



Eastern Banded Tigersnail

(Anguispira kochi kochi) in Ontario

Ontario Recovery Strategy Series

Draft

2019

About the Ontario Recovery Strategy Series

This series presents the collection of recovery strategies that are prepared or adopted as advice to the Province of Ontario on the recommended approach to recover species at risk. The Province ensures the preparation of recovery strategies to meet its commitments to recover species at risk under the *Endangered Species Act 2007* (ESA) and the Accord for the Protection of Species at Risk in Canada.

What is recovery?

Recovery of species at risk is the process by which the decline of an endangered, threatened, or extirpated species is arrested or reversed, and threats are removed or reduced to improve the likelihood of a species' persistence in the wild.

What is a recovery strategy?

Under the ESA a recovery strategy provides the best available scientific knowledge on what is required to achieve recovery of a species. A recovery strategy outlines the habitat needs and the threats to the survival and recovery of the species. It also makes recommendations on the objectives for protection and recovery, the approaches to achieve those objectives, and the area that should be considered in the development of a habitat regulation. Sections 11 to 15 of the ESA outline the required content and timelines for developing recovery strategies published in this series.

Recovery strategies are required to be prepared for endangered and threatened species within one or two years respectively of the species being added to the Species at Risk in Ontario list. Recovery strategies are required to be prepared for extirpated species only if reintroduction is considered feasible.

What's next?

Nine months after the completion of a recovery strategy a government response statement will be published which summarizes the actions that the Government of Ontario intends to take in response to the strategy. The implementation of recovery strategies depends on the continued cooperation and actions of government agencies, individuals, communities, land users, and conservationists.

For more information

To learn more about species at risk recovery in Ontario, please visit the Ministry of Environment, Conservation and Parks Species at Risk webpage at: www.ontario.ca/speciesatrisk

1 **Recommended citation**

2 Wyshynski, S., A.R. Eads and A. Nicolai. 2019. DRAFT Recovery Strategy for the
3 Eastern Banded Tigersnail (*Anguispira kochi kochi*) in Ontario. Ontario Recovery
4 Strategy Series. Prepared for the Ministry of the Environment, Conservation and Parks,
5 Peterborough, Ontario. v + 35 pp.

6 Cover illustration: Photo by Annegret Nicolai

7 © Queen's Printer for Ontario, 2019

8 ISBN [*MECP will insert prior to final publication.*]

9 Content (excluding illustrations) may be used without permission, with appropriate credit
10 to the source.

11 Cette publication hautement spécialisée « Recovery strategies prepared under the
12 *Endangered Species Act, 2007* », n'est disponible qu'en anglais en vertu du Règlement
13 411/97 qui en exempte l'application de la [Loi sur les services en français](#). Pour obtenir
14 de l'aide en français, veuillez communiquer avec recovery.planning@ontario.ca.

15 **Authors**

16 Sarah Wyshynski – Ecological Consultant

17 Angela Eads – Trent University

18 Annegret Nicolai – Université Rennes 1, Biological Station Paimpont

19 **Declaration**

20 The recovery strategy for the Eastern Banded Tigersnail was developed in accordance
21 with the requirements of the *Endangered Species Act, 2007* (ESA). This recovery
22 strategy has been prepared as advice to the Government of Ontario, other responsible
23 jurisdictions and the many different constituencies that may be involved in recovering
24 the species.

25 The recovery strategy does not necessarily represent the views of all individuals who
26 provided advice or contributed to its preparation, or the official positions of the
27 organizations with which the individuals are associated.

28 The recommended goals, objectives and recovery approaches identified in the strategy
29 are based on the best available knowledge and are subject to revision as new
30 information becomes available. Implementation of this strategy is subject to
31 appropriations, priorities and budgetary constraints of the participating jurisdictions and
32 organizations.

33 Success in the recovery of this species depends on the commitment and cooperation of
34 many different constituencies that will be involved in implementing the directions set out
35 in this strategy.

36 **Responsible jurisdictions**

37 Ministry of the Environment, Conservation and Parks
38 Environment and Climate Change Canada – Canadian Wildlife Service, Ontario
39 Parks Canada Agency

40 **Executive summary**

41 The Eastern Banded Tigersnail is a large, terrestrial snail that has distinctive dark
42 banding around its yellow-brown shell with an opening in the centre when viewed from
43 below. There can be variations in shell size, thickness, and colour, as well as the
44 visibility of bands, especially on weathered or older snails. The Eastern Banded
45 Tigersnail hibernates from early October until April, and lays eggs in late spring and late
46 summer. Terrestrial snails in general have a low physiological resistance to fluctuating
47 environmental factors and a very low dispersal ability. The Eastern Banded Tigersnail is
48 part of the unique faunas of the Carolinian ecosystem, and has significance for
49 ecosystem functioning, research, and conservation.

50 The species range extends south to Tennessee, east to Pennsylvania, and west to
51 Missouri. In Ontario, the Eastern Banded Tigersnail remains only on Pelee Island and
52 Middle Island in Lake Erie. The species is listed as endangered in Ontario under the
53 Ontario's *Endangered Species Act, 2007* due to its small range, decline and loss of
54 subpopulations, and habitat alteration and fragmentation.

55 Threats to the Canadian population include, but are not limited to: climate change,
56 habitat loss and degradation, ecosystem modification because of invasive and non-
57 native species, predation, competition and disturbance from recreational activities.
58 Climate change is the most serious threat to the persistence of the Eastern Banded
59 Tigersnail, and will increase the likelihood of severe storms, flooding, and habitat
60 erosion. Habitat on Middle Island is already severely altered by overabundant native
61 Double-crested Cormorants. Eastern Banded Tigersnails are likely to be further
62 impacted by competition with introduced slugs, increased predation pressure from Wild
63 Turkeys and introduced snails, modifications to soil and leaf litter due to introduced
64 plants and earthworms, as well as fire. Increasing tourism (trail development and traffic)
65 may also impact the Eastern Banded Tigersnail, as well as pesticide run-off.

66 The recommended recovery goal is to maintain the current subpopulations of the
67 Eastern Banded Tigersnail throughout their current range in Ontario, by maintaining,
68 protecting and enhancing habitat, and reducing other threats. The recommended
69 protection and recovery objectives are to:

- 70 1. Secure protection for Eastern Banded Tigersnail habitats through active
71 engagement with all levels of government and landowners within the species
72 range;
- 73 2. Implement a monitoring program for Eastern Banded Tigersnail subpopulations,
74 habitats and threats on Pelee Island and Middle Island, including surveys of
75 suitable habitat;
- 76 3. Assess and mitigate threats to all known sites in Ontario; and
- 77 4. Address knowledge gaps related to biology, habitat requirements and threats that
78 may assist in recovery efforts.

