COSEWIC
Assessment and Status Report

on the

Eastern Banded Tigersnail
Anguispira kochi kochi

and

Western Banded Tigersnail
Anguispira kochi occidentalis

in Canada

Eastern Banded Tigersnail – ENDANGERED
Western Banded Tigersnail – NOT AT RISK
2017

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:

COSEWIC. 2017. COSEWIC assessment and status report on the Eastern Banded Tigersnail *Anguispira kochi kochi* and the Western Banded Tigersnail *Anguispira kochi occidentalis*, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xv + 82 pp. (http://www.registrelep-sararegistry.gc.ca/default.asp?lang=en&n=24F7211B-1).

Production note:
COSEWIC would like to acknowledge Annegret Nicolai and Kristiina Ovaska for writing the status report on the Eastern Banded Tigersnail and the Western Banded Tigersnail. 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.

For additional copies contact:

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

Tel.: 819-938-4125
Fax: 819-938-3984
E-mail: ec.cosepac-cosewic.ec@canada.ca
http://www.cosewic.gc.ca

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur l'Escargot-tigre à bandes de l'Est (*Anguispira kochi kochi*) et l'Escargot-tigre à bandes de l'Ouest (*Anguispira kochi occidentalis*), au Canada.

Cover illustration/photo:
Eastern Banded Tigersnail *Anguispira kochi kochi* and Western Banded Tigersnail *Anguispira kochi occidentalis* — Annegret Nicolai, 1 May 2013, Fish Point, Pelee Island).

Catalogue No. CW69-14/753-2017E-PDF
ISBN 978-0-660-09213-3

COSEWIC
Assessment Summary

Assessment Summary – April 2017

Common name
Eastern Banded Tigersnail

Scientific name
Anguispira kochi kochi

Status
Endangered

Reason for designation
This large terrestrial snail remains in small isolated habitat patches on Middle and Pelee islands, in Lake Erie. The loss of subpopulations on some smaller islands was probably due to habitat destruction from overabundant Double-crested Cormorants, which colonized the islands in the early 1980s, as well as human activities. Habitat loss and alteration on Pelee Island likely led to subpopulation declines and fragmentation. Climate change is the most serious threat.

Occurrence
Ontario

Status history
Designated Endangered in April 2017.

Assessment Summary – April 2017

Common name
Western Banded Tigersnail

Scientific name
Anguispira kochi occidentalis

Status
Not at Risk

Reason for designation
This large terrestrial snail is known from numerous sites and appears to be abundant in southeastern British Columbia. Most records come from the West Kootenay region where it is mainly found in riparian and floodplain habitats. Continuing low-impact threats include habitat loss from residential development, roads, logging, fire, silvicultural activity, and droughts, and temperature extremes related to climate change. Given the current circumstances, this species is not at risk.

Occurrence
British Columbia

Status history
Designated Not at Risk in April 2017.

COSEWIC
Executive Summary

Eastern Banded Tigersnail
Anguispira kochi kochi

and

Western Banded Tigersnail
Anguispira kochi occidentalis

Wildlife Species Description and Significance

Banded Tigersnail is a large land snail (adult shell width 2.0 – 2.5 cm) with a globular, yellow to brown shell that has an opening in the centre when viewed from below and a light-coloured spiral band bordered by a darker band on either side. Variations include size, shell thickness, and colour of the shell, as well as the visibility of bands. Two subspecies are currently recognized: *Anguispira kochi kochi* on the Lake Erie islands in Ontario, and *A. k. occidentalis* in British Columbia. The Eastern and Western subspecies are part of the unique faunas of the Carolinian and northern Columbia Basin ecosystems, respectively, and have significance for biodiversity, research, and conservation. As part of the gastropod community in forest ecosystems, Banded Tigersnail plays a role in litter decomposition and nutrient cycling.

Distribution

The distribution of Banded Tigersnail is disjunct, consisting of an eastern and western North American component, and extends from southern Canada southward to Tennessee in the east and to Oregon in the west. In Canada, the Ontario and British Columbia populations are separated by over 2000 km with no connections through the US. In Ontario, Eastern Banded Tigersnail is currently known to occur on two islands in Lake Erie (Pelee and Middle islands). In British Columbia, Western Banded Tigersnail occurs in the southeastern part of the province with most records from the West Kootenay region.

Habitat

In Ontario, Chinquapin Oak-Nodding Onion treed alvar, dry-fresh Hackberry deciduous forest, dry-fresh Sugar Maple-White Ash deciduous forest, and dry Black Oak woodland are preferred habitats of the Banded Tigersnail. These habitats, encompassing approximately 98 ha in total, are characterized by the proximity of limestone bedrock to

topsoil or a sandy soil with a substantial leaf litter layer. Pelee Island is largely developed for agriculture, and habitat loss is historical. Habitats continue to be affected by flooding and management measures such as invasive species control and prescribed burning, as well as erosion of the tip of Fish Point on Pelee Island. Middle Island has been uninhabited by humans since the 1980s, but habitats continue to be modified by storms and overabundant Double-Crested Cormorants.

In British Columbia, the snails inhabit moist, well-vegetated mixed-wood forests and are often found in riparian areas along lakes, rivers, and creeks, especially where Cottonwoods are present. A well-developed litter layer and coarse woody debris on the forest floor provide hiding places and refuges from inclement weather. Historically, land conversions for residential and industrial developments and for agriculture have resulted in loss of habitat at lower elevations, especially along river valleys, lake shores, and highways. Habitats across the snails' range continue to be modified and fragmented by forestry, road networks, expanding urban development, and increasing frequency and duration of droughts projected under climate change.

Biology

Banded Tigersnail is an air-breathing (pulmonate), simultaneous hermaphrodite (possesses both male and female reproductive organs), egg-laying snail. 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. Snails are prone to freezing in winter and dehydration in summer. They rely on sheltered refuges and snow cover to buffer them from freezing during winter. Dormancy in summer may occur during prolonged drought. Sexual maturity is probably reached at 2 – 3 years of age. The generation time is probably 5 - 6 years. Active dispersal for colonization of new areas is in the order of tens of metres over several years. 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

Eastern Banded Tigersnail could be confirmed only on Middle Island and Pelee Island during fieldwork in 2013 – 2015; historical habitat disturbance suggests a reduction in abundance in some sites on these islands. The species has apparently disappeared from Middle Sister Island, East Sister Island, and a property near Alvinston in Lambton County on the mainland. The persistence of the species on Hen and North Harbour islands is uncertain. The population is currently estimated at about 800,000 mature individuals. Recruitment was observed in most sites where the species was found alive. Rescue from outside Canada is not possible due to Lake Erie acting as a barrier.

Nothing is known of densities and population trends of Western Banded Tigersnail, but it is probable that the species was historically more widespread and abundant than currently, particularly in larger river valleys. Most distribution records are recent (since the 1990s), and there are insufficient historical records to allow for comparisons. Threats to habitats continue from various sources and may result in declines in the future. Several records of the species exist from the vicinity of the Canada – US border, and where habitat is continuous, there is potential for rescue. However, due to poor dispersal ability of the snails and habitat fragmentation, rescue of British Columbia subpopulations from the US is of limited importance.

Threats and Limiting Factors

In Canada, Banded Tigersnail exists at the northern limit of its range. Low dispersal ability and low physiological resistance to fluctuating environmental factors such as temperature and humidity are considered limiting factors.

In Ontario, climate change represents an important but poorly understood threat to the snails through storms on Middle Island and erosion and flooding of forest on Pelee Island. Moreover, risk of droughts and extreme temperatures, resulting in spring frost, are a threat at all sites. Other threats include competition with introduced snails and slugs and increased predation pressure from introduced omnivorous Wild Turkeys and Ring-necked Pheasants on Pelee Island. On Middle Island, nesting native Double-crested Cormorants have severely altered habitats, resulting in alteration of soil chemistry, tree dieback, reduced plant species' richness, and an increase in exotic species. Exotic plants and earthworms on Pelee Island also contribute to modification of the litter layer and habitat structure. Prescribed fire affects potential habitat.

In British Columbia, threats include habitat loss, alteration, and fragmentation by logging, roads, urban development, and wildfires, as well as increased frequency and intensity of droughts, storms and flooding, as predicted under climate change. Prolonged summer droughts associated with climate change are likely to exacerbate the effects of logging and wildfires. Climate change and forest disturbance may facilitate the spread of introduced invertebrates such as slugs, snails, and ground beetles, which may compete with or prey on tigersnails.

Protection, Status and Ranks

Banded Tigersnail has no legal designations. It is ranked as globally secure and nationally secure in the US but vulnerable in Canada. It is ranked as imperilled in Ontario and vulnerable in British Columbia. In Ontario, most of the species' range is on protected lands managed by Parks Canada, Nature Conservancy Canada, or Ontario Ministry of Natural Resources and Forestry. In British Columbia, land ownership varies across the species' range, but most records are from unprotected provincial forestry lands. In British Columbia, the species has been recorded from five provincial parks; several other provincial parks and other protected areas exist within its range.

TECHNICAL SUMMARY – Eastern Banded Tigersnail

Anguispira kochi kochi

Eastern Banded Tigersnail

Escargot-tigre à bandes de l'Est

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)	~5 – 6 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes (reduction of occupied sites and low abundance in some sites)
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. Unknown b. Yes, for the smaller Lake Erie Islands, but Unknown for sites on Pelee Island c. No.
Are there extreme fluctuations in number of mature individuals?	Unknown

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	102 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	36 km²
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. Yes

Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	2-7 Two if most serious and plausible threat is a change in frequency and severity of hard, killing frosts or droughts; seven if the most serious and plausible threats are changes in frost/drought patterns and flooding.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes (loss of three island and one mainland subpopulations)

Is there an [observed, inferred, or projected] decline in number of "locations"*?	Yes (same as subpopulations)
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes (Middle Island, within last 30 years), Unknown (Pelee Island, within last 30 years), Yes (habitat loss and degradation on Pelee Island starting in the 19th century)
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 total Fish Point Provincial Nature Reserve Florian Diamante Nature Reserve Richard and Beryl Ivey Property Winery Woods (could be part of RBIP) Middle Point Woods Stone Road Alvar (including Krestel Property)	About 700,000-900,000 total 552,000-612,000 (FP) 146,720 (FDNR) 26,850-179,000 (RBIP) No estimate available No estimate available No estimate available
Middle Island	About 4,000-32,000
Total	~ 800,000

Quantitative Analysis

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

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

years] ?	

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 (High-low impact)
ii. Human intrusion & disturbance (Low impact)
iii. Transportation & service corridors (Negligible impact)
iv. Pollution (Negligible impact)
v. Natural system modifications (Unknown impact)
vi. Invasive species (Unknown impact)

What additional limiting factors are relevant? Low dispersal or migration capacity

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Ohio (SNR), Michigan (SU)
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?[1]	Habitat quality continues to decline
Are conditions for the source population 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

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 remains in small isolated habitat patches on Middle and Pelee islands, in Lake Erie. The loss of subpopulations on some smaller islands was probably due to habitat destruction from overabundant Double-crested Cormorants, which colonized the islands in the early 1980s, as well as human activities. Habitat loss and alteration on Pelee Island likely led to subpopulation declines and fragmentation. Climate change is the most serious threat.

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

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Does not meet criteria. EOO has declined from historical loss of some island and the single mainland subpopulation but this decline most likely occurred before the most recent 3 generation timeframe. 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 (102 km^2) and IAO (36 km^2) based on presence of live individuals or fresh shells observed between 2000 and 2015 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 expected to continue to decline.
Criterion C (Small and Declining Number of Mature Individuals): Does not meet criteria. The number of mature individuals is uncertain but estimated to be over 700,000 at a minimum. 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 because the number of mature individuals is uncertain but estimated to be over 700,000 at a minimum. D2 Threatened is applicable because while the IAO (36 km^2) is above the typical 20 km^2 threshold, the number of locations is below the typical threshold (5 or fewer) and the species is prone to the effects of human activities or stochastic events in an uncertain future that once they occur, means the species will rapidly meet the thresholds for critically endangered within 1 or 2 generations (5-12 years) or become extirpated. Although D2 Threatened was met, the species' status was determined to be more at risk and Endangered under criterion B.
Criterion E (Quantitative Analysis): Not applicable as analyses have not been done.

TECHNICAL SUMMARY – Western Banded Tignersnail

Anguispira kochi occidentalis

Western Banded Tigersnail

Escargot-tigre à bandes de l'Ouest

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

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)	~5 – 6 yrs, based on data from other areas
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Uncertain but possible inferred decline based on habitat trends and threats
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. Unknown b. No c. No
Are there extreme fluctuations in number of mature individuals?	Unknown, probably not

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	19,520 km^2
Index of area of occupancy (IAO) (Always report 2x2 grid value).	308 km^2 (discrete value based on known records); this value is most likely an underestimate as survey effort in potential habitats is incomplete.
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. Unknown
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	>>10

Is there an [observed, inferred, or projected] decline in extent of occurrence?	Unknown
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Unknown
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Unknown
Is there an [observed, inferred, or projected] decline in number of "locations"[2]?	Unknown
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations" [3]?	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**
	Unknown
Total	Unknown but probably >>10,000 adults; possibly 100,000s, based on density data for populations in Ontario.

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 due to lack of data

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

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

Was a threats calculator completed for this species? Yes

i. Residential & commercial development (Low impact)
ii. Transportation & service corridors (Low impact)
iii. Biological resource use (Low impact)
iv. Natural system modifications (Low impact)
v. Climate change & severe weather (Low impact)
vi. Agriculture & aquaculture (Negligible impact)
vii. Energy production & mining (Negligible impact)
viii. Human intrusion & disturbance (Negligible impact)
ix. Invasive species (Unknown impact)
x. Pollution (Unknown impact)
xi. Geological events (Unknown impact)

What additional limiting factors are relevant?

- Low dispersal ability, low physiological resistance to fluctuating environmental factors such as temperature and humidity
- Dependence on moist refuges that buffer environmental fluctuations

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Idaho SNR (status not ranked); Montana (S5); Washington S3S4 (vulnerable/apparently secure)
Is immigration known or possible?	Not known but possible near the Canada-US border
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?[4]	Possibly
Are conditions for the source population deteriorating?[+]	Unknown
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	Possible but of limited importance and restricted to areas near the Canada-US border

Data Sensitive Species

Is this a data sensitive species?	No

Status and Reasons for Designation:

Status: Not at Risk	**Alpha-numeric codes:** Not applicable

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

Reasons for designation:
This large terrestrial snail is known from numerous sites and appears to be abundant in southeastern British Columbia. Most records come from the West Kootenay region where it is mainly found in riparian and floodplain habitats. Continuing low-impact threats include habitat loss from residential development, roads, logging, fire, silvicultural activity, and droughts, and temperature extremes related to climate change. Given the current circumstances, this species is not at risk.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Does not meet criteria. The threats assessment suggests a future decline; however, the magnitude of the decline is uncertain.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not meet criteria. While both EOO and IAO are below thresholds for Threatened (EOO < 20,000 km^2) or Endangered (IAO < 500 km^2, most likely underestimated but certainly < 2000 km^2 for Threatened), there are more than 10 locations and the population is not severely fragmented. However, there is an inferred and projected continuing decline in area, extent, and quality of habitat.
Criterion C (Small and Declining Number of Mature Individuals): Does not meet criteria. The number of mature individuals is unknown and the magnitude of potential future decline is unknown.
Criterion D (Very Small or Restricted Population): D1 is not applicable; the number of mature individuals is unknown but certainly above the thresholds. D2 Threatened is not applicable as IAO and number of locations are well above thresholds.
Criterion E (Quantitative Analysis): Not applicable as 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
(2017)

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

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

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

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

Environment and Climate Change Canada
Canadian Wildlife Service
Environnement et Changement climatique Canada
Service canadien de la faune
Canada

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

COSEWIC Status Report

on the

Eastern Banded Tigersnail
Anguispira kochi kochi

and

Western Banded Tigersnail
Anguispira kochi occidentalis

in Canada

2017

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: Discidae

Genus: *Anguispira*

Species: *Anguispira kochi* (Pfeiffer, 1846)

Common English name: Banded Tigersnail

Common French name: Escargot-tigre à bandes

Originally recognized as *Helix solitaria* by Say in 1821, the species was also named *Patula solitaria* and *Pyramidula solitaria*, before receiving the name *Helix kochi* by Pfeiffer in 1846 (Pilsbry 1948). Ahlstrom (1930) used the name *Anguispira solitaria* and Pilsbry (1948) presented the species as *Anguispira kochi* as currently accepted (Turgeon *et al.* 1998). Note that *Helix solitaria* Say, 1821 is invalid due to homonymy; *Anguispira kochi* Pfeiffer, 1845 was actually published in 1846, while *Anguispira kochi* Pfeiffer, 1821 is incorrect. Turgeon *et al.* (1998) and NatureServe (2016) use this incorrect name.

Two of 13 species of the genus *Anguispira* are found in Canada: *A. kochi* (Banded Tigersnail) in British Columbia (BC) and Ontario and *Anguispira alternata* (Flamed Tigersnail) over much of eastern Canada, where it is relatively common. Clapp (1916) described several subspecies of *A. kochi* based on shell morphology (see **Morphological Description** for discussion on subspecies).

Morphological Description

Banded Tigersnail, *Anguispira kochi,* is a relatively large land snail with adult size 2.0-2.5 cm (measured as maximum shell breadth) with a heliciform shell (Forsyth 2004; Grimm *et al.* 2010). The shell has an open umbilicus, incremental striae (shallow grooves on the surface of the shell), and an apertural lip that is only slightly thickened in adults. A diagnostic feature is a narrow, light-coloured spiral band slightly above the periphery of the

shell, bordered by a darker band on either side, on a yellow to brown background (Figure on cover page, Figure 1). The animal has a grey head while the foot is tinged with orange-red to brown (Figure 1). In Ontario, variations in shell colouration and morphology range from heavy, coarsely striate and straw-coloured without externally visible bands (Figures 2A and 2C, bands visible only on the inside) to narrow, nearly smooth with low incremental striae and yellow-brown with two dark brown spiral bands (Figures 2B and 2D); intermediate forms also exist. Older animals lose their periostracum (outer covering of the shell) from weathering (Figures 2B and 2D). When disturbed the species produces slightly orange mucus.

A B

Figure 1. Banded Tigersnail A) from British Columbia, *Anguisipra kochi occidentalis* (west of Kaslo, 22 September 2015; photo by Kristiina Ovaska), B) from Ontario, *Anguispira kochi kochi* (Fish Point Provincial Nature Reserve on Pelee Island, 1 May 2013; photo by Annegret Nicolai).

Pilsbry (1948) used shell morphology (colouration, thickness and size) to distinguish species and subspecies, as proposed in original descriptions:

- *Anguispira kochi* (Pfeiffer, 1846) (= *A. kochi kochi,* see LaRocque 1953; Natureserve 2016) from the eastern US including West Sister Island (Clapp 1916) and Sugar Island, both in Lake Erie, Ohio): 20-31 mm in diameter, solid, depressed-globose, honey-yellow colour, two bands. While Pelee Island was not mentioned as an occurrence site by Pilsbry (1948), the first records from Pelee Island in 1955 by Wood (Canadian Museum of Nature Mollusc Collection: CMNML 091769, 091872) were identified as *A. kochi*, probably referring to *A. k. kochi.*
- *Anguispira kochi strontiana* (Clapp, 1916) from Middle Sister Island, Ontario (Clapp 1916; Goodrich 1916): smaller, heavier, higher spire, coarsely striate, uniform straw colour, without bands.

- *Anguispira kochi roseo-apicata* (Clapp, 1916) from North Harbour Island, East Sister Island, Middle Island, Ontario (Clapp 1916; Goodrich 1916): small, heavier, higher, brown to brownish straw colour, pink apex, without bands
- *Anguispira kochi occidentalis* (Von Martens, 1882) from the western US and Nelson, BC (Oughton collection in Royal Ontario Museum, from June 1928): higher, narrower umbilicus, chestnut-brown colour, bands less conspicuous (Figure 1A). However, Pilsbry (1948) also noticed that some specimens "seem quite indistinguishable" from eastern specimens, although "the majority of specimens are readily separable". Burke (2013) considered snails at the western extremity of the distribution of *A. k. occidentalis* in Oregon and Washington a separate subspecies, *A. k. eyerdami* (Clench and Banks, 1939), based on shell morphology. Pilsby (1948) could not distinguish *A. k. eyerdami* from *A. k. occidentalis*.

Based on the descriptions in Pilsbry (1948) for the eastern part of the range, *A. k. roseo-apicata, A. k. strontiana* and *A. k. kochi* were found on both Pelee Island and Middle Island in 2013-2015, with all three simultaneously present at each occupied site. The descriptions of *A. k. roseo-apicata* and *A. k. strontiana* correspond strongly to live snails in Figures 2A and 2C (periostracum lost from apex so colouration is not visible). They have one-half to one more whorl and the shell is thicker compared to *A. k. kochi,* best represented by Figure 1B and the figure on the cover page. In contrast to the original descriptions for *A. k. roseo-apicata* and *A. k. strontiana*, reproduced by Pilsbry (1948), bands are always visible, but only on the inside of the shell (Figures 2C). These observations suggest that *A. k. roseo-apicata* and *A. k. strontiana* can not be differentiated from *A. k. kochi* but might just be older individuals. Clapp (1916) also observed "the gradual loss of the bands" in *A. k. roseo-apicata*. In 80% of shells collected by Clapp (1916) the bands were not visible on the outside of the shell, but he did not associate the observation with an aging process, probably due to a lack of juvenile and young adults in the collection. Because the shell is thicker in the "band-less variant", the weathering process might take longer, and the probability of finding these shells is higher than for the smaller, thinner shells. This might explain the distinction of subspecies made by Clapp (1916). Consequently, the description of *A. k. roseo-apicata* and *A. k. strontiana* seems only to correspond to older adults of *A. k. kochi*.

The name *A. k. kochi* will be used for Eastern Banded Tigersnails on the Lake Erie islands of Ontario. The name *A. k. occidentalis* will be used for Western Banded Tigersnail in BC (see also **Global Range**). NatureServe (2016) also uses *A. kochi kochi* and *A. kochi occidentalis* to distinguish the eastern and western populations, respectively.

