property, NCC, Pelee Island	4	AGH; AN,MM	May 2; Aug 27	Aug 3			16 Aug	No
Krestel Parcel, NCC, Pelee Island	5	AGH, AN, RGF	May 1	Aug 3	Aug 11		15 Aug	No

Site	Effort (personhours)	Observers	Date(s) 2013	Date(s) 2014	Date(s) 2015	Date(s) 2016	Date(s) 2017	*W. m.* records
Finley Parcel, NCC, Pelee Island	1	AN		Aug 4				No
Fronzier Parcel, NCC, Pelee Island	1	AN, RGF			Aug 12			No
Florian Diamante Nature Reserve, NCC, Pelee Island	11.5	AGH, RFF, AN, RGF	May 2	Aug 2	Aug 11, 12	02 Sep	14 Aug	No
Sheridan Point, Pelee island	1	AN					14 Aug	No
Point Pelee National Park (6 sites)	26	AGH, AN, MJO, RFF, RGF, TD2	Apr 28, 29			30 Aug	11 Aug	Alive
Oxley Swamp, NCC	3	AN, HU	May 20				12 Aug	No
Cedar Creek CA	4	RFF, AGH, AN	April 29				13 Aug	No
Kopegaron Woods CA	5	RFF, AGH, AN, MJO	Apr 29, 30				12 Aug	No
Two Creeks CA	3	MJO, AN	May 18				13 Aug	No
Andrew Murray O'Neil Memorial Woods CA	1	AN					13 Aug	No
Canard River CA	2	AN, MJO	April 29					No
Canard River Scout Camp (former)	3	AN, RGF				29 Aug		No
For the Birds (East of Gore Rd, Road 13)	1	AN, RGF				29 Aug		No
Maidstone CA	2	RFF, AGH	April 29					No
Rondeau Provincial Park	6.5	MJO, JMB; AGH	May 17; Sep 4					No
Wheatley Provincial Park	2	AN					14 Aug	No
Sinclair's Bush	2	MJO, JMB	May 17					No
Thames Grove CA	1	AN, JMB	May 3					No
Moraviantown First Nation (2 sites)	9	AN, JMB	June 7					No
John E. Pearce Provincial Park	2	MJO	May 15					No
Newport Forest, TTLT	3	AN; AN, HU	April 21; Sep 01					No
Wardsville Woods TTLT	1	JMB	May 17					No
Backus Woods, NCC	6	MJO; AGH; AN	May 15; Sep 2				9 Aug	No
Lake Erie Farms, NCC	1	AN					9 Aug	No
St. Williams Conservation Reserve	2	MJO	May 15					No
Calton Swamp	1	MJO	May 15					No

Site	Effort (personhours)	Observers	Date(s) 2013	Date(s) 2014	Date(s) 2015	Date(s) 2016	Date(s) 2017	*W. m.* records
Lake Whittaker CA	2	AN, HU	June 8					No
Westminster Ponds, London	1	AN	April 7					No
Komoka Provincial Park	1	AN, HU	Jan 13					No
Western University, London	0.5	AN	April 15					No
Canatara Park, Sarnia	7	JMB, MJO; AGH; AN, LC, RGF	May 16, August 3; Sep 22			28 Aug		No
Tremblay Beach CA	1	AN, RGF				29 Aug		No
Ruscom Shores CA	1	AN, RGF				29 Aug		No
Killaly Meadows, London	1	AN	May 4					No
Lambton United Church Camp	2	AGH	August 3					No
Highland Glen CA	1	AGH	August 3					No
Joany's Woods TTLT	1	AN, JMB	April 1					No
Port Franks	2	AGH	August 4					No
Pinery Provincial Park	2	AN	May 5; July 07					No
C.M. Wilson CA	2	MJO, JMB	May 16					No
Paxton Wood, Chatham	2	MJO, JMB	May 16					No
Skunk's Misery	2	MJO, JMB	May 16					No
Avon trail near St. Mary's	1	AN	Jul 27					No
Long Point Provincial Park	2	AGH	Sep 2					No
Bickford Oak Woods Conservation Reserve	4	AN, LC, RGF	Sep 22			28 Aug		Shells
Brigden Crown Game Reserve (3 sites)	5	AN, LC, RGF	Sep 22			28 Aug		No
Wawanosh CA	1	AN, RGF				28 Aug		No
Moore Wildlife Refuge CA	2	AN, LC	Sep 22					No
Perch Creek CA	2	AN, LC	Sep 21					No
Floodway CA	2	AN, LC	Sep 21					No
Petrolia CA	1	AN, LC	Sep 22					No
Rouge Park, Scarborough	4	AN	Sep 14, 15					No
High Park, Grenadier Pond, Toronto	1	MM	Sep 22					No

Site	Effort (personhours)	Observers	Date(s) 2013	Date(s) 2014	Date(s) 2015	Date(s) 2016	Date(s) 2017	*W. m.* records
Clements Property, Alvinston	4	MJO, RGF, AN			Aug 14, Sep 1			No
Karner Blue Parcel, NCC, Port Franks	4	RGF, AN			Aug 17			No
Tall Grass Restoration Site, Port Franks	1	RGF, AN			Aug 17			No
Kettle Point, Indian Reserve	1	RGF, AN			Aug 17			No
Bruce trail, Burlington	2	RGF, AN			Aug 18			No
Britton Tract, Haltonville	2	RGF, AN			Aug 18			No
Cape Croker Park	1	AN			Aug 31			No
Elora Gorges CA	3	AN, KL, 1 student		Aug 5				No
Speed River Trail, Guelph	3	AN, KL, 1 student		Aug 5				No
Gorba Trail, Guelph	3	AN, KL, 1 student		Aug 5				No
Arboretum Guelph	1	AN		Aug 5				No
Bruce Peninsula National Park (11 sites)	11	AN		Jul 21, 22, 23				No
Rare, Charitable Research Area, Cambridge	4	AN, RGF			Aug 16			No
Ottawa/Gatineau (14 sites)	40	AN, RGF, PC				Aug 23-26, Sep 6-7		No
North Stormont	2	RGF				Sep 6		No
Papineau MRC: Plaisance	8	AN, RGF				Aug 24		No
Metcalfe (near Ottawa)	6	AN, PC, RGF				Aug 25		No
Edwardsburgh/Cardinal	2	RGF				Sep 7		No
Casselman	2	RGF				Sep 7		No
Morris Island CA	3	AN, RGF				Aug 23		No
Dundas Valley CA	4	AN					Aug 7	No
Royal Botanical Garden conservation land (Hamilton)	5	AN					Aug 8	No
AW Campbell CA	2	AN					Aug 10	No

The current range in Ontario includes sites from two counties (Essex and Lambton), where live individuals or shells have been found recently (Table 1; Figure 3). It is uncertain whether the species is still extant in Middle Point Woods on Pelee Island, because only old shells have been found since 2013 (Table 1). The species is known to be extant in Fish

Point PNR and Stone Road Alvar on Pelee Island and on the mainland in Bickford Oak Woods Conservation Reserve, Walpole Island, and Point Pelee National Park. The known occurrences of Striped Whitelip were reduced from 12 to seven sites (42% reduction), because it has not been seen alive despite repeated and recent searches during the last 20 years at the sites in Chatham, Sarnia, Devonwood Conservation Area and Canard River Scout Camp near Windsor, and Lighthouse Point on Pelee Island (Table 1; Figure 3).

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EOO) of Striped Whitelip in Canada is 887 km^2 as measured by the minimum convex polygon method, excluding those sites where the species is presumed to be extirpated, but including those sites where the status is unknown (Table 1). Much of this area is covered by water (Lake Erie) and unsuitable land. The index of area of occupancy (IAO) is 104 km^2 (i.e., the species occurs in 26 2 km x 2 km grid cells), assuming as extant only those sites where living snails or recently dead shells were observed. The IAO calculations for Pelee Island and Point Pelee National Park are discrete and includes the entire area surveyed where the species was observed. In contrast, IAO calculations for Walpole Island and Bickford Oak Woods Conservation Area were continous and inferred from intact, continous habitat, because the entire areas could not be surveyed. If all historical records are included, the IAO is 124 km^2, using one grid cell each for Chatham, Sarnia, Devonwood Conservation Area, Canard River Scout Camp near Windsor, and Lighthouse Point on Pelee Island. There has been a reduction in IAO by about 16% within the last 20 years (Table 1).

Search Effort

The probability of detecting Striped Whitelip is relatively high, both due to its large size and because empty shells remain on the forest floor for some time after the animals have died. However, the shell is not very thick and does not last as long as other shells, such as those of Eastern Banded Tigersnail *Anguispira kochi kochi* that can remain as subfossils (COSEWIC 2017).

Notable historical surveys include those by John Oughton between about 1930 and 1940 (Oughton 1948). Grimm collected extensively in southern and eastern Ontario between 1970 and the mid-1990s (Grimm 1996), but his collection has been only partially examined.

Surveys between 1992 and 2012 were general land snail searches rather than targeted searches for Striped Whitelip. All species combined, there are 2,349 geo-referenced collection records from searches by M.J. Oldham between 1992 and 2012. Surveys by J.M. Bowles in 1994 and by A. Nicolai in 2012 yielded an additional 113 and 364 geo-referenced collection records, respectively. The most recent records of Striped Whitelip from these surveys are summarized in Table 1.

During the 2013–2017 general gastropod survey in southwest Ontario, 135 sites were visited and re-visited for a total search effort of 460 person-hours (Table 2). The surveys in

2014–2017 targeted Striped Whitelip and focused mainly on known sites and collected data for population analyses, while the surveys in 2013 focused on collecting specimens of multiple species. The surveys in 2013 resulted in approximately 210 alcohol-preserved samples of about 60 species being deposited at the BIO and 200 shell samples of about 40 species, currently being curated by R. Forsyth. Voucher specimens (n = 7) from Fish Point PNR on Pelee Island have been deposited at the BIO with the following Sample IDs: BIOUG09922-B02, B03, BIOUG15235-B11, B12, C01, BIOUG027664-B10, and B11. All Striped Whitelip collected from different sites during this survey as well as site verifications are shown in Table 1.

HABITAT

Habitat Requirements

The habitat of Striped Whitelip in Canada is similar to that used in the eastern US and described by Hubricht (1985) as “low, wet places, in marshes, floodplains, meadows, and margins of lakes and ponds, under litter and drift”. Striped Whitelip habitat near Iowa City was characterized by Pilsbry (1940) as “wet marshes” and “weedy, willow covered islands which were submerged annually by the spring freshets”. In Wisconsin and Michigan, Nekola (2003b) has found the species with the same occurrence frequency of <3% in rock outcrop and lowland and highland forests. In Illinois, Strode (1893) found the species in “heavily wooded districts bordering the banks of the stream” and “further back near the bluffs” as well as “on swamp prairie land”. In Nebraska, Cadwell (1971) found several subpopulations scattered about a large area along the Missouri River; he noted the species prefers river banks. In Ontario, the species was found in wet, lowland forest, at the margins of periodically flooded patches or in continuously wet parts.