79 Specific steps are recommended to achieve each of the protection and recovery
80 objectives.

81 Given that Eastern Banded Tigersnails have an extremely limited distribution in Ontario,
82 low dispersal ability and that information pertaining to habitat use throughout various life
83 stages and seasons is lacking, it is recommended that a precautionary approach be
84 applied in defining habitat for the Eastern Banded Tigersnail. The area to be defined as
85 habitat should include sufficient suitable habitat necessary for mating, nesting, foraging,
86 aestivation and hibernation, along with dispersal. It is therefore recommended that the
87 entire Ecological Land Classification (ELC) ecosite polygon occupied by an extant
88 subpopulation of Eastern Banded Tigersnail be prescribed as habitat in a habitat
89 regulation. In addition, it is recommended that a buffer of 50 m be added to the ELC
90 ecosite polygon, to account for dispersal into neighbouring habitat, to reduce edge
91 effects and to maintain microhabitat conditions important to Eastern Banded Tigersnails.
92 This 50 m buffer of suitable habitat around the ELC ecosite polygon will take into
93 account the longest dispersal distance measured (32 m) in similar sized species
94 (Edworthy et al. 2012), along with ensuring protection of habitat that may be used by
95 snails at different times of year. Habitat known to be unsuitable (e.g., roads, lakes) for
96 Eastern Banded Tigersnails can be excluded from this buffer. Information on spatial
97 limits of habitat used by the Eastern Banded Tigersnail is lacking. Using a contiguous
98 ecological area to define habitat for the Eastern Banded Tigersnail, increases the
99 likelihood that all habitat elements required by the species are included.

100 **Table of contents**

101 Recommended citation i

102 Authors i

103 Declaration ii

104 Responsible jurisdictions ii

105 Executive summary iii

106 1.0 Background information 1

107 1.1 Species assessment and classification 1

108 1.2 Species description and biology 1

109 1.3 Distribution, abundance and population trends 3

110 1.4 Habitat needs 9

111 1.5 Limiting factors 10

112 1.6 Threats to survival and recovery 10

113 1.7 Knowledge gaps 13

114 1.8 Recovery actions completed or underway 13

115 2.0 Recovery 14

116 2.1 Recommended recovery goal 14

117 2.2 Recommended protection and recovery objectives 14

118 2.3 Recommended approaches to recovery 15

119 2.4 Area for consideration in developing a habitat regulation 28

120 Glossary 30

121 List of abbreviations 31

122 References 32

123 Personal communications 35

124

125 **List of figures**

126 Figure 1. Eastern Banded Tigersnail (*Anguispira kochi kochi*) in Fish Point Provincial
127 Nature Reserve on Pelee Island and Middle Island 2

128 Figure 2. Current Ontario distribution of Eastern Banded Tigersnail (*Anguispira kochi*
129 *kochi*) including historical records and sites with unknown subpopulation
130 status 4

131 Figure 3. Occurrences of Eastern Banded Tigersnail (*Anguispira kochi kochi*) on Pelee
132 Island 6

133 Figure 4. Global range of Eastern Banded Tigersnail (*Anguispira kochi kochi*) 8

134

135 **1.0 Background information**

136 **1.1 Species assessment and classification**

137 The following list is assessment and classification information for the Eastern Banded
138 Tigersnail (*Anguispira kochi kochi*). Note: The glossary provides definitions for
139 abbreviations and technical terms in this document.

- 140 • SARO List Classification: Endangered
- 141 • SARO List History: Endangered (2018)
- 142 • COSEWIC Assessment History: Endangered (2017)
- 143 • SARA Schedule 1: No schedule, no status
- 144 • Conservation Status Rankings: G-rank: G5; N-rank: N3; S-rank: S1S2

145 **1.2 Species description and biology**

146 **Species description**

147 The Eastern Banded Tigersnail (*Anguispira kochi kochi*) is a large terrestrial snail (adult
148 shell width up to 2.5 cm). The yellow or brown shell is a robust, globular shape with
149 broad whorls forming a spiral, and distinctively encircled by two dark longitudinal bands
150 (Figure 1). The shell also has shallow radial grooves (striae) on the surface (Grimm et
151 al. 2010, Pilsbry 1948). There can be large variations in shell size, thickness, and
152 colouration, as well as the visibility of banding and grooves (Figure 1). Weathered, older
153 animals can have a deteriorated periostracum (outer covering of the shell), losing the
154 distinctive colour and textural features of the shell; however, colour bands are visible on
155 the inside of the shell (COSEWIC 2017). The opening of the shell is slightly thickened in
156 adults, and the umbilicus (the hollow in the underside around which the shell coils) is
157 open and large. The animal is mostly grey, though the head and the foot may be slightly
158 orange-red to brown (Figure 1) and can produce a slightly orange mucus when
159 disturbed. When aestivating and hibernating the shell is closed with an orange or white
160 mucus foam (COSEWIC 2017).



161
162 Figure 1. Eastern Banded Tigersnail (*Anguispira kochi kochi*) in Fish Point Provincial
163 Nature Reserve on Pelee Island (A, B) and Middle Island (C, D). Pictures were taken in
164 spring 2013 and illustrate the development of shell thickness, roughness, and colour
165 banding pattern with age in adult snails: thin, smoother, with visible bands in younger
166 adults (A & B) versus thick, rough and visible bands only inside shells of older adults (C
167 & D). Usually, snails of all ages are found at each site. (©Annegret Nicolai)

168 **Species biology**

169 The Eastern Banded Tigersnail is a pulmonate (air-breathing), egg-laying simultaneous
170 hermaphrodite (possesses both male and female reproductive organs) terrestrial snail
171 (Pilsbry 1948). There is little else known about the life history of this species in Canada
172 but based on field observations and similarities to related gastropods, the following can
173 be assumed. Sexual maturity is reached after two to three years and their lifespan is
174 possibly up to 10 years (COSEWIC 2017). Mating likely occurs multiple times per year,
175 in mid-spring and mid-summer, with egg-laying in late spring and late summer, when
176 egg clutches of unknown size are deposited in shallow holes excavated in moist soil
177 (Barker 2001).