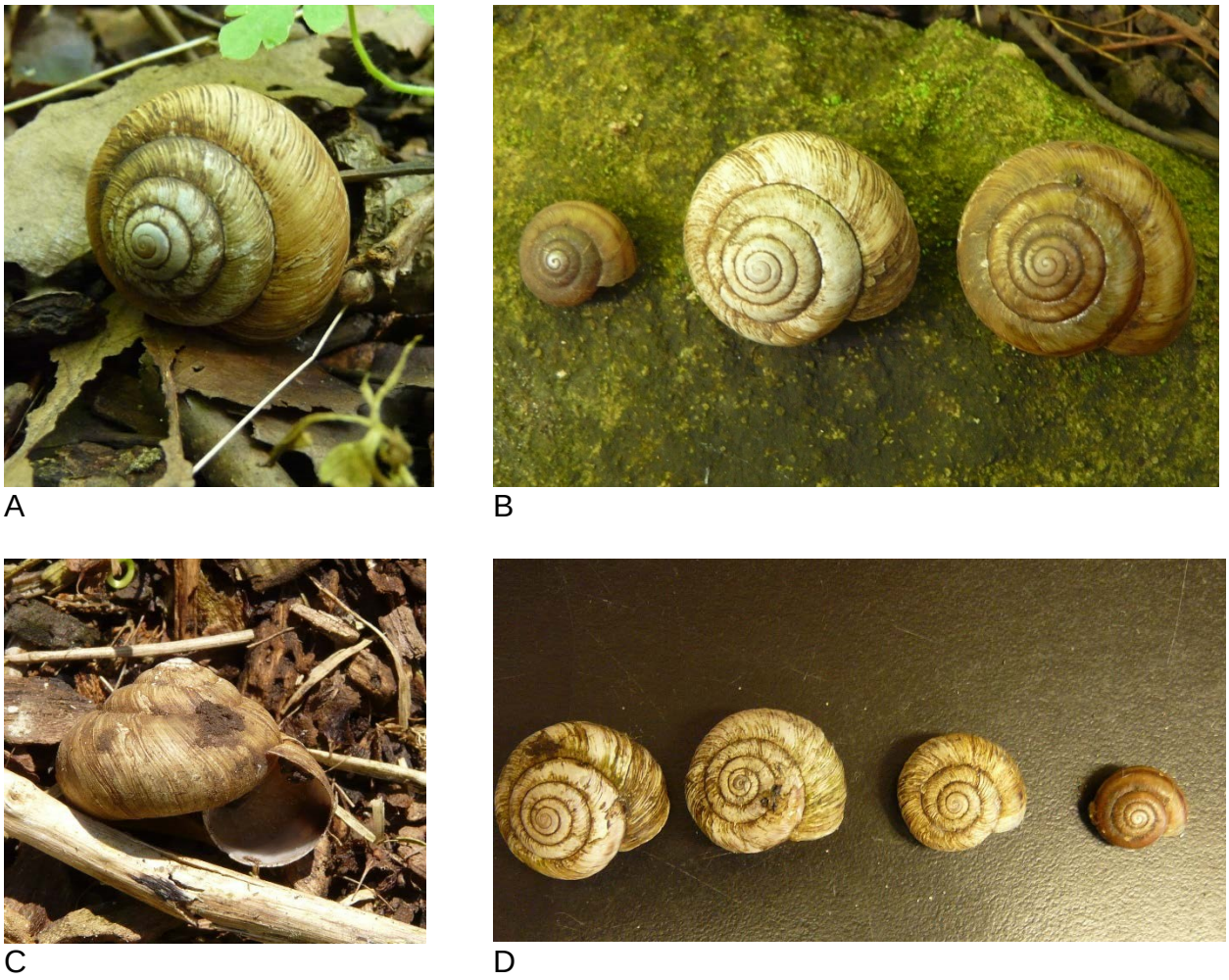

Figure 2. Shell pattern of live Banded Tigersnails observed in (A-B) The Richard and Beryl Ivey Property on Pelee Island and Fish Point Provincial Nature Reserve on Pelee Island (12 August 2015, photos by Annegret Nicolai) and on (C-D) Middle Island (30 April 2013, photos by Annegret Nicolai). Note that bands are always visible on the inside of the shell as in C.

Population Spatial Structure and Variability

In Canada, there is a clear range disjunction, separated by over 2,000 km making genetic exchange between BC and Ontario populations of Banded Tigersnail impossible (Figure 3).

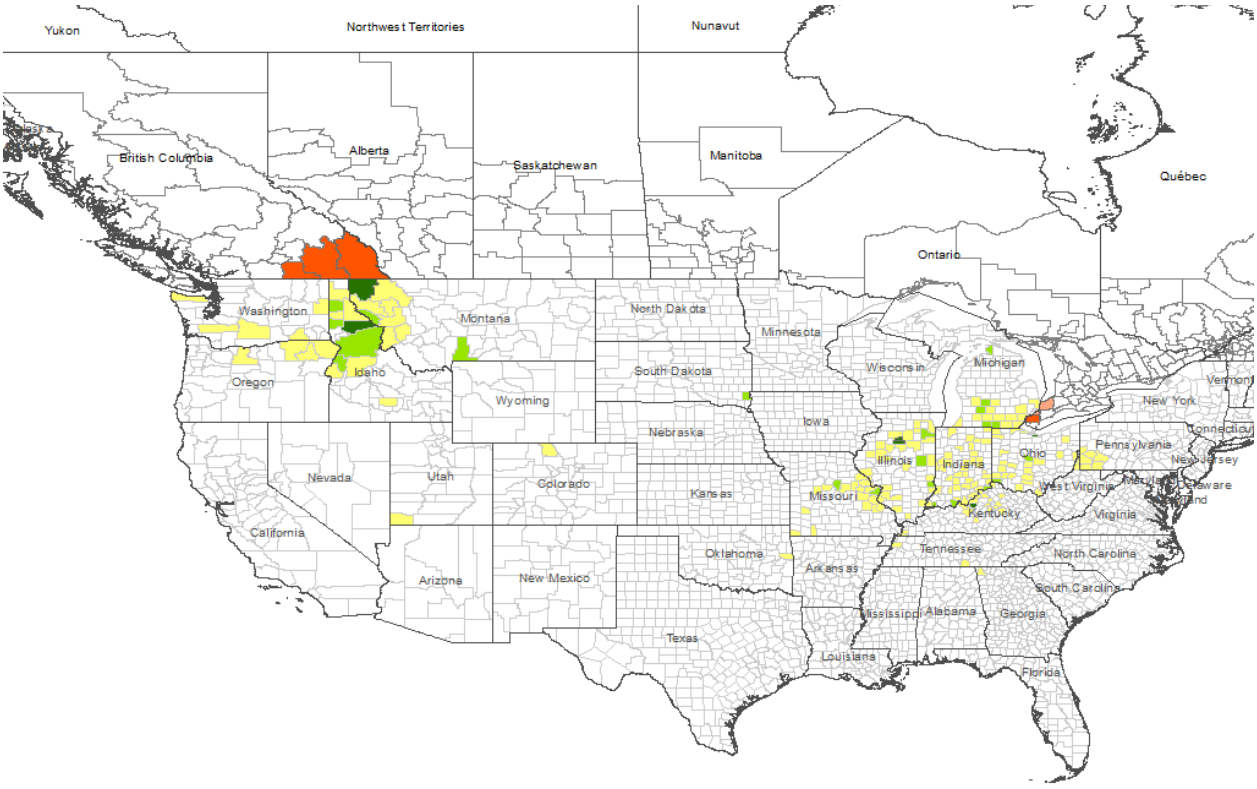

Figure 3. Global distribution of Banded Tigersnail *Anguispira kochi*. Canadian Regional Districts in British Columbia or counties in Ontario (dark orange: current occurrence, light orange: historical occurrence, for exact distribution of Eastern and Western Banded Tigersnail refer to Figures 4 and 5, respectively) and US counties (dark green) where Banded Tigersnail currently occurs (1990-2015) are indicated. US records older than 1990 are shown in light green, and without collection date in light yellow. Note that the species does not occur in the entire coloured areas. Occurrences per county or Regional Districts based on records starting in 1860 (see Collections Examined, Hubricht 1985, map prepared by Muriel Guérnion, University Rennes 1). Number of occurrences per county ranges from 1 to 58.

Within the range in BC, there are no obvious geographical disjunctions, although several subpopulations probably exist based on habitat availability and fragmentation. On a broad scale, the distribution in BC is contiguous with that in Washington State across the international border, but there is no connectivity between BC and Ontario through the US (Pilsbry 1948; Hubricht 1985; NatureServe 2016; Figure 3). Within Ontario, at least two subpopulations currently exist, one each on two islands in Lake Erie, Middle Island and Pelee Island, separated by approximately 5 km of open water. Given the size of the islands, there is the possibility of genetic exchange among individuals on each island, assuming habitat patches are currently or could be connected in the future. The likelihood of genetic exchange among individuals on Middle Island is higher than that on Pelee Island because the remaining habitat is not patchy on Middle Island. 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 earlier than 4,500 years ago, when rising lake levels isolated the islands from the mainland (Duncan *et al.* 2011). The species was able to sustain itself on these

small islands (3 to 42 ha) until the 21st century without any connection allowing gene flow. While different subspecies (based on slight morphological differences in shell characteristics) were described from different islands (see **Morphological Description**), a closer examination revealed no substantial differences and mixture of putative Lake Erie Island subspecies on each currently occupied island.

A genetic study of barcodes by A. Nicolai 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 all occupied sites in Ontario (Table 1) and from six localities in BC. One to four specimens per site (e.g., Figure 2D) were sent to BIO for extraction, amplification and sequencing of the COI gene using a standardized method for molluscs (Layton *et al.* 2014). 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 10 Eastern Banded Tigersnails, six from Pelee Island (Fish Point: N = 4, Richard & Beryl Ivey Property: N = 1, Winery Woods: N = 1) and four from Middle Island, are very similar (similarity > 99%, dissimilarity = 0.34 ± 0.09 %). Therefore, all specimens from Ontario are assigned to the same BIN in the Barcode of Life Database (BOLD; Ratnasingham and Hebert 2007): ACL3694. Only one sequence of high quality could be recovered from the snails from BC. This COI sequence is highly divergent from the Ontario sequences (dissimilarity = 21.23 ± 0.09 %) and was assigned to a different BIN: ADA2812. These preliminary results show a substantial genetic distance between these subspecies but need to be confirmed by a larger sample size from BC (analysis in progress).

Table 1. Collections of *Anguispira kochi kochi* from Ontario (1915-2015) and observations during fieldwork in 2015. Collections are curated by the Carnegie Museum of Natural History (CMNH) as dry samples (shells collected), by the Biodiversity Institute of Ontario, University of Guelph (BIOUG) as vouchers with museum ID (individuals collected alive and stored in 95% alcohol) and as barcodes (COI gene sequences), and by R.G. Forsyth as wet (individuals collected alive and stored in 95% alcohol) and dry samples (shells collected). The F.W. Grimm collection has not completely been examined yet. Population studies occurred where population density was suspected to be the highest.

Locality	Date of most recent collection	Habitat Description (ELC)	Collectors	State of collected material (Collection/Museum ID of most recent material)	Year of verification	Status of occurrence
Clements Property, Alvinston, Lambton Co.	20-May-1991	Deciduous woods, wet (no ELC available)	M.J. Oldham	Shells (MJO12499d in Grimm Collection)	Not found in 2015	Historical
Middle Sister Island, private, Lake Erie, Essex Co.	30-Apr-2013	Deciduous woods, rocks (no ELC available)	M.J. Oldham, A. Nicolai, A.G. Harris, R.F. Foster	Shells (ANi D028b in Forsyth Collection)	Shells in 2013 (no live snails since 1996)	Historical

Locality	Date of most recent collection	Habitat Description (ELC)	Collectors	State of collected material (Collection/Museum ID of most recent material)	Year of verification	Status of occurrence
East Sister Island PP, Essex Co.	3-Jul-1915	Hackberry/Sugar Maple Forest (FOD7-5)	Walker, Bryant, C. Goodrich, G. H. Clapp	Shells (CMNH_102498, Clapp 2016, Goodrich 2016)	Not found in 2013 and 2015	Historical
North Harbour Island, private, Lake Erie, Essex Co.	1916		G.H. Clapp	Shells (CMNH 102540)	No snails in 2015 (verified by owner)	Historical
Middle Point Woods (Ivey Field Station), NCC, Pelee Island, Essex Co.	1-Sep-2012	Dry-fresh Hackberry deciduous forest (FOD4-3)	A. Lischka	Shells (ANi 19.0912 in Forsyth Collection)	Not found in 2015	Current
Stone Road Alvar (Krestel), NCC, Pelee Island, Essex Co.	23-Jun-2006	Chinquapin Oak-Nodding Onion treed alvar (RBTA1-1)	M.J. Oldham	Alive (MJO32823e in Forsyth Collection)	Not found in 2015	Current
Middle Island, Point Pelee National Park, Lake Erie, Essex Co.	29-Aug-2013	Dry-fresh Hackberry deciduous forest (FOD4-3)	M.J. Oldham, A. Nicolai	Alive (BIOUG09922-A10 to A12, B01)	Population study in 2015	Current
Richard and Beryl Ivey Nature Reserve, NCC, Pelee Island, Essex Co.	1-May-2013	Chinquapin Oak-Nodding Onion treed alvar (RBTA1-1)	M.J. Oldham, A.G. Harris, A. Nicolai, R.F. Foster	Alive (BIOUG09922-A09)	Population study in 2015	Current
Fish Point Provincial Nature Reserve, Pelee Island, Essex Co.	1-May-2013, 3-Aug-2014	Dry-fresh Hackberry deciduous forest (FOD4-3) + Dry-Fresh Sugar Maple-White Ash Deciduous Forest (FODM5-8) + Dry Black Oak Woodland (WODM3-2)	A.G. Harris, M.J. Oldham, A. Nicolai	Alive (BIOUG15234-C11; BIOUG15001C11 to C12, D01)	Population study in 2015	Current
Florian Diamante Nature Reserve (south part), NCC, Pelee Island, Essex Co.	2-May-2013	Chinquapin Oak-Nodding Onion treed alvar (RBTA1-1)	M.J. Oldham	Alive (MJO40575b at BIO, in process)	Partial population study in 2015	Current
Winery Woods, Pelee Island Winery, Pelee Island, Essex Co.	2-May-2013	Chinquapin Oak-Nodding Onion treed alvar (RBTA1-1) + Dry-Fresh Sugar Maple-White Ash Deciduous Forest (FODM5-8)	M.J. Oldham A. Nicolai	Alive (BIOUG15234-C03)	Shells found in 2014	Current
Stone Road Alvar, ON Nature, Pelee Island, Essex Co.	16-Jun-2010	Chinquapin Oak-Nodding Onion treed alvar (RBTA1-1) + Dry-fresh Hackberry deciduous forest (FOD4-3)	M.J. Oldham	Shells (MJO37411f in Forsyth Collection)	Shells found in 2015	Current
Stone Road Alvar (south part), NCC, Pelee Island, Essex Co.	1-Sep-2012	Chinquapin Oak-Nodding Onion treed alvar (RBTA1-1)	A. Lischka	Shells (ANi 59.0912-63.0912 in Forsyth Collection)	Shells found in 2015	Current

Locality	Date of most recent collection	Habitat Description (ELC)	Collectors	State of collected material (Collection/Museum ID of most recent material)	Year of verification	Status of occurrence
Stone Road Alvar (Shaughnessy), NCC, Pelee Island, Essex Co.	26-Aug-2013	Chinquapin Oak-Nodding Onion treed alvar (RBTA1-1)	A. Nicolai	Shells (ANi D031d in Forsyth Collection)	Shells found in 2014	Current
Middle Point Woods (Novatney), NCC, Pelee Island, Essex Co.	1-May-2013	Dry-fresh Hackberry deciduous forest (FOD4-3)	A. Nicolai, M.J. Oldham	Shells (ANi D011a in Forsyth Collection)	Shells found in 2014	Current
Municipal Campground, Pelee Island, Essex Co.	17-May-1995	Deciduous woods, rocks (no ELC available)	M.J. Oldham	Shells (MJO16981d in Grimm Collection)	Not checked	Unknown
E of West Shore Road, N of B&B, Pelee Island, Essex Co.	18-Aug-1997	Deciduous woods, rocks (no ELC available)	M.J. Oldham	Shells (MJO20401c in Grimm Collection)	Not checked	Unknown
Hen Island, private, Lake Erie, Essex Co.	Oct-1916		W.P. Holt	Shells (CMNH 102511)	Not checked	Unknown

Designatable Units

The distribution of Banded Tigersnail in Canada is spatially discrete (Ontario and BC) and evolutionarily significant based on the following factors:

- distance between the ranges in Ontario and BC of about 2,000 km preventing gene flow (Figure 3);
- differences in morphology and genetic structure forming two operational taxonomic units for COI genes (BIN): ACL3694 in Ontario and ADA2812 in BC with a genetic dissimilarity of about 21% (Figure 1; see **Morphological Description** and **Population Spatial Structure and Variability**)**;**
- two separate named and recognized subspecies (Pilsbry 1948; NatureServe 2016) corresponding to the determined BINs, *A. k. kochi* in Ontario and *A. k. occidentalis* in BC (see **Morphological Description** and **Population Spatial Structure and Variability**);
- occurrence in two different COSEWIC National Ecological Areas: Great Lake Plains and Southern Mountain.

Therefore, two COSEWIC designatable units (DUs), referred to as Eastern Banded Tigersnail (in Ontario) and Western Banded Tigersnail (in BC) are proposed. The differentiation of additional subspecies within Ontario could not be confirmed through morphological observations nor genetic analysis (see **Morphological Description** and **Population Spatial Structure and Variability**).

Special Significance

Two Ontario subpopulations of Eastern Banded Tigersnail are found on two separate islands: Middle Island and Pelee Island in Lake Erie. They occur in the Carolinian Forest Region near the northern limit of the species' global range. Western Banded Tigersnail is a regional endemic to moist forests of the northern Columbia Basin, an area that extends from southeastern BC and northeastern Washington State through the Idaho panhandle to northwestern Montana and contains many unique plants and animals (Brunsfeld *et al.* 2001). Both the Eastern and Western populations have significance for biodiversity, research, and conservation.

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 other 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).

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

DISTRIBUTION

Global Range

The distribution of Banded Tigersnail is disjunct, consisting of an eastern and a western North American component (Pilsbry 1948; NatureServe 2016; Figure 3). Eastern Banded Tigersnail's distribution extends into the US south to Tennessee, east to western Pennsylvania, and west to Missouri. One record from 1943 by Goodrich has been found in the collection of the Academy of Natural Sciences Philadelphia (ANSP 109445) for Georgia, and one record from 1965 by Hubricht is in the Field Museum (FMNH_238471) for Oklahoma, but it is unknown whether the species is still extant in these two states (Figure 3). Western Banded Tigersnail's distribution extends from southeastern BC southwards to Oregon and Idaho and to western Montana. One record from 1860 by Cooper in the Carnegie Museum of Natural History (CMNH_102529) is from Utah, and one record without a date by Haines in the US National Museum (USNM_853254.517595) is from Colorado, but it is unknown whether the species is still extant in these two states (Figure 3). See **Non-Legal Status and Ranks** for the detailed list of US states where the species currently occurs.

Canadian Range

Eastern Banded Tigersnail

In Ontario, Eastern Banded Tigersnail is historically known from the following western Lake Erie islands: Middle Island, Middle Sister Island, East Sister Island, and North Harbour Island (Clapp 1916; Goodrich 1916; Ahlstrom 1930; plus records in some collections listed in **COLLECTIONS EXAMINED**). Two early records in the Canadian Museum of Nature by Wood in 1955 document the presence of the species on Pelee Island (CMNML 091769; CMNML 091872), two records in the Carnegie Museum of Natural History exist from Hen Island by Holt in 1916 (CMNH 102511, 102576), and one record from the Clements Property near Alvinston, Lambton Co. (mainland Ontario) by Oldham in 1991 exists in the Ontario Natural Heritage Information Centre (CH_168435187).

The current range in Ontario includes sites on Middle Island and Pelee Island where live individuals or fresh shells have been found recently (2006-2015) (Table 1; Figure 4). It is uncertain whether the species is still extant on North Harbour or Hen islands, or at two sites on Pelee Island (Table 1, Figure 4). Access for verification on these two privately owned islands was not granted although the owner of North Harbour Island suggested it has not been seen alive recently (Gottron pers. comm. 2015) and little natural habitat currently exists. Hen Island, owned by the Quinnebog Fishing Club (2017), retains intact forest. On Pelee Island, one private site has not been verified because ownership was unclear, and the municipal campground was not searched because of limited time for field verification. The species seems to be extirpated from Middle Sister Island, East Sister Island, North Harbour, and the Clements Property (Table 1; Figure 4), because it has not been seen alive during the last 20 years at these sites (see **Search Effort**). Moreover, habitat degradation on Middle Sister Island, East Sister Island, and North Harbour Island suggests that the species would not be able to persist (see **Habitat Trends**). The 1991 record from the Clements Property could not be verified: while the shells in the Grimm collection were not yet available for examination, no shells at all were found on the Clements Property in 2015. Similarly, no shell was found on East Sister Island in 2013-2015 (Tables 1 and 2). Only old weathered shells of several species were found in 1996 as well as in 2013 on Middle Sister; the most recently observed shells were under a 40 cm layer of mulch that covers the entire Middle Sister Island (no shells were found on the mulch surface, Tables 1 and 2).

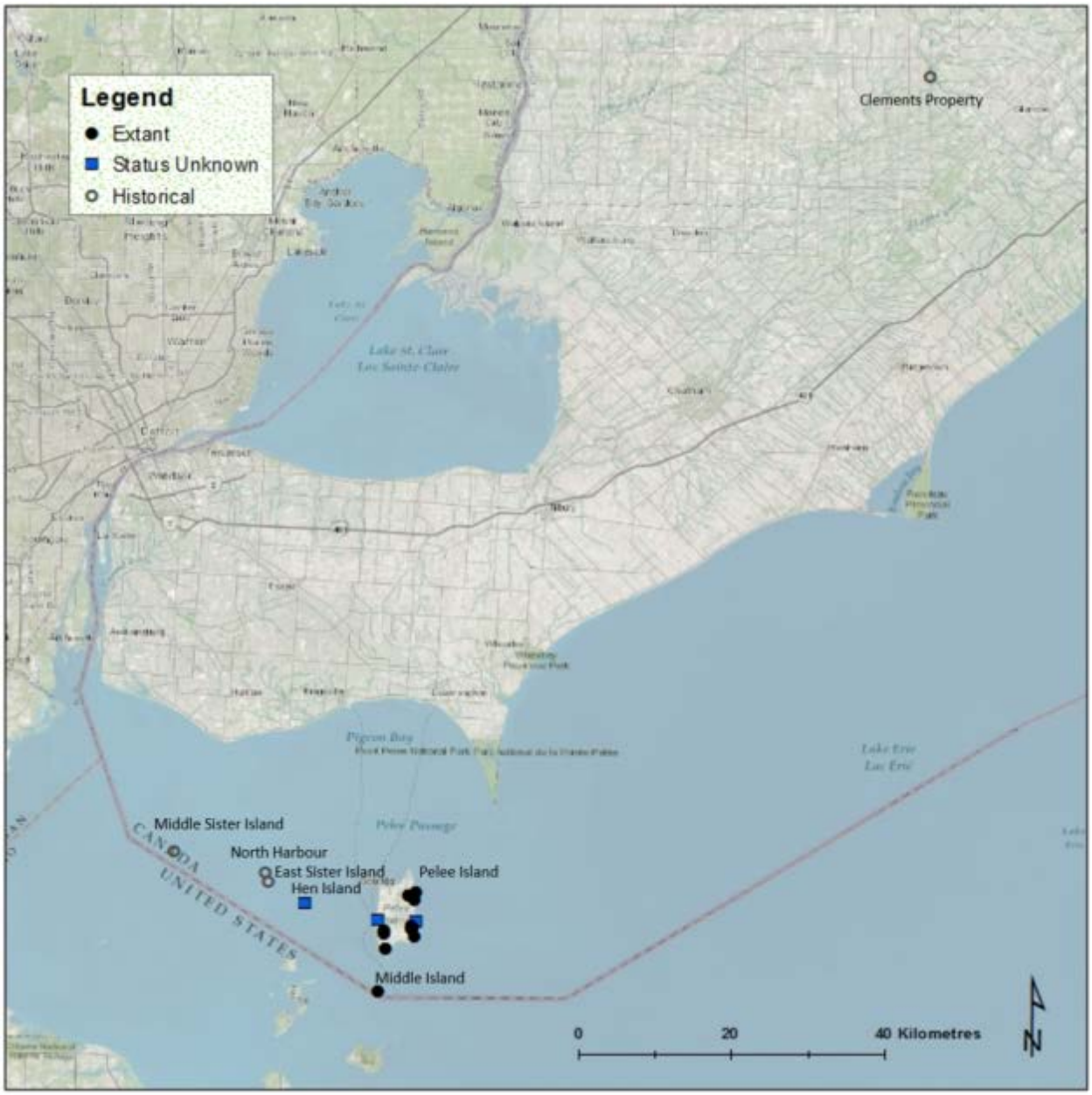

Figure 4. Distribution of Eastern Banded Tigersnail *Anguispira kochi kochi* in Ontario. Map prepared by Alain Filion (COSEWIC Secretariat) based on records compiled for this report. Kelley's Island, Ohio, not labelled, is the large island directly south of Middle Island.