In Illinois, Striped Whitelip is found in damp woods of oak, hickory, box elder, tamarack, maple, and cottonwood (Leonard 1959; specific species not stated). In Ontario, habitat description was based on sampling in mainland sites and on Pelee Island using Ecological Land Classification (ELC, Lee *et al.* 1998). On the Essex Regional Conservation Authority (ERCA) property on Stone Road Alvar it was only found in the Swamp White Oak-Chinquapin Oak Savannah (which covers about 20% of the 64 ha property, ERCA-ELC map) while on the Nature Conservancy of Canada (NCC) Porchuk property on Stone Road Alvar it was found at the edge of a forest complex composed of Dry-Fresh Sugar Maple Deciduous Forest (4.5 ha), Dry-Fresh Oak-Hickory Deciduous Forest (2.6 ha), Dry-Fresh Calcareous Bedrock Deciduous Woodland (8.0 ha), and Fresh-Moist Green Ash-Hardwood Lowland Deciduous Forest (about 10 ha) – in total about 25 ha (NCC map: ELC_Stone_Road_Alvar-53743). At Fish Point PNR it was found on lower ground and close to the swamp mainly in the Dry-Moist Sugar Maple Deciduous Forest (which covers about 25% of the 110 ha property; Dobbyn and Hoare 2009). The total size of currently used habitat on Pelee Island is about 55 ha out of 735 ha of protected land on the island. Added to this is the possible habitat of 18 ha in Middle Point Woods (about 7 ha Dry-Moist Sugar Maple Deciduous Forest and about 11 ha of Moist Ash Lowland and Oak-Maple Forests, NCC map: ELC-Novatney_2012-53538), where the presence of the species is

likely. On the mainland, about 400 ha of forest (Dougan & Associates 2007) in Point Pelee National Park is probably used by Striped Whitelip. Bickford Oak Woods Conservation Reserve contains about 215 ha of interior forest around a 100 ha wetland (MNR 2009) with Swamp White Oak Mineral Deciduous Swamp, Green Ash Mineral Deciduous Swamp, and a mosaic of Swamp White Oak Mineral Deciduous Swamp and Fresh-Moist Oak-Sugar Maple Deciduous Forest. Walpole Island has 1783 ha of forest scattered around wetlands (Jacobs 2006); all these are highly suitable habitat for Striped Whitelip and its presence is likely.

Pilsbry (1940) reported Striped Whitelip "climbing about on weeds and blades of grass, apparently endeavoring to avoid the water collected beneath it." In Ontario, distribution within a habitat or site was extremely heterogeneous, obviously linked to the requirement of moist microsites in the dry season provided by rotting bark, logs, and twigs. Particularly large logs and big pieces of bark (old growth forests) or artificial cover, such as boards or corrugated iron, were observed to be preferred by the species over leaf litter that tended to dry out during longer drought periods. In general, snails are more abundant in complex habitat (Anderson and Coppolino 2008). Strode (1893) observed "thousands of them [Striped Whitelip]" in a swamp prairie next to a wood "where rotten logs, decaying leaves and vegetation are in greatest abundance".

For hibernation in wet habitat such as swamps and flooded forest, Striped Whitelip needs a place protected from flooding, such as "the tops of Carex-bogs" (Pilsbry 1940) or higher ground with a litter layer for concealment, respectively. Therefore, the species can be recorded on beaches (dunes), as reported in Pilsbry (1940) and observed in Fish Point PNR, or in the savannah, such as behind the beach in Point Pelee National Park and in Stone Road Alvar, or in prairie, such as on Walpole Island, or in drier forest on higher ground, such as in Point Pelee National Park and as reported by Nekola (2003b), or on rock outcrop (Nekola 2003b).

Habitat Trends

Climate change

The climate on islands in and land near Lake Erie is much warmer than expected for its latitude because of the lake's moderating effect. Two-thirds of the year is frost-free. The warmer climate plays an extremely important role in allowing the persistence of flora and fauna at the northern edges of their ranges (North - South Environmental Inc. 2004).

Although the wetland on Pelee Island has been drained, flooding of forest still occurs every year in Fish Point PNR, Middle Point Woods, and the Stone Road Alvar. The flooding is less intense since 1970–1972 because much of the island's shoreline was fortified with armour stone, and a network of dykes crisscrosses the island (NCC 2008); however, these fortifications are absent from Fish Point PNR.

Even though the species is at its northern edge in Canada, climate change will not necessarily result in conditions more comparable to the core of its range in the US. Hydrological regimes, snow cover, and temperatures can all influence survival at different times in the lifecycle. An increase in the frequency of extreme weather events, such as storms, freeze-thaw cycles, and droughts seen in northern parts of the range, may not be similar to what the species experiences further south. Using the prediction model from 1960–1990 to 2015–2045 on the Ontario climate change data portal (PRECIS model under A1B emissions scenario, Wang and Huang 2013), some climate change observations and predictions are as follows:

- Average winter temperatures will increase by 3°C in southwestern Ontario (from -3.8°C in 1960–1990 to -0.5°C in 2015–2045), except on Pelee Island where the influence of Lake Erie keeps climate stable (about 0.4°C in 1960–1990 and 2015–2045 combined). Mean temperature close to 0°C increases the chances of more frequent freeze-thaw cycles in fall/winter (Nicolai and Sinclair 2013) and more spring frosts (Augspurger 2013). On Pelee Island, winter precipitation is about 100 mm higher than on the mainland (314 mm versus 198 mm, respectively) which results in a thicker, more stable, and longer-lasting snow cover that insulates snails from extreme temperatures (Nicolai *et al.* 2011).
- The average amount of precipitation per year on Pelee Island (about 1,500 mm/year) is about 400 mm higher than on the mainland (about 1130 mm). With climate change, the intensity of precipitation on the islands will increase by about 10 mm/hr with an increase in the average amount of monthly precipitation of about 10 mm in summer and 40 mm in winter, thereby likely increasing the flooding on Pelee Island. On the mainland, intensity of precipitation will increase by up to 20 mm/hr with an increase in the average amount of monthly precipitation of about 20 mm in summer and winter. This means heavier storms and more water in wet areas.
- There will also be longer periods between rainfall events with a greater risk of droughts especially in mid-continental regions (Meehl *et al.* 2007). Under climate change scenarios, changes to average and extreme temperatures will alter microhabitat conditions within the snails' habitat; both beneficial and adverse effects may ensue, but the overall effects are difficult to predict (Angiletta 2009; Sears *et al.* 2011). Additionally, anthropogenic activity influences microhabitat structure although the link between habitat choice and physiology is poorly understood (Deutsch *et al.* 2008).

Land management

After being logged in the mid-1880s, Pelee Island has largely been developed for agriculture (NCC 2008). Viticulture and soybean farming occur mainly on tile-drained marshland between the former four bedrock islands. On these former islands, some alvar habitats are now protected, most of them being former prairies or logged woodlots. About 15 to 20% of the natural vegetation cover is still intact (ERCA 2002), most of which is under management by the NCC or the Ontario Ministry of Natural Resources and Forestry

(MNRF). NCC controls invasive plants by mechanical removal or periodically with chemicals (NCC 2008). Herbicide use at a larger scale is still restricted to study plots (study in progress by NCC). Prescribed fire would be mainly applied to grasses in the savannah on the Stone Road Alvar owned by ERCA, Ontario Nature (ON Nature), and NCC. A test burn is planned for 2018 (Lebedyk pers. comm. 2016) which includes habitat of Striped Whitelip. Access for the public is possible on walking trails that go through the ERCA and ON Nature properties of Stone Road Alvar. Logging and grazing are forbidden, while hunting is still allowed on almost all NCC properties. The management plan for Fish Point PNR focuses mainly on the regulation of access, including trail maintenance or construction, and on education (Ontario Parks 2005). There are also efforts to eradicate invasive species and to enhance habitat of species at risk.

Habitat connections were re-established by restoring former fields adjacent to forested areas to forest and wetland on Pelee Island by NCC (NCC 2008), but some habitat patches are still unconnected at the micro-scale suitable for gastropods by former fields (now thickets). Colonization or exchanges between habitats on distant properties on Pelee Island is even more difficult because of barriers between the protected areas. Ditches as well as paved and unpaved roads or tracks as narrow as 3 m with both high and low traffic densities are barriers to snail dispersal (Baur and Baur 1990; Wirth *et al.* 1999). Disturbed habitats such as cultivated or grazed fields and small cultured woodlots between fields do not seem to act as movement corridors, because no native snail or slug was found in such sites on Pelee Island in 2013–2017.

Point Pelee National Park was established in 1918, because of its important ecological functions as a major staging and nesting area for migratory birds. Today, the park's national and international significance is because of the Carolinian vegetation (the only national park in Canada in this vegetation zone), marsh biodiversity (about 70% of the park area is marsh), and insect and bird migration (Dougan & Associates 2007). An ecosystem-based recovery strategy for all Lake Erie Sand Spit Savannahs (LESSS) was initiated to protect and restore the integrity of this extremely rare ecosystem. The LESSS management strategy involves maintaining the natural dynamics of sand spit formations, minimizing human threats, and restoring and/or mimicking key natural disturbances. Actions planned in 2017–2018 include small prescribed burns in open savannah areas, test burns in oak woodlands as well as clearing of invasive shrub thickets from former savannah areas, and thinning of some rare woodland forest to prevent succession to more common closed canopy mature forest types. Some of this work will occur in forested areas that were artificially opened by former settlements, such as the former orchard near the south tip and at DeLaurier homestead. These historically changed forests are currently rare ELC types (e.g., Coniferous Woodland) within a park dominated by deciduous, mostly older growth. These islands of younger forest within older-growth forest harbour species at risk and are therefore managed to preserve and enhance species at risk habitat. Vegetation thinning is beneficial for these species at risk and is similar to forest openings caused by storms because fallen trees will be retained.

Bickford Oak Woods Conservation Reserve is the largest protected Carolinian clay plain forest in Canada, with scattered wetland pockets that provide habitat for a diversity of Carolinian species (MNR 2009). Drainage, cattle grazing, and petroleum wells and pipelines have changed the forest. Since 1970 the area is of conservation interest for the MNRF. The management plan includes the restoration and/or preservation of vegetation communities by restoring natural drainage, fire suppression and prescribed burns, control for invasive species, pest suppression, and enhancement of habitat (MNR 2009).

Walpole Island was inhabited by First Nations as early as 6000 years ago. Today, the land has 54 species at risk and rare vegetation communities, such as tall grass prairie and oak savannah (Jacobs 2006); 4,800 ha are used for agriculture and the remaining land is natural and used for hunting and fishing, gathering plants for medicine and food, spiritual connection, and enjoyment. While caring for their land is an ancestral tradition, the First Nation community secures habitat for conservation purposes (68 ha so far), builds partnerships to combine traditional knowledge and science, and invests efforts in ecological education. The challenge is human population growth which increases pressure on natural habitats (Jacobs 2006).