178 Eastern Banded Tigersnails have been observed feeding on dead plant material, may
179 also feed on micro-fungi, and are often found in the leaf litter and under decaying logs
180 (COSEWIC 2017). Terrestrial snails require calcium from the soil for different

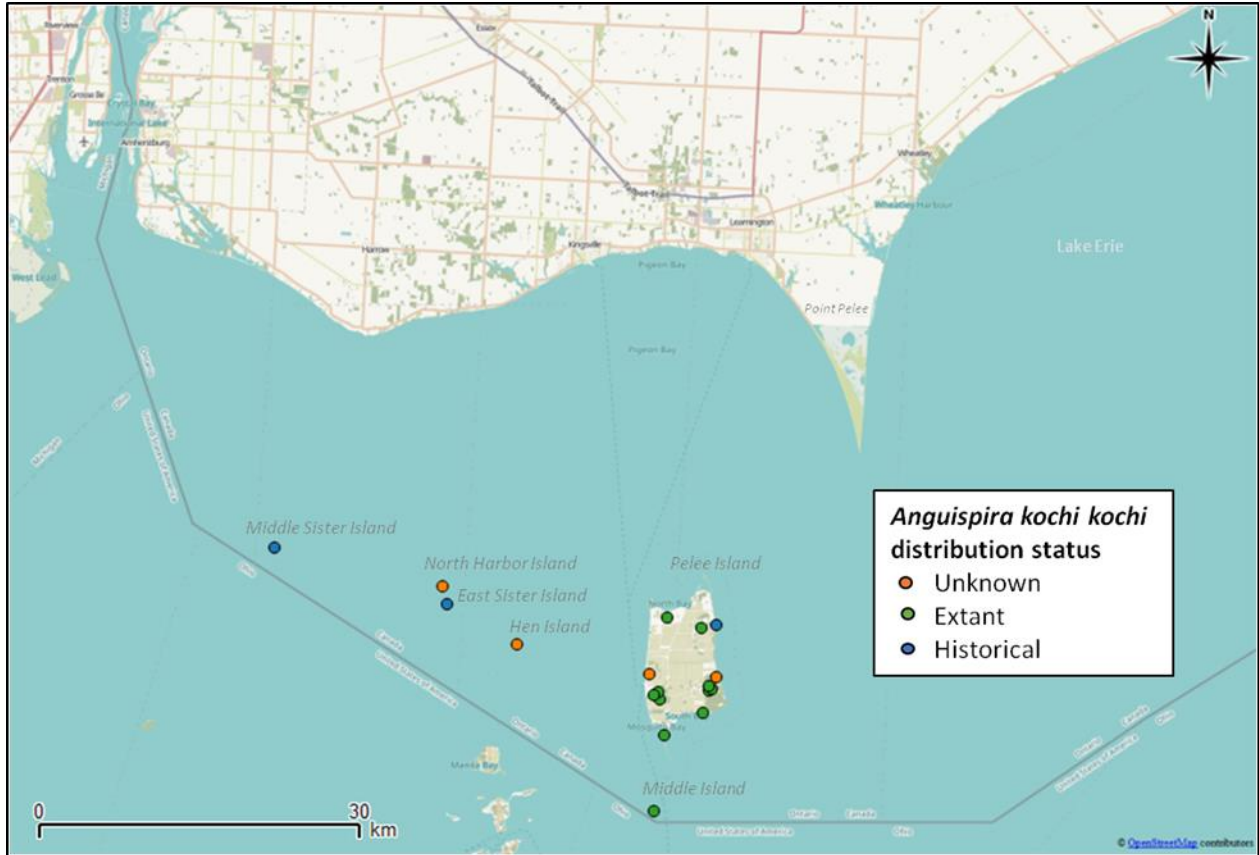
181 physiological processes, such as growth, reproduction and heat protection (Wäreborn
182 1979, Hotopp 2002, Nicolai et al. 2013).

183 Snails have a low physiological resistance to fluctuating environmental factors, such as
184 temperature and humidity, and the availability of moist refuges that buffer environmental
185 fluctuations is a key limiting factor for population growth and persistence of most
186 terrestrial snails (Burch and Pearce 1990). Snails are prone to dehydration in summer
187 and may become dormant during prolonged periods of drought. They have developed
188 physiological processes to maintain survival; however, unusually long heat and drought
189 periods increase mortality rates (Nicolai et al. 2011). Snails will hibernate from early
190 October until April, when they may take shelter in refuges insulated by snow to buffer
191 them from freezing during winter (Nicolai and Ansart 2017). Terrestrial gastropods use
192 various behavioural and physiological strategies to survive to sub-zero temperatures
193 (Ansart and Vernon 2003).

194 The Eastern Banded Tigersnail has a very low dispersal ability and is very unlikely to
195 colonize new areas unassisted. Species of similar size are known to move between 120
196 and 220 cm per day within a home range of 80 to 800 m² (e.g., *Anguispira alternata*,
197 Pearce 1990), have a net displacement of 32 m over three years (e.g., *Allogona*
198 *townsendiana*, Edworthy et al. 2012), or have home ranges greater than 50 m² but
199 return to hibernation sites (e.g., *Allogona profunda*, Blinn 1963). Passive dispersal by
200 flooding of rivers (Vagvolgyi 1975) or transportation by birds (Kawakami et al. 2008) is
201 possible but has not been documented in this species. There is no evidence that the
202 species is transported by humans.

203 **1.3 Distribution, abundance and population trends**

204 Two subspecies of *Anguispira kochi* are currently recognized in Canada: *A. k. kochi* (the
205 Eastern Banded Tigersnail) on the Lake Erie islands in Ontario, and *A. k. occidentalis*
206 (the Western Banded Tigersnail) in British Columbia (Pilsbry 1948, COSEWIC 2017).
207 The extent of occurrence (i.e. the zone encompassing all the known present
208 occurrences) of the Eastern Banded Tigersnail in Canada is 102 km², though much of
209 this calculated area is in Lake Erie, while the actual area of occupancy is estimated to
210 be 36 km² (COSEWIC 2017). Within Ontario, extant (i.e. existing or surviving)
211 subpopulations of the Eastern Banded Tigersnail were observed on Pelee Island and
212 Middle Island in Lake Erie during widespread surveys undertaken in 2013 to 2015
213 (Figure 2). The most recent genetic information suggests little divergence between
214 these subpopulations, though they are separated by approximately five kilometres of
215 open water (COSEWIC 2017). Within each subpopulation, there is the possibility of
216 genetic exchange among individuals, assuming habitat patches are currently or could
217 be connected in the future. However, habitat patches (only known in conservation
218 properties) on Pelee Island are fragmented with some isolated by up to four kilometres.