Western Banded Tigersnail

Western Banded Tigersnail occurs in southeastern BC (Forsyth 2004; Figure 5). Its distribution includes southern portions of the Kootenay and Columbia river valleys, north to at least 50.5°N, and areas between. The northernmost records are from the south end of Trout Lake[1]. Most records are from the West Kootenays in the Central Kootenay and Kootenay Boundary regional districts in the West Kootenays (BC Conservation Data Centre 2016). The species' distribution barely extends to the East Kootenays, and it appears to be absent from closer to the Rocky Mountains; recent survey efforts targeting terrestrial gastropods have failed to find it there (Ovaska *et al*. 2010).

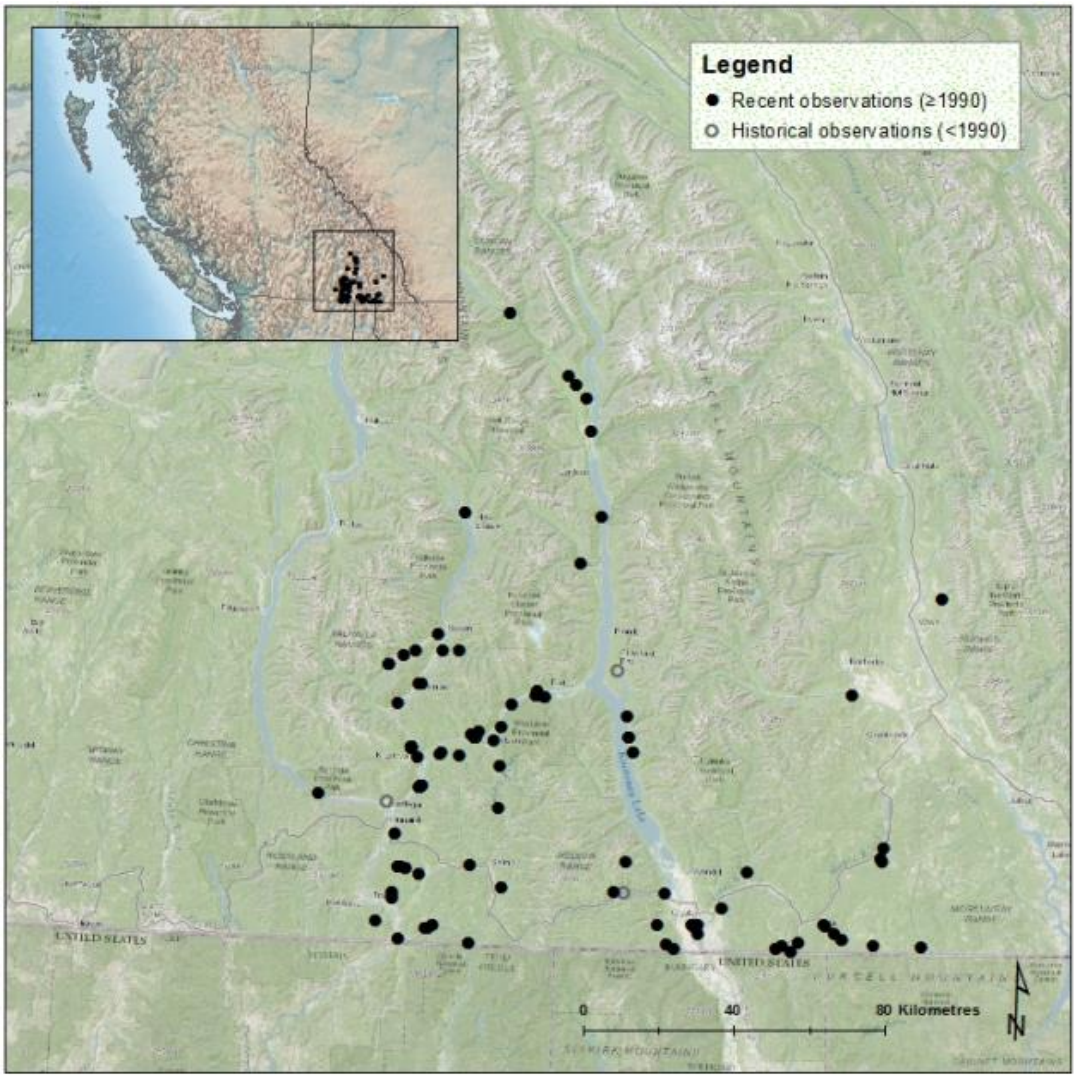

Figure 5. Distribution of Western Banded Tigersnail *Anguispira kochi occidentalis* in British Columbia. Map prepared by Alain Filion (COSEWIC Secretariat) based on records compiled for this report.

[1] Latitude for a specimen of *A. kochi occidentalis* from the Nelson area in the online catalogue of the Academy of Natural Sciences of Philadelphia (ANSP 169469) is erroneously given as 59.55°.

Extent of Occurrence and Area of Occupancy

Eastern Banded Tigersnail

The extent of occurrence (EOO) of Eastern Banded Tigersnail in Canada is 102 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 water (Lake Erie) and not habitat. The index of area of occupancy (IAO) is 36 km^2 (i.e., the species occurs in nine 2 km x 2 km grid cells), assuming that only those sites where living snails or recently dead shells were observed are extant. If all historical records are included, the IAO is 46 km^2, using one grid cell each for Middle Sister Island, East Sister Island, North Harbour, and the Clements Property. There has been a reduction in IAO by about 22% within the last 100 years: between 1916 (Clapp 1916; Goodrich 1916) and 2013 – 2015 (Table 1).

Western Banded Tigersnail

The EOO of Western Banded Tigersnail was calculated as 19,520 km^2 using the minimum convex polygon method joining the outermost occurrence records. The IAO (grid of 2 km x 2 km cells on known occurrence records) was calculated as 308 km^2. The actual IAO is most likely larger, as gastropod surveys in southeastern BC have not specifically targeted this species.

Search Effort

The probability of detecting Banded Tigersnail can be expected to be relatively high, both due to their large size and because empty shells remain on the forest floor for some time after the animals have died; their condition can be used to infer past or recent presence. Goodrich (Mollusca of Michigan, cited *in* Pilsbry 1948, p. 592) noted that "because of its thick shell, protecting it against fast disintegration, the species is a common one among the subfossil shells of the forest loam and the gravel and sand banks of streams that have changed their course".

Eastern Banded Tigersnail

Notable historical surveys include those conducted on the Lake Erie islands by Clapp (1916), Goodrich (1916), and Ahlstrom (1930), and the efforts of 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 Banded Tigersnail. There are 2,349 geo-referenced collection records from searches by M.J. Oldham between 1992 and 2012. A few more surveys were done by J.M. Bowles in 1994 with 113 geo-referenced collection records and by A. Nicolai in 2012 with 364 geo-referenced collection records. The most recent records of Eastern Banded Tigersnail from these surveys are summarized in Table 1.

During the 2013 – 2015 general gastropod survey in southwest Ontario, 101 sites were visited and revisited with a total search effort of 310 person-hours (Table 2). The surveys in 2014 and 2015 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 (included in BOLD) and 200 shell samples of about 40 species, currently being curated by Robert Forsyth. All Eastern Banded Tigersnails collected from different sites during this survey as well as site verifications are shown in Table 1.

Table 2. Summary of general gastropod survey sites in Ontario, 2013-2015; if *Anguispira kochi kochi* had been present, it would have been detected. Observers were Jane Bowles (JMB), Tammie Dobbie (TD), 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). CA – Conservation Area, NCC – Nature Conservancy of Canada, TTLT – Thames Talbot Land Trust.

Site	Effort (person-hours)	Observers	Date(s) 2013	Date(s) 2014	Date(s) 2015	*A. k. kochi* found ?
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
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, TD, RG, RGF, 2 park staff, 1 student	May 1; Aug 29		Aug 13	Alive
East Sister Island Provincial Park, Lake Erie	16.5	TD, RFF, AGH, AN, MJO, RGF, RG, 2 park staff	Apr 30		Aug 13	No

Site	Effort (person-hours)	Observers	Date(s) 2013	Date(s) 2014	Date(s) 2015	*A. k. kochi* found ?
Middle Sister Island, Lake Erie	3.5	TD, RFF, AGH, AN, MJO	Apr 30			Shells
Lighthouse Point Provincial Nature Reserve, Pelee Island	5.5	RFF, AN, MJO; AN, RGF	May 1; Aug 25		Aug 12	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	3.5	AGH, RFF, MJO, AN; AN	May 2; Aug 25		Aug 14	Shells
Gibwood Property, NCC, Pelee Island	2	AN, MJO	May 2			No
Richard and Beryl Ivey Nature Reserve, NCC, Pelee Island	7	RFF, AGH, AN, RGF	May 1	Aug 2	Aug 12	Alive
Winery property, Pelee Island	4.5	RFF, AGH, AN, MJO	May 2	Aug 2		Shells
Porchuk Property, NCC, Pelee Island	2	AN, MJO	May 2			No
Fish Point Provincial Nature Reserve, Pelee Island	11	RFF, AGH, AN, RGF	May 1	Aug 3	Aug 11	Alive
Fleck Property, Pelee Island	1	RFF	May 2			No
Essex Region Conservation Authority Stone Road Alvar, Pelee Island	2	AGH, AN	May 2		Aug 11	No
Ontario Nature Stone Road Alvar, Pelee Island	7	AGH; AN, MM, RGF	May 2; Aug 27		Aug 11	Shells
NCC Stone Road Alvar, Pelee Island	2	RGF, AN			Aug 11	Shells
Cohen Shaughnessy Property, NCC, Pelee Island	3.5	AGH; AN,MM	May 2; Aug 27	Aug 3		Shells
Krestel Parcel, NCC, Pelee Island	4	AGH, AN, RGF	May 1	Aug 3	Aug 11	No
Finley Parcel, NCC, Pelee Island	1	AN		Aug 4		No
Fronzier Parcel, NCC, Pelee Island	1	AN, RGF			Aug 12	No
Middle Point Woods – south part, NCC, Pelee Island	6	RFF, AGH, AN; AN	May 1, 2; Aug 26	Aug 3		Shells
Florian Diamante Nature Reserve, NCC, Pelee Island	7.5	AGH, RFF, AN, RGF	May 2	Aug 2	Aug 11, 12	Alive
Point Pelee National Park (6 sites)	12	AGH, AN, MJO, RFF	Apr 28, 29			No
Oxley Swamp, NCC	2	AN, HU	May 20			No
Cedar Creek CA	3	RFF, AGH	April 29			No
Kopegaron Woods CA	4	RFF, AGH, AN, MJO	Apr 29, 30			No
Two Creeks CA	2	MJO	May 18			No
Canard River CA	2	AN, MJO	April 29			No
Maidstone CA	2	RFF, AGH	April 29			No
Rondeau Provincial Park	6.5	MJO, JMB; AGH	May 17; Sep 4			No
Sinclair's Bush	2	MJO, JMB	May 17			No
Thames Grove CA	1	AN, JMB	May 3			No
Moraviantown First Nation	6	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

Site	Effort (person-hours)	Observers	Date(s) 2013	Date(s) 2014	Date(s) 2015	*A. k. kochi* found ?
Backus Woods, NCC	4	MJO; AGH	May 15; Sep 2			No
St. Williams Conservation Reserve	2	MJO	May 15			No
Calton Swamp	1	MJO	May 15			No
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	3	JMB, MJO; AGH; AN, LC	May 16, August 3; Sep 22			No
Kilally 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 CA	2	AN, LC	Sep 22			No
Brigden Crown Game Preserve	2	AN, LC	Sep 22			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
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

Site	Effort (person-hours)	Observers	Date(s) 2013	Date(s) 2014	Date(s) 2015	*A. k. kochi* found ?
Rare, Charitable Research Area, Cambridge	4	AN, RGF			Aug 16	No
Total search effort	310					

Fieldwork in 2015 focused on a population study at sites on Pelee Island where live individuals were recorded previously. However, some sites were not included in the population study for the following reasons:

- The Krestel property (owned by Nature Conservancy of Canada [NCC]) was visited several times in 2013-2015 without finding shells. However, the property's wood patches have not been thoroughly checked, because of a high abundance of Poison Ivy, *Toxicodendron radicans*.
- In Winery Woods (owned by Pelee Island Winery), one live specimen was found in 2013, but was accidentally included with a sample from another site. The error was not discovered until fieldwork ended in 2015 and so no population study occurred at this site.
- The Florian Diamante Nature Reserve (FDNR, owned by NCC) has been visited several times in 2013 and 2014, but resulted in only one record of a live specimen. The survey in 2015 focused on detecting this species on the property. Towards the end of the survey, a wood patch with several live individuals was discovered, but could only be studied briefly, due to time constraints.

Western Banded Tigersnail

Little information exists on survey efforts in southeastern BC before the 1990s. Since the 1990s, several surveys targeting terrestrial gastropods and other forest floor invertebrates have occurred in this area; as a result, hundreds of sites have been surveyed across the range of Western Banded Tigersnail (Table 3). Although none of these surveys has specifically targeted this species, surveys by R. Forsyth, Biolinx Environmental Research Ltd. (K. Ovaska and L. Sopuck), and others documented all gastropods found (Table 3). Recently (2015 – 2016), R. Durand has conducted targeted surveys for this species in the Slocan Valley and surrounding areas. Most sites have been surveyed only once with the objective to increase survey coverage over the large and often rugged landscape.

Table 3. Summary of survey effort for terrestrial gastropods in southeastern British Columbia. Number of non-overlapping survey sites were calculated from GIS maps by Biolinx Environmental Research Ltd.

Year	Months	# sites	Search time	Surveys conducted by:	Source or project
1998-1999	September (1 in July)	40	Unknown	RBCM (Kelly Sendall, Phil Lambert)	Living Landscape project; RBCM files
1990-2013	Various	135	Unknown	Robert Forsyth	R. Forsyth personal main database (current up to 2013) and other unique sites; includes Flathead Bioblitz 2012
2007	July, September	63	66.1 person-hours	Biolinx Environmental Research Ltd (Kristiina Ovaska, Lennart Sopuck)	Ovaska and Sopuck 2009a
2008	September, October	45	48 person-hours	Biolinx Environmental Research Ltd (Kristiina Ovaska, Lennart Sopuck)	Ovaska and Sopuck 2009a
2009	October	17	20.9 person-hours	Biolinx Environmental Research Ltd (Kristiina Ovaska, Lennart Sopuck)	Ovaska and Sopuck 2009b
2009 - 2013	July - September	96	Unknown	Claudia and Darren Copley	C. Copley data files
2008 - 2011	Various	85	Unknown	Dwayne Lepitzki	Surveys in Alberta and BC; Lepitzki personal database
2010	September	56	67.9 person-hours	Biolinx Environmental Research Ltd (Kristiina Ovaska, Lennart Sopuck)	Ovaska *et al.* 2010
2011	August, September	29	Unknown	Jeff Nekola, Brian Coles, Michael Horsek	Surveys for Valhalla Wilderness Society; Nekola *et al.* 2011
2012	August	6	Unknown	Melissa Frey	Flathead Bioblitz; RBCM database; Note: additional sites that overlap with those of Forsyth are excluded.
2013	September	36	31.7 person-hours	Biolinx Environmental Research Ltd (Kristiina Ovaska, Lennart Sopuck)	Fieldwork associated with the preparation of COSEWIC status report for the Pygmy Slug (*Kootenaia burkei*)
2013	June	14	Unknown	Dwayne & Brenda Lepitzki	Flathead Bioblitz; Lepitzki data files
2014	September	72	72.2 person-hours	Kristiina Ovaska & Lennart Sopuck	Gastropod surveys for BC Ministry of Environment and fieldwork associated with the preparation of COSEWIC status report for the Sheathed Slug (*Zacoleus idahoensis*)
2014	October	12	unknown	Dwayne & Brenda Lepitzki	Lepitzki and Lepitzki 2015
2015	September	36*	38.5 person-hours	Kristiina Ovaska & Lennart Sopuck	Gastropod surveys for BC Ministry of Environment
2015, 2016	June - October	146	Unknown	Ryan Durand	Species-at-risk surveys and targeted surveys for Banded Tigersnail for MSc thesis at Edinburgh Napier University, Scotland

HABITAT

Habitat Requirements

In Canada, Banded Tigersnail inhabits mesic mature hardwood or mixed-wood forests (see below). In the eastern US, Hubricht (1985) describes habitat as: “Usually found on river bluffs, crawling about on the ground in wet weather, or under the leaves in dry weather. Also found in ravines and upland woods, sometimes in rather dry situations.” Goodrich (*in* Pilsbry 1948) characterizes Banded Tigersnail as being “one of the typical molluscs of the old forest, and seldom found even in thick second-growth timber. It hides during hours of bright days under rotting leaves or decaying logs.”

Eastern Banded Tigersnail

Live Eastern Banded Tigersnail occurrences observed in 2015 were overlain on vegetation maps (Ecological Land Classification [ELC] by Lee *et al.* 1998) of Middle Island (North - South Environmental Inc. 2004) and Pelee Island (maps provided by NCC for their two properties: ELC_FDNR 2014-131660 and Ivey_ELC_21Feb08-2183 [Richard and Beryl Ivey Property, RBIP] while the map for Fish Point Provincial Nature Reserve, owned by Ontario Parks, was provided in Dobbyn and Hoare 2009). The absence of live individuals and shells in other habitats at the same sites suggests a certain affinity for specific habitats. Chinquapin Oak-Nodding Onion treed alvar (RBTA1-1) and dry-fresh Hackberry deciduous forest (FOD4-3) were the preferred habitat types on NCC properties and on Middle Island (Table 4). Dry-fresh Sugar Maple-White Ash deciduous forest (FODM5-8) and dry Black Oak woodland (WODM3-2) were the preferred habitat types at Fish Point (Table 4). The snails showed a clear affinity for rocky ground consisting of limestone (alvar) with herbaceous vegetation cover on NCC properties and for sandy soil with a substantial leaf litter layer (10-20 cm, FOD; Dobbyn and Hoare 2009) at Fish Point (Table 4). The current size of the habitat used by Eastern Banded Tigersnail, based on habitat patch size for properties where live individuals or shells were found in 2006-2015, is about 98 ha (Table 5).

Table 4. Subpopulation size estimation of *Anguispira kochi kochi* based on size of habitat type (classified following ELC [Lee *et al.* 1998], RBTA1-1: Chinquapin Oak-Nodding Onion treed alvar, FOD4-3: Dry-Fresh Hackberry Deciduous Forest, FODM5-8: Dry-Fresh Sugar Maple-White Ash Deciduous Forest and WODM3-2: Dry Black Oak Woodland) in 2015. Abundance of adult snails was measured where snails have been found since 2013: in three sites of Pelee Island (RBIP-Richard & Beryl Ivey Property, FDNR-Florian Diamante Nature Reserve, FP-Fish Point) and on Middle Island (MI).

		RBIP	FDNR	FP		MI	Total
Habitat size (ha)	RBTA1-1	8.95	10.48				19.43
	FOD4-3					4	4
	FOD5-8			16			16
	WODM3-2				3		3
Mean abundance (N/m^2)		1.1	1.4	3.3	1.8	0.3	
Mean population size		100,688	146,720	520,000	52,500	12,333	**832,241**

	RBIP	FDNR		FP	MI	Total
Number of plots studied	2	1	2	2	3	
Range of abundance (N/m^2)	0.3-2.0	1.4	3.3-3.3	0.8-2.8	0.1-0.8	
Minimal population size	26,850	146,720	528,000	24,000	4,000	**729,570**
Maximal population size	179,000	146,720	528,000	84,000	32,000	**969,720**

Table 5. Current and potential size of habitat for *Anguispira kochi kochi* shown by block of protected area and detailed for the four habitat types (classified following ELC [Lee *et al.* 1998], RBTA1-1: Chinquapin Oak-Nodding Onion treed alvar, FOD4-3: Dry-Fresh Hackberry Deciduous Forest, FOD5-8: Dry-Fresh Sugar Maple-White Ash Deciduous Forest and WODM3-2: Dry Black Oak Woodland) where the species has been observed alive or as shells between 2006 and 2015. Besides the currently used habitat of the species (habitat where the species is present alive or as shell), suitable habitat is available in other protected areas on Pelee Island managed by Nature Conservancy Canada (NCC), ON Nature, ON Parks, and the Essex Regional Conservation Authority (ERCA), where the species is currently absent. In Winery Woods information on the presence of habitat types is available (Nature Conservancy Canada 2008).

	Owner	Protected area (ha)	area RBTA1-1 (ha)	area FOD4-3 (ha)	area FOD5-8 (ha)	area WODM3-2 (ha)	Presence of *A. k. kochi*
Middle Island	Parks Ca	18.5	0	4	0	0	**alive**
Middle Point Woods	NCC	28	0	7.23	0	0	**shells**
Florian Diamante Nature Reserve	NCC	184	10.48	12.45	0	0	**alive**
Richard & Beryl Ivey Property	NCC	51	8.95	0	0	0	**alive**
Gibwood	NCC	14	0	1.95	0	0	absent
Stone Road Alvar	NCC	137	14.97	1.55	0	0	**shells**
	ON Nature	42	16.8				**shells**
	ERCA	64	15*				absent
Lighthouse Point	ON Parks	96	0 yes		0	0	absent
	ERCA	9.6					absent
Fish Point	ON Parks	110	0 3		16	3	**alive**
Winery Woods	Pelee Island Winery	33.6	yes		yes		**alive**
Total (ha)		**787.7**					

* Note: Estimation of habitat size based on Kirk (1994) plus field observations and aerial photographs.

Size of all suitable habitat was estimated for all the protected land using vegetation maps when available and other available information sources (Kirk 1994; North - South Environmental Inc. 2004; Nature Conservancy of Canada 2008 maps: ELC_Gibwood 2011-22419, ELC_Stone_Road_Alvar-53743, and ELC_Novatney_2012-53538 [Novatney in Middle Point Woods, owned by NCC]; Dobbyn and Hoare 2009). None of the smaller islands was included in the suitable habitat size estimation, because dispersal over Lake Erie is unlikely and habitat is heavily degraded by a dramatic increase in nesting Double-crested Cormorants, *Phalacrocorax auritus*, on East Sister and Middle Sister islands (Figure 6) and by human activity on North Harbour Island. Presence of Eastern Banded Tigersnail and habitat conditions could not be studied on Hen Island. These islands also were not included in the habitat analysis.

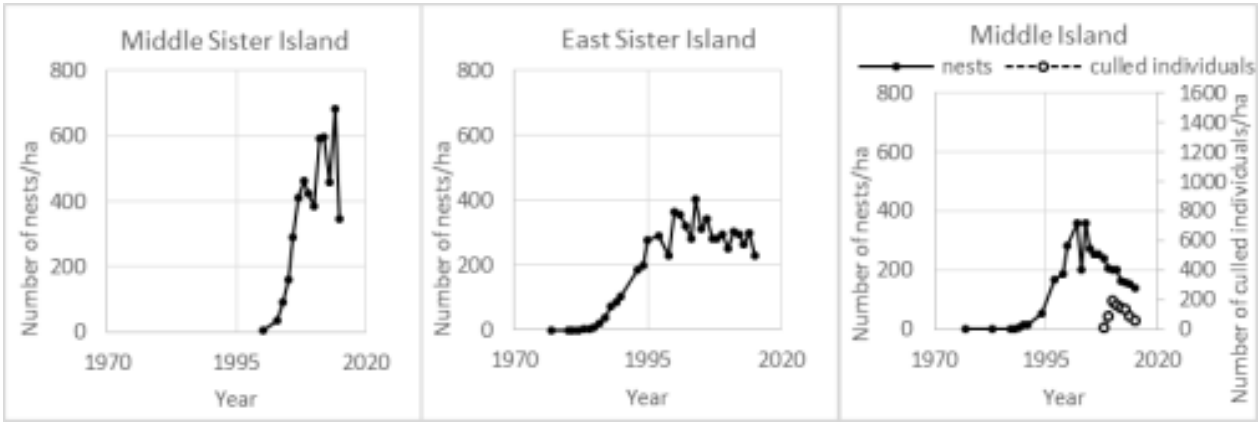

Figure 6. Cormorant nest density on three of the Canadian Lake Erie islands. Only the Middle Island cormorants are culled once per year since 2008. Nest counts are done each spring before culling on the three islands. Data provided by Point Pelee National Park.