Sand erosion

The tips of Fish Point PNR and Point Pelee National Park are subject to a natural process of sand erosion on the east side and deposition on the west side (Kamstra *et al.* 1995), but this process has not been studied at Fish Point. The tip of Point Pelee is expected to retreat by 50 m over the next 50 years, because the coupled process of erosion and deposition of sand is disrupted (BaMasoud and Byrne 2011). This disruption of the sand budget at the tip of Point Pelee has been caused by historical offshore sand mining and public and private shoreline protection as well as new harbour structures (Dobbie pers. comm. 2016). Climate change can also involve higher wind speed and longer, more frequent storms, thereby increasing erosion, but no data are available to confirm this possibility. Erosion at Fish Point PNR was seen in 2013–2017 and has led to loss of trees and incursion of lake water inland at the south end into the wet zone where most Striped Whitelip occur.

Habitat quality ranking

The habitats currently occupied by Striped Whitelip were ranked AC (Excellent to Fair) for their capacity to sustain a viable snail population using the element of occurrence ranking key of NatureServe (Tomaino *et al.* 2008) on the best available information. This means the occurrences may persist for the foreseeable future with appropriate and ongoing protection or management. This is second growth forest or old growth forest that has historically been disturbed by logging and grazing. Spatial distribution of Striped Whitelip across each site is patchy. Suitable habitat is fragmented. Corridors between properties could be developed in the near future on Pelee Island.

BIOLOGY

Little information is available about the biology of Striped Whitelip. General aspects of terrestrial snail biology are provided by the review of Barker (2001). Some information from other Polygyridae is available. However, this information could give misleading conclusions about the capacity of Striped Whitelip to survive or to adjust to specific conditions, because Polygyridae include common species that are not of conservation concern.

Life Cycle and Reproduction

Striped Whitelip is an air-breathing (pulmonate) snail that is a simultaneous hermaphrodite (possesses both male and female reproductive organs) and lays eggs (Pilsbry 1940). In general, both members of a mating pair exchange sperm and produce eggs. In another polygyrid snail, Whitelip Snail *Neohelix albolabris*, self-fertilization can occur if mating probability is extremely low, resulting in very low reproductive success (McCracken and Brussard 2008). Usually, the frequency of such inbreeding is very low in most populations (McCracken and Brussard 2008). Coitus in Striped Whitelip can last as long as 9 hr, which immobilizes the mating pair for this time (Webb 1948). In an *ex situ* breeding colony of 30 Striped Whitelip adults, 241 juveniles were produced (Cadwell 1971), but the number of egg-laying adults was not determined, so clutch size is unknown. In most snail species, larger individuals lay more eggs than smaller ones (Heller 2001). Because no hibernation marks were observed on the shells of juveniles of different sizes during fieldwork in 2013–2016, reproduction is inferred to occur twice a year in Ontario: mating occurs in mid-spring and mid-summer with oviposition in late spring and late summer, respectively. In general, egg clutches are deposited in shallow holes excavated in moist soil (Barker 2001).

Hibernation of Striped Whitelip probably extends from early October until mid-April; the exact timing is expected to vary depending on conditions in particular years. In Ontario, hibernating Striped Whitelip were observed in the soil in November, and active individuals were observed at the end of April in 2013. Typical hibernation sites in other species are shallow depressions in the forest floor covered with leaf litter or soil at depths of 5 to 10 cm (Pearce and Örstan 2006). In Pilsbry (1940), hibernation sites in marshes are described as the “top of carex-bogs” where a large number of snails concentrate in “shallow excavations on the bog, concealed beneath the tufts of dead grass”. In the forest, Striped Whitelip seems also to be gregarious as it buries into the soil or the leaf litter (Leonard 1959).

In temperate regions, aestivation in various species of snails occurs occasionally during periods of prolonged heat and drought (Nicolai *et al.* 2011). During aestivation, snails usually remain inactive in moist microhabitats, such as in soil, under leaf litter, and under logs. During these longer periods of inactivity, hibernation and aestivation, the snails cover their shell opening by a slightly calcified epiphragm. Aestivating Striped Whitelip were observed in August 2016, attached by the epiphragm to moist logs and bark on the ground. On Pelee Island, all observed snail species were mainly active in morning hours or after rain. However, most gastropods are also crepuscular or nocturnal, and sympatric species often have different activity patterns (Asami 1993).

In general, growth occurs only during periods of activity (spring to fall). In other species (e.g., Brown Garden Snail *Cornu aspersum*, Roman Snail *Helix pomatia*, and Corsica Helix *Tyrrhenaria ceratina*), the adult shell size (~2 cm in width) is reached after 1 to 2 years and sexual maturity after 2 to 3 years (Nicolai 2010; Nicolai *et al*. 2010; Charrier *et al.* 2013). In 2013–2017, live adults with old and already weathered shells, as in Broad-Banded Forestsnail (COSEWIC 2014a) and Eastern Banded Tigersnail (COSEWIC 2017), were not observed. Longevity in Striped Whitelip seems to be shorter than in these other species. The thin shell and the high abundance of Striped Whitelip in some places (Ontario: Bell 1861; Illinois: Strode 1893) indicate that the species is short-lived (maybe about 5-6 years) with a high reproduction rate. The estimated generation time for Striped Whitelip is somewhere between the age at sexual maturity and longevity, probably 4 years.

Physiology and Adaptability

Physiological responses to environmental factors and their plasticity and adaptability have not been studied intensively. Details of diet and feeding behaviour are unknown. Striped Whitelip might be mainly a ground-dwelling species when searching for food, in contrast to Broad-banded Forestsnail that was also seen climbing on plants up to 1.5 m high in August 2016. In Point Pelee National Park, Striped Whitelip was observed by Dunster (1992) to be the main grazer on germinating plants, such as Dwarf Hackberry *Celtis tenuifolia* seedlings, compared to other snail species present in the vicinity (Broad-banded Forestsnail*,* Dished Threetooth *Triodopsis vulgata*, Tigersnail *Anguispira alternata*, and Whitelip Snail). In 24 hr, three snails completely consumed 62% of 356 tree seedlings stored beside the visitor building of Point Pelee National Park, and Dunster (1992) concluded that the low numbers of seedlings of *C. tenuifolia* around each of the 182 adult trees in the park are correlated to the presence of Striped Whitelip. Germinating plants might be the easiest to reach for this ground-dwelling snail.

Striped Whitelip seemed also to be the species that is the easiest to rear in the laboratory, on a sterile substrate fed with lettuce and carrots, in comparison to Meadow Slug *Deroceras laeve* and Grey Fieldslug *Deroceras reticulatum* under the same conditions; Forest Disc *Discus cronkhitei*, Multiribbed Vallonia *Vallonia gracilicosta*, Lovely Vallonia *Vallonia pulchella*, Variable Vertigo *Vertigo gouldii*, and Quick Gloss *Zonitoides arboreus* needed organic leaf-litter substrate that simulated environmental conditions (Gray *et al.* 1985). Occasionally Striped Whitelip feeds on carrion and can appear carnivorous in captivity (Crabb 1928), sometimes just before reproduction when snails need cholesterol for egg production (Nicolai *et al.* 2012) or for accelerating growth (Saveanu *et al.* 2016). Easy rearing and trophic flexibility is a relevant trait in the potential for organisms to establish widely, maintain high abundances, and spread after invasion. Striped Whitelip occurred at very high densities in some sites in the last century, but it did not become a pest or invasive. It is absent from agricultural land, probably more because of its affinity to wetlands or moist forest with abundant dead tree material on the forest floor, than because of food restrictions on arable land. Nevertheless, the requirement for fresh plant material means Striped Whitelip needs to move relatively large distances in the search for food, compared to other species, such as Broad-banded Forestsnail (COSEWIC 2014a) and Eastern

Banded Tigersnail (COSEWIC 2017), that eat decaying plants (everywhere in the leaf litter) or microfungi on the log on which they sit. Striped Whitelip was the most observed species crossing trails and roads in Fish Point PNR on Pelee Island and in Point Pelee National Park during fieldwork in 2013–2017. In Point Pelee, it was even observed in the artificially established green space around the visitor building, separated from the forest by roads, trails, and the tourist train stop. Also Strode (1893) observed the species crossing the road along the forest to reach prairie vegetation.

In general, snails require calcium for shell formation. Soil and bedrock calcium availability influence the snail species richness (i.e., number of species) of an area (Nekola 2005) and physiological processes, such as heat resistance in eggs (Nicolai *et al.* 2013). Heavy metals and pesticides in the soil are accumulated in tissues and may disturb physiological processes (Barker 2001).

Snails in regions with prolonged periods of drought and heat generally aestivate in buffered refuges and seal their shell aperture to avoid evaporation (Barker 2001; Pearce and Örstan 2006). In temperate regions, many species only aestivate in extreme summer conditions for a short period and have developed biochemical stress reactions that protect cellular architecture and processes (such as membrane fluidity, osmoregulation, and enzyme activity), and hence maintain survival mechanisms. Striped Whitelip seemed to withstand warm conditions better than other species, because it was the only species among the forest community crawling during warm days (Leonard 1959). Unusually long hot and dry periods with unusual timing (e.g., in early spring or late autumn) can increase mortality, e.g., up to 70% in Roman Snail right after arousal from hibernation (Nicolai *et al.* 2011). Because Striped Whitelip increases the galactogen reserve in the albumen gland for reproduction during the first 12 days after arousal from hibernation (Rudolph 1975), spring droughts would also have a negative impact on survival or reproduction.

Snails are prone to freezing in winter. Different strategies that are somewhat plastic have evolved to enable survival at sub-zero temperatures (see review by Ansart and Vernon 2003). Freeze tolerance means that species freeze at sub-zero temperatures close to zero and can survive freezing of their body for some time, while freeze avoidance means that species can supercool (body fluids stay liquid) to very low temperatures (due to the accumulation of cryoprotectants in the hemolymph), but die when their body freezes. Striped Whitelip uses both strategies: it is freeze tolerant (Supercooling Point, temperature at which body fluids start to freeze, SCP, = -3°C) during activity periods (spring to fall) and becomes freeze avoidant (SCP = -12 to -16°C, due to accumulation of glucose as cryoprotectant) during inactive periods (Franke 1985). Grove Snail *Cepaea nemoralis* has the same strategy and could become invasive in Canada, probably because of its good cold hardiness (Nicolai and Ansart 2017). Striped Whitelip's SCP in winter is lower than that of Grove Snail (SCP = -10 to -12°C) which had a survival rate of about 43% in a winter without snow and temperature variations (up to 40 hr at -10 to -15°C; Nicolai and Sinclair 2013). Mortality during hibernation is usually around 40% in some species and drives population dynamics (Peake 1978; Cain 1983). As a consequence, Striped Whitelip's supercooling ability should give it quite a good winter survival rate with or without snow. Usually, snails hibernate in buffered microsites which are additionally insulated by snow in

temperate regions (Nicolai *et al.* 2011). Burch and Pearce (1990) suggest refuges with buffered environmental conditions, such as temperature and humidity, may be the most important factor limiting terrestrial snail abundance. This is still true for spring and fall frosts, especially when snails start being active and switch strategies. They rely then on buffered microsites, because repeated freeze-thaw events decrease survival and reproduction (Nicolai and Sinclair 2013).