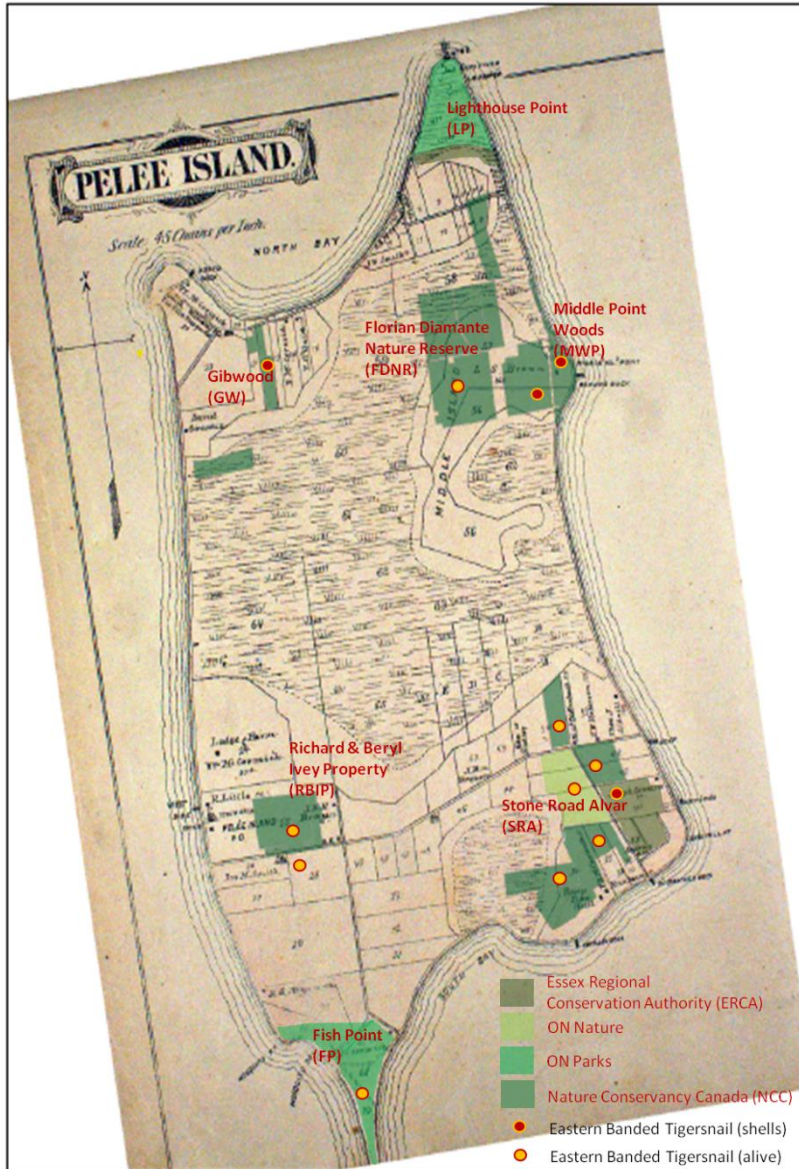


219

220 Figure 2. Current Ontario distribution of Eastern Banded Tigersnail (*Anguispira kochi*
 221 *kochi*) including historical records (Clapp 1916, Goodrich 1916) and sites with unknown
 222 subpopulation status (COSEWIC 2017).

223 From 2016 to 2018, annual comprehensive surveys were conducted across Pelee
 224 Island for snail species of conservation concern. Live Eastern Banded Tigersnails were
 225 observed at Fish Point Provincial Nature Reserve, Ontario Nature Stone Road Alvar
 226 property, Shaughnessy Cohen Memorial Savanna (eastern Nature Conservancy of
 227 Canada (NCC) Stone Road Alvar property), Florian Diamante Nature Reserve (NCC)
 228 and the Richard and Beryl Ivey Nature Reserve (NCC). No live snails were found in the
 229 Gibwood property (NCC), the Essex Region Conservation Authority (ERCA) Stone
 230 Road Alvar property or the southern and western NCC Stone Road Alvar properties
 231 from 2012 to 2015, but live individuals or fresh shells of Eastern Banded Tigersnails
 232 were found in 2016 or 2018, highlighting the cryptic nature of terrestrial snails. Only old,
 233 weathered shells have been found in Middle Point Woods (NCC) since 2006, when
 234 significant forest flooding occurred. The Krestel property (northern NCC Stone Road
 235 Alvar property) and Winery Woods likely still host a small number of Eastern Banded
 236 Tigersnails even though no live individual has been observed in either location since
 237 2006 and 2013, respectively. Habitat has not been disturbed on these conservation
 238 properties, whereas habitat conditions may have changed through human activities on
 239 the East Park campground and private land (not recently surveyed) where shells were
 240 last found in 1995 and 1997, respectively. Historically, Pelee Island was composed of

241 four bedrock islands separated by marshland; however, to develop the island for
242 agriculture in the 1890s, the marshes were dredged and the water pumped out to the
243 lake (Figure 3). The distribution of the Eastern Banded Tigersnail on Pelee Island is
244 determined by this historical segregation, as well as by current and historical activities
245 on each property, such as logging, grazing and agriculture).