A total of about 115 ha out of 788 ha of protected land on Pelee and Middle islands represents currently used and other suitable habitat for the species (Table 5). Colonization of habitats on isolated properties on Pelee Island might be difficult because the protected areas are not connected at the micro-scale suitable for gastropods. Ditches as well as paved and unpaved roads or tracks as narrow as 3 m with both high and low traffic densities can be barriers to snail dispersal (Baur and Baur 1990; Wirth *et al.* 1999). Even a narrow path (0.7 m), if devoid of leaf litter, can be a barrier to movement for some species (Meadows 2002). 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 2013-2015.

Western Banded Tigersnail

Western Banded Tigersnail has been reported from elevations up to 1709 m above sea level (asl) (Ovaska and Sopuck 2015), but most records are from 500 – 1000 m asl. Forsyth (2004) described the habitat of the species as “moist, well-vegetated forests, often near the shores of lakes or streams”. Observations during surveys from 2007 – 2015 by Biolinx Environmental Research Ltd. (Ovaska and Sopuck, unpubl. data 2007-2015) support this description; the species was usually found in riparian habitats in mixed-wood or deciduous stands, including Cottonwood (*Populus balsamifera trichocarpa*) floodplains and riparian zones along rivers and creeks (Ovaska and Sopuck 2009a,b, 2014, 2015; Ovaska *et al*. 2010). In the above surveys, a deciduous component was present at 82% of the 33 sites where the species was found; Cottonwood was present at 61% of the sites. Other tree species included Paper Birch (*Betula papyrifera*), Mountain Alder (*Alnus tenuifolia*), Douglas-fir (*Pseudotsuga menziesii*), Engelmann Spruce (*Picea engelmannii*), Western Redcedar (*Thuja plicata*), and Western Hemlock (*Tsuga heterophylla*). Common understory plants included Thimbleberry (*Rubus parviflorus*), indicative of moist conditions, as well as Douglas Maple (*Acer glabrum*), Saskatoon (*Amelanchier alnifolia*), Red-osier Dogwood (*Cornus stolonifera*), Rose (*Rosa* sp.), and various herbaceous plants. A deep to moderately deep leaf litter layer (> 5 cm deep) was usually present, and the snails were often found buried in the litter or under coarse woody debris. An apparent hibernation site, with over 60 Western Banded Tigersnails, was found on a southeast slope (aspect 130°, slope 28°) in a canopy gap with abundant herbaceous growth (23 September 2014; Ovaska and Sopuck 2014), suggesting that the snails may seek drier sites for hibernation that are unlikely to be affected by flooding.

Habitat Trends

Eastern Banded Tigersnail

The climate on the Lake Erie islands is much warmer than expected for its latitude because of the moderating effect of Lake Erie. 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). The predominant natural disturbance on Middle Island is from violent storms (Dobbie and Kehoe 2008), with waves immersing large parts on the south side of the island. Vegetation and the litter layer on the ground are affected. Since the draining of a wetland on Pelee Island, flooding of forest occurs every year in Fish Point, Middle Point Woods, and the Stone Road Alvar. The flooding has been less intense since 1970-1972 because much of the island’s shoreline was fortified with armour stone, and a network of dykes criss-crosses the island (Nature Conservancy Canada 2008); however, these fortifications are absent from Fish Point.

Even though the species is at its northern distributional limit 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 (Wang and Huang 2013), some climate change observations and predictions that could affect the snails are as follows:

- Average fall temperatures are 3°C higher on the Canadian Lake Erie Islands than in other areas of southwestern Ontario (about 12°C *versus* 9°C), thereby increasing length of growing season for vegetation as well as activity season for gastropods. With climate change, the average temperature will increase by 3°C for all seasons (14°C *versus* 11°C in fall, for example), which can lead to increased frequency of freeze-thaw cycles in fall/winter (Nicolai and Sinclair 2013) and more spring frosts (Augspurger 2013).
- The average amount of precipitation per year on the Canadian Lake Erie islands (about 1,500 mm/year) is 200-600 mm higher than on the mainland. With climate change, the intensity of precipitation on the islands will increase by about 10 mm/h with an increase in the average amount of precipitation of about 10 mm in summer and 40 mm in winter, thereby likely increasing the flooding on Pelee Island. There would 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).

After being logged in the mid-1880s, Pelee Island has since largely been developed for agriculture (Nature Conservancy Canada 2008). Viticulture and soybean farming is 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 (Essex Region Conservation Authority 2002), most of which is under management by the Nature Conservancy of Canada (NCC) or the Ministry of Natural Resources and Forestry (MNRF). NCC plans to re-establish habitat connections by restoring former fields adjacent to forested areas and mechanically removing invasive plants (Nature Conservancy Canada 2008). Herbicide use is still restricted to study plots (study in progress by NCC). The Pelee Island Winery collaborates with NCC for Red Cedar savannah restoration and habitat conservation (Nature Conservancy Canada 2008). Prescribed fire would be mainly applied to grasses in the savannah on the Stone Road Alvar owned by Essex Regional Conservation Authority, Ontario Nature, and NCC. A test burn is planned for 2017-2018

(pers. comm. Lebedyk 2015) which includes potential habitat for Eastern Banded Tigersnail. Access for the public is possible on one biking and walking trail that goes through the savannah in the Florian Diamante Nature Reserve and on the Richard and Beryl Ivey Property, and through the forest in Winery Woods. Logging and grazing is forbidden, while hunting is still allowed on almost all NCC properties. The management plan for Fish Point 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.

The tip of Fish Point is subjected to a natural process of sand erosion on the east side and deposition on the west side. This process is most likely similar to that occurring at Point Pelee (Kamstra *et al.* 1995) but it 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 deposit of sand is disrupted (BaMasoud and Byrne 2011). Erosion at the tip of Point Pelee also has been accelerated by sand extraction activity (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 was seen in 2013-2015, including loss of trees, and incursion of lake water inland at the south end. Although maybe not directly affecting snails in the short-term, there might be indirect effects such as increased exposure of the inner higher ground of Fish Point.

Middle Island, added to Point Pelee National Park in 2000 (Parks Canada 2010), has been uninhabited since the 1980s, but the disturbance by a former driveway and lawns is still visible in vegetation composition and canopy density (North - South Environmental Inc. 2004). Over 40% of the forest cover on Middle Island was lost between 1995 and 2006 as a result of the invasion of Double-crested Cormorants (Dobbie and Kehoe 2008). Parks Canada has been culling cormorants every year since 2008 (Figure 6), thereby decreasing overall nest density on the island. Boutin *et al.* (2011) showed that the seed bank is less affected by nest density than is the forest cover, suggesting resilience. While many exotic species are found in the aboveground vegetation, several native species of conservation interest persist on the island. Acidification and high salinity in the soil were observed (North - South Environmental Inc. 2004).

The habitats currently occupied by Eastern Banded Tigersnail were ranked for their capacity to sustain a viable snail population using the element of occurrence (EO) ranking key of NatureServe (Tomaino *et al.* 2008) on the best available information:

- NCC properties on Pelee Island: Rank = AC: Excellent to Fair viability (EO that may persist for the foreseeable future with appropriate and ongoing protection or management). Second growth forest or old growth forest that has historically been disturbed by flooding, logging and grazing. Compared to other sites, abundance of Eastern Banded Tigersnail is medium (Table 4) and spatial distribution over each property is patchy. Suitable habitat within a property is surrounded by potential habitat, but also by less suitable habitat such as restored fields and alvar

savannah. Corridors between properties are poorly developed. Management plan with habitat and species-at-risk protection in place.

- Fish Point Provincial Nature Reserve: Rank = AB: Excellent to Good viability (Population size and quality and quantity of occupied habitat are highly favourable to optimal; EO is expected to persist in its current condition; EO has highly favourable and higher-quality characteristics). Old growth forest with a substantial leaf litter layer, but surrounded by Lake Erie and by wet to marshy forest that is widely flooded during most of the year and therefore unsuitable for the species. Among all the occurrence sites, Fish Point has the highest abundance of Eastern Banded Tigersnail (Table 4). Slow degradation by erosion. Management plan with habitat and species at risk protection in place.
- Middle Island (Point Pelee National Park): Rank = C: Fair viability (Few aspects of condition, landscape context, and quality and quantity of occupied habitat are favourable; there is some uncertainty about the long-term persistence of the EO and its current quality). Island of small size, completely isolated, mainly destroyed second growth forest, disturbed by overabundant cormorant population (Figure 6) and yearly storms. Thick mulch layer with high acidity and salinity in some places of the island is not favourable for the species. Abundance of Eastern Banded Tigersnail is relatively low (Table 4). Management plan with habitat and species at risk protection in place.

Habitat also has been lost or altered due to overabundant Double-crested Cormorants on Middle Sister and East Sister islands (Figure 6). North Harbour Island has suffered from artificialization (Gottron pers. comm. 2015; verified with aerial photographs). The species is considered extirpated on these three islands (see **Canadian Range**).

Western Banded Tigersnail

Habitats of Western Banded Tigersnail in BC have been and continue to be affected by land conversions for residential and industrial developments, forestry, livestock grazing, mining, hydroelectric development, and other human activities. Superimposed on human activities are changing patterns of temperature and precipitation associated with climate change, particularly more frequent, prolonged droughts that decrease substrate moisture and so degrade habitat for the snails.

Land conversions for residential and industrial developments and for agriculture have resulted in the permanent loss of habitat mainly at lower elevations, especially along river valleys, lake shores, and highways. Riparian Cottonwood habitats in larger valleys, in particular, were heavily modified by early settlers due to their flat lands, productive soils, and abundance of water (BC Ministry of Environment, Lands and Parks 1997). Remnants of these forests continue to be under pressure for urban expansion and transportation corridors. Several remnant Cottonwood plant communities have been identified to be provincially at risk; plant communities from the southeast that provide potential habitat for Western Banded Tigersnail include Cottonwood/Water Birch (*Populus*

balsamifera trichocarpa/*Betula occidentalis*), Cottonwood/Red-osier Dogwood/Nootka Rose (*P. b. trichocarpa/Cornus stolonifera/Rosa nutkana*), and Cottonwood/Common Snowberry/Nootka Rose (*P. b. trichocarpa*/*Symphoricarpos albus*/*Rosa nutkana* species) communities (BC Ministry of Environment 2016).

Larger human population centres within the species' range occur at Trail, Fruitvale, Castlegar, Nelson, Creston, and Cranbrook, and a few much smaller communities occur at Kaslo, Nakusp, Slocan Valley, Moyie Lake, and Yahk. However, the human population density of the West Kootenay region is relatively low compared to other areas of southern BC, such as the Okanagan Valley and eastern Columbia Basin. Since 2001, the human population in the West Kootenay region has increased at a rate of only 1.3% per decade, reaching 64,379 people in 2011 (Columbia Basin Rural Development Institute 2012).

The removal of tree cover, building of forestry roads, and silvicultural activities associated with forestry activities continue to fragment habitats throughout the West Kootenay region. Western Banded Tigersnail has been found from young (30 – 40 year old) to old growth forest stands (Ovaska and Sopuck 2009a,b, 2014, 2015; Ovaska *et al*. 2010) but requires moist substrates and well-developed litter layer, which are disturbed during logging. Within logged landscapes, forested riparian buffers provide important refuges for the snails. While the BC *Forest and Range Practices Act* requires riparian buffers along larger, fish-bearing streams, there are no such requirements for small, fishless streams (S6 streams), and the buffering of such streams is left to the discretion of individual forest companies. Similarly, there are no requirements for buffers for non-classified drainage features, such as seepages.

Livestock grazing on provincial crown forest lands is confined mainly to the drier southern and eastern portions of the species' range (iMapBC 2016). Range tenures on crown lands are managed to avoid excessive grazing, potentially reducing impacts on riparian areas.

Mining and quarrying activities involve a small percentage of the species' range. However, mining and placer claims occur throughout the range, especially in the Trail, Nelson, Salmo, Moyie Lake, and New Denver/Silverton areas, and several mineral exploration projects are underway (Grieve 2010). Extensive habitat degradation from air pollution has occurred over the past 100 years in the vicinity of the lead-zinc smelter in Trail, on the southwestern periphery of the species' range.

Reservoirs associated with hydroelectric development have flooded large areas of habitat over the past century (Kootenay Lake, Pend D'Oreille, Arrow Lakes, Duncan Lake). Several projects are underway to upgrade hydro power stations, but no large scale creation or expansion of reservoirs is known to be planned in the near future (iMapBC 2016). Power transmission line corridors are relatively common in the species' range and several more will likely be built to serve expanded hydro operations. Numerous smaller scale run-of river hydroelectric projects are also proposed or approved.

Climate change models for the West Kootenay region predict higher mean seasonal temperatures that increase progressively by the 2020s, 2050s and 2080s (Utzig 2012). By 2080, winters are predicted to be 2 – 5 C° warmer and 10 – 25% wetter and summers 3 – 7°C warmer and up to 30% drier than during the baseline period (poorest performance models excluded). Increase in the magnitude and frequency of extreme events, such as high intensity rain events, severe droughts, and wind storms, are also predicted (Utzig 2012). Increase in summer moisture stress and potential increase in wildfires associated with these changes are expected to have deleterious effects on populations and habitats of Western Banded Tigersnail. Changes in seasonal stream flow patterns as a result of reduced snow-packs and summer droughts would also shrink riparian habitats important for the snails.

BIOLOGY

Almost no information is available about the biology of Banded Tigersnail. General aspects of terrestrial snail biology are provided by the review of Barker (2001). Some information from Flamed Tigersnail, *Anguispira alternata*, a common and widespread eastern North American species, is available. However, this information could give misleading conclusions about the capacity of Banded Tigersnail to survive or to adjust to specific conditions, because *A. alternata* is still extant in areas of Ontario where Eastern Banded Tigersnail has been extirpated (e.g., East Sister Island).

Life Cycle and Reproduction

Banded Tigersnail is an air-breathing (pulmonate), simultaneous hermaphrodite (possesses both male and female reproductive organs), egg-laying snail (Pilsbry 1948). In general, both members of a mating pair exchange sperm and produce eggs. 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 2013-2015, reproduction probably occurs twice a year in Ontario: mating occurs in mid-spring and mid-summer with ovipositioning in late spring and late summer, respectively. In general, egg clutches are deposited in shallow holes excavated in moist soil (Barker 2001). Clutch size is unknown for this species.

In general, growth occurs only during periods of activity (spring to fall). In other species (e.g., Brown Gardensnail *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). Based on field observations in 2013-2015 in Ontario, thick and weathered shells of live individuals of Eastern Banded Tigersnail indicate a long lifespan, probably 5 – 10 years. The estimated generation time is somewhere between the age at sexual maturity and longevity, probably 5 – 6 years.

Both in Ontario and BC, the hibernation period of Banded Tigersnail probably extends from early October until mid-April; the exact timing is expected to vary depending on conditions in particular years. In Ontario, hibernating Eastern Banded Tigersnails were observed in the soil in November, and active individuals were observed at the end of April during fieldwork in 2013. Typical hibernation sites in other species of the family Discidae are shallow depressions in the forest floor covered with leaf litter or soil at depths of 5 to 10 cm (Pearce and Örstan 2006). Aestivation in various species of snails in temperate regions occurs occasionally during periods of prolonged heat and drought (Nicolai *et al.* 2011). However, Eastern Banded Tigersnail has also been observed active "in rather dry conditions" (Hubricht 1985). During aestivation, snails usually remain inactive in moist microhabitats, such as in soil, under leaf litter, and under logs. On Pelee Island, all extant snail species were observed to be 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 BC, a concentration of over 60 Western Banded Tigersnails over an area of approximately 10 m in radius was found on a southeast slope on 23 September 2014 (American Creek Forest Service Road, east of Yahk). The snails were in small clusters of up to five individuals and buried in the litter; the shell aperture was closed by a thickened epiphragm. In other years and sites, active Western Banded Tigersnails were found in late-September (Ovaska and Sopuck unpubl. data 2007 – 2015).

Physiology and Adaptability

Physiological responses to environmental factors and their plasticity and adaptability have not been investigated in Banded Tigersnail. There is some literature on *A. alternata*, including information about cold hardiness (Riddle 1981; Riddle and Miller 1988) and adjustment to resource availability (Atkinson 2003).

Eastern Banded Tigersnails were observed to feed on dead plant material during fieldwork in 2013 – 2015. They were often found in the leaf litter and under decaying logs, maybe also feeding on micro-fungi. In general, snails require calcium for shell formation. Soil and bedrock calcium availability influence the snail species' richness 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 cells and maintain survival mechanisms, such as membrane fluidity, osmoregulation, and enzyme activity. Unusually long heat and drought periods increase mortality, in some species up to 70% (Nicolai *et al.* 2011).

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). Because snails hibernate in the soil or the litter layer, they rely on snow cover for optimal temperature buffering in temperate regions (Nicolai *et al.* 2011). Mortality during hibernation is around 40% in some species and drives population dynamics (Peake 1978; Cain 1983). 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.

Many terrestrial gastropods can be reared in captivity with relative ease (see Ansart *et al.* 2014 for a study involving short-term rearing of over 30 different species). The long-term success of rearing depends on the knowledge of a species' specific requirements and has not been studied yet for Banded Tigersnail.

Dispersal and Migration

Active movement distances of Banded Tigersnail are unknown, but species 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 (Pearce 1990). In contrast, mark-recapture methods used for short-term observations underestimate the capacity of movement in snails because many species are homing. However, dispersal in general is low in land snails, e.g., 32 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 Sinclair 2013), 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 Banded Tigersnail is unknown, but is probably small.

In Ontario, the likelihood of dispersal between the two occupied islands in Canada or from the US is non-existent given the limited distribution of the species on islands and the snails' poor dispersal capabilities (see **Population Spatial Structure and Variability** and/or **Rescue Effect**). In general, a potential northern expansion of the peripheral Eastern Banded Tigersnail under climate warming could be largely negated by the anthropogenic pressures of historical and current habitat loss and degradation (see Gibson *et al.* 2009 for discussion of the importance of conserving peripheral populations under climate change).

In BC, where riparian zones provide habitat connectivity, gene flow among sites within the same drainages could be maintained by active movements of the snails and by flooding events that could passively transport snails. While active dispersal would be relevant only at long time-scales, passive dispersal by water could transport snails relatively rapidly. Dispersal between drainages is expected to be non-existent.

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 Banded Tigersnail is synanthropic or has been transported by humans.

Interspecific Interactions

Snails, including *A. alternata*, have been noted to be one of the intermediate hosts of the meningeal worm *Parelaphostrongylus tenuis* (Rowley *et al.* 1987; Bird and Garvon 2005). 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). Parasites could therefore be a potential threat, especially in combination with other environmental factors, such as climate change or pollution.

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.” Introduced predators or an increase in abundance of native predators due to ecological disturbance can increase mortality due to predation.

Competition with other terrestrial gastropods, including exotic species such as Grove Snail (*Cepaea nemoralis*) and various species of slugs, is a possibility for Banded Tigersnail but has not been documented.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Eastern Banded Tigersnail

Community composition of gastropods with a shell size larger than 0.5 cm in breadth or height was measured at three sites in 2015: Middle Island and Fish Point and the Richard and Beryl Ivey Property on Pelee Island. In 4 – 7 randomly distributed 2x2 m plots per site, all gastropods on the surface and in the leaf litter were identified to species, separated into juveniles and adults, and counted by 2 – 6 persons. The plots on Middle Island corresponded to vegetation monitoring plots (Thorndyke and Dobbie 2013), and one plot in the Richard and Beryl Ivey Property corresponded to a research plot for invasive plant management. The plots were searched with the most productive plot being completely searched after 20 min by two people. Relative abundance (% of individuals within the community) was calculated (adults and juveniles) for each observed species.

Live adult and juveniles of four species of conservation concern were counted in 2013 in Fish Point on two transects: *A. k. kochi*, *Webbhelix multilineata* (Striped Whitelip), *Allogona profunda* (Broad-banded Forestsnail) and *Philomycus carolinianus* (Carolinian Mantleslug). The transects were 181 m and 282 m long, respectively, and 0.5 m wide. Only the surface was thoroughly searched by one person. Relative abundance of mature adults was calculated and compared to the relative abundance of mature adults for these four species on three plots from 2015, the plots being located on the transects from 2013. The comparison estimates the change in relative abundance of mature individuals within the community of these four species, the largest litter dwelling gastropods at Fish Point (2 – 3 cm for snails, up to 10 cm for the slug).

During fieldwork in 2015, the size of Eastern Banded Tigersnails was measured as the maximum shell breadth in all individuals found in the plots at three sites: Middle Island and Fish Point and the Richard and Beryl Ivey Property on Pelee Island (described above). In addition, the surface of the forest floor on one 5x5 m plot in the Florian Diamante Nature Reserve on Pelee Island was searched for 5 min by two people and shell size measured. Size classes in each site, all plots per site combined, were generated and tested for normal distribution (Shapiro-Wilks test) using the software R 3.03 (2014). Shell size was compared among sites using a Kruskal-Wallis test followed *post hoc* by multiple Mann-Whitney tests with Bonferroni correction ($p < 0.008$).

Subpopulation sizes for Middle and Pelee islands were estimated by calculating the mean abundance of adult Eastern Banded Tigersnail per m^2 in each site using only plots where it was found alive. These plots were overlain on vegetation maps (Ecological Land Classification [ELC] by Lee *et al.* 1998) of Middle Island (North - South Environmental Inc. 2004) and of the two NCC properties on Pelee Island (maps provided by NCC: ELC_FDNR 2014-131660 and Ivey_ELC_21Feb08-2183 [RBIP]). The size of the corresponding habitat area (corresponding ELC in properties where the species was found alive; properties with shells only excluded) was used to calculate the subpopulation size per site assuming that the species only uses this habitat. The absence of live individuals and shells in other plots of the same site with different habitat suggests a certain affinity for specific habitats. The exact habitat size on Middle Island was not available, so has been estimated from the vegetation map.

Western Banded Tigersnail

In southeastern BC, efforts have focused on documenting the distribution of terrestrial gastropods, particularly species on provincial or national lists of species at risk (Table 3). Apart from these surveys, there have been no studies addressing Western Banded Tigersnails; densities and subpopulation sizes remain unknown.