Dispersal and Migration

Active movement distances of Striped Whitelip are unknown, but other Polygyridae of similar size move between 120 and 220 cm per day within a home range of 80 to 800 m^2, measured with the spooling technique (spool with thread attached to snail's shell) in Whitelip Snail and Whitelip Globe *Mesodon thyroidus*, respectively (Pearce 1990). Striped Whitelip might even have a larger home range due its foraging habits (see **Physiology and Adaptability**). In contrast, mark-recapture methods used for short-term observations underestimate the capacity of movement in snails because many species are homing. However, dispersal (i.e., displacement of home range) in general is low in land snails, e.g., 32.2 m over a 3-year study of the Oregon Forestsnail *Allogona townsendiana* (Edworthy *et al.* 2012). Eggs and immature stages are not known to be dispersed by wind. However, some snails can survive short periods in water, in hypoxia (Nicolai and Ansart 2017), and the passage through bird intestines (Wada *et al.* 2012). Other snails have been found to be dispersed by bird migration (Kawakami *et al.* 2008) or, especially in riparian populations, by rafting on floating objects (Vagvolgyi 1975) or by fish (Altaba 2015). The likelihood of aerial or aquatic transport of Striped Whitelip is unknown, but is probably small.

In Ontario, the likelihood of dispersal from Pelee Island and the mainland sites, or from the US, is nonexistent given the limited distribution and the snails' poor dispersal capabilities (see **Population Spatial Structure and Variability** and/or **Rescue Effect**). A potential northern expansion of the peripheral Canadian population of Striped Whitelip could be largely negated by historical and current habitat loss and degradation, important factors to consider for range peripheral species under climate warming (Gibson *et al.* 2009). Some terrestrial gastropods can be easily transported by human activity, for example with horticultural or agricultural products, and therefore be introduced to new habitats (Robinson 1999; Robinson and Slapcinsky 2005). There is no evidence that Striped Whitelip is synanthropic or has been transported by humans.

Interspecific Interactions

The trematodes *Panopistus pricei* and *Brachylaima thompsoni* use Striped Whitelip as an intermediate host (Barger and Hnida 2008; Barger 2011). Free-swimming or attached flagellates *Cryptobia sp.* were observed in the reproductive tract of Striped Whitelip (Current 2007). Parasitic mites are also common in snails in general with infection rates within a population typically 45–75%. Depending on the mite species, infections can cause high mortality, reproductive perturbations, and reduced cold hardiness in some snail species (Baur and Baur 2005).

Nematodes can also infect a snail population and increase mortality rate in juveniles (Morand *et al.* 2004). In snails reared in the laboratory, thus in a confined space, nematodes can cause extremely high mortality (Örstan 2006), while they were not efficient in controlling pest gastropods in an urban green space (Fredon Inc. unpubl. data).

Predation can be a source of mortality for land snails. Potential predators have been reviewed by Jordan and Black (2012): "Gastropods are an important food source to a vast number of species, including salamanders, frogs, toads, turtles, snakes, lizards, birds, shrews, voles, moles, rats, mice, chipmunks, and squirrels. Invertebrate predators of terrestrial mollusks include sciomyzid fly larvae, firefly larvae, parasitic wasp larvae, carabid and staphylinid beetles, ants, spiders, and harvestmen." Among carnivorous gastropods Draparnaud's Glass Snail *Oxychilus draparnaudi* includes forest snails in its diet, especially Striped Whitelip, Bristled Slitmouth *Stenotrema barbatum*, and Tigersnail (often observed in the same sites, Örstan 2006). Garlic Glass Snail *Oxychilus alliarius*, an invasive predatory snail negatively affecting native Hawaiian land snails (Curry *et al.* 2016), was observed (Nicolai pers. obs.) on East Sister Island, Lake Erie, Ontario. Introduced predators or an increase in abundance of native predators due to ecological disturbance can increase mortality due to predation.

Competition for food with other terrestrial gastropods, including exotic species, is a possibility for Striped Whitelip but has not been documented. Introduced exotic gastropods, such as Grove Snail and various species of slugs, such as Grey Fieldslug, present on Pelee Island and in Point Pelee National Park, or Dusky Slug *Arion subfuscus/fuscus*, present in Bickford Oak Woods Conservation Reserve and in Point Pelee National Park, might not be in direct competition for food as these species mainly eat decaying plant material or fungi.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Gastropod community composition

Community composition of gastropods of a shell size larger than 0.5 cm in breadth or height was measured at two sites in 2016: Fish Point PNR on Pelee Island and Point Pelee National Park. In five randomly distributed 2x2 m plots per site, covering different habitat types within the site, all gastropods were collected by two persons without time constraint until the surface and leaf litter of the entire plot was thoroughly searched. The species were identified, counted, and separated into juveniles and adults. For Striped Whitelip and other polygyrids, adults were determined by the presence of a flared and thickened apertural lip. The plots in Point Pelee National Park were chosen to represent the different habitat types: savannah, forest, and restored forest. Abundance (number of individuals per m^2) and relative abundance (% of individuals within the community) was calculated for adults and juveniles for each observed species.

Live adult and juveniles of four species of conservation concern were counted in 2013 in Fish Point PNR on two transects: Striped Whitelip, Eastern Banded Tigersnail, Broad-banded Forestsnail, and Carolinian Mantleslug *Philomycus carolinianus*. Transects were 181 m and 282 m long and 0.5 m wide. Only the surface was thoroughly searched by one person without time constraint. Relative abundance of mature adults was calculated and compared to the relative abundance for these four species on three plots from 2015 and one plot from 2016 (same plot from 2015) located on the transects from 2013. Because relative abundance is the proportion of each species within the community, it can be compared between years even though different methods have been used as long as the method does not influence the detection of the species (in this case, they were all surface searches). Only adult counts were used to calculate relative abundance in the three years (2013, 2015, and 2016). The comparison allows an estimation of fluctuation in relative abundance of mature individuals within the community of these four species that are the largest litter dwelling gastropods in Fish Point PNR (2-3 cm for snails, up to 10 cm for the slug). Currently, the comparison can only be qualitative, because sample sizes are small. It is also important to note that the plots and transects are located on higher ground, on former dunes on the west side of the protected area.

Shell and subpopulation sizes

In 2016, the shell size was measured as the maximum shell breadth in all individuals of Striped Whitelip found in the plots of community composition analysis at two sites: Fish Point PNR on Pelee Island and Point Pelee National Park. Size class distributions in each site, for all plots combined, were generated and tested for normality (Shapiro-Wilks test) using the software R 3.03 (R Development Core Team 2014). Shell size was compared between sites using a *t*-test.

Subpopulation sizes for each site could not be determined because distribution of Striped Whitelip was extremely heterogeneous. Patches with high densities, mainly moist microsites, could only be discovered by wandering searches. Summer drought may have reduced the overall detection probability and subpopulation size estimations would then be incorrect. However, densities (number of individuals and mature adults/m^2) were calculated for Fish Point PNR and Point Pelee National Park using plot sampling and subpopulation sizes (number of mature adults per site) were estimated.

Abundance

In 2015, the abundance of Striped Whitelip (measured in one plot of each habitat type) varied between 2.3 individuals/m^2 in the lowland forest plot and 0.5 individual/m^2 in the plot on higher ground of forested dunes in Fish Point PNR on Pelee Island. In 2016, the abundance was null in the same plots. Fieldwork occurred in August of each year, but 2016 was a particular dry summer with a long drought period in August (even ditches were dry on Pelee Island, see **Fluctuations and Trends**). Therefore, three new plots were investigated: two in the most southern part of Fish Point PNR where the forest is usually swampy and one in the northern part at the margin of periodically flooded forest. The mean abundance across all habitat types within Fish Point PNR was 1.25 ± 0.72 individuals/m^2 or 0.75 ± 0.37

mature adults/m^2 (mean ± standard error). A similar result was obtained in Point Pelee National Park where sampling included wet forest and savannah: 1.38 ± 0.54 individuals/m^2 or 0.5 ± 0.24 mature adults/m^2. Even though the abundances were similar in the two sites, Striped Whitelip was only the second most abundant species in the gastropod community in Fish Point PNR, whereas in Point Pelee National Park it was the most abundant species (Table 3). Given used habitat size of about 27.5 ha in Fish Point PNR, subpopulation size may range between 104,500 and 280,500 mature adults. In Point Pelee National Park, 1,040,000 – 2,960,000 mature adults might live in the habitat of about 400 ha. However, these numbers are most likely over-estimates because the species is very heterogeneously distributed.

On Stone Road Alvar (ERCA and NCC-Porchuck properties), Striped Whitelip was only sporadically found after a large search effort of randomly flipping logs, bark, artificial cover material, or searching in moist holes or crevices. Therefore, Fish Point PNR might host 80-90% of the total subpopulation on Pelee Island. In Bickford Oak Woods Conservation Reserve, Striped Whitelip could not be found in 2016 although fresh shells were found there in 2013 (Table 1).

Table 3. Gastropod community composition represented as abundance (N/m^2) of adults plus juveniles (mean ± standard error) measured in five plots in each site in 2016, Fish Point PNR on Pelee Island and Point Pelee National Park. Where indicated, species richness includes records from 2013 and 2015. * indicates introduced species.

Species	Fish Point PNR	Point Pelee National Park
*Allogona profunda (*Broad-banded Forestsnail)	2.85 ± 2.18	0.35 ± 0.10
*Anguispira alternata (*Tigersnail)	0.55 ± 0.29	0.50 ± 0.30
*Anguispira kochi kochi (*Eastern Banded Tigersnail)	1.6 ± 0.97	—
*Arion fuscus/subfuscus (*Dusky Slug)*	—	Present in 2013
*Cepaea nemoralis (*Grove Snail)*	0.15 ± 0.1	Present in 2013
*Deroceras reticulatum (*Grey Fieldslug)*	—	0.15 ± 0.1
*Mesodon thyroidus (*Whitelip Globe)	0.5 ± 0.38	Present in 2015
*Neohelix albolabris (*Whitelip Snail)	0.1 ± 0.1	0.25 ± 0.09
*Novisuccinea ovalis (*Oval Ambersnail)	Present in 2015	0.17 ± 0.11
*Philomycus carolinianus (*Carolinian Mantleslug)	Present in 2015	—
Stenotrema hirsutum (Hairy Slitmouth)	—	Present in 2015
*Triodopsis vulgata (*Dished Threetooth)	0.3 ± 0.2	0.75 ± 0.46
*Webbhelix multilineata (*Striped Whitelip)	1.25 ± 0.72	1.38 ± 0.54

Species	Fish Point PNR	Point Pelee National Park
Native Species Richness	**9**	**8**
Exotic Species Richness	**1**	**3**

Fluctuations and Trends

In Ontario, the population study began in 2015. Therefore, it is impossible to determine if the adult population undergoes extreme fluctuations. Relative abundance in adults recorded on higher ground in Fish Point PNR on Pelee Island changed between 2013, 2015, and 2016 (Figure 4) which is probably due to different weather conditions in each year. In 2013, sampling began at the end of April when snails ended hibernation and are very active. Temperature increased by over 15°C on some days in the second part of the month (mean temperature of April = 11°C) and precipitation totalled 88 mm for the entire month (climate data from Kingsville, Government of Canada 2016). When the first sampling for the population study began in August 2015, average temperature was 21°C with a total monthly precipitation of 48 mm (climate data from Kingsville, Government of Canada 2016), while in August 2016 average temperature was 4°C higher and total monthly precipitation (58 mm) was similar (temperature data from Kingsville, Government of Canada 2016, precipitation data from Pelee Island, Meteoblue 2016). As a result of the higher temperature, August 2016 was therefore a much drier month (despite receiving 10 mm more precipitation) which could explain these community composition changes.