246

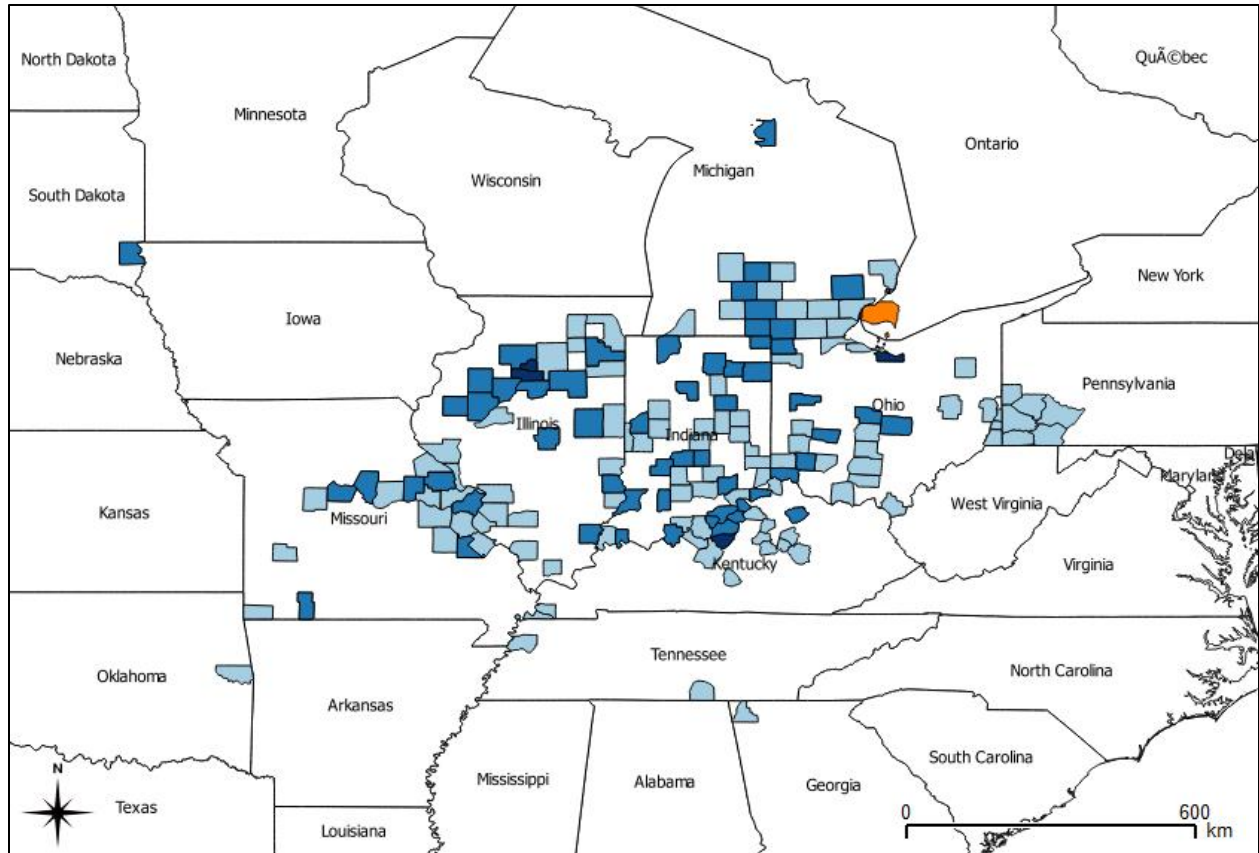
247 Figure 3. Occurrences of Eastern Banded Tigersnail (*Anguispira kochi kochi*) on Pelee
 248 Island. Current conservation blocks are plotted on this historical map from the 19th
 249 century. The Stone Road Alvar block encompasses properties of different land owners:
 250 Ontario Nature (ON Nature in the legend), ERCA and NCC (Krestel in the north,
 251 Shaughnessy Cohen Memorial Savanna in the east and southern and western
 252 properties). Former islands have a plain white background, while between the islands is
 253 marshland.

254 The subpopulation on Middle Island (part of Point Pelee National Park) may have been
 255 dramatically reduced since the early 1980s due to habitat destruction from the
 256 overabundant Double-crested Cormorants (*Phalacrocorax auritus*) (Dobbie and Kehoe
 257 2008). Historically, Eastern Banded Tigersnails were found on many other western Lake
 258 Erie islands (Clapp 1916, Goodrich 1916, Ahlstrom 1930 and see collection records in

259 COSEWIC 2017). However, no live Eastern Banded Tigersnails have been sighted on
260 East Sister Island or on Middle Sister Island since specimens were collected there in
261 1916 and 1996, respectively (COSEWIC 2017). North Harbour Island and Hen Island
262 are not accessible due to private ownership and so have not been recently surveyed.
263 Habitat on East Sister and Middle Sister Islands was also heavily degraded by the
264 Double-crested Cormorant, while North Harbour Island has been developed and little
265 natural habitat remains. The Eastern Banded Tigersnail is considered extirpated on
266 these three islands (COSEWIC 2017). Only Hen Island still harbours intact forest that is
267 suitable habitat for the species. In 1991, shells were collected near Alvinston, Lambton
268 County, on what is now a property of the St. Clair River Conservation Authority and
269 recorded as Eastern Banded Tigersnails. However, the specimens for this record were
270 lost and presumed to be erroneous (Forsyth, pers. comm., 2017-2018). The property
271 has been surveyed repeatedly in 2015 and 2017; no shells were found, and habitat
272 conditions appear unsuitable for this species.

273 The Canadian population of Eastern Banded Tigersnails was estimated at about
274 800,000 mature individuals in 2015 (COSEWIC 2017). Recruitment has been observed
275 in most sites where the species was found alive. In 2018, the most dense occurrence of
276 Eastern Banded Tigersnails was found in the Fish Point Provincial Nature Reserve,
277 which has a much higher abundance (mean 4.1 snails/m²) compared to all the other
278 sites (e.g., Richard and Beryl Ivey Nature Reserve 0.7 snails/m²). Anthropogenic
279 pressure (logging, grazing, and agriculture) on Pelee Island might have reduced
280 abundance in the other conservation properties compared to Fish Point. The
281 subpopulation of Eastern Banded Tigersnails on Middle Island was broadly estimated to
282 be between 4,000 and 32,000 individuals in 2015. In the three monitoring plots on the
283 island, mean abundance was 0.3 snails/m² in 2015, 0.9 snails/m² in 2016 and 1.8
284 snails/m² in 2017. The small increases in abundance may indicate a recovery related to
285 Double-crested Cormorant culls that have occurred annually since 2008, or may simply
286 be due to natural population size fluctuations.

287 The distribution of the Eastern Banded Tigersnail in the USA extends from Tennessee
288 in the south, Pennsylvania to the east, west to Missouri, and across Michigan (Hubricht
289 1985 and collection records in COSEWIC 2017, Figure 4). However, increased genetic
290 diversity and population augmentation via immigration from these populations outside of
291 Canada are not possible due to Lake Erie acting as a barrier.



292

293 Figure 4. Global range of Eastern Banded Tigersnail (*Anguispira kochi kochi*)
294 (COSEWIC 2017). Essex County in Canada with an extant population is indicated in
295 orange. US counties where Eastern Banded Tigersnail currently occurs (1990-2015) are
296 indicated in dark blue. US counties with records older than 1990 are shown in blue and
297 those without a collection date in light blue. Note that the species doesn't necessarily
298 occur across the whole county.