Abundance

Eastern Banded Tigersnail

In Ontario, the population of Eastern Banded Tigersnail is estimated to be about 800,000 ± 100,000 mature individuals occupying habitat of about 42 ha with an overall abundance of about 2.0 snails/m^2 (Table 4; based on habitat in properties where live individuals were found in 2015: Middle Island and Fish Point and the Richard and Beryl Ivey Property on Pelee Island; properties where only shells were found are excluded from this analysis). Fish Point has the highest abundance of Eastern Banded Tigersnails (3.3 snails/m^2 in the largest habitat area) compared to all other sites (Table 4) and also has the highest species' richness of the sites examined (Species Richness = 9; all native species; Table 6). The abundance of Eastern Banded Tigersnail was similar to that of *W. multilineata*, another species of conservation concern, both still being less abundant than *A. profunda* (Endangered, COSEWIC 2014a). In contrast, two exotic slug species, Grey Fieldslug *Deroceras reticulatum* and Orange-banded Arion *Arion fasciatus* were observed on the Richard and Beryl Ivey Property, where the community had fewer species. The forest in the Richard and Beryl Ivey Property was historically logged, used as prairie and was, until 2012, adjacent to soy bean fields. These disturbances probably reduced the native species' richness, allowing the expansion of exotic slug species. Middle Island harbours the least rich gastropod community, with Shagreen *Inflectarius inflectus*, a species of conservation concern, being the most abundant species (Table 6).

Table 6. Gastropod community composition represented as range of abundance (N/m^2) of adults plus juveniles and species richness measured in *n* plots in two sites of Pelee Island, FP-Fish Point (*n*=4 plots) and RBIP-Richard and Beryl Ivey Property (*n*=5 plots), and on MI-Middle Island (*n*=7 plots) in 2015. Live individuals of Eastern Banded Tigersnail, *Anguispira kochi kochi*, were also found on Pelee Island in the Florian Diamante Nature Reserve in 2015, but community composition was not analyzed. * indicates introduced species.

Species	FP	RBIP	MI
Allogona profunda	0.5-21.3		
Anguispira alternata	0-9.3		0-0.3
Anguispira kochi kochi	1.0-4.5	0-2.0	0-1.0
Arion fasciatus*		0-0.3	
Deroceras laeve		0-0.8	0-2.0
Deroceras reticulatum*		0-0.3	
Mesodon thyroidus	0-5.5	0-1.0	
Neohelix albolabris	0-2.3	0-0.8	
Novisuccinea ovalis	0-0.3		
Philomycus carolinianus	0-0.3		
Philomycus togatus		0-0.3	

Species	FP	RBIP	MI
Inflectarius inflectus			0-2.8
Triodopsis vulgata	0-1.3		0-0.8
Webbhelix multilineata	0-2.3		
Native Species Richness	**9**	**5**	**5**
Exotic Species Richness	**0**	**2**	**0**

Western Banded Tigersnail

Densities and patterns of abundance of Western Banded Tigersnail in BC are unknown. However, the species appears to be locally abundant at sites where it does occur. Over ten individuals (10 – 60 snails) per site were found at 27% of 33 sites where the species was detected (with average search time of 76 person-min/site) during surveys by Biolinx Environmental Research Ltd. (Ovaska and Sopuck unpubl. data 2007 – 2015). While the population size is unknown, it can be speculated that it is probably well over 10,000 adults, possibly 100,000s, based on densities of subpopulations in Ontario.

Fluctuations and Trends

Eastern Banded Tigersnail

It is impossible to determine if the adult population undergoes extreme fluctuation because the only population study in Ontario began in 2015. Relative abundance in adults only slightly decreased between 2013 and 2015 (Figure 7). Differences in shell size among sites (Figure 8, *Kruskal-Wallis*, $W = 12.4096$, $df = 3$, $p = 0.006$) were mainly due to the larger number of juveniles at Fish Point (Figure 9). The large variability in shell size on Middle Island (Figure 8) is also reflected in the shell size distribution (Figure 9). Very small juveniles (0.5 – 1.0 cm) were found on Middle Island and at Fish Point, while juveniles were larger (1.0 – 2.0 cm) in the Florian Diamante Nature Reserve and in the Richard and Beryl Ivey Property. With the exception of the Florian Diamante Nature Reserve, the distribution of shell size is not normal, but rather binomial showing that recruitment occurred in some sites (*Shapiro Wilks*; Florian Diamante Nature Reserve: $W = 0.96$, $p = 0.79$; Middle Island: $W = 0.81$, $p = 0.04$; Richard and Beryl Ivey Property: $W = 0.74$, $p = 0.003$; Fish Point: $W = 0.87$, $p < 0.0001$). The sampling method at the Florian Diamante Nature Reserve was insufficient and did not detect juveniles within the leaf litter.

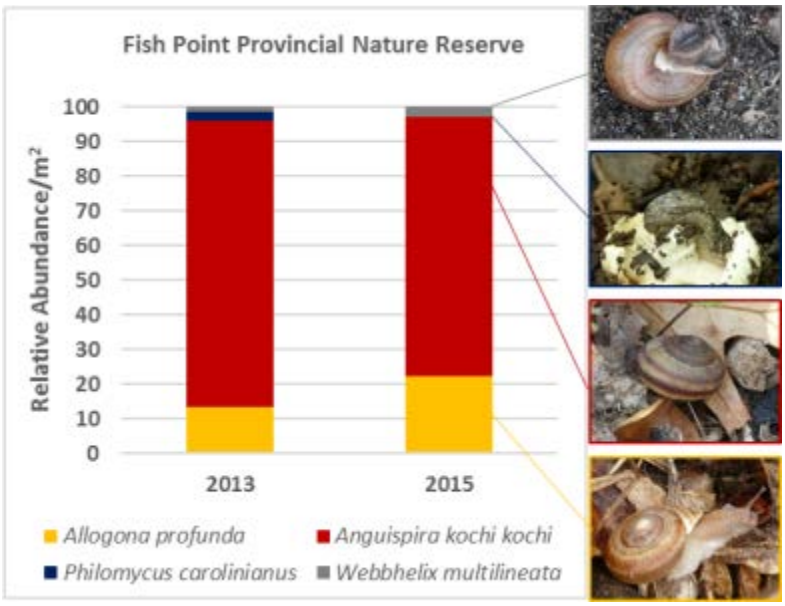

Figure 7. Relative abundance of mature individuals of four species of conservation concern at Fish Point in spring 2013 (mean abundance/m^2 of two transects) and in summer 2015 (mean abundance/m^2 of three plots) in the same area of the site (forested dunes along the west shore).

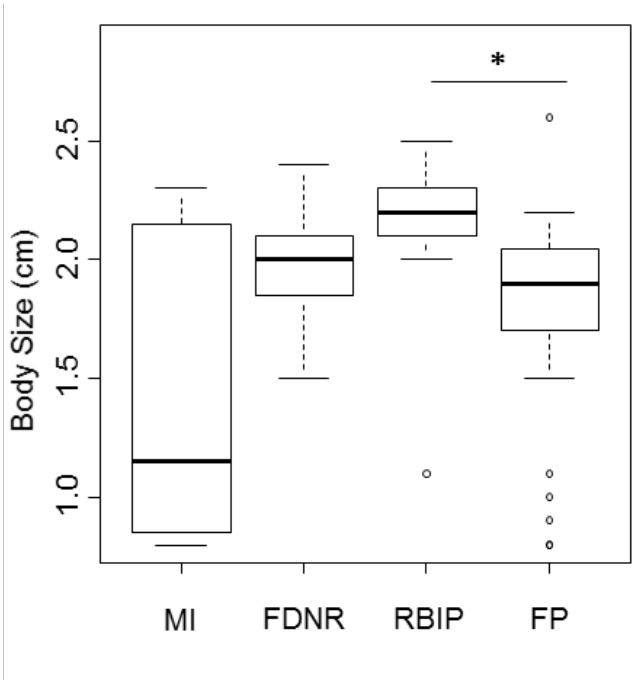

Figure 8. Shell size of *Anguispira kochi kochi* represented as median (black line), quartile (box) and minimal/maximal values (dotted bars) on Middle Island (MI, N = 8) and in three sites of Pelee Island: the Florian Diamante Nature Reserve (FDNR, N = 8), the Richard and Beryl Ivey Property (RBIP, N = 10) and Fish Point (FP, N = 48), in 2015. The circles indicate extreme values. The star indicates a significant difference in body size between the sites FP and RBIP (*Kruskal Wallis* test followed by *post hoc* multiple *Mann-Whitney* tests with *Bonferroni* correction, $p < 0.008$).

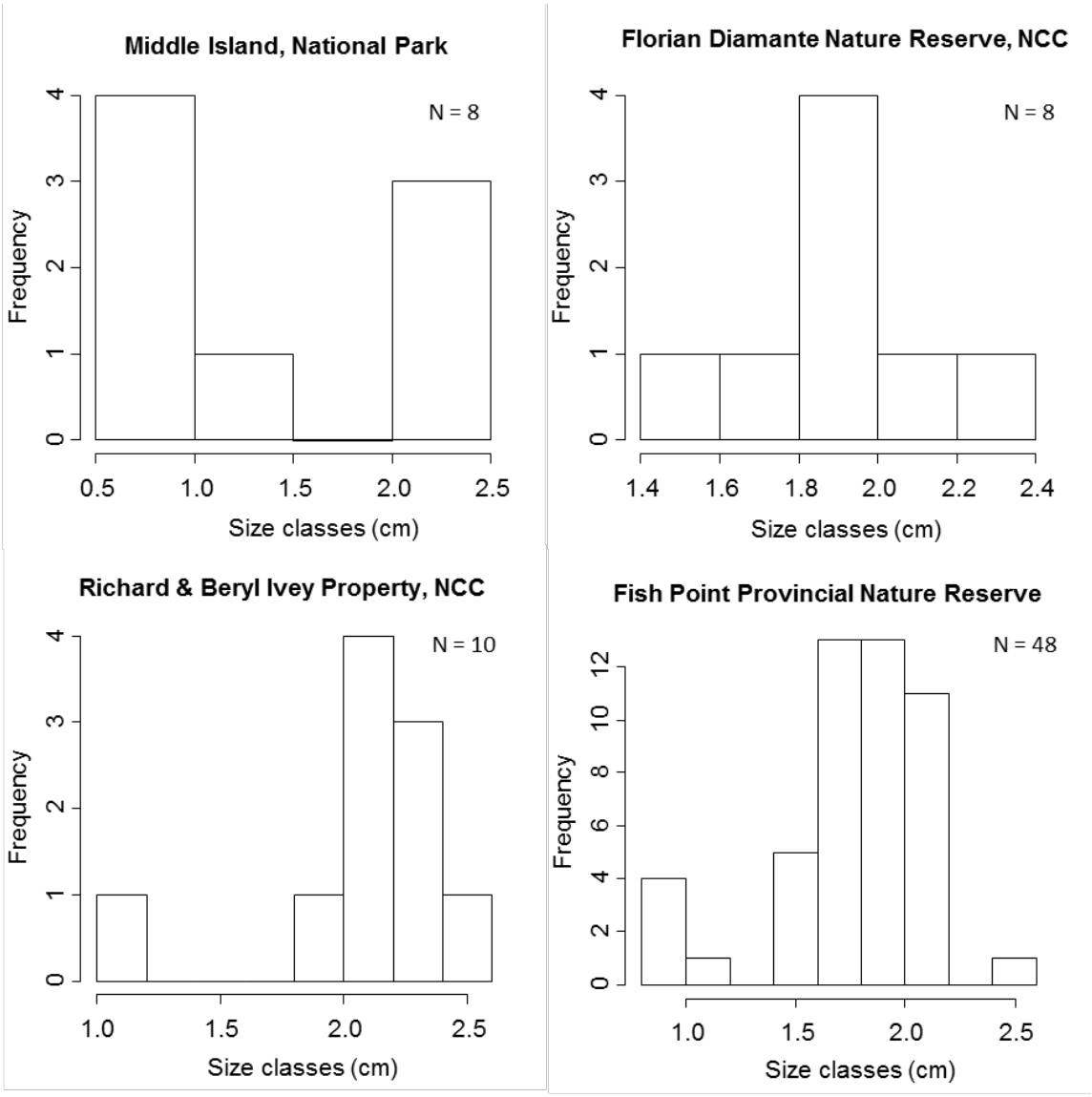

Figure 9. Shell size distribution of *Anguispira kochi kochi* on Middle Island and in three sites of Pelee Island: the Florian Diamante Nature Reserve (FDNR, N = 8), the Richard and Beryl Ivey Property (RBIP, N = 10) and Fish Point (FP, N = 48), in 2015. Only in FDNR is body size distributed normally (*Shapiro-Wilks*, $W = 0.96$, $p = 0.79$).

There has probably been a population size reduction in the last 30 years due to the extirpation of the species from East Sister and Middle Sister islands following the rapid increase of cormorant nest densities (Figure 6). Development on North Harbour has probably rendered that island unsuitable with an additional loss of snails resulting. Piles of dead shells and a low abundance of live individuals on Middle Island, due to storms and cormorant nesting, also suggest a subpopulation decline on this island. Anthropogenic pressure (logging, grazing, and agriculture) on Pelee Island might also have reduced abundance in the Richard and Beryl Ivey Property and the Florian Diamante Nature Reserve compared to Fish Point (Table 4). Only a few, difficult to detect individuals may remain in sites where only shells were observed in 2013 – 2015: the Stone Road Alvar and Middle Point Woods (Table 1). These sites were affected by forest flooding. The Krestel property might still have a few live individuals in some wood patches. Middle Point Woods may or may not have live individuals, because no shells have been found recently (Table 1).

Western Banded Tigersnail

Nothing is known of the population trends of Western Banded Tigersnail in BC due to lack of baseline data. Most records of the species are recent (since the 1990s), and there are insufficient historical records to allow comparisons. However, it is probable that the species was more widespread and abundant, particularly in larger river valleys, before European settlement. Threats to habitats continue from various human activities and climate change, and may result in declines of unknown magnitude in the future (see **Threats**).

Rescue Effect

Eastern Banded Tigersnail

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 subpopulation is on Kelley's Island, Lake Erie, Ohio with the most recent record being by M.J. Oldham and A.W. Cusick in 1996 (MJO19566); Kelley's Island is separated from Middle Island by at least 5 km of Lake Erie (Figure 4). The most recent record from Michigan is from Eaton County (Figure 3) by L. Hubricht in 1947 (FMNH-238441).

Western Banded Tigersnail

Potential for movements of Western Banded Tigersnails across the Canada-US border exists east and west of Creston, where several records are from the vicinity of the border of BC with Idaho; the closest Canadian record, at Kings Gate, is only 0.3 km north of the border. It is unknown but likely that the species also occurs on the US side. On the US side of the border, the Kaniksu National Forest provides relatively undisturbed habitat. In other areas to the east and west there are also records of Western Banded Tigersnail from the vicinity of the border (within 3 km) with Washington State and Montana, respectively. However, the habitat on both sides of the border is heavily fragmented by logging, hindering dispersal. Overall, while rescue from the US is a possibility, it is likely to be confined to a few areas near the border and is of limited importance to Western Banded Tigersnail.

THREATS AND LIMITING FACTORS

Threats

Eastern Banded Tigersnail

The threats calculation was based on the extant subpopulations on Middle Island and Pelee Island, including all sites with live snails and sites with potential habitat where empty shells were observed in 2013-2015 (Table 1). The mainland population and those of the other Lake Erie islands were considered to be extirpated and were not included in the threats assessment. The overall calculated threat impact is HIGH-LOW (Appendix 1, one high-low impact and one low impact threat). 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 subcategories of the threat calculator.

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

Threat 11.1: Habitat Shifting and Alteration (LOW IMPACT)

Most of the habitat with the highest Eastern Banded Tigersnail abundance is in the centre of Fish Point, which will not be affected by erosion in the near future (see **Habitat Trends**). However, a small part of the subpopulation is found near the east shore, which could be gradually lost in the future. About 2 ha of the habitat with about 36,000 individuals might be affected (see Table 4), so 5% of the habitat and 5% of the subpopulation.

Threat 11.2: Droughts, Threat 11.3: Temperature Extremes (HIGH-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). 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%, Nicolai and Sinclair 2013). Droughts can cause high mortality in some species depending on the presence of shelter (e.g., 75% in *H. pomatia*, Nicolai *et al.* 2011). Specific responses to the projected temperature changes and droughts within the range of the Eastern Banded Tigersnail are uncertain, hence the large range for severity (reduction in the proportion of the population exposed to these threats in the next three generations), but the threat is ongoing and many snail species are highly susceptible to droughts and freezing. Large snails are especially susceptible to freezing and rely on shelter and snow cover for buffering ambient temperatures (Ansart *et al.* 2014). Furthermore, habitat specialists explore (i.e., look for shelter) less than generalists (Dahirel *et al.* 2015). Using the framework for assessing species' vulnerability to climate change by Foden *et al.* (2013), Eastern Banded Tigersnail can be considered highly vulnerable, because (i) it is exposed to climate change, (ii) it is sensitive (rare, specific microhabitat conditions, limited thermal tolerance), and (iii) it has a low adaptive capacity (low dispersal).

Threat 11.4: Storms and flooding (LOW IMPACT)

Storms were identified as a predominant natural disturbance on Middle Island (Dobbie and Kehoe 2008), immersing the south side of the island. During fieldwork in 2013-2015 large piles of weathered shells of several species were found on the south side of the island. They could be the result of massive mortality due to violent storms. Many sites on Pelee Island are seasonally flooded wet forest on the former bedrock islands (Nature Conservancy Canada 2008); this flooding may be responsible for the lack of live individuals being found at Middle Point Woods and the east side of Stone Road Alvar in 2014-2015 (Table 1). While much of Pelee Island was wetland habitat before it was diked 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** for Eastern Banded Tigersnail). With increased precipitation due to climate change, flooding can be expected over a larger area. Parts of Fish Point are affected as well as sites with potential and suitable habitat, such as Middle Point Woods and parts of the Stone Road Alvar. Only weathered shells have been found in these sites (Table 1), indicating that snails have been dead for at least 5-10 years (Pearce 2008). The threat should also be considered when contemplating the potential of recolonization.

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 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 (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. Trampling of snails by pedestrians has not been studied but was noted repeatedly during fieldwork in 2013-2015. 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. Their leaf-litter-like colour makes it difficult even for snail researchers to see them. Visitors might not even pay attention to live snails on the ground.

Visitor numbers are lower at NCC properties on Pelee Island, paths are wider and few snails were observed on trails during fieldwork in 2013-2015. Hunting is allowed on all NCC properties and trampling of snails and their habitat by hunters is possible. Due to lower snail densities in these properties, the likelihood of crushing snails is lower. No visitors are allowed on Middle Island.

Threat 6.3: Work & Other Activities (NEGLIGIBLE IMPACT)

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

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

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

Competition with exotic terrestrial molluscs such as Grove Snail and slugs (*Arion* spp., *Deroceras* spp.) has not been documented but is a potential threat (Whitson 2005; Grimm *et al.* 2010). During fieldwork in 2013-2015, Grove Snail was restricted to the vicinity of the parking lot and was not observed in areas of Fish Point with large native snail densities. Exotic slugs were recorded only on the Richard and Beryl Ivey Property during fieldwork in 2013-2015. This forest was disturbed by agricultural activities and logging. Because invasive species usually settle in disturbed habitat, it is difficult to differentiate between anthropogenic habitat impacts and invasive species' impacts (Douglas *et al.* 2013; Calinger *et al.* 2015). Exotic slugs can compete for resources and shelter with the remaining native species. Using Blackburn *et al.*'s (2014) framework for classifying the environmental impact of invasive species (their impact scheme ranges from minimal to massive impact classes), exotic slugs can be assigned to the minor through major impact classes. Minor means that

there is a reduction in individual fitness of the native species but there is no decline in native population densities. Major means that there could be local or population extinction of at least one native species and reversible changes in the structure of communities and the abiotic and biotic composition of ecosystems. No data of the gastropod community evolution on the Richard and Beryl Ivey Property are available, which makes it difficult to accurately assess the impact of exotic slugs.

Wild Turkeys *Meleagris gallopavo* were reintroduced to 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 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 in November 2010 (Gibson pers. comm. 2013). Similarly, Ring-necked Pheasants *Phasianus colchicus* were introduced to Pelee Island in the late 1920s and increased to 50,000 to 100,000 birds 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 of the bird species are omnivorous and include snails in their diet (Sandilands 2005). Patches of ground at the Florian Diamante Nature Reserve were found to be intensively scratched and disturbed, presumably by turkeys, in 2016, at the exact same spot where live Eastern Banded Tigersnails were found in 2015; no snails were found there in 2016 (Nicolai and Forsyth pers. obs.).The impacts on snail populations are unknown, but they are a potential additional source of predation on Eastern Banded Tigersnails and were recently listed as an ongoing threat to the Endangered Broad-banded Forestsnail (COSEWIC 2014a) and the Endangered Small-mouthed Salamander *Ambystoma texanum* (COSEWIC 2014b).

Threat 7: Natural system modifications – UNKNOWN IMPACT

Threat 7.1: Fire & Fire Suppression (NEGLIGIBLE 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 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 Ontario Nature (ON Nature) and the Essex Regional Conservation Authority (ERCA) in 1993, 1997, 1999, and 2005 (Nature Conservancy Canada 2008). There are plans by ERCA, ON Nature, and NCC for test burns of the alvar to enhance snake habitat on the Stone Road Alvar (pers. comm. Lebedyk 2015). 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. Direct impact of fire on snail populations may be reduced when habitat is widespread and recolonization from unburned areas is possible. 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. The study design and the extent of the prescribed burn are currently unknown. No live snails were found in the Stone Road Alvar during fieldwork in 2013-2015; only weathered snail shells (without periostracum) were found, indicating that the snails have been dead for at least 5-10 years (Pearce 2008). However, the threat should be considered for wood patches that might still harbour Eastern Banded Tigersnails and when considering the potential of recolonization if prescribed burns are ongoing.

Threat 7.3: Other ecosystem modifications (UNKNOWN IMPACT)

Double-crested Cormorant nesting colonies have increased dramatically on Lake Erie islands since the early 1980s (Figure 6). Nesting cormorants break tree branches and cause accumulation of guano leading to soil chemistry modification, tree dieback, reduced plant species' richness, and an increased proportion of exotic species (North - South Environmental Inc. 2004; Boutin *et al.* 2011). The change in plant diversity and density might reduce nutritional resources and degrade microhabitat structure that would affect snails (Nicolai *et al.* 2011, 2012). Low soil pH and reduced calcium availability (Breuning-Madsen *et al.* 2010) might reduce growth/shell formation and suppress reproduction (Wäreborn 1979; Dallinger *et al*. 2001; Hotopp 2002). High soil salinity might affect homeostasis and disturb physiological processes in snails. Therefore, cormorants on Middle Island represent a threat, as they might have been the main reason for extirpation of Eastern Banded Tigersnail on Middle Sister and East Sister islands. Cormorants are unlikely to establish nesting colonies on Pelee Island given their preference for small islands (typically less than 1.2 ha, Sandilands 2005). Cormorants apparently do not nest on Hen or North Harbour islands (no cormorant impact visible from the boat during fieldwork in 2013-2015), possibly due to human presence on those islands. Cormorant culls have occurred on Middle Island since 2008 (Thorndyke and Dobbie 2013); however, the long-term effectiveness could be low (Guillaumet *et al*. 2014).

Highly invasive plants on Pelee Island and on Middle Island within Eastern Banded Tigersnail habitat include Garlic Mustard, *Alliaria petiolata*, and species of the grass family Poaceae (Nature Conservancy Canada 2008; Boutin *et al*. 2011). They were observed displacing native vegetation and altering soil nutrient cycles, thereby slowing down restoration progress (Boutin *et al.* 2011; Catling *et al*. 2015). Using Blackburn *et al.*'s (2014) framework, exotic plants can be assigned to the minor through major impact classes (see Threat 8.1 for Blackburn *et al.*'s definitions of impacts). Although the impacts of these invasive plants on land snails on Pelee Island or Middle Island have not been documented, invasive plants can lead to a decrease in endangered snail abundance, as shown in Europe (Stoll *et al.* 2012).