The overall mean shell size was 1.7 ± 0.3 cm (± standard deviation, n = 39) for Fish Point PNR and Point Pelee National Park combined. The site had no significant effect on body size (Figure 5; *t*-test, $t = 1.59$, $df = 23.7$, $P = 0.12$). Distribution of shell size is normal (Figure 6; Shapiro-Wilks; Fish Point PNR: $W = 0.94$, $P = 0.26$; Point Pelee: $W = 0.94$, $P = 0.29$). Juveniles were observed at the two sites, so recruitment was ongoing.

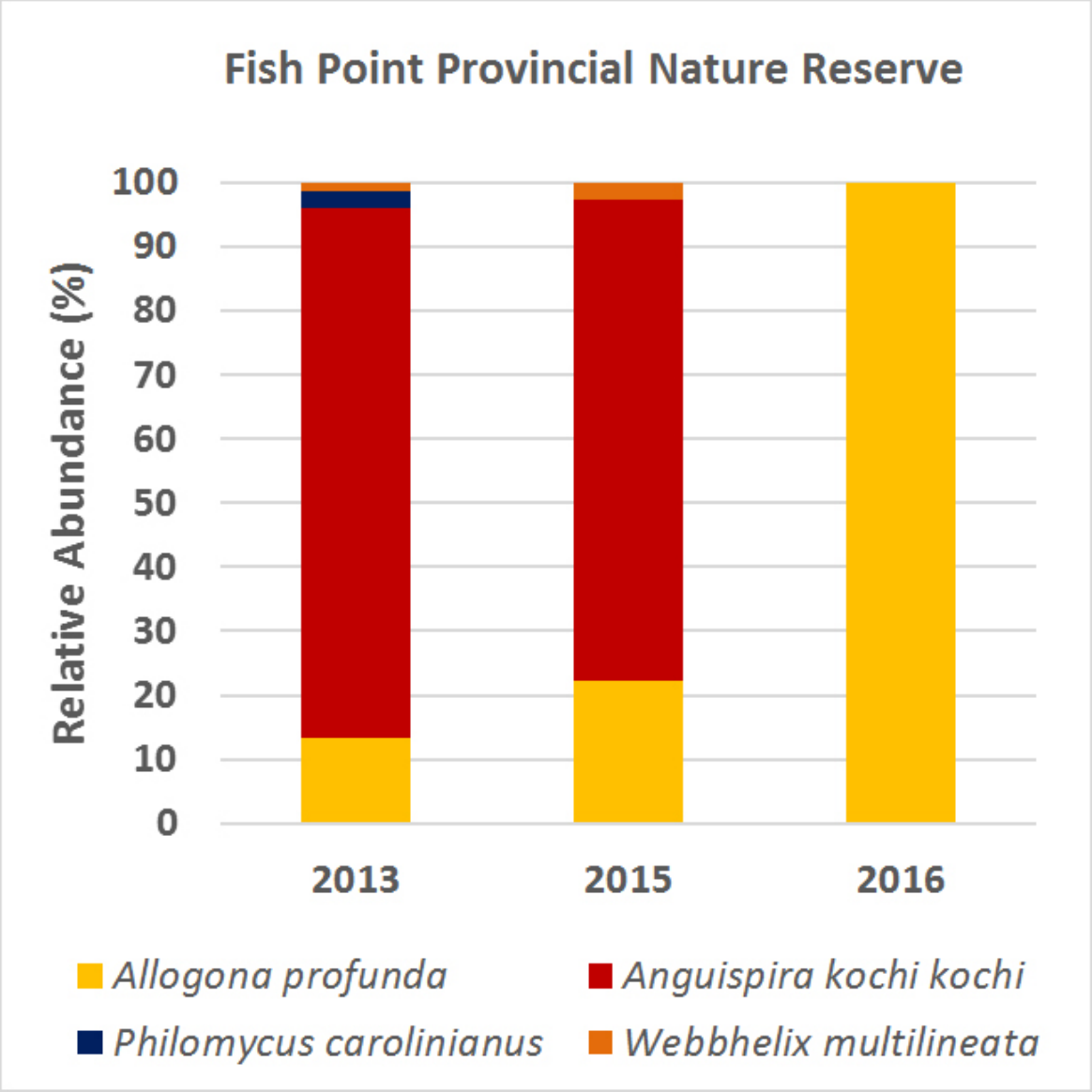

Figure 4. Relative abundance (in %) of four species of conservation concern at Fish Point in spring 2013 (calculated from mean abundance/m^2 of two transects), summer 2015 (calculated from mean abundance/m^2 of three plots) and summer 2016 (calculated from abundance/m^2 of one plot) in the same area of the site: forested dunes along the west shore.

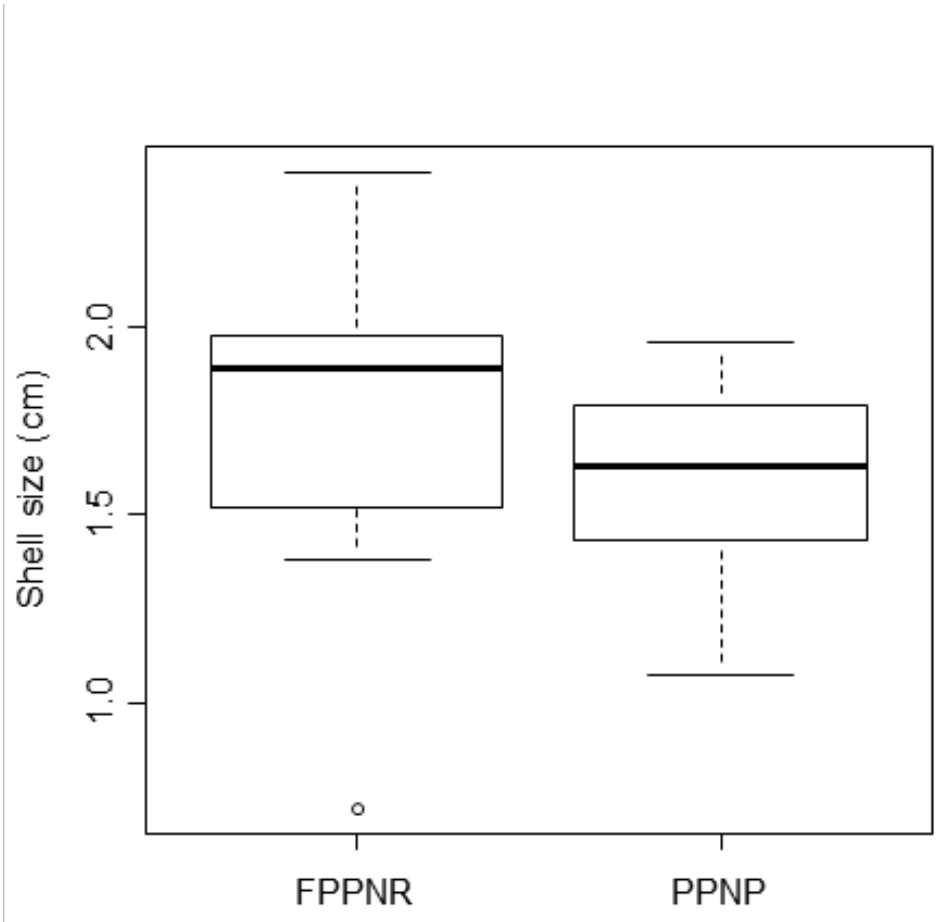

Figure 5. Shell size of *Webbhelix multilineata* represented as median (black line), quartile (box), and minimal/maximal values (dotted bars) in Fish Point Provincial Nature Reserve (FPPNR, n = 17) and in Point Pelee National Park (PPNP, n = 22), in three plots of different habitat at each site, in 2016. The circle indicates an extreme value.

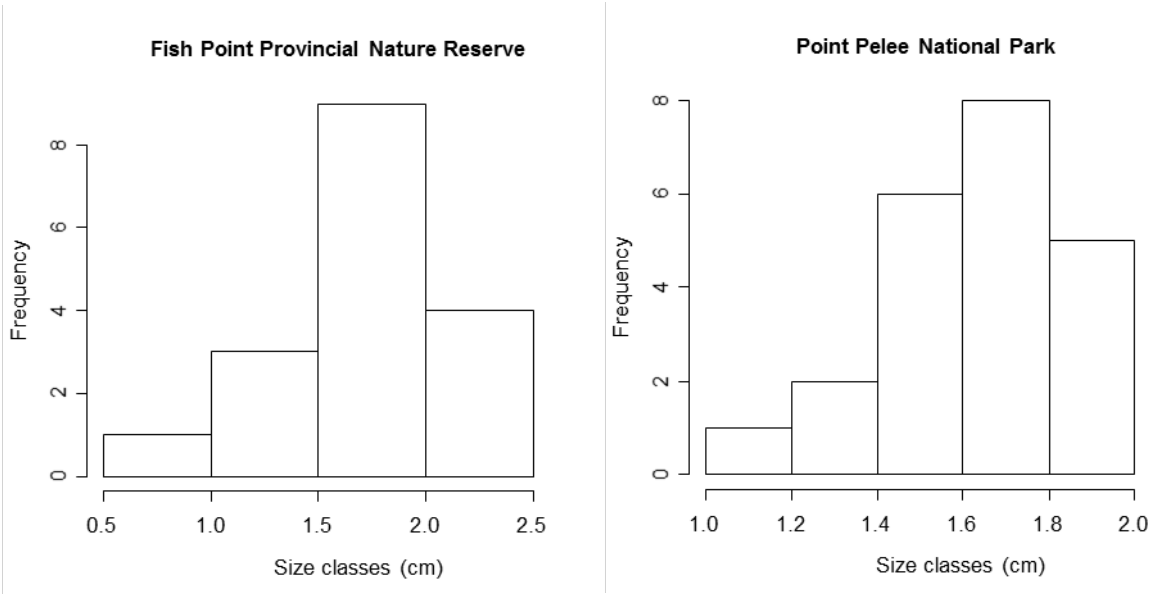

Figure 6. Shell size distribution of *Webbhelix multilineata* in Fish Point Provincial Nature Reserve (FPPNR, n = 17) and in Point Pelee National Park (PPNP, n = 22), in 2016.