299 NatureServe (2018) provides the following ranks for US states:

- 300 1. US States adjoining southwestern Ontario:
301 Michigan: SU
302 Pennsylvania: S3
303 Ohio: SNR
304 New York: not present
- 305 2. Other US states where Eastern Banded Tigersnail occurs:
306 Illinois: SNR
307 Indiana: SNR
308 Kentucky: S2
309 West Virginia: S1
310 Missouri: SNR
311 Tennessee: S2

312 (SNR – not ranked sub-nationally, SU – unrankable, S1 – critically imperiled sub-
313 nationally, S2 – imperiled sub-nationally, S3 – vulnerable sub-nationally, S4 –
314 apparently secure sub-nationally)

315 **1.4 Habitat needs**

316 In Canada, the Eastern Banded Tigersnail inhabits mesic mature hardwood or mixed-
317 wood forests. Goodrich (in Pilsbry 1948) characterizes the Eastern Banded Tigersnail
318 as being “one of the typical molluscs of the old forest, and seldom found even in thick
319 second-growth timber”. The Eastern Banded Tigersnail has been observed in
320 Chinquapin Oak-Nodding Onion treed alvar and dry-fresh Hackberry deciduous forest
321 on Middle Island and on Pelee Island, as well as in dry-fresh Sugar Maple-White Ash
322 deciduous forest and dry Black Oak woodland at Fish Point on Pelee Island (COSEWIC
323 2017). These habitats have either rocky ground consisting of limestone with herbaceous
324 vegetation cover (alvar) or sandy, humus-rich soil with a substantial leaf litter layer (10-
325 20 cm). The forests where the species is found also have decaying logs and wood
326 material. Leaf litter, logs and humus-rich soil provide temperature-buffered and moist
327 microhabitat sites for hibernation, aestivation, and egg laying, while limestone and
328 calcium-rich plants provide nutrients. About 115 ha out of the total 788 ha of protected
329 land (conservation properties of NCC, Ontario Nature, ERCA, Ontario Parks, Pelee
330 Island Winery) on Pelee and Middle Islands (Parks Canada) represent suitable habitat
331 for the species (COSEWIC 2017).

332 When Pelee Island was dredged and developed for agriculture, habitat loss was high
333 due to significant deforestation. About 15 to 20 percent of the natural forest cover is still
334 intact, most of which is under management by the Nature Conservancy of Canada
335 (NCC) or the Ministry of Environment Conservation and Parks (MECP). No native snails
336 or slugs were found in former marshland (e.g., cultivated fields or small cultured
337 woodlots between fields) on Pelee Island during surveys from 2013 to 2015, indicating
338 that these environments do not represent suitable habitat and do not act as habitat or
339 movement corridors.

340 The climate of the Lake Erie islands is much warmer than expected for its latitude
341 because of the moderating effect of Lake Erie, and two-thirds of the year they are frost-
342 free. This warmer climate plays an extremely important role in the persistence of flora
343 and fauna at their northern range limits (North – South Environmental Inc. 2004). The
344 warmer climate also leads to increased snowfall due to a higher precipitation rate, and
345 this thicker snow cover is imperative for Eastern Banded Tigersnail winter survival when
346 temperature variations are high.

347 **1.5 Limiting factors**

348 The Eastern Banded Tigersnail persists in small isolated forested habitat patches on
349 Middle and Pelee Islands in Lake Erie. Eastern Banded Tigersnails have a very low
350 dispersal ability and without corridor habitats at a suitable micro-scale, they are very
351 unlikely to colonize new areas unassisted, to escape short-term threats or to recover
352 from negative impacts (Nicolai and Ansart 2017). Fragmentation of habitat or
353 encroachment into habitat due to agriculture, roads and water barriers all increase
354 dispersal difficulty and restrict gene flow among subpopulations.

355 Eastern Banded Tigersnails have a low physiological resistance to fluctuating
356 environmental factors, such as temperature and humidity, and the availability of moist
357 refuges that buffer environmental fluctuations is a key limiting factor for population
358 growth and persistence of most terrestrial snails (Burch and Pearce 1990). Their
359 adaptability to changing climate conditions might be limited (Nicolai and Ansart 2017).
360 Eastern Banded Tigersnails are restricted to mesic mature hardwood or mixed-wood
361 forests and alvars, which are limited habitats across south-western Ontario. Eastern
362 Banded Tigersnails require specific habitat and climate conditions to avoid dehydration
363 in hot and dry periods and hibernate through winter.

364 **1.6 Threats to survival and recovery**

365 The broad threats to the ongoing persistence of snail subpopulations are habitat
366 destruction or modification, increased predation or competition, and significant weather
367 events and climate change. These threats co-occur and can interact to increase the
368 overall negative impact on snails; these cumulative impacts substantially elevate the
369 level of overall threat for the Eastern Banded Tigersnail.

370 **Climate change and severe weather**

371 Climate change represents a significant but poorly understood threat to Eastern Banded
372 Tigersnails. South-western Ontario is projected to have more extreme weather events
373 including droughts, floods, and temperature extremes under climate change models
374 (Varrin et al. 2007). Extreme temperatures are more likely, which result in more frequent
375 and severe spring frosts (Augspurger 2013). There is high snail mortality when snow
376 cover is absent (Nicolai and Ansart 2017). Snails are vulnerable to increasing average

377 temperatures accompanied by increased occurrences of drought (Pearce and Paustian
378 2013), which can cause high mortality in some species that rely on shelter (Nicolai et al.
379 2011). With increased precipitation due to climate change, storms on Middle Island are
380 predicted to become more violent, and erosion and flooding of forest habitats on Pelee
381 Island are likely to occur more often, last longer, and disturb larger areas. Eastern
382 Banded Tigersnails are found near the eastern shore of Pelee Island, which is being
383 gradually eroded (COSEWIC 2017). Eastern Banded Tigersnails are likely already
384 affected by storm and flood damage, as only weathered shells have been found in
385 multiple sites where these weather events take place. These threats need to be
386 considered when assessing potential sites for recolonization.