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). This change in forest floor structure profoundly affects plant and litter-dwelling invertebrate communities (Addison 2008; Dobbsen and Blossey 2015) as well as bird abundance and nesting success (Loss *et al.* 2012). Using the extensive literature reviewed by CABI (2016) and Blackburn *et al.*'s (2014) framework, exotic earthworms can have minor to major impacts on the ecosystem (see Threat 8.1 for Blackburn *et al.*'s definitions of impacts). Norden (2010) and Forsyth *et al*. (2016) suggested that invasive earthworms could alter terrestrial snail communities, although direct evidence is lacking. 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 documented in Eastern Banded Tigersnail habitat.

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). No snails were observed crossing roads during fieldwork in 2013-2015, but snails were found drowned 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.* 1997) 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 (Nature Conservancy Canada 2008), mainly on invasive grasses in the alvar savannah and not in forested habitat where Eastern Banded Tigersnail occurs. The close proximity of agricultural land to Eastern Banded Tigersnail habitat on Pelee Island may also expose snails to pesticide drift. No herbicides are used on Middle Island for invasive plant control.

Western Banded Tigersnail

Threat calculator assessment identified five low impact threats, resulting in an overall threat impact of medium (Appendix 2). These threats, as well as those assessed as unknown or negligible, are described below, in their perceived order of importance. The numbering of threats corresponds to the categories and subcategories of the threat calculator.

Threat 5: Biological Resource Use – LOW IMPACT

Logging (clearcut, selective cut) occurs throughout the range of Western Banded Tigersnail, and landscapes over much of its range consist of a mosaic of recently cut areas (see Figure 10 for an example). While logging is ongoing and can be expected to expand over the next ten years, quantitative information is lacking and difficult to obtain as numerous logging companies operate in the area and the release of logging plans is no longer required. Second growth harvesting occurs at least at some sites. Riparian buffers mitigate logging impacts on the snails that preferentially occur in these habitats, and predominantly deciduous stands are not targeted by forestry. However, much of the habitat of Western Banded Tigersnail is in mixed-wood stands, which would be subjected to logging. Furthermore, forestry buffers are not required in small creeks with no fish (S6 streams), although some forestry companies voluntarily leave buffers along them (Stuart-Smith pers. comm. 2014). There are no buffering requirements for non-classified drainages, such as seepages. Impacts on the snails are expected to be from disturbance to the forest floor litter layer and soils during active logging and from reduction in moisture and exposure to temperature extremes as a result of canopy removal. Effects of recent logging on the snails in habitat patches within heavily logged landscapes could be ongoing through edge effects, including drying of forest floor and reduction in habitat connectivity.

Figure 10. Example of recent logging within the distribution of Western Banded Tigersnail in the West Kootenays, British Columbia (GoogleEarth image, prepared by Kristiina Ovaska). Red symbols represent *A. kochi occidentalis* records from 2007 – 2015. The horizontal line represents the Canada-US border. Appendix 1. Threat calculator for Eastern Banded Tigersnail (*Anguispira kochi kochi*).

Threat 11: Climate change & severe weather – LOW IMPACT

Impacts on the snails are expected to accrue mainly from more prolonged and severe summer droughts, with a smaller contribution from temperature extremes and from storms and associated flooding that are predicted for the West Kootenays under climate change scenarios (see **Habitat Trends**). Temperature extremes are probably not as important an issue for Western Banded Tigersnails in BC as for Eastern Banded Tigersnails in Ontario, because the snails occur in BC across a relatively broad area under varied terrain and habitat conditions, where they are likely to encounter a greater variety of refuges from adverse environmental conditions.

The thick shell of Banded Tigersnail and its ability to seal the aperture with layers of hardened mucus (epiphragm) allow it to withstand some degree of desiccation, but specifics of its tolerance to droughts are unknown. In land snails, evaporative water loss through the epiphragm is very slow; some degree of water loss may also occur through the shell (Machin 1967). The wide distribution of both the Western and Eastern Banded Tigersnails in North America suggests an ability to adapt and tolerate a broad range of environmental conditions, but tolerance may vary across the range, as well as among subspecies and regions. Although climate patterns and droughts would be region-wide, snails in different parts of the range in BC may be affected differently because of variability

in moisture regimes due to hydrology and terrain and availability of refuges. Much uncertainty exists about the severity of the impacts of climate change and severe weather on this species, except that impacts are expected to be negative. The impact is calculated as low across the Canadian range for Western Banded Tigersnail over the next 10-years/3-generations but is expected to increase over the long term as climate change proceeds.

The snails have an affinity to riparian and floodplain habitats and probably have some capability of surviving floods, which are a natural seasonal event. However, if flooding becomes more extensive and prolonged with climate change, adverse effects are possible. At sites on flat terrain, flooding could result in declines of local populations.

Threat 7: Natural system modifications – LOW IMPACT

The impacts on the snails accrue mainly from fire and fire suppression (Threat 7.1). In the West Kootenay region, more frequent and severe fires are predicted as climate change proceeds. Although the Interior Cedar Hemlock (ICH) biogeoclimatic zone is relatively wet, fires may occur especially in the drier areas of the zone. Historical fire regimes and projections for the future under climate change have been examined in detail for the southern portion of the West Kootenays (Utzig *et al*. 2011). Over the first half of the 20th century, fires occurred almost annually and burned large areas, with annual burn exceeding 30,000 ha in some years (Figures 2 and 3 in Utzig *et al*. 2011). A threshold appeared to have been reached around 1940 with greatly diminished annual fire frequency until the 1980s, with slight increases thereafter. The decrease was associated with a cooling trend in spring and summer and fire suppression efforts in the latter half of the century. Projected into the future, all models showed increases in the area burned. Reflecting uncertainty, there is much variability in the outputs from the different models about the magnitude of the increase in fire frequency, but by 2050, the mean projected increase for the southern West Kootenays could be 15-fold. The projected increases are more modest by 2020 (Figure 9 in Utzig *et al*. 2011).

The size and intensity of the burn are expected to greatly influence the outcome for gastropod populations; greatest effects are expected when the burn covers a large continuous area and extends deep into the ground, while smaller, discontinuous, and less severe burns would be less devastating. Riparian areas may be somewhat protected from fires that sweep the landscape. Fires harm terrestrial gastropods by causing direct mortality and by altering habitat through reduction in shelter and food sources (review in Jordan and Black 2012). Due to their generally low mobility, gastropods are both unable to escape fire events by moving away and are slow to recolonize burned areas. Snails seem to be particularly vulnerable (Nekola 2002; Duncan 2005). In southwestern Oregon, both the distribution and abundance of four species of terrestrial gastropods studied were reduced after low-intensity wildfire. These were: Blue-Grey Taildropper (*Prophysaon coeruleum*), Chace Sideband (*Monadenia chaceana*), Pacific Sideband (*M. fidelis*), and Oregon Shoulderband (*Helminthoglypta hertleini*) (Duncan 2005). The greatest impacts were on adult snails (only one live individual was found after the fire at 26 study plots). However, that study was in drier, fire-maintained ecosystems of oak and pine woodlands with grassy

understory. Fire retardants used in fighting fires can also be detrimental to terrestrial gastropods, but no data are available.

The threat from dams and water management/use (Threat 7.2) is mostly historical, and the impact was calculated as negligible. In the past, hydroelectric reservoirs have flooded large areas of habitat (Kootenay Lake, Pend D'Oreille, Arrow Lakes, Duncan Lake). Run-of-river projects could affect riparian habitats of the species, and several are approved or proposed within the species' range. However, there is much uncertainty about the scope and impacts. The impact of other ecosystem modifications (Threat 7.3), including the long-term habitat modification from mixed-wood to conifer stands through silviculture, as well as indirect effects of non-native species such as introduced earthworms on the snails' habitat, was calculated as unknown.

Threat 1: Residential & Commercial Development – LOW IMPACT

This threat accrues mainly from expanding housing and urban development (Threat 1.1) with a smaller contribution from commercial and industrial areas (Threat 1.2) The human population of the West Kootenay region continues to expand, albeit at a lower rate than some other areas, such as the Okanagan (see **Habitat Trends**). Potential expansion of urbanization is likely in the vicinity of population centres, such as Trail, Nelson, Creston, Yahk, and Cranbrook. Recent records of Western Banded Tigersnail exist from the vicinity of these areas. The scope of the threat is probably close to 1% considering the entire Canadian range of the subspecies, and may even be negligible. Habitat loss associated with both urban and industrial development is permanent; therefore, the severity of the impact on the snails is expected to be extreme.

Threat 4: Transportation & service corridors – LOW IMPACT

The scope of this threat is probably close to 1%. The impact is mostly from roads and railroads (Threat 4.1), while the impact of land clearing associated with utility and service lines (Threat 4.2) is calculated as negligible. The range of Western Banded Tigersnail is intersected by highways and criss-crossed by numerous resource roads. New roads associated with forestry and other resource extraction are likely to increase over the next ten years at largely unknown rates with the expansion of these activities to new areas or reactivation of roads in previously logged areas. Adverse effects on the snails from new roads result from habitat loss along the road corridor and through edge effects that can extend far into the forest and include drier forest floor conditions due to increased exposure to wind and solar radiation. Road corridors may also act as barriers to movements, resulting in increased isolation of subpopulations; snails do not tend to cross roads, and even narrow, low traffic roads can hinder their movements (Baur and Baur 1990; review in Jordan and Black 2012). Roadkill is not an issue for these snails.

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

Introduced invertebrates, including other gastropods, could compete with or prey on Western Banded Tigersnails, but there are no data. The introduced Grove Snail, a large snail that occupies similar habitats and ecological niche as Western Banded Tigersnail, is widespread in BC and occurs sporadically in the southeastern part of the province (Ovaska and Sopuck 2009a, 2014). While co-occurrence with Western Banded Tigersnail does not appear to be common, Lepitzki and Lepitzki (2015) did find both species within several metres of each other in Grohman Narrows Provincial Park in October 2014. Various species of introduced slugs also occur throughout southeast BC, especially near human settlements, camp sites, and other human use areas. In surveys by Biolinx Environmental Research Ltd., introduced slugs (Chocolate Arion *Arion rufus*; *Arion* sp.; Grey Fieldslug *D. reticulatum*; Giant Gardenslug *Limax maximus*) were found at 18% of the sites where Western Banded Tigersnail was detected (Ovaska and Sopuck unpubl. data 2007 – 2015). Wild Turkeys occur in the interior of BC and are known to include land snails in their diet (Sandilands 2005); however, there is no specific information on predation on this species. At this time, the severity of the impact of this threat cannot be assessed with any confidence.

Threat 9: Pollution – UNKNOWN IMPACT

Pesticides and herbicides are generally not used in forestry in the region but may be used sporadically and at smaller scales. Fertilizers are occasionally applied to planted areas on forestry lands, but this is not a common practice. A large smelter in Trail in the southwestern part of the range has been processing lead and zinc since its establishment in 1896. Forest habitats in the surrounding area are exposed to smoke from the smelter, which could adversely affect the snails and their habitats, although stack and dust emissions reductions are currently in place (Trail Area Health & Environment Program 2016). For humans, emission of lead remains the main health risk, although lead concentrations have been reduced drastically since the early 2000s. Arsenic in the emissions is identified as a secondary risk factor. Across the range of Western Banded Tigersnail, traffic on roads may contribute to habitat degradation by contamination from dust, road salts, oil from spillages or accidents, or other pollutants. There is much uncertainty about the scope and severity of the impacts, which resulted in a calculated impact of unknown.

Threats with NEGLIBLE IMPACTS

The impacts of four threat categories were assessed as negligible at present: agriculture (Threat 2), energy production and mining (Threat 3), human intrusions and disturbance (Threat 6), and geological events (Threat 10). While having a negligible impact for the entire range of Western Banded Tigersnail in Canada, these threats can be locally important and significant for local subpopulations.

Impacts of agricultural activities (Threat 2.1) on the habitat have been extensive in the past and have resulted in permanent habitat loss. Some expansion of agricultural activities is possible but is expected to be of negligible importance to the BC population as a whole. Livestock ranching (Threat 2.3) is largely restricted to drier areas of the West Kootenays, but there is some overlap with the range of the snail. Cattle tend to concentrate in riparian areas, where they can disturb understory plants and riparian areas by compacting soils and removing vegetation cover. Mining exploration (Threat 3.2) has occurred historically and continues at present across the range, but the likelihood of new operating mines is moderate over the next ten years. Mining and quarrying activities involve a small percentage of the range. Recreational activities (Threat 6.1) occur sporadically throughout the range. Local impacts accrue mainly from off-trail all-terrain vehicle use that can damage habitats. Landslides (Threat 10.3) occur frequently in the rugged terrain of the West Kootenays and could have local impacts on snail subpopulations that occupy ravines or steep slopes. Large landslides may be increasing in frequency as a result of severe storms associated with climate change. However, such occurrences are limited in scope and impact.

Cumulative Effects

Cumulative impacts result from additive or synergistic interactions among two or more threats, which would elevate the level of the overall threat and occur for both the Western and Eastern Banded Tigersnail. In BC, increased frequency and severity of prolonged summer droughts associated with climate change and severe weather is likely to exacerbate the effects of logging and wildfires. For example, narrow forested riparian buffer zones that would otherwise support viable snail populations may no longer do so under prolonged and more frequent droughts. In general, logging, mining, agriculture, and the establishment of second growth forest increases the abundance of invasive plants (Calinger *et al.* 2015). Any activities that increase human access in BC and Ontario, such as resource roads, increase the potential for the introduction or spread of invasive, non-native gastropods and other invertebrates. Increase in recreational use could also directly kill more snails through trampling and degrade habitats through soil compaction. Climate change and forest disturbance may also facilitate the spread of introduced species with largely unknown and untracked, but potentially serious impacts, on native gastropod faunas.

Limiting Factors

In Canada, Banded Tigersnails exist at the northern limits of their distributions, and their northward expansion is probably limited by harsh winters. Fragmentation of habitats by human activities and physical barriers, such as the extensive bodies of water surrounding the island subpopulations in Ontario, further restricts dispersal across the landscape. Low dispersal ability, together with low physiological resistance to fluctuating environmental factors such as temperature and humidity, restricts 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).

Number of Locations

Eastern Banded Tigersnail

There are 2-7 locations, based on climate change and severe weather (droughts, extreme temperatures, storms and flooding) and/or natural system modifications (cormorants on Middle Island). Middle Island is a separate subpopulation and location with the most serious and plausible threat being a change in frost regime or flooding caused by storms or the continuing effects of the Double-crested Cormorant infestation. The number of locations on Pelee Island ranges from one through six depending on the threat or combination of threats and the distribution of the properties where Eastern Banded Tigersnail occurs in that a single threatening event could rapidly affect all individuals of a taxon present (IUCN 2015). While the most serious and plausible threat on Pelee Island is climate change, the number of locations varies depending on which aspect of climate change is chosen. Because increasing frequency of droughts or hard, killing spring frosts, especially in the absence of a covering layer of snow, could affect the whole island, the entire island could be one location. If increased flooding occurred simultaneously at Fish Point, in Middle Point Woods, and in the southeastern NCC and ERCA properties of the Stone Road Alvar, these occupied sites could be combined into one location due to their similar elevation and closeness to the edge of Lake Erie. The other occupied sites (Richard and Beryl Ivey Property + Winery Woods; northwestern Stone Road Alvar including Krestel Property; and Florian Diamante Nature Reserve) would be separate locations. Therefore with flooding alone, there could be four locations on Pelee Island. However, if flooding and spring frost or drought act differently in different areas of the island, each block of protected area might be considered one location, as follows, with the recent (2006-2015) presence of live individuals or fresh shells indicated:

1. Fish Point (live),
2. Richard and Beryl Ivey Property (live) and Winery Woods (live),
3. Northwestern NCC properties including Krestel (live) and ON Nature properties of Stone Road Alvar (shells),
4. Southeastern NCC and ERCA properties of Stone Road Alvar (shells),
5. Florian Diamante Nature Reserve (live),
6. Middle Point Woods (shells).

Western Banded Tigersnail

The number of locations of Western Banded Tigersnail in BC is unknown but is presumed to be much larger than ten, given the number of widely spaced occurrences that span over hundreds of kilometres. Each occurrence or cluster of occurrences would be faced with a separate set of threats where a single event could affect the snail subpopulation within a short time frame. Droughts associated with climate change have been identified as a plausible and significant threat and would be region-wide across the subspecies' range (see **Threats** for Western Banded Tigersnail). However, the buffering capacity of the habitat at different sites (such as the availability of moist refuges and substrate moisture) is likely to vary among sites, modifying the impacts on the snails, and increasing the number of locations.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Banded Tigersnail is not protected by any legislation, regulations, customs, or conditions. It is not listed on the IUCN Red List (IUCN 2015), under the US *Endangered Species Act* (US FWS 2015), or under any provincial acts. It is not listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2015).

Non-Legal Status and Ranks

NatureServe (2016) provides the following ranks for Banded Tigersnail, *A. kochi;* subspecies are not given separate ranks:

- Global Rank: G5 - secure (last reviewed 22 Oct 2009)
- National Rank (Canada): N3 - vulnerable (last reviewed 24 Jan 2013)
- National Rank (US): N5 - secure (last reviewed 8 Dec 2004)

Subnational Ranks (S-ranks) as provided by NatureServe (2016) are as follows:

- Oregon, Idaho, Missouri, Illinois, Indiana, Ohio: SNR - species not ranked
- Michigan: SU - unrankable
- Montana: S5 - secure
- Washington: S3S4 - vulnerable - apparently secure
- British Columbia: S3 - vulnerable
- Ontario: S2S3 - imperilled - vulnerable
- Tennessee, Kentucky: S2? - imperilled
- Pennsylvania: S2
- West Virginia: SH - possibly extirpated

Habitat Protection and Ownership

Eastern Banded Tigersnail

Ownership of current and potential habitat in Ontario is shown in Table 5. Sites owned by Parks Canada, Ontario Parks, Essex Regional Conservation Authority, Nature Conservancy Canada, and Ontario Nature are protected from development. Management plans were reviewed in **Habitat Trends**. A few privately owned sites on Pelee Island, North Harbour Island, and Hen Island, where the species was historically recorded, could not be surveyed. If the snail is still extant there, protection of the habitat is uncertain. Winery Woods has natural habitat that is currently publicly accessible; long-term protection is uncertain.

Western Banded Tigersnail

Much of the distribution of Western Banded Tigersnail in BC is on provincial crown lands used for forestry, while habitats in the larger valleys and around larger settlements, such as Trail, Creston, Nelson, and Cranbrook, in particular, are under private ownership. Most distribution records are from crown lands, but private lands are underrepresented in survey efforts due to access constraints.

Records for Western Banded Tigersnail exist from Kokanee Creek, Grohman Narrows, Lockhart Creek, Syringa Creek, and Champion Lakes provincial parks. Several other provincial parks exist within the range including Valhalla, Kokanee Glacier, West Arm, Kianuko, Stagleap, and Gilnockie. Additionally, smaller municipal parks, community watersheds, and conservation areas, such as the Darkwoods Conservation Area (55,000 ha; owned by Nature Conservancy of Canada) protect potential habitat for the species. In March 2014, Bill 4, an amendment to the *Parks Act* was passed by the BC government. The Bill allows for exploratory drilling, ore sampling, and road building within BC provincial parks.

As a provincially blue-listed species (i.e., indigenous species or subspecies that are of special concern) impacted by forest and range practices, Western Banded Tigersnail is potentially eligible for management under the Identified Wildlife Management Strategy of the BC *Forest and Range Practices Act*. However, it is not listed as identified wildlife at present, and hence no specific management measures are available or required. Riparian reserves around fish-bearing streams required under the *Act* may help the snails to persist in logged areas.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

Many thanks to Robert Forsyth who assisted with fieldwork, identification, databasing, curation of Ontario specimens, and who provided useful information. The Nature Conservancy of Canada granted us permission to access their properties on Pelee Island and provided accommodation at the Ivey Research Station. Tammy Dobbie and her team

from Point Pelee National Park assisted with fieldwork. Parks Canada granted permission to conduct surveys on Middle Island. Ontario Parks is thanked for providing a collecting permit and permission to access provincial parks and protected areas. Ron Gould from Ontario Parks assisted with fieldwork on Middle Island and East Sister Island and provided vegetation maps. Michael J. Oldham from the Natural Heritage Information Centre, Ontario Ministry of Natural Resources and Forestry, assisted with field surveys and provided information about the historical records. We also thank Northern Bioscience Inc. for assisting with field surveys in 2013.

In BC, Michelle York and Lea Gelling compiled and generously shared with us distribution records from the BC Conservation Data Centre. Heidi Gartner promptly responded to our queries and provided records from the Royal British Columbia Museum. Dwayne Lepitzki generously shared with us his distribution records of *A. kochi*. Lennart Sopuck helped with mapping records in GoogleEarth. Gastropod surveys in the Kootenay region from 2007 – 2015 by Biolinx Environmental Research Ltd. (L. Sopuck and K. Ovaska) that resulted in many of the recent records of *A. kochi occidentalis* were supported, in large part, by the Ministry of Environment and commissioned by Jennifer Heron. R. Durand (Durand Ecological Ltd., Crescent Valley, British Columbia and MSc student at Edinburgh Napier University, Scotland) kindly provided his unpublished survey data.

Alain Filion (COSEWIC Secretariat) prepared distribution maps and provided EOO and IAO calculations. Muriel Guérnion (University Rennes 1) prepared the global range map. Valérie Briand (University Rennes 1) compiled the information sources. Funding for fieldwork in Ontario and the preparation of this status report came from Environment and Climate Change Canada.

Authorities contacted are listed below:

- Canadian Wildlife Service:
  - Pacific and Yukon Region (Rhonda Millikin, Randal Lake, Nov 5, 2015)
  - Ontario Region (Rich Russell, Nov 5, 2015)

- Museums:
  - Royal Ontario Museum (Maureen Z., Jul 24, 2015)
  - Canadian Museum of Nature (J. M. Gagnon, Nov 5, 2015)
  - Carnegie Museum of Natural History, Pittsburgh (T. Pearce, Jan 12, 2016)
  - Royal British Columbia Museum, Victoria (Heidi Gartner, Collection Manager-Molluscs)

- Parks:
  - Parks Canada (Tammy Dobbie, many times in 2015)
  - Ontario Parks (Ron Gould, many times in 2015)

- Provincial / territorial representatives:
  - BC (Dave Fraser, Nov 5, 2015)
  - ON (Colin Jones, Nov 5, 2015)

- Conservation Data Centres or Natural Heritage Information Centres:
  - BC : B.C. Conservation Data Centre, Victoria, BC (Lea Gelling; Michelle York, Nov 5, 2015)
  - ON : Natural Heritage Information Centre (Michael Oldham, many times in 2015)

- COSEWIC Secretariat:
  - ATK (Neil Jones, Jul 7, 2015)
  - Maps (Alain Filion, Sep 14, 2015)

- Conservation organizations:
  - NCC (Mhairi McFarlane, many times in 2015)
  - ON Nature (Tanya P., Nov 5, 2015)
  - ERCA (Dan Lebedyk)

INFORMATION SOURCES

Addison, J.A. 2008. Distribution and impacts of invasive earthworms in Canadian forest ecosystems. Biological Invasions 11:59-79.

Ahlstrom, E.H. 1930. Mollusks collected in Bass Island region, Lake Erie. Nautilus 44:44-48.

Altaba, C.R. 2015. Once a land of big wild rivers: specialism is context-dependent for riparian snails (Pulmonata: Valloniidae) in central Europe. Biological Journal of the Linnean Society 115:826–841.

Angilletta, M.J. 2009. Thermal adaptation – A theoretical and empirical synthesis. Oxford University Press, New York. 304 pp.