Rescue Effect

Although snails have some capacity for passive dispersal (see **Dispersal and Migration**), rescue from outside Canada is unlikely due to barriers and population disjunction. The closest US subpopulations in Ohio and Michigan are separated by at least 5 km of Lake Erie and the St. Clair River, respectively (Figure 3).

THREATS AND LIMITING FACTORS

Threats

The threats assessment was based on the extant subpopulations in Point Pelee National Park, in Bickford Oak Woods Conservation Reserve, and on Pelee Island, including all sites with live snails and sites with potential habitat where empty shells were observed in 2013–2017 (Table 1). Walpole Island was not specifically included in the threat calculation, because exact sites of occurrence are unknown and threats are uncertain. For the threats assessment, Pelee Island habitat represents 10%, Bickford Oak Woods Conservation Reserve 30%, and Point Pelee National Park 60% of the total habitat. The highest abundance of Striped Whitelip on Pelee Island occurs in Fish Point PNR on about one third of the occupied habitat. Because Bickford Oak Woods Conservation Reserve harbours only a small proportion of the total Canadian population (here estimated as about 10%; the Walpole Island subpopulation was included in this 10%), Point Pelee National Park might have the largest portion of the population (here estimated as about 70%) with all sites combined on Pelee Island representing about 20%. Because the Walpole Island

subpopulation probably contributes less than 10% to the entire Canadian population, its exclusion from the threats assessment would not unduly skew the results. The overall calculated threat impact is MEDIUM-LOW (Appendix 1, medium because of the one medium and two low impact threats and low because of the three low impact threats). The threats are listed below according to their calculated level of impact, from highest to lowest impact. The numbering of threats corresponds to the categories and sub-categories of the threat calculator.

Threat 11: Climate change & severe weather – MEDIUM-LOW IMPACT

Using the framework for assessing species' vulnerability to climate change by Foden *et al.* (2013), Striped Whitelip can be considered highly vulnerable, because (i) it is exposed to climate change (spring frosts, absence of snow cover, droughts), (ii) it is sensitive (habitat specialist, specific microhabitat conditions), and (iii) it has a low adaptive capacity (low extrinsic dispersal possibilities because of restricted habitat available).

Threat 11.1: Habitat Shifting and Alteration (LOW IMPACT)

Most of the habitat with the highest Striped Whitelip abundance in Fish Point PNR is in the wet forest, near the east shore which could be gradually lost in the future (see **Habitat Trends**). Although this is a long and slow process, most of the subpopulation at Fish Point PNR could be threatened. In Point Pelee National Park the process is similar, but only a small portion of the habitat and the subpopulation is affected.

Threat 11.2: Droughts, and Threat 11.3: Temperature Extremes (both MEDIUM-LOW IMPACT)

Southwestern Ontario is projected to have more extreme weather events including droughts, floods, and temperature extremes under climate change models (Varrin *et al.* 2007). Snails may be vulnerable to increasing average temperatures accompanied by increased incidences of drought (Pearce and Paustian 2013). Numbers of snails found in 2016 were low compared to 2015, which indicates some vulnerability to drought. With increasing average temperature, spring frost is more frequent (Augspurger 2013), which can cause spring mortality in snails when snow cover is absent (e.g., up to 90%, A. Nicolai unpubl. data). Large snails are especially susceptible to freezing and rely on snow cover (Ansart *et al.* 2014). While Striped Whitelip has good cold hardiness, it is still vulnerable to spring frosts. Droughts can cause high mortality in some species depending on the presence of shelter (e.g., 75% in Roman Snail, Nicolai *et al.* 2011). Striped Whitelip seems to be a species that can deal with warm and dry periods as long as shelter is available. As a habitat specialist, Striped Whitelip might explore (i.e., look for shelter) less than generalists (Dahirel *et al.* 2015). Specific responses to the projected temperature changes and droughts within the range of Striped Whitelip are uncertain, hence the range for severity (reduction in the proportion of the population exposed to these threats in the next three generations), but the threat is ongoing.

Threat 11.4: Storms and flooding (LOW IMPACT)

Many sites on Pelee Island and in Bickford Oak Woods Conservation Reserve are seasonally flooded wet forest (NCC 2008; MNR 2009). While much of Pelee Island was wetland habitat before it was dyked and drained for agriculture, all native snail species on the island are found only on the former four bedrock islands and not in the former wetlands (see **Habitat Trends**). With increased precipitation due to climate change, flooding can be expected over a larger area. Even though Striped Whitelip is a specialist of wet forest, unusual high floods in the winter and spring when the snails are inactive can increase mortality. Parts of Fish Point PNR, Stone Road Alvar, and Middle Point Woods are affected. Only weathered shells have been found in Middle Point Woods (Table 1) indicating that snails have been dead for at least 5-10 years (Pearce 2008).

Threat 6: Human intrusions & disturbance – LOW IMPACT

Threat 6.1: Recreational Activities (LOW IMPACT)

Since the ferry service expanded in 1992, there has been a marked increase in tourism on Pelee Island. Given the global trends in tourism and ecotourism, these increases can be expected to continue. Fish Point PNR and the Stone Road Alvar are prominent in Pelee Island ecotourism. The sites attract significant numbers of birders, photographers, tourists, ecologists, and researchers. Annual visitation is estimated at 7,500 people at Fish Point PNR (Ontario Parks 2005). Most visitors use the main park trail, which extends over 1 km across the forest and 1 km along the beach. The park is open year-round. Point Pelee National Park has several hundred thousand visitors per year. Visitor numbers increased by about 20% from 202,424 in 2008–2009 to 245,780 in 2012–2013 (Parks Canada 2013). Most visitors use the main park trails, which total over 10 km within Striped Whitelip habitat. Trampling of snails by pedestrians has not been studied but was noted repeatedly during fieldwork in 2013–2017. Snails are actively crossing or feeding on trails especially in the morning hours under damp conditions and during the day after it has rained, from spring to autumn. Striped Whitelip in particular has been noted to move across roads in the search for food (see **Physiology and Adaptability**). Their leaf-litter-like colour makes it difficult for unaware visitors to see them.

Visitor numbers are lower at Stone Road Alvar and Middle Point Woods on Pelee Island, and in Bickford Oak Woods Conservation Reserve. Due to lower snail densities in these properties, the likelihood of crushing snails is lower.

Threat 6.3: Work & Other Activities (NEGLIGIBLE IMPACT)

Vegetation and species-at-risk monitoring (including snails) will continue on Pelee Island and in Point Pelee National Park. Snails will not be collected, but they could be affected by trampling and modifying microhabitat conditions in small areas of each site.

Threat 7: Natural system modifications – LOW IMPACT

Threat 7.1: Fire & Fire Suppression (LOW IMPACT)

Prescribed fire has become an important management tool for prairie and forest conservation in North America (Gottesfeld 1994; Williams 2000), particularly to limit the invasion of exotic species (Brooks and Lusk 2008) and to promote growth and reproduction of native prairie species (Towne and Owensby 1984). Burning directly and indirectly affects survival of ground nesting animals, litter dwelling organisms, and soil invertebrates, including snails (Nekola 2002). Fire reduces and modifies organic substrates and residues, which are sources of nutrients and buffer and shelter for these organisms. Fire also changes microclimate when post-burn bare soil is heated by the sun, thereby increasing soil evaporation (reviewed by Saestedt and Ramundo 1990; Knapp *et al.* 2009). Fire destroys the upper part of soil habitat, the litter and uppermost humus layer, which is the most important factor affecting survival for litter-soil organisms (Bellido 1987).

Portions of the Stone Road Alvar on Pelee Island were subjected to prescribed burns by ON Nature and the ERCA in 1993, 1997, 1999, and 2005 (NCC 2008). There are plans by ERCA, ON Nature, and NCC for test burns of the alvar (representing one third of Striped Whitelip's habitat on Pelee Island) to enhance snake habitat on the Stone Road Alvar in 2018 (Lebedyk pers. comm. 2016). NCC is particularly interested in understanding how fire frequency, patchiness, and intensity could be adapted to the habitat type, the plant species being controlled, and the animal and plant species for which habitat is being enhanced. Impacts on snail populations can be reduced by following guidelines on frequency, intensity, patchiness, and timing of prescribed burns (see MN DNR 2013). Direct impact of fire on snail populations may be reduced when habitat is widespread and recolonization from unburned areas is possible (Kiss and Magnin 2003, 2006). When habitat areas are small, larger fires are expected to be detrimental to populations, while fires that are very patchy and restricted to an overall small area would be less harmful. Strode (1893) noted that Striped Whitelip was abundant in a recently burned, swampy prairie. He assumed that snails survived the fire under logs or in grass tufts that were not burned. A prairie fire might be less intense than a fire in open shrubby areas. Moreover, more intense fire can reduce the litter layer (buffered microsites) and thereby reduce resistance to unsuitable weather conditions. Burns of the swampy areas as well as the alvar savannah on the Stone Road Alvar are planned before winter. While snails might be absent from the savannah during the non-feeding season (late autumn), they will hibernate in the swampy areas. Thus, the fire can affect their survival directly or indirectly by the higher soil temperature that would be reached in fall fires compared to spring fires (MN DNR 2013). However, a prescribed fire in savannah could increase the vegetative food supply for Striped Whitelip.

Parts of the forest/woodland in Point Pelee National Park are also planned to be burned or mechanically thinned (considered under threat 7.3 in Appendix 1) in 2017–2018. The purpose is to open the forest where early settlers had formerly converted forest into arable land (orchards, fields) and to restore savannah. Although the managed areas including prescribed burn sites are small, they may additionally fragment Striped Whitelip habitat. Burning of semi-open woodland for savannah restoration along the west shore

might increase feeding habitat for Striped Whitelip and would therefore be beneficial. Mechanical thinning of historically disturbed forests, which are currently young, rare forest types within older-growth forest, could provide additional logs and litter as microhabitat for Striped Whitelip. However, the amount of fragmentation from prescribed burns and/or mechanical thinning Striped Whitelip can withstand is uncertain. Vegetation thinning is similar to forest openings caused by windfall from storms. These openings can have positive as well as negative impacts on snails, depending on specific habitat requirements, population density, and spatial distribution of the species (Willig *et al.* 2007). Dispersal from adjacent intact habitat may no longer be possible.

Threat 7.3: Other ecosystem modifications (UNKNOWN IMPACT)

Highly invasive plants on Pelee Island habitat include Garlic Mustard *Alliaria petiolata* and species of the grass family Poaceae (NCC 2008). They were observed displacing native vegetation and altering soil nutrient cycles, thereby slowing restoration (Catling *et al.* 2015). Although the impacts of these invasive plants on land snails on Pelee Island have not been documented, invasive plants can lead to a decrease or increase in endangered snail abundance, as shown in Europe (Stoll *et al.* 2012). This depends on snail diet preferences, with exotics either displacing native plants that are snail food (negative impact) or providing a new food source for snails (positive impact). Striped Whitelip seems to easily accept different food (see **Physiology and Adaptability**).