387 **Ecosystem and habitat modification**

388 Nesting colonies of Double-crested Cormorants have increased dramatically on the
389 Lake Erie islands since the early 1980s and are presumed the main reason for the
390 extirpation of Eastern Banded Tigersnail on Middle Sister and East Sister Islands.
391 Double-crested Cormorants have severely decreased the available forest habitat on
392 Middle Island (Dobbie and Kehoe 2008) and have modified soil chemistry and
393 community assemblages (North – South Environmental Inc. 2004; Boutin et al. 2011).
394 Low soil pH and high soil salinity disturb physiological processes in snails. The change
395 in plant diversity and density might reduce nutritional resources and degrade
396 microhabitat structure for snails. Double-crested Cormorant culls have occurred on
397 Middle Island since 2008 (Thorndyke and Dobbie 2013), but their effectiveness still
398 needs to be verified (Guillaumet et al. 2014).

399 There are several highly invasive plants on the islands in south-western Lake Erie,
400 including Garlic Mustard (*Alliaria petiolata*) in forests and grasses of the family Poaceae
401 in alvars. For instance, Garlic Mustard has been observed displacing native vegetation
402 and altering soil nutrient cycles, thereby slowing restoration (Catling et al. 2015).
403 Invasive plants are actively controlled using herbicides, mechanical control or
404 prescribed burns. However, the impact of the invasive plants on the Eastern Banded
405 Tigersnail is unknown (COSEWIC 2017).

406 Non-native earthworms have invaded parts of Canada relatively recently. They have
407 been shown to have major impacts on ecosystems and could indirectly affect terrestrial
408 snail communities (Norden 2010, Forsyth et al. 2016). Earthworms alter forest floor
409 habitats by reducing or eliminating the natural leaf litter layer and digging up and mixing
410 the mineral soil with the organic surface layer (Qiu and Turner 2017), thereby changing
411 understory vegetation composition (Drouin et al. 2016) thus reducing available food
412 plants and microhabitat for snails.

413 **Invasive competitors and predators**

414 Competition with exotic terrestrial gastropods is a potential threat (Whitson 2005, Grimm
415 et al. 2010, Campbell et al. 2014) through aggression (Kimura and Chiba 2010), density
416 effects, and/or food competition (Baur and Baur 1990b). The Dusky Arion (*Arion*

417 *subfuscus*), Orange-banded Arion (*Arion fasciatus*), Grey Fieldslug (*Deroceras*
418 *reticulatum*), and Grovesnail (*Cepaea nemoralis*) are present in the Eastern Banded
419 Tigersnail's habitat; however, their impact is unknown (COSEWIC 2017). Additionally,
420 predation by exotic carnivorous snails may be a threat to the Eastern Banded Tigersnail
421 on Middle Island, as species of the Glass Snail genus *Oxychilus* were observed on
422 Middle Island in 2013 (records MJO 40569a and ANi033e in the Forsyth-Nicolai
423 Collection, Forsyth pers. comm. 2017-2018.). Wild Turkeys (*Meleagris gallopavo*) were
424 introduced to Pelee Island in 2002, where they spread rapidly and are now naturalized
425 with several flocks over 200 individuals. They are actively hunted in the spring.
426 Similarly, Ring-necked Pheasants (*Phasianus colchicus*) were introduced to Pelee
427 Island in the late 1920s for hunting. Both bird species are omnivorous and include snails
428 in their diet (Sandilands 2005) and are known to disturb ground habitat by their intensive
429 scratching. The impacts of these birds on snail subpopulations remain unstudied.

430 **Human intrusions and disturbances**

431 There has been a marked increase in tourism on Pelee Island since the ferry service
432 expanded in 1992. The island attracts significant numbers of birders, photographers,
433 tourists, hunters, and researchers, with annual visitation estimated to be 7,500 people
434 just at Fish Point (Ontario Parks 2005). Wide trails represent barriers for snail
435 movement (Wirth et al. 1999). Moreover, trampling by pedestrians is a known threat for
436 some snail species (Baur and Baur 1990a). Since visitors are only allowed on Middle
437 Island from September to February, mostly a period of snail inactivity, they may not be a
438 threat for Eastern Banded Tigersnails. Disturbance by targeted research activities for
439 species of conservation concern appear low as researchers usually take care to
440 minimize habitat disturbance. Specific gastropod research takes place in only a few
441 monitoring plots within each habitat on Middle and Pelee Islands where snail stress is
442 actively limited.

443 Fire has become an important management tool for forest and prairie conservation.
444 Portions of the Stone Road Alvar on Pelee Island have been subjected to prescribed
445 burns by Ontario Nature and ERCA in 1993, 1997, 1999, and 2005 (NCC 2008). There
446 are plans by Ontario Nature for a burn in October 2019 to enhance snake habitat on
447 parts of their Stone Road Alvar property (Horrigan, pers. comm., 2018) where the
448 Eastern Banded Tigersnail co-occurs. Burning directly and indirectly affects survival of
449 litter-dwelling and soil invertebrates including terrestrial snails (Nekola 2002). Fire
450 reduces and modifies organic substrates and residues (litter layer), which serve as both
451 nutrients and shelter for these organisms (Bellido 1987). Fire can change the
452 microclimate due to the sun warming post-burn bare soil and increasing soil evaporation
453 (Knapp et al. 2009).

454 **Transportation and service corridors**

455 Conservation properties on Pelee Island are separated by roads, canals, and ditches.
456 Snails are highly vulnerable when crossing roads, and rarely attempt to do so; as such,
457 paved roads with high traffic densities fragment snail populations (Baur and Baur

458 1990a). Canals, ditches, paved and unpaved roads or tracks with both high and low
459 traffic densities, or even a narrow footpath devoid of leaf litter, can all be barriers to snail
460 dispersal (Baur and Baur 1990a; Wirth et al. 1999, Meadows 2002).

461 **Pollution**

462 Air- and water-borne pollution from roads (e.g., heavy metals and road salt) represents
463 a potential threat to snails (Viard et al. 2004). However, traffic on Pelee Island is low
464 and absent on Middle Island. Agricultural effluents and herbicide use in the control of
465 invasive plants in conservation properties on Pelee and Middle Islands may represent a
466 threat for the Eastern Banded Tigersnail, though the impacts of pesticides on terrestrial
467 gastropods are poorly understood. Laboratory studies have shown that exposure to
468 some herbicides increases mortality of some snail species (Koprivnikar and Walker
469 2011) and could affect reproduction (Druart et al. 2011), thereby affecting population
470 dynamics.