Ansart, A., A. Guiller, O. Moine, M.-C. Martin, and L. Madec. 2014. Is cold hardiness size-constrained? A comparative approach in land snails. Evolutionary Ecology 28:471-493.

Ansart, A., and P. Vernon. 2003. Cold hardiness in molluscs. Acta Oecologica 24:95-102.

Asami, T. 1993. Divergence of activity patterns in coexisting species of land snails. Malacologia 35:399-406.

Atkinson, J.W. 2003. Foraging strategy switch in detour behavior of the land snail *Anguispira alternate* (Say). Invertebrate Biology 122(4):326-333.

Augspurger, C.K. 2013. Reconstructing patterns of temperature, phenology, and frost damage over 124 years: spring damage risk is increasing. Ecology 94:41–50.

BaMasoud, A., and M. Byrne. 2011. Analysis of shoreline changes (1959-2004) in Point Pelee National Park, Canada. Journal of Coastal Research 27(5):839-846.

Barker, G.M. 2001. The Biology of Terrestrial Molluscs. CABI Publishing, New York. 558 pp.

Baur, A., and B. Baur. 1990. Are roads barriers to dispersal in the land snail *Arianta arbustorum*? Canadian Journal of Zoology 68:613-617.

Baur, A., and B. Baur. 2005. Interpopulation variation in the prevalence and intensity of parasitic mite infection in the land snail *Arianta arbustorum*. Invertebrate Biology 124(3):194-201.

BC Conservation Data Centre. 2016. Species Summary (last updated in 2004). *Anguispira kochi* Banded Tigersnail. [accessed January 2016].

BC Ministry of Environment. 2016. BC Species and Ecosystems Explorer. Website: http://a100.gov.bc.ca/pub/eswp/ [accessed January 2016].

BC Ministry of Environment, Lands and Parks. 1997. Cottonwood riparian ecosystems of the Southern Interior. Ecosystems in British Columbia At Risk series. B.C. Ministry of Environment, Lands and Parks, Victoria, British Columbia. 6 pp.

Bellido, A. 1987. Field Experiment about direct effect of a heathland prescribed fire on microarthropod community. Revue d'Ecologie et de Biologie du Sol 24:603-633.

Bird, J.M., and J. Garvon. 2005. Attraction of the land snail *Anguispira alternata* to fresh faeces of white-tailed deer: implications in the transmission of *Parelaphostrongylus tenuis*. Canadian Journal of Zoology 83(2):358-362.

Blackburn, T.M., F. Essl, T. Evans, P.E. Hulme, J.M. Jeschke, I. Kühn, S. Kumschick, Z. Markova, A. Mrugała, W. Nentwig, J. Pergl, P. Pyšek, W. Rabitsch, A. Ricciardi, D.M. Richardson, A. Sendek, M. Vila, J.R.U. Wilson, M. Winter, P. Genovesi, and S. Bacher. 2014. An unified classification of alien species based on the magnitude of their environmental impacts. PLOS One 12(5):e1001850.

Boutin, C., T. Dobbie, D. Carpenter, and C.E. Hebert. 2011. Effects of double-crested cormorants (*Phalacrocorax auritus* Less.) on island vegetation, seedbank, and soil chemistry: evaluating island restoration potential. Restoration Ecology 19(6):720-727.

Breuning-Madsen, H., C. Ehlers-Koch, J. Gregersen, and C. Lund Løjtnant. 2010. Influence of perennial colonies of piscivorous birds on soil nutrient contents in a temperate humid climate. Danish Journal of Geography 110(1):25-35.

Brooks, M., and M. Lusk. 2008. Fire Management and Invasive Plants: a Handbook. United States Fish and Wildlife Service, Arlington, Virginia, 27 pp.

Brunsfeld, S.J., J. Sullivan, D.E. Soltis, and P.S. Soltis. 2001. Comparative phylogeography of Northwestern North America: A synthesis. Pp. 319–339 *in* J. Silvertown and J. Antonovics (eds.). Integrating Ecological and Evolutionary Processes in a Spatial Context. Blackwell Science, Oxford.

Burch, J.B., and T.A. Pearce. 1990. Terrestrial gastropods. Pp. 201-309 *in* D.L. Dindal (ed.). Soil Biology Guide. John Wiley and Sons, New York.

Burke, T. 2013. Snails and slugs of the Pacific Northwest. Oregon State University Press, Cornvallis, Oregon. 337 pp.

CABI (CAB International). 2016. Invasive Species Compendium. Datasheet *Lumbricus rubellus*. Website: http://www.cabi.org/isc/?compid=5&dsid=76781&loadmodule=datasheet&page=481&site=144 [accessed July 2016].

Cain, A.J. 1983. Ecology and ecogenetics of terrestrial molluscan populations. Pp. 597-647 *in* W.D. Russel Hunter (ed.). The Mollusca, Volume VI, Academic Press, New York.

Calinger, K., E. Calhoon, H.-C. Chang, J. Whitacre, J. Wenzel, L. Comita, and S. Queenborough. 2015. Historic mining and agriculture as indicators of occurrence and abundance of widespread invasive plant species. PLOSone, DOI:10.1371/journal.pone.0128161.

Catling, P.M., G. Mitrow, and A. Ward. 2015. Major invasive alien plants of natural habitats in Canada. 12. Garlic Mustard, *Alliaire officinale*: *Alliaria petiolata* (M. Bieberstein) Cavara & Grande. The Canadian Botanical Association – Bulletin de l'Association Botanique du Canada Bulletin 48:51-60.

Charrier, M., A. Nicolai, M.-P. Dabard, and A. Crave. 2013. Plan National d'Actions de *Tyrrhenaria ceratina*, escargot terrestre endémique de Corse. PNA, Ministère de l'Ecologie, de l'Energie, du Développement Durable et de la Mer, Paris. 92 pp.

Churchfield, S. 1984. Dietary separation in three species of shrew inhabiting watercress beds. Journal of Zoology 204:211–228.

CITES. 2015. Checklist of CITES species. Website: http://checklist.cites.org/#/en [accessed November 5, 2015].

Clapp, G.H. 1916. Notes on the land shells of the islands at the western end of Lake Erie and description of new varieties. Annals of the Carnegie Museum 10:532-540.

Clench, W.J., and G. Banks. 1939. A newsubspecies of *Anguispira kochi* from Washington. Memorias de la Sociedad Cubana de Historia Natural 13: 285, plate 36, figure 3.

Columbia Basin Rural Development Institute. 2012. The last 10 years: Growth corridors stabilize population in the Basin Boundary. Website: http://cbrdi.ca/wpcontent/uploads/The-Last-10-Years-Population-Trends-Analysis3.pdf [accessed January 2016].

COSEWIC. 2014a. COSEWIC status report on the Broad-banded Forestsnail *Allogona profunda* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 64 pp.

COSEWIC. 2014b. COSEWIC status appraisal summary on Small-mouthed Salamander (*Ambystoma texanum*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 10 pp.

Dahirel, M., E. Olivier, A. Guiller, M.-C. Martin, L. Madec, and A. Ansart. 2015. Movement propensity and ability correlate with ecological specialization in European land snails: comparative analysis of a dispersal syndrome. Journal of Animal Ecology 84:228–238.

Dallinger, R., B. Berger, R. Triebskorn-Köhler, and H. Köhler. 2001. Soil biology and ecology. Pp. 489-525 *in* G.M. Barker (ed.). The Biology of Terrestrial Molluscs. CABI Publishing, New York.

Deutsch, C.A., J.J. Tewksbury, R.B. Huey, K.S. Sheldon, C.K. Ghalambor, D.C. Haak, and P.R. Martin. 2008. Impacts of climate warming on terrestrial ectotherms across latitude. Proceedings of the National Academy of Sciences 105(18):6668-6672.

Dobbie, T., pers. comm. 2016. *Statement made during threats calculator teleconference.* 14 July 2016. Point Pelee National Park, Parks Canada.

Dobbie, T., and J. Kehoe. 2008. Point Pelee National Park of Canada. Middle Island Conservation Plan 2008-2012. Parks Canada, Leamington, Ontario. 44 pp.

Dobbsen, A., and B. Blossey. 2015. Earthworm invasion, white-tailed deer and seedling establishment in deciduous forests of north-eastern North America. Journal of Ecology 103:153-164.

Dobbyn, S., and J. Hoare. 2009. Ecological Land Classification of Fish Point and Lighthouse Point Provincial Nature Reserves. Ontario Parks, Ontario Ministry of Natural Resources. Iv + 39 pp.

Douglas, D.D., D.R. Brown, and N. Pederson. 2013. Land snail diversity can reflect degrees of anthropogenic disturbance. Ecosphere 4:28.

Druart, C., M. Millet, R. Scheifler, O. Delhomme, and A. de Vaufleury. 2011. Glyphosate and glufosinate-based herbicides: fate in soil, transfer to, and effects on land snails. Journal of Soil Sediments 11:1373-1384.

Duncan, N. 2005. Monitoring of sensitive mollusk populations following low-intensity wildfire in old growth coniferous forest. Unpublished report prepared for USDI Bureau of Land Management, Roseburg District Office, Oregon 97470, USA. 12 pp.

Duncan, T., J. Kartesz, M.J. Oldham, and R.L. Stuckey. 2011. Flora of the Erie Islands: a review of floristic, ecological and historical research and conservation activities, 1976–2010. Ohio Journal of Science 110(2):3-12.

Edworthy, A.B., K.M.M. Steensma, H.M. Zandberg, and P.L. Lilley. 2012. Dispersal, home-range size, and habitat use of an endangered land snail, the Oregon forestsnail (*Allogona townsendiana*). Canadian Journal of Zoology 90(7):875-884.

Essex Region Conservation Authority (ERCA). 2002. Essex Region Biodiversity Conservation Strategy - Habitat Restoration and Enhancement Guidelines (Comprehensive Version). Dan Lebedyk, Project Co-ordinator. Essex, Ontario. 181 pp.

Evers, A.K., A.M. Gordon, P.A. Gray, and W.I. Dunlop. 2012. Implications of a potential range expansion of invasive earthworms in Ontario's forested ecosystems: a preliminary vulnerability analysis. Climate Change Research Report CCRR-23. Science and Information Resources Division. Ontario Ministry of Natural Resources, Ottawa. 46 pp.

Foden W.B., S.H.M. Butchart, S.N. Stuart, J.-C. Vié, H.R. Akçakaya, A. Angulo, L.M. DeVantier, A. Gutsche, E. Turak, L. Cao, S.D. Donner, V. Katariya, R. Bernard, R.A. Holland, A.F. Hughes, S.E. O'Hanlon, S.T. Garnett, C.H. Şekercioğlu, and G.M. Mace. 2013. Identifying the world's most climate change vulnerable species: a systematic trait-based assessment of all birds, amphibians and corals. PLoS ONE 8(6): e65427.

Forsyth, J.L. 1988. The geologic setting of the Erie Islands. Pp. 13-23 *in* J.F. Downhower (ed.). The Biogeography of the Island Region of Western Lake Erie. Ohio State University Press, Columbus, Ohio.

Forsyth, R.G. 2004. Land Snails of British Columbia. Royal British Columbia Museum: Victoria, British Columbia, Canada. 188 pp.

Forsyth, R.G., P. Catling, B. Kostiuk, S. McKay-Kuja, and A. Kuja. 2016. Pre-settlement snail fauna on the Sandbanks Baymouth Bar, Lake Ontario, compared with nearby contemporary faunas. Canadian Field-Naturalist 130:152-157.

Frest, T.J., and E.J. Johannes. 1995. Interior Columbia Basin mollusk species of special concern. Deixis Consultants, Seattle, Washington. Prepared for the U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management, Upper Columbia River Basin Ecosystem Management Project. 274 pp. + appendices.

GBIF. 2013. Global Biodiversity Information Facility. Website: http://www.gbif.org/ [accessed November 10, 2013].

Gibson, G., pers. comm. 2013. *Email correspondence to A. Harris*. September 2013. Pelee Island Bird Observatory.

Gibson, S.Y., R.C. Van der Marel, and B.M. Starzomski. 2009. Climate change and conservation of leading-edge peripheral populations. Conservation Biology 23(6):1369-1373.

Goodrich, C. 1916. A trip to the islands in Lake Erie. Annals of the Carnegie Museum 10:527-531.

Gottron, K., pers. comm. 2015. *E-mail correspondance to A. Nicolai*. July 2015. Owner of North Harbour Island.

Gottesfeld, L.M.J. 1994. Aboriginal burning for vegetative management in northwestern British Columbia. Human Ecology 22:171-188.

Grieve, D. 2010. Exploration and mining in the Kootenay-Boundary region, British Columbia. Website: http://www.empr.gov.bc.ca/Mining/Geoscience/Publications Catalogue/ExplorationinBC/Documents/2011/BCEx-Mining2011_Kootenay Boundary.pdf [accessed January 2016].

Grimm, F.W. 1996. Terrestrial molluscs. *In* I.M. Smith, Assessment of species diversity in the Mixedwood Plains ecosystem. Ecological Monitoring and Assessment Network. Website: http://www.naturewatch.ca/Mixedwood/landsnail/snail8.htm [accessed November 20, 2013].

Grimm, F.W., R.G. Forsyth, F.W. Schueler, and A. Karstad. 2010. Identifying Land Snails and Slugs in Canada: Introduced Species and Native Genera. Canadian Food Inspection Agency, Ottawa, Ontario. 168 pp.

Guillaumet, A., B.S. Dorr, G. Wang, and T.J. Doyle. 2014. The cumulative effects of management on the population dynamics of the Double-crested Cormorant *Phalacrocorax auritus* in the Great Lakes. IBIS 156:141-152.

Hawkins, J.W., M.W. Lankester, R.A. Lautenschlager, and F.W. Bell. 1997. Effects of alternative conifer release treatments on terrestrial gastropods in northwestern Ontario. The Forestry Chronicle 73(1):91-98.

Hebert, P.D.N., A. Cywinska, S.L. Ball, and J.R. deWaard. 2003. Biological identifications through DNA barcodes. Proceedings of the Royal Society of London B Biological Sciences 270:313–321.

Heller, J. 2001. Life history strategies. Pp. 413-445 *in* G.M. Barker (ed.). The Biology of Terrestrial Molluscs. CABI Publishing, New York.

Hotopp, K.P. 2002. Land snails and soil calcium in central Appalachian mountain forest. Southeastern Naturalist 1(1):27-44.

Hubricht, L. 1985. The distributions of the native land mollusks of the Eastern United States. Fieldiana Zoology 24:47-171.

iMapBC. 2016. British Columbia Government, Data BC, Geographic Services, iMapBC 2.0. Website: http://www.data.gov.bc.ca/dbc/geographic/view_and_analyze/imapbc/index.page?WT.svl=LeftNav [accessed January 2016].

IUCN. 2015. The IUCN Red List of Threatened Species (Version 4). Website : http://www.iucnredlist.org [accessed November 5, 2015].

Jennings, T.J., and J.P. Barkham. 1979. Litter decomposition by slugs in mixed deciduous woodland. Holarctic Ecology 2:21-29.

Jones, L. 1912a. A study of the avifauna of the Lake Erie islands with particular reference to the migration phenomena. Wilson Bulletin 78:6-18.

Jones, L. 1912b. A study of the avifauna of the Lake Erie islands with particular reference to the migration phenomena. Wilson Bulletin 79:95-108.

Jones, L. 1912c. A study of the avifauna of the Lake Erie islands with particular reference to the migration phenomena. Wilson Bulletin 80:142-153.

Jones, L. 1912d. A study of the avifauna of the Lake Erie islands with particular reference to the migration phenomena. Wilson Bulletin 81:171-186.

Jordan, S.F., and S.H. Black. 2012. Effects of forest land management on terrestrial mollusks: a literature review. USDA Forest Service, Region 6 USDI Oregon/Washington, Bureau of Land Management. 87 pp.

Kamstra, J., M.J. Oldham, and P.A. Woodliffe. 1995. A Life Science Inventory and Evaluation of Six Natural Areas in the Erie Islands (Ontario). Ontario Ministry of Natural Resources. 140 pp. + appendices + maps.

Kawakami, K., S. Wada, and S. Chiba. 2008. Possible dispersal of land snails by birds. Ornithological Science 7:167–171.

Kirk, D.A. 1994. Stone Road Alvar, Pelee Island: management of an unusual oak savannah community in the western Lake Erie Archipelago. 13th North American Prairie Conference: “Spirit of the Land, our prairie legacy”, Department of Parks and Recreation, Windsor, Canada.

Knapp, E.E., B.L. Estes, and C.N. Skinner. 2009. Ecological effects of prescribed fire season: a literature review and synthesis for managers. USDA General Technical Report. Albany, California. 80 pp.

Koprivnikar, J., and P.A. Walker. 2011. Effects of the herbicide Atrazine's metabolites on host snail mortality and production of trematode cercariae. Journal of Parasitology 97(5):822-827.

LaRocque, A. 1953. Catalogue of the recent Mollusca of Canada. National Museum of Canada Bulletin 129;i-ix, 1-406.

Layton, K.K.S., A.L. Martel, and P.D.N. Hebert. 2014. Patterns of DNA barcode variation in Canadian marine molluscs. PLoS ONE 9(4):e95003.

Lebedyk, D. pers. comm. 2015. *Email correspondence to A. Nicolai*. December 7, 2015. Essex Regional Conservation Authority.

Lee, H., W. Bakowsky, J. Riley, J. Bowles, M. Puddister, P. Uhling, and S. McMurray. 1998. Ecological land classification for southern Ontario: first approximation and its application. Ontario Ministry of Natural Resources, South-central Science Section, Science Development Transfer Branch. 87 pp.

Lepitzki, D.A.W., and B.M. Lepitzki. 2015. Freshwater and terrestrial mollusc searches in British Columbia Provincial Parks from Banff, Alberta to Trail, British Columbia and return, 6-11 October 2014. A field report prepared for B.C. Ministry of Environment, Vancouver, British Columbia. 27 February. 10 pp.

Loss, S.R., G.J. Niemi, and R.B. Blair. 2012. Invasions of non-native earthworms related to population declines of ground-nesting songbirds across a regional extent in northern hardwood forests of North America. Landscape Ecology 27(5):683-696.

Machin, J. 1967. The permeability of the epiphragm of terrestrial snails to water vapor. Biological Bulletin 134:87–95.

Martin, S.M. 2000. Terrestrial snails and slugs (Mollusca: Gastropoda) of Maine. Northeastern Naturalist 7:33–88.

Mason, C.F. 1970a. Food, feeding rates and assimilation in woodland snails. Oecologia 4:358-373.

Mason, C.F. 1970b. Snail populations, beech litter production, and the role of snails in litter decomposition. Oecologia 5:215–239.

Meadows, D.W. 2002. The effects of roads and trails on movement of the Odgen Rocky Mountain snail (*Oreohelix peripherica wasatchnesis*). Western North American Naturalist 62:377-380.

Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver, and Z.-C. Zhao. 2007. Global climate projections. Pp. 749-844 *in* S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.). Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, USA.

Nature Conservancy of Canada. 2008. Management Guidelines: Pelee Island Alvars. NCC – Southwestern Ontario Region, London, Ontario. 43 pp.

NatureServe. 2016. NatureServe Explorer: an online encyclopedia of life. Version 7.1. NatureServe Arlington, Virginia. Website: http://explorer.natureserve.org [accessed August 2016].

Nekola, J.C. 2002. Effects of fire management on the richness and abundance of central North American grassland land snail faunas. Animal Biodiversity and Conservation 25(2):53-66.

Nekola, J.C. 2005. Geographic variation in richness and shell size of eastern North American land snail communities. Records of the Western Australian Museum Supplement No.68:39–51.

Nekola, J., B. Coles, and M. Horsak. 2011. Land snail biodiversity assessment for the Selkirk Mountains Park region in southeastern British Columbia. Unpublished report prepared for the Valhalla Wilderness Society. 24 pp.

Nicolai, A. 2010. The impact of diet treatment on reproduction and thermo-physiological processes in the land snails *Cornu aspersum* and *Helix pomatia*. Thèse de Doctorat en co-tutelle, Universität Bremen, Allemagne/ Université Rennes 1, France, 205 pp.

Nicolai, A., J. Filser, V. Briand, and M. Charrier. 2010. Seasonally contrasting life history strategies in the land snail *Cornu aspersum*: physiological and ecological implications. Canadian Journal of Zoology 88:995-1002.

Nicolai, A., J. Filser, R. Lenz, C. Bertrand, and M. Charrier. 2011. Adjustment of metabolite composition in the haemolymph to seasonal variations in the land snail *Helix pomatia*. Journal of Comparative Physiology B 181:457-466.

Nicolai, A., J. Filser, R. Lenz, V. Briand, and M. Charrier. 2012. Composition of body storage compounds influences egg quality and reproductive investment in the land snail *Cornu aspersum*. Canadian Journal of Zoology 90:1161-1170.

Nicolai A., and B.J. Sinclair. 2013. Prolonged cold exposure drives strategy switch in the land snail *Cepaea nemoralis*. Annual meeting of the Canadian Society of Zoologists, Guelph, Ontario.

Nicolai, A., P. Vernon, R. Lenz, J. Le Lannic, V. Briand, and M. Charrier. 2013. Well wrapped eggs: effects of egg shell structure on heat resistance and hatchling mass in the invasive land snail *Cornu aspersum*. Journal of Experimental Zoology A 319:63-73.

Norden, A.W. 2010. Invasive earthworms: a threat to eastern North American forest snails? Tentacle 18:29-30.

North - South Environmental Inc. 2004. Vegetation Communities and Significant Vascular Plant Species of Middle Island, Lake Erie. Research Report of Point Pelee National Park of Canada. 97 pp.

Nyffeler, M., and W.O.P. Symondson. 2001. Spiders and harvestmen as gastropod predators. Ecological Entomology 26:617-628.

Ontario Parks. 2005. Fish Point and Lighthouse Point. Park Management Plan of Wheatley Provincial Park, Wheatley, Ontario. 27 pp.

Oughton, J. 1948. A Zoogeographical Study of the Land Snails of Ontario. University of Toronto Press, Toronto. 128 pp.

Ovaska, K., and L. Sopuck. 2009a. Surveys for terrestrial gastropods at risk in southeastern British Columbia in 2008, and synthesis with 2007 data. Unpublished report prepared by Biolinx Environmental Research Ltd. for BC Ministry of Environment, Victoria, British Columbia. 92 pp.

Ovaska, K., and L. Sopuck. 2009b. Surveys for terrestrial gastropods at risk within Ktunaxa Traditional Territory, October 2009. Unpublished report prepared by Biolinx Environmental Research Ltd. for BC Ministry of Environment, Victoria, British Columbia. 27 pp.

Ovaska, K., and L. Sopuck. 2014. Terrestrial gastropod surveys in the Kootenay Region, September 2014. Unpublished report prepared by Biolinx Environmental Research Ltd. for the Ministry of Environment, Victoria, British Columbia. 46 pp.

Ovaska, K., and L. Sopuck. 2015. Terrestrial gastropod surveys in the Kootenay Region, British Columbia, September 2015. Unpublished report prepared by Biolinx Environmental Research Ltd. under contract PA16-JHQ-073 for BC Ministry of Environment, Wildlife Science Section, Vancouver, British Columbia. 51 pp.

Ovaska, K., and L. Sopuck, unpubl. data. 2007 – 2015. Data collected by Biolinx Environmental Research Ltd., Sidney, British Columbia, during terrestrial gastropod surveys in the Kootenay region as part of various projects for B.C. Ministry of Environment and for COSEWIC in support of preparation of status reports for the *Magnipelta mycophaga* (in 2009), *Kootenaia burkei* (in 2013), and *Zacoleus idahoensis* (in 2014).

Ovaska, K., L. Sopuck, and J. Heron. 2010. Gastropod surveys on private and municipal land in the Kootenay region, British Columbia, BC Ministry of Environment, Terrestrial Conservation Science Section, UBC Campus, 315 – 2202 Main Mall, Vancouver, British Columbia. 47 pp.

Parks Canada. 2007. Point Pelee National Park of Canada State of the Park Report 2006. Her Majesty the Queen in Right of Canada. Leamington, Ontario. 44 pp.

Parks Canada. 2010. Point Pelee National Park of Canada Management Plan. Her Majesty the Queen in right of Canada. Leamington, Ontario. 81 pp.

Peake, J. 1978. Distribution and Ecology of the Stylommatophora. Pp. 429-526 in V. Fretter and J. Peake (eds.). Pulmonates, Academic Press, London. 540 pp.

Pearce, T.A. 1990. Spooling and line technique for tracing field movements of terrestrial snails. Walkerana 4(12):307-316.

Pearce, T.A. 2008. When a snail dies in the forest, how long will the shell persist? Effect of dissolution and micro-bioerosion. American Malacological Bulletin 26:111-117.

Pearce, T.A., and A. Örstan. 2006. Terrestrial gastropoda. Pp. 261-285 *in* C.F. Sturm, T.A. Pearce, and A. Valdés (eds.). The Mollusks: A Guide to Their Study, Collection, and Preservation. American Malacological Society, Pittsburgh, Pennsylvania. 445 pp.

Pearce, T.A., and M.E. Paustian. 2013. Are temperate land snails susceptible to climate change through reduced altitudinal ranges? A Pennsylvania example. American Malacological Bulletin 31(2):213–224.

Pfeiffer, L. 1845 [1846]. Description of thirty-six new species of *Helix*, belonging to the collection of H. Cuming, Esq. Proceedings of the Zoological Society of London 1845:126-133.

Pilsbry, H.A. 1948. Land Mollusca of North America (North of Mexico). Volume 2, Part 2. Academy of Natural Sciences of Philadelphia, Monograph 3:i–xlvii + 521–1113.

Quinnebog Fishing Club. 2017. Quinnebog Fishing Club. Website: http://www.quinnebogfishingclub.com [accessed 25 January 2017].

Ratnasingham, S., and P.D.N. Hebert. 2007. Barcoding. BOLD: The Barcode of Life Data System (www.barcodinglife.org). Molecular Ecology Notes. Website: www.boldsystems.org [accessed January 5, 2016].

Ratnasingham, S., and P.D.N. Hebert. 2013. A DNA-based registry for all animal species: the Barcode Index Number (BIN) system. PLoS ONE 8:e66213.

Reynolds, J.W. 2011. The earthworms (Oligochaeta: Lumbricidae) of Pelee Island, Ontario, Canada. Megadrilogica 15(3):23-33.

Riddle, W.A. 1981. Cold hardiness in the woodland snail *Anguispira alternata* (Say) (Endodontidae). Journal of Thermal Biology 6:117–120.

Riddle, W.A., and V.J. Miller. 1988. Cold-hardiness in several species of land snails. Journal of Thermal Biology 13:163–167.

Robinson, D.G. 1999. Alien invasions: the effects of the global economy on non-marine gastropod introduction into the United States. Malacologia 41:413-438.

Robinson, D., and J. Slapcinsky. 2005. Recent introductions of alien gastropods into North America. American Malacological Bulletin 20:89-93.

Rowley, M.A., E.S. Loker, J.F. Pagels, and R.J. Montali. 1987. Terrestrial gastropod hosts of *Parelaphostrongylus tenuis* at the National Zoological Park's Conservation and Research Center, Virginia. Journal of Parasitology 73:1084-1089.

Roy, D.B., D.A. Bohan, A.J. Haughton, M.O. Hill, J.L. Osborne, S.J. Clark, J.N. Perry, P. Rothery, R.J. Scott, D.R. Brooks, G.T. Champion, C. Hawes, M.S. Heard, and L.G. Firbank. 2003. Invertebrates and vegetation of field margins adjacent to crops subject to contrasting herbicide regimes in the Farm Scale Evaluations of genetically modified herbicide-tolerant crops. Philosophical Transactions of the Royal Society London B 358:1879-1898.

Saestedt, T.R., and R.A. Ramundo. 1990. The influence of fire on below ground processes of Tallgrass prairie. Pp. 99-117 *in* S.L. Collins and L.L. Wallace (eds.). Fire in North American tall Grass Prairies. University of Oklahoma Press, Norman.

Sandilands, A. 2005. Birds of Ontario. Birds of Ontario: Habitat Requirements, Limiting Factors, and Status. Volume 1. Nonpasserines: Waterfowl through Cranes. University of British Columbia Press. Vancouver, British Columbia. 365 pp.

Sears, M.W., E. Raskin, and M.J. Angilletta. 2011. The world is not flat: defining relevant thermal landscapes in the context of climate change. Integrative and Comparative Biology 51(5):666-675.

South, A. 1980. A technique for the assessment of predation by birds and mammals on the slug *Deroceras reticulatum* (Müller) (Pulmonata: Limacidae). Journal of Conchology 30:229–234.

Stoll, P., K. Gatzsch, H. Rusterholz, and B. Baur. 2012. Response of plant and gastropod species to knotweed invasion. Basic and Applied Ecology 13:232-240.

Stuart-Smith, K., pers. comm. 2014. *Telephone correspondence during threats calculator conference call for the Sheathed Slug*. 5 February 2014. Biologist, CanFor, Cranbrook, British Columbia.

Thorndyke, R., and T. Dobbie. 2013. Point Pelee National Park of Canada. Report on research and monitoring for year 5 (2012) of the Middle Island Conservation Plan. Parks Canada, Leamington, Ontario. 34 pp.

Tomaino, A., J. Cordeiro, L. Oliver, and J. Nichols. 2008. Key for ranking species element occurrences using the generic approach. NatureServe. 3 pp.

Towne, G., and C. Owensby. 1984. Long–term effects of annual burning at different dates in ungrazed Kansas tallgrass prairie. Journal of Range Management 37:392–397.

Trail Area Health & Environment Program. 2016. Trail area health & environment program. Website: http://www.thep.ca/pages/airquality [accessed July 2016].

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and Scientific Names of Aquatic Invertebrates from the United States and Canada: Mollusks, Second Edition. American Fisheries Society Special Publication. 26. Bethesda, Maryland. 526 pp.

Utzig, G. 2012. Climate Change Projections for the West Kootenays. Report # 3 from the West Kootenay Climate Vulnerability and Resilience Project. Website: www.kootenayresilience.org [accessed January 2014].

Utzig, G., J. Boulanger, and R.F Holt. 2011. Climate Change and Area Burned: Projections for the West Kootenays. Report #4 from the West Kootenay Climate Vulnerability and Resilience Project. Website: http://www.westkootenayresilience.org/Report4_Fire-Draft.pdf [accessed January 2016].

US FWS (US Fish and Wildlife Service). 2015. Endangered Species. Website: http://www.fws.gov/endangered/ [accessed November 5, 2015].

Vagvolgyi, J. 1975. Body size, aerial dispersal, and origin of pacific land snail fauna. Systematic Zoology 24:465-488.

Varrin, R., J. Bowman, and P.A. Gray. 2007. The known and potential effects of climate change on biodiversity in Ontario's terrestrial ecosystems: case studies and recommendations for adaptation. Climate Change Research Report CCRR-09. Ontario Ministry of Natural Resources and Forestry. Queen's Printer for Ontario, Toronto. 47. 1379 pp.

Wada, S., K. Kawakami, and S. Chiba. 2012. Snails can survive passage through a bird's digestive system. Journal of Biogeography 39:69–73.

Wang, X., and G. Huang. 2013. Ontario Climate Change Data Portal. http://www.ontarioccdp.ca [accessed January 5, 2016].

Wäreborn, I. 1979. Reproduction of two species of land snails in relation to calcium salts in the foerna layer. Malacologia 18:177-180.

Whitson, M. 2005. *Cepaea nemoralis* (Gastropoda, Helicidae): the invited invader. Journal of the Kentucky Academy of Science 66:82–88.

Williams, G.W. 2000. Reintroducing Indian type fire: implications for land managers. Fire Management Today 60(3):40-48.

Wirth, T., P. Oggier, and B. Baur. 1999. Effect of road width on dispersal and population genetic structure in the land snail *Helicella itala*. Journal of Nature Conservation 8:23-29.

BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Annegret Nicolai is a biologist at the UMR CNRS 6553 EcoBio/OSUR of the University Rennes 1, France. She has a PhD 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 of 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.

Kristiina Ovaska, PhD, MSc, received her doctoral degree in biology from the University of Victoria, after which she completed two post-doctoral studies in animal behaviour and population biology with McGill University and University of British Columbia, respectively. Presently, she is a partner in Biolinx Environmental Research Ltd., biologist with Habitat Acquisition Trust, and research associate at the Royal British Columbia Museum. Her experience with terrestrial gastropods includes research into effects of forestry practices, studies on patterns of abundance and distribution of species at risk, and numerous surveys in different parts of British Columbia, including surveys in the Kootenays from 2007 – 2015. She has prepared status reports, recovery documents, and best management practices guidelines for terrestrial gastropods. Her photographs of gastropods appeared in the Royal B.C. Museum Handbook “Land Snails of British Columbia” by R. Forsyth. She is the author of more than 40 publications in the refereed scientific literature, including several papers on terrestrial gastropods.

COLLECTIONS EXAMINED

The collections of the Canadian Museum of Nature, the Royal British Columbia Museum, 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 2013). This allowed the checking of a wide range of museum records for *A. kochi* including:

- NatureServe Central Databases doi:10.15468/lysaex
- California Academy of Sciences: CAS Invertebrate Zoology (IZ) doi:10.15468/tiac99
- Senckenberg: Collection Malakologie - SNSD doi:10.15468/dmitnd
- Florida Museum of Natural History: invertebrate zoology doi:10.15468/sm6qo6
- Museum of Comparative Zoology, Harvard University: Museum of Comparative Zoology, Harvard University doi:10.15468/p5rupv
- Naturalis Biodiversity Center: Naturalis Biodiversity Center (NL) - Mollusca doi:10.15468/yefvnk
- Biologiezentrum Linz Oberoesterreich: Biologiezentrum Linz doi:10.15468/ynjblx
- Academy of Natural Sciences: MAL doi:10.15468/xp1dhx
- SysTax: SysTax - Zoological Collections doi:10.15468/zyqkbl
- Field Museum: Field Museum of Natural History (Zoology) Invertebrate Collection doi:10.15468/6q5vuc
- National Museum of Natural History, Smithsonian Institution: NMNH occurrence DwC-A doi:10.15468/dipjcr
- Museo Argentino de Ciencias Naturales: Colección Nacional de Invertebrados - Museo Argentino de Ciencias Naturales 'Bernardino Rivadavia' doi:10.15468/uuz636
- Queensland Museum: Queensland Museum provider for OZCAM doi:10.15468/lotsye

Appendix 1. Threat calculator for Eastern Banded Tigersnail (*Anguispira kochi kochi*).

Species Name	*Anguispira kochi kochi* (Eastern Banded Tigersnail)
Date :	
Assessor(s):	Joseph Carney, Jill Crosthwaite, Tammy Dobbie, Robert Forsyth, David Fraser, Lea Gelling, Dwayne Lepitzki, Mhairi McFarlane, Kate Mackenzie, Annegret Nicolai, Kristiina Ovaska, Daelyn Woolnough; (Bev McBride, COSEWIC secretariat)
References:	Draft threats assessment provided with draft status report; teleconference on 14 July 2016.

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

Assigned Overall Threat Impact:	**BD = High - Low**
Impact Adjustment Reasons:	Large range in the overall threat impact is a consequence of the uncertainty for scores of severity for climate change.
Overall Threat Comments	

	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	**Residential & commercial development**						
1.1	Housing & urban areas						
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas						No new tourism or recreation expansions are planned. Potential trail expansion on Nature Conservancy of Canada (NCC) properties will not overlap species' habitat.
2	**Agriculture & aquaculture**						
2.1	Annual & perennial non-timber crops						No agricultural expansion is anticipated.
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture						
3	**Energy production & mining**						
3.1	Oil & gas drilling						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3.2	Mining & quarrying						
3.3	Renewable energy						
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.
4.2	Utility & service lines						
4.3	Shipping lanes						
4.4	Flight paths						
5	**Biological resource use**						
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting						Historical threat but not happening now and not expected to increase.
5.4	Fishing & harvesting aquatic resources						
6	**Human intrusions & disturbance**	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	
6.1	Recreational activities	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Trampling risk at Fish Point and on NCC properties.
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.
7	**Natural system modifications**		Unknown	Large (31-70%)	Unknown	High (Continuing)	
7.1	Fire & fire suppression		Negligible	Negligible (<1%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Prescribed burns will happen in savannah habitat and not in forested *A. kochi kochi* habitat. There is still a risk that fire could reach the forest.
7.2	Dams & water management/use						
7.3	Other ecosystem modifications		Unknown	Large (31-70%)	Unknown	High (Continuing)	Invasive plants (such as Garlic Mustard) are found in about 60% of the habitat containing about 30% of the population. Intervention program seems to be helping reduce the effects of Double-crested Cormorants on habitat on Middle Island. Invasive earthworms affect habitat by changing soil chemistry, potentially affecting the species. Invasive slugs are found in about 20% of the habitat with 12% of the population; however, it is not known if these are a threat.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8	**Invasive & other problematic species & genes**		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
8.1	Invasive non-native/alien species		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Introduced Wild Turkeys and Ring-necked Pheasants on Pelee Island could consume snails, potentially the species of interest.
8.2	Problematic native species						
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	Household sewage & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	NCC restores fields in adjacent properties. Light use of herbicides on NCC properties, in the past and probably in the future. 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**	BD	High - Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	
11.1	Habitat shifting & alteration	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Erosion at Fish Point due to (among other causes) lack of ice cover in fall and winter which protects the shoreline.
11.2	Droughts	BD	High – Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	Effects of drought would most likely encompass entire range although severity of impacts may be reduced in some microhabitats.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.3	Temperature extremes	BD	High – Low	Pervasive (71-100%)	Serious - Slight (1-70%)	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.
11.4	Storms & flooding	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	Storms on Middle Island cause flooding affecting 1.5% of the Canadian population. Flooding is a factor on the parts of Pelee Island created by draining between former, smaller islands. Shells have been found in the lowland forest which is often flooded.
11.5	Other impacts						

Appendix 2. Threat calculator for Western Banded Tigersnail (*Anguispira kochi occidentalis*).

Species Name	*Anguispira kochi occidentalis* (Western Banded Tigersnail)
Date :	
Assessor(s):	Joseph Carney, Jill Crosthwaite, Tammy Dobbie, Robert Forsyth, David Fraser, Lea Gelling, Dwayne Lepitzki, Mhairi McFarlane, Kate Mackenzie, Annegret Nicolai, Kristiina Ovaska, Daelyn Woolnough; (Bev McBride, COSEWIC secretariat)
References :	Draft threats assessment provided with draft status report; teleconference on 14 July 2016. Severity for threat 7.1 subsequently adjusted.

		Level 1 Threat Impact Counts	
Threat Impact		**high range**	**low range**
A	Very High	0	0
B	High	0	0
C	Medium	0	0
D	Low	5	5
Calculated Overall Threat Impact:		**Medium**	**Medium**

Assigned Overall Threat Impact:	**C = Medium**
Impact Adjustment Reasons:	
Overall Threat Comments	Medium overall threat impact because of the cumulative effect of 5 Low impact threats (1, 4, 5, 7, 11).

	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	**Residential & commercial development**	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	Potential expansion in the vicinity of population centres, such as Trail, Nelson, and Creston, and in larger river valleys. Scope is probably close to 1%, may even be negligible.
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
1.3	Tourism & recreation areas						No known plans for new developments.
2	**Agriculture & aquaculture**		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
2.1	Annual & perennial non-timber crops		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Mostly historical but some expansion of agricultural activities (hayfields and orchards) is possible.
2.2	Wood & pulp plantations						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.3	Livestock farming & ranching		Negligible	Negligible (<1%)	Moderate (11-30%)	High (Continuing)	Ranching occurs mostly in drier areas of West Kootenays; no free-range cattle in most areas within the species' range. Cattle tend to concentrate in riparian areas, where they can affect understory plants and riparian areas by compacting soils and removing vegetation. There are some examples of habitat degradation from cattle grazing in river valleys where tigersnails occur.
2.4	Marine & freshwater aquaculture						
3	**Energy production & mining**		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
3.1	Oil & gas drilling						No oil and gas drilling or extraction within the species' range at present.
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Lots of exploration. Moderate likelihood of new mines coming into operation; no immediate plans known.
3.3	Renewable energy						
4	**Transportation & service corridors**	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	
4.1	Roads & railroads	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	The species' range is intersected by highways and crisscrossed by numerous resource roads, the latter of which are expanding to new areas with resource extraction. Effects of road construction are from habitat loss (corridor & edge effects), through possible changes to drainage patterns. Both new and existing roads create barriers to movements and contribute to habitat fragmentation. Roads often parallel rivers and may impact riparian habitats occupied by tigersnails, but new resource roads are seldom built along creeks but will cross them. Scope is around 1%. Roadkill is not an issue for this species.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
4.2	Utility & service lines		Negligible	Negligible (<1%)	Moderate (11-30%)	High (Continuing)	The likelihood of expansion of power transmission lines within the next 10 years is probably low, apart from minor ones to individual houses. Effects are from land clearing associated with the expansion of existing lines or construction of new lines. Severity higher than for roads because of larger footprint and edge effects.
4.3	Shipping lanes						
4.4	Flight paths						
5	**Biological resource use**	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	Logging (clearcut, selective cut) occurs throughout the species' range. GoogleEarth images show a mosaic of cut areas in many places with tigersnail records, especially toward the south such as in the Yahk River Valley (east of Yahk). While logging is ongoing and can be expected to expand over the next 10 years, quantitative information is lacking and difficult to obtain as many different logging companies operate in the area. Second growth harvesting occurs at least at some sites. Riparian buffers mitigate logging impacts on the snails that preferentially occur in these habitats. However, forestry buffers are not required in small creeks with no fish (S6 streams), although some forestry companies voluntarily leave buffers along them (Kari Stuart Smith pers. comm. 2013). Non-classified drainages (such as seepages) don't need to be buffered. Impacts on the snails are expected to be from disturbance to the forest floor litter layer and soils, reduction in moisture, and exposure to temperature extremes.
5.4	Fishing & harvesting aquatic resources						
6	**Human intrusions & disturbance**		Negligible	Restricted (11-30%)	Negligible (<1%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.1	Recreational activities		Negligible	Restricted (11-30%)	Negligible (<1%)	High (Continuing)	From ATVs & snowmobiles (soil compaction, damage to veg), hiking on trails little or no impact.
6.2	War, civil unrest & military exercises						
6.3	Work & other activities		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Research on the species.
7	**Natural system modifications**	D	Low	Small (1-10%)	Moderate – Slight (1-30%)	High (Continuing)	
7.1	Fire & fire suppression	D	Low	Small (1-10%)	Moderate – Slight (1-30%)	High (Continuing)	ICH biogeoclimatic zone is relatively wet, and stand-replacing events from fire are rare, but fires may occur in drier areas of the zone. Fire suppression and climate change are contributing to more severe and larger fires when they do occur. Wildfires seem to be getting hotter and more severe in the area. Fire retardants used in fighting fires can also be detrimental to gastropods, but no data are available. Snails in general are highly susceptible to fires (e.g., Nekola 2002; Duncan 2005). The impacts of fires will depend on the intensity of the fire and the buffering capacity of the habitat on the forest floor, such as the availability of refuges. Severity changed from moderate to moderate-slight during subsequent review.
7.2	Dams & water management/use		Negligible	Negligible (<1%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Historically, hydroelectric reservoirs have flooded large areas of habitat (Kootenay Lake, Pend D'Oreille, Arrow Lakes, Duncan Lake). Run-of-river projects could affect riparian habitats of the species, and several are approved or proposed within the species' range. However, there is much uncertainty about the scope and impacts.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.3	Other ecosystem modifications		Unknown	Restricted - Small (1-30%)	Unknown	High (Continuing)	Silviculture systems are modifying forest compositions, e.g., predominant planting of Douglas-fir. Over the long term, conversion of mixed-wood stands into conifer stands will hinder recovery of suitable habitat conditions for the snails. Introduced invertebrates, such as earthworms, are modifying the habitat with unknown impacts on the snails. Scoring is based on silviculture systems and possible impact to habitat by invasive vegetation.
8	**Invasive & other problematic species & genes**		Unknown	Restricted (11-30%)	Unknown	High (Continuing)	
8.1	Invasive non-native/alien species		Unknown	Restricted (11-30%)	Unknown	High (Continuing)	Introduced invertebrates, including other gastropods, could compete with or predate on tigersnails, but there are no data. Introduced gastropods occur sporadically throughout the range of the species in human-used areas, and introduced slugs (*Arion* sp., *Limax maximus*, *Deroceras reticulatum)* have been recorded at sites with tigersnails. The Grove Snail (*Cepaea nemoralis),* in particular, could compete with *A. k. occidentalis* as it occupies similar habitats and ecological niche; it has been documented from one site in the Kootenays with *A. k. occidentalis*. At this time, the severity of impact cannot be assessed with any confidence. Introduced Wild Turkeys consume snails, but they also eat non-native snails and this could be a benefit to tigersnails.
8.2	Problematic native species						
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**		Unknown	Small (1-10%)	Unknown	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.1	Household sewage & urban waste water		Unknown	Small (1-10%)	Unknown	High (Continuing)	Traffic on roads contributes to habitat degradation (e.g., dust, road salts, other pollutants). Impacts on the snails are unknown.
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents		Unknown	Unknown	Unknown	High (Continuing)	Pesticides and herbicides are generally not used in forestry in the area, but there is uncertainty about scope. Fertilizers are occasionally applied to planted areas, but this is not a common practice.
9.4	Garbage & solid waste						
9.5	Air-borne pollutants		Negligible	Negligible (<1%)	Unknown	High (Continuing)	Smelter in Trail, processing lead and zinc. Snails and their habitats could be affected by emissions, particularly of lead and arsenic, although emission reduction methods are in place. Lead in emissions has decreased drastically since the early 2000s, but is considered a risk factor for humans.
9.6	Excess energy						
10	**Geological events**		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Landslides occur regularly within the range of the species and can range from small to large. Probably of only minor importance to this species.
11	**Climate change & severe weather**	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	
11.1	Habitat shifting & alteration		Unknown	Unknown	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	May be an issue over the moderate term.
11.2	Droughts	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	More prolonged and severe summer droughts are predicted (drought conditions that extended well into the fall in 2015). Although climate patterns and droughts would be region-wide, snails in different parts of the range may be affected differently because of differences in moisture regimes due to hydrology and terrain and availability of refuges. Over the long term (>10 years), the impacts are expected to become more severe.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.3	Temperature extremes	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	*A. k. occidentalis* is at the northern limits of its distribution in BC, and has a distribution that extends much farther south, and where the snails experience a range of temperature regimes. Probably a smaller issue for tigersnails in BC than in Ontario due to wider range and associated greater variety of habitats and refuges where they can shelter from temperature extremes.
11.4	Storms & flooding		Unknown	Restricted - Small (1-30%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	The snails have an affinity for riparian and floodplain habitats and probably have some capability of surviving floods, which are a natural seasonal event. However, if flooding becomes more extensive and prolonged with climate change, adverse effects are possible. Spring freshets may be more intense in the future, although probably of short duration. At sites on flat terrain, flooding could result in extirpation of local populations. Severity is scored as Unknown because the snails' capacity to survive floods is unknown and they may have some adaptations to seasonal flooding of their habitats.
11.5	Other impacts						