Non-native earthworms have invaded parts of Canada relatively recently and have altered forest floor habitats by reducing or eliminating the natural leaf litter layer and digging up and mixing the mineral soil with the organic surface layer (CABI 2016). Using the extensive literature reviewed by CABI (2016) exotic earthworms can have major impacts on the ecosystem. While direct evidence of effects of exotic earthworms on terrestrial gastropods is lacking, Norden (2010) and Forsyth *et al.* (2016) suggested that invasive earthworms could indirectly alter terrestrial snail communities (see also Dobson 2017 and Lee 2017 for photographs of the effects of exotic earthworms on soil duff layers). Other indirect effects could result from earthworms feeding on forest plant seeds (Cassin and Kotanen 2016) or by altering plant-fungi mutualism (Paudel *et al.* 2016) thereby affecting understorey vegetation composition (Drouin *et al.* 2015) and potentially reducing available food plants. Earthworms, such as the Asian genus *Amynthas* that removes the surface leaf litter (Qui and Turner 2017), where snails live, would be a particular threat. The two species studied by Qui and Turner (2017) were recently observed in Windsor (Reynolds 2014). This change in forest floor structure profoundly affects plant and litter-dwelling invertebrate communities (Addison 2009; Dobson and Blossey 2015) as well as bird abundance and nesting success (Loss *et al.* 2012). While invasive earthworms are present on the north shore of Lake Erie (Evers *et al.* 2012) and on Pelee Island (Reynolds 2011), changes in leaf litter or forest soils have apparently not been reported.

Threat 4: Transportation & service corridors – NEGLIGIBLE IMPACT

Threat 4.1: Roads and Railroads (NEGLIGIBLE IMPACT)

Properties on Pelee Island are separated by road and ditches. Paved roads with high traffic densities may fragment snail populations because snails tend not to cross roads (Baur and Baur 1990). Road mortality has been recognized as a threat for wildlife in Point Pelee National Park (Parks Canada 2007). Unless snails are crushed, Striped Whitelip is well adapted to cross unsuitable areas in the search for food (see **Physiology and Adaptability**). Snails have been observed to drown in ditches.

Threat 9: Pollution – NEGLIGIBLE IMPACT

Threat 9.3: Agriculture and Forestry Effluents (NEGLIGIBLE IMPACT)

The impacts of pesticides on terrestrial gastropods are poorly known. Population level impacts of herbicides on terrestrial snails and slugs were not detected in agricultural (Roy *et al.* 2003) or forested (Hawkins *et al.* 1997a) landscapes, but laboratory studies have shown that exposure to some herbicides increases mortality of some snail species (Koprivnikar and Walker 2011) and could affect reproduction (Druart *et al.* 2011). Glyphosate is used on NCC properties on Pelee Island (NCC 2008), mainly on invasive grasses in the alvar savannah, such as the Stone Road Alvar, where Striped Whitelip potentially feeds. The herbicide is used infrequently and in carefully controlled conditions. A study by NCC is currently in progress to test a broader use on invasive grass species (including effect on gastropods). Neonicotinoid insecticides are increasingly used as a coating on soya bean and maize seeds (Douglas and Tooker 2015) and were not harmful to Grey Fieldslug, but to mollusc-predating arthropods (Douglas *et al.* 2015). It is currently unknown how these pesticides act on native gastropod species. The close proximity of agricultural land to Striped Whitelip habitat on Pelee Island (e.g., soy bean fields) and in Bickford Oak Woods Conservation Reserve may also expose snails to pesticide drift.

Threat 8: Invasive & other problematic species & genes – UNKNOWN IMPACT

Threat 8.1: Invasive non-native/alien species (UNKNOWN IMPACT)

Competition with exotic terrestrial molluscs such as Grove Snail and slugs (Dusky Slug, Grey Fieldslug) is considered a potential threat (Whitson 2005; Grimm *et al.* 2010). Exotic gastropods can compete for resources and shelter with the remaining native species. However, diet seems to be different in these species (see **Interspecific Interactions**). Draparnaud's Glass Snail, an introduced, carnivorous species, found on Lake Erie islands and in Sarnia, can be a threat to Striped Whitelip if this species reaches Striped Whitelip habitat (see **Interspecific Interactions**); Garlic Glass Snail also was observed on East Sister Island.

Wild Turkeys *Meleagris gallopavo* were introduced to Pelee Island about ten years ago and now number in the hundreds. There are no historical records indicating that the species occurred naturally on the island (Jones 1912a-d). A flock of 250 individuals was observed by Pelee Island Bird Observatory staff in a field adjacent to Fish Point PNR in November 2010 (Gibson pers. comm. 2013). Similarly, Ring-necked Pheasants *Phasianus colchicus* were introduced to Ontario and specifically to Pelee Island in the late 1920s and increased to 50,000 to 100,000 birds on the island by 1934 (Sandilands 2005). Populations are supplemented by annual releases of up to 25,000 birds to support hunting. However, only a few birds survive hunts and winter. Both bird species are omnivorous and include snails in their diet (Sandilands 2005). The impacts on snail populations are unknown, but they are a potential additional source of predation on Striped Whitelip and were recently listed as ongoing threats to the Endangered Broad-banded Forestsnail (COSEWIC 2014a), the Endangered Small-mouthed Salamander *Ambystoma texanum* (COSEWIC 2014b), and Banded Tigersnail *A. kochi* (two designatable units including Endangered Eastern Banded Tigersnail; COSEWIC 2017).

Cumulative Effects

Increased frequency and severity of prolonged summer droughts associated with climate change and severe weather is likely to exacerbate the effects of prescribed burns. In general, logging, mining, agriculture, and the establishment of second growth forest increase the abundance of invasive plants (Calinger *et al.* 2015). Any activity that increases human access, such as resource roads, increases the potential for the introduction or spread of invasive, non-native gastropods, and other invertebrates. Increased numbers of humans recreating in protected areas also could be detrimental. Climate change and forest disturbance may also facilitate the spread of introduced species in Canada with largely unknown and untracked, but potentially serious impacts, on native gastropod faunas.

Limiting Factors

In Canada, Striped Whitelip exists at the northern limits of its distribution and northward expansion is probably limited by harsh winters, but more through human-caused fragmentation and habitat loss (Gibson *et al.* 2009), and physical barriers, such as the extensive bodies of water. Low dispersal ability, together with low physiological resistance to fluctuating environmental factors such as temperature and humidity, restrict gene flow among subpopulations. At the microhabitat scale, availability of moist refuges that buffer environmental fluctuations is probably a limiting factor for population growth and persistence of land snails in general at particular sites (Burch and Pearce 1990).

Wild Turkeys were reintroduced to mainland southwestern Ontario in the mid-1980s, after being extirpated in the early 1900s. By the early 2000s, about 40,000 birds were estimated to be in Ontario (Sandilands 2005). Turkeys re-colonized Point Pelee National Park in 2006 and increased to over 100 by 2008, before decreasing to about 40 to 60 birds between 2010 and 2013 (Dobbie pers. comm. 2013) with the most recent population estimate, acquired through aerial surveys and Christmas Bird Counts, being 80–100 (Dobbie pers. comm. 2017). They could be considered a limiting factor to Striped Whitelip subpopulation expansion.

Number of Locations

Considering all sites where Striped Whitelip has been observed, there are at least four locations: Bickford Oak Woods Conservation Reserve, Walpole Island, Point Pelee National Park, and Pelee Island. The most serious and plausible threats are prescribed burns, droughts, and turkeys as predators. The number of locations on Pelee Island can range from one through three depending on the threat or combination of threats and the distribution of the sites where Striped Whitelip occurs in that a single threatening event could rapidly affect all individuals of a taxon present (IUCN 2016). Because increasing frequency of droughts could affect the whole island and turkeys also explore the whole island, the entire island could be one location. If prescribed burns occur on Stone Road Alvar, there are two separate locations on Pelee Island. However, if drought acts differently in different areas of the island each block of protected area might be considered one location each: Fish Point PNR, Stone Road Alvar, and Middle Point Woods (3 locations). In summary, the number of locations ranges between four and six.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Striped Whitelip is not protected by any legislation, regulations, customs, or conditions. It is not listed on the IUCN Red List (IUCN 2016), under the US *Endangered Species Act* (US FWS 2016), or under any provincial acts. It is not listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2016).

Non-Legal Status and Ranks

NatureServe (2018) and CESCC (2016) provide the following ranks for Striped Whitelip in the U.S. and Canada, respectively:

Global Rank: G5 – secure (last reviewed 4 Dec 2009)

National Rank (U.S.): N5 - secure (last reviewed 9 Sep 2004)

National Rank (Canada): N1N2 - critically imperilled-imperilled (last reviewed 25 Jan 2013) by NatureServe (2018) but N2 by CESCC (2016).

Subnational Ranks (S-ranks) as provided by NatureServe (2018) for the U.S. and by CESCC (2016) for Canada are as follows:

SX: Arkansas

SNR: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, New York, Ohio

S1: Maryland, West Virginia

S1S2: Kentucky, Pennsylvania

S2: Tennessee

S5: Wisconsin

S2S3 (imperilled-vulnerable): Ontario (NatureServe 2018) but S1S3 (CESCC 2016).

Habitat Protection and Ownership

Ownership of currently occupied habitat in Ontario is shown in Table 1. Sites owned by Parks Canada, Ontario Parks, Ministry of Natural Resources and Forestry, Essex Regional Conservation Authority, Nature Conservancy Canada, and Ontario Nature are protected areas. Management plans were reviewed in **Habitat Trends**.

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  - Ontario Region (5 January 2017)

- Museums:
  - Royal Ontario Museum (August 2015)
  - Canadian Museum of Nature (29 November 2016)
  - Carnegie Museum of Natural History, Pittsburgh (29 November 2016)

- Field Museum of Natural History, Chicago (9 January 2017
- University of Michigan, Museum of Zoology (29 November 2016)

- Parks:
  - Parks Canada (many times in 2013-2016)
  - Ontario Parks (many times in 2013-2016)

- Provincial / territorial representatives:
  - ON (5 January 2017)

- Conservation Data Centres or Natural Heritage Information Centres:
  - ON : Natural Heritage Information Centre (many times in 2013-2016)

- COSEWIC Secretariat:
  - ATK (7 July 2016)
  - Maps (15 December 2016)

- Conservation organizations:
  - NCC (many times in 2013-2016)
  - ON Nature (9 December 2016)
  - ERCA (9 December 2016)

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Annegret Nicolai is a biologist at the UMR CNRS 6553 EcoBio/OSUR of the University Rennes 1, France. She has a Ph.D. from the University of Bremen in Germany and from the University Rennes 1 in France. Her research involves investigating eco-physiological questions in terrestrial snails, specifically about the impact of climate change and resource availability on the physiology and reproduction in endangered and invasive species. She has very specific knowledge about the biology, anatomy, physiology, and ecology of terrestrial gastropods. In Germany she developed a captive-breeding program for the

protected *Helix pomatia* and in France she was coauthor of the National Action Plan for the conservation of *Tyrrhenaria ceratina* in Corsica. In the Sinclair lab at Western University, Ontario, she investigated the overwintering strategy of the invasive species *Cepaea nemoralis*. Since 2012 she has been surveying terrestrial gastropods in Ontario and participating in the “barcoding of life” project at the University of Guelph. She became a member of the mollusc subcommittee of COSEWIC in 2014.