471 **1.7 Knowledge gaps**

472 Limited knowledge of the species distribution and biology, specifically diet, physiological
473 responses to environmental factors, and interactions with exotic species may hinder the
474 efficacy of protection strategies for the Eastern Banded Tigersnail. Research on the
475 following knowledge gaps would contribute to a more complete understanding for the
476 protection and recovery of this species and its habitat:

- 477 • population viability analysis and genetic diversity;
- 478 • life history traits: growth, reproduction, life span, dispersal;
- 479 • habitat requirements: diet, physico-chemical parameters in the soil and litter,
480 habitat structure (physical elements, vegetation composition);
- 481 • interspecific interactions: especially the impact of exotic terrestrial gastropods,
482 plants and earthworms through habitat changes or competition for food and
483 shelter (density effects);
- 484 • physiological tolerances and adaptability: heat and cold resistance, responses to
485 pesticides and changes in climatic conditions and soil characteristics;
- 486 • predation risk: predation impact of birds and carnivorous gastropods;
- 487 • subpopulation-level responses to habitat management measures, such as
488 mechanical vegetation-thinning and prescribed burns, through monitoring of
489 changes in distribution, mortality, demography and re-colonization from buffer
490 zones.

491 **1.8 Recovery actions completed or underway**

492 To date, no specific recovery actions have been implemented, though the regular
493 monitoring of a few plots on Middle and Pelee Islands was initiated in 2015.

494 **2.0 Recovery**

495 **2.1 Recommended recovery goal**

496 The recommended recovery goal is to maintain the current subpopulations of Eastern
497 Banded Tigersnail throughout their current range in Ontario, by maintaining, enhancing
498 and protecting habitat, and reducing other threats.
499

500 **2.2 Recommended protection and recovery objectives**

- 501 1. Secure protection for Eastern Banded Tigersnail habitats through active
502 engagement with all levels of government and landowners within the species'
503 range.
- 504 2. Implement a monitoring program for Eastern Banded Tigersnail subpopulations,
505 habitats and threats on Pelee Island and Middle Island, including surveys of suitable
506 habitat.
- 507 3. Assess and mitigate threats to all known sites in Ontario.
- 508 4. Address knowledge gaps related to biology, habitat requirements and threats that
509 may assist in recovery efforts.

510 **2.3 Recommended approaches to recovery**

511 Table 1. Recommended approaches to recovery of the Eastern Banded Tigersnail in Ontario.

512 Objective 1: Secure protection for Eastern Banded Tigersnail habitats through active engagement with all levels of
 513 government and landowners within the species range.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Short-term	Protection, Management	1.1 Develop a habitat description or habitat regulation to provide clarity on the area defined as habitat for Eastern Banded Tigersnail in Ontario.	Threats: • Habitat loss and degradation
Necessary	Short-term	Protection, Management	1.2 Identify existing and potential Eastern Banded Tigersnail habitat. <ul style="list-style-type: none"> • Map areas of protected and non-protected habitat. • Clarify ownership of any non-protected habitat, to determine habitat protection options (e.g., regulation, stewardship, securement). • Identify sites that may be affected by future development and ensure that measures are in place to protect Eastern Banded Tigersnail and its habitat. 	Threats: • Habitat loss and degradation

DRAFT Recovery Strategy for the Eastern Banded Tigersnail in Ontario

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Ongoing	Management, Stewardship	<p>1.3 Work with relevant agencies, organizations and landowners (NCC, Ontario Nature, ERCA, Parks Canada, MECP) to develop and implement habitat management and protection programs for Eastern Banded Tigersnail.</p> <ul style="list-style-type: none"> • Provide advice and support to land managers and landowners on habitat improvement or restoration activities. • Ensure Eastern Banded Tigersnail is integrated into management plans. • Monitor management activities and protection programs, determine efficacy and make changes when necessary. 	<p>Threats:</p> <ul style="list-style-type: none"> • Habitat loss and degradation
Necessary	Ongoing	Protection, Management, Stewardship	<p>1.4 Support the protection and securement of land important for Eastern Banded Tigersnail (lands owned and/or managed by NCC, ERCA, Ontario Nature, MECP).</p>	<p>Threats:</p> <ul style="list-style-type: none"> • Habitat loss and degradation
Necessary	Ongoing	Education, Outreach, Communications, Stewardship	<p>1.5 Work with NCC, additional non-government organizations as well as government partners to increase public understanding and knowledge of Eastern Banded Tigersnail.</p> <ul style="list-style-type: none"> • Develop education and outreach material (signage, fact sheets) for the general public and staff (Parks Canada, NCC, Ontario Nature, ERCA and MECP employees) working in Eastern Banded Tigersnail habitat, to raise awareness of threats to the species and aid in its identification. 	<p>Threats:</p> <ul style="list-style-type: none"> • Human disturbance, habitat loss and degradation

514 Objective 2: Implement a monitoring program for Eastern Banded Tigersnail subpopulations, habitats, and threats on
 515 Pelee Island and Middle Island including surveys of suitable habitat.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Short-term	Inventory and Monitoring	2.1 Develop identification material to aid in accurate recognition of this species including how to distinguish it from other similar species.	Knowledge gaps: <ul style="list-style-type: none"> • Snail identification resources for southern Ontario are limited.
Critical	Short-term	Inventory and Monitoring	2.2 Develop standardized protocol for Eastern Banded Tigersnail presence/absence surveys along with subpopulation inventorying and monitoring surveys. Protocol should include: <ul style="list-style-type: none"> • guidance on frequency of monitoring, appropriate time of day and year, consistent methods for documenting both positive and negative search effort, appropriate marking techniques, and direction on submission of data to the Natural Heritage Information Centre. 	Knowledge gaps: <ul style="list-style-type: none"> • Size and distribution of population unknown.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Short-term	Inventory and Monitoring	<p>2.3 Develop standardized protocol for inventorying and monitoring habitat information at each site. Habitat parameters should include:</p> <ul style="list-style-type: none"> • parameters that will aid in determining what habitat attributes are favoured by the species. • indicators that will aid in monitoring threats to the species or habitat (e.g., water levels, erosion, severe weather, changes in vegetation structure, invasive species removal and management programs, recreational activities, presence of problematic species). 	<p>Threats:</p> <ul style="list-style-type: none"> • Climate change/severe weather • Problematic non-native (birds, earthworms, gastropods) and native (Double-crested Cormorants) species • Habitat degradation and loss <p>Knowledge gaps:</p