COLLECTIONS EXAMINED

The collections of the Canadian Museum of Nature, the Royal Museum of Ontario, Bishops Mills Natural History Centre, the Academy of Natural Sciences, Philadelphia, Carnegie Museum of Natural History, Pittsburgh, and occurrence data from the Natural Heritage Information Centre of Ontario were examined by contacting curators (see **ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED**). A global survey of museum records was searched through the Global Biodiversity Information Facility (GBIF 2016). This allowed the checking of a wide range of museum records including Canadian records:

- NatureServe Central Databases (accessed through GBIF data portal, http://data.gbif.org/datasets/resource/607, [29 November 2016]) doi:10.15468/lysaex
- Field Museum: Field Museum of Natural History (Zoology) Invertebrate Collection doi:10.15468/6q5vuc
- Academy of Natural Sciences: MAL doi:10.15468/xp1dhx

and US records:

- NatureServe Central Databases (accessed through GBIF data portal, http://data.gbif.org/datasets/resource/607, [29 November 2016]) doi:10.15468/lysaex
- Colección de Malacología, MCNB, http://www.gbif.org/dataset/71d46a30-f762-11e1-a439-00145eb45e9a doi:10.15468/pnkuwh
- Museum of Comparative Zoology, Harvard University (2016): Museum of Comparative Zoology, Harvard University. Dataset/Occurrence. http://digir.mcz.harvard.edu/ipt/resource?r=mczbase doi:10.15468/p5rupv, doi:10.15468/p5rupv doi:10.15468/p5rupv
- Field Museum: Field Museum of Natural History (Zoology) Invertebrate Collection doi:10.15468/6q5vuc
- Florida Museum of Natural History: UF Invertebrate Zoology doi:10.15468/sm6qo6
- Bailey-Matthews National Shell Museum (BMSM) doi:10.15468/49s45k

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- Queensland Museum: Queensland Museum provider for OZCAM doi:10.15468/lotsye
- Academy of Natural Sciences: MAL doi:10.15468/xp1dhx
- Biologiezentrum Linz Oberoesterreich: Biologiezentrum Linz doi:10.15468/ynjblx
- Museo Argentino de Ciencias Naturales: Colección Nacional de Invertebrados - Museo Argentino de Ciencias Naturales 'Bernardino Rivadavia' doi:10.15468/uuz636

Appendix 1. Threats calculator for Striped Whitelip (*Webbhelix multilineata*).

Species Scientific Name	*Webbhelix multilineata* (Striped Whitelip)
Date :	9/11/2017
Assessor(s):	Dwayne Lepitzki (Moderator & Co-chair) SSC members: Joe Carney (Co-chair), Annegret Nicolai (SR writer), Andrew Hebda, Robert Forsyth External experts: Jill Crossthwaite (NCC), Tammie Dobbie (Parks)
References:	draft threats calculator by report writer provided with draft status report discussed and modified during threats teleconference

Overall Threat Impact Calculation:		**Level 1 Threat Impact Counts**	
Threat Impact		**high range**	**low range**
A	Very High	0	0
B	High	0	0
C	Medium	1	0
D	Low	2	3
Calculated Overall Threat Impact:		Medium	Low

Assigned Overall Threat Impact:	**CD = Medium - Low**
Impact Adjustment Reasons:	Group agreed that the overall predicted range of a 0 to 30% Canadian population decline in the next 3 generation (= 12 years) was realistic based on the available information and correctly captured the uncertainty.
Overall Threat Comments	Generation time 4 years therefore severity and timing scored for 12 years into the future. Extant mainland subpopulations in Bickford Oak Woods (based on fresh shells collected in 2013), Point Pelee NP (live individuals), and probably Walpole Island (fresh shells in 2013). Live snails also found on Pelee Island (most at Fish Point, some live at Stone Road Alvar, but only old shells at Middle Point Woods). Based on available habitat and relative abundance, estimated that ~70% of the Canadian population occurs in Point Pelee NP (PPNP), 20% on Pelee Island (mostly Fish Point), and 10% in Bickford Oak Woods and Walpole Island. Difficult to assess threats for Walpole Island subpopulation because of lack of data. Threats assessment could be updated if additional information from Walpole becomes available.

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development						
1.1	Housing & urban areas						Unknown if threat would affect subpopulation at Walpole Island. Other subpopulations confined to protected areas.
1.2	Commercial & industrial areas						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1.3	Tourism & recreation areas						No new tourism or recreational expansion are planned. Potential trail expansion on Nature Conservancy of Canada (NCC) properties will not overlap species' habitat. Uncertainty with Walpole Island.
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						No agricultural expansion is anticipated; uncertain if threat exists on Walpole.
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						Possibly at Walpole Island but just don't know.
2.4	Marine & freshwater aquaculture						
3	Energy production & mining						
3.1	Oil & gas drilling						In Bickford Oak Conservation Reserve gas drilling is historical.
3.2	Mining & quarrying						
3.3	Renewable energy						Windfarm developments not anticipated.
4	Transportation & service corridors		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
4.1	Roads & railroads		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Snails have been observed drowned in ditches on Pelee Island. No road expansion expected for Point Pelee and no documented snail road kill. Most of the suitable habitat is mainly on the south tip while most of the cars and roads are mainly in the north.
4.2	Utility & service lines		Negligible	Negligible (<1%)	Negligible (<1%)	Low (Possibly in the long term, >10 yrs/3 gen)	The more recent plans for replacing and burying powerlines at Point Pelee (see COSEWIC 2014a on Broad-banded Forestsnail) now expected to have less impact than previously thought due to changes in work procedures; habitat preference also differs between the two snail species but scores are the same.
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.1	Hunting & collecting terrestrial animals						A few snails have been taken for barcoding, but their removal is not a population level threat and no plans for additional removal for genetic analysis in the future.
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting						Historical threat but not happening now and not expected to begin again.
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	
6.1	Recreational activities	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	Trampling risk at Fish Point and in Point Pelee NP. Scope is on the higher end of the chosen range. Smaller scope but higher severity score than for Broad-banded Forestsnail (COSEWIC 2014a): Striped Whitelip move more than Broad-banded Forestsnail, but they prefer wetter areas; Striped Whitelip often observed on trails, especially after rain, but may be more difficult for visitors to see due to their colour.
6.2	War, civil unrest & military exercises						
6.3	Work & other activities		Negligible	Restricted (11-30%)	Negligible (<1%)	High (Continuing)	Population studies and monitoring of the species continues. Scope score lower (due to Striped Whitelip habitat preference) but severity the same as for Broad-banded Forestsnail: other workers at Point Pelee but fewer than number of visitors so impact lower (COSEWIC 2014a).
7	Natural system modifications	D	Low	Small (1-10%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.1	Fire & fire suppression	D	Low	Small (1-10%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Timing is dependent on sufficient funding of prescribed burns. Prescribed burns on Pelee Island would be at Stone Road Alvar, which has fewer snails than Fish Point. Species has survived prescribed burns in the past. Not expected to have consecutive burns in same areas so subpopulation recovery from refuges is possible over the 3 generation time frame, hence severity is slight. Prescribed burns are expected only in the savannah-like areas of Point Pelee National Park.
7.2	Dams & water management/use						
7.3	Other ecosystem modifications		Unknown	Large (31-70%)	Unknown	High (Continuing)	Scope is on the higher end of the chosen range and based more on earthworms (which may have a larger impact) than Garlic Mustard or grasses. Invasive species might cover a large area but they do not occur everywhere the snail is found. In addition, thinning of the forest is expected in the former orchard (wet forest) areas of Point Pelee National Park.
8	Invasive & other problematic species & genes		Unknown	Large (31-70%)	Unknown	High (Continuing)	
8.1	Invasive non-native/alien species/diseases		Unknown	Large (31-70%)	Unknown	High (Continuing)	Ring-neck Pheasants are introduced to Pelee Island and the mainland (Point Pelee) while Wild Turkeys, originally native to the mainland, have been introduced to Pelee Island; both species could consume snails, potentially Striped Whitelip but population impacts are unknown (same severity as for Broad-banded Forestsnail and Eastern Banded Tigersnail; COSEWIC 2014a, 2017).
8.2	Problematic native species/diseases						PPNP has 80-120 turkeys. As long as the Coyote (*Canis latrans*) population in the park is stable, the turkey population will be stable so more of a limiting factor than threat. Raccoon (*Procyon lotor*) populations are probably higher than normal (due to human activities) and they probably eat snails too but no data.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.3	Introduced genetic material						
8.4	Problematic species/diseases of unknown origin						
8.5	Viral/prion-induced diseases						
8.6	Diseases of unknown cause						
9	Pollution		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
9.1	Domestic & urban waste water						Road salt is not an issue. Sand is used in PPNP and on Pelee Island; roads are not adjacent to snail habitat and therefore, there would be a minimal effect if road salt was used.
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	NCC restores fields in adjacent properties and there is spot treatment on individual plants rather than spraying in Point Pelee. Light use of herbicides on NCC properties, in the past and probably in the future (sprays are targetted and within small patches). Uncertain if this is a threat at Walpole. Population level impacts of Glyphosate not detected in agriculture or forested landscapes but have been found in lab studies.
9.4	Garbage & solid waste						
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	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.1	Habitat shifting & alteration	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Erosion at Fish Point and Point Pelee due to (among other causes) lack of ice cover in fall and winter which protect the shoreline. Score for severity lower for Striped Whitelip than Broad-banded Forestsnail (COSEWIC 2014a) because of habitat preference differences.
11.2	Droughts	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	Effects of drought would most likely encompass entire range although severity of impacts may be reduced in some microhabitats. Scope the same as for Eastern Banded Tigersnail (COSEWIC 2017) but severity uncertainty range lower for Striped Whitelip because Striped Whitelip is more tolerant of drought due to habitat preference assuming presence of suitable refuge shelters.
11.3	Temperature extremes	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	Closely tied with droughts. Changes to spring/fall frost regimes (frost without snow cover) would most likely encompass entire range but severity would vary among microhabitats. Severity uncertainty range lower for Striped Whitelip than Eastern Banded Tigersnail (COSEWIC 2017) because Striped Whitelip has better cold hardiness although it is still susceptible to spring frosts.
11.4	Storms & flooding	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Flooding is a factor on the parts of Pelee Island and Point Pelee created by draining between former, smaller islands. Species is a specialist of the lowland forest and should be able to deal with flooding, hence lower severity score than for Eastern Banded Tigersnail (COSEWIC 2017). However, unusual high floods can cause some mortality.
11.5	Other impacts						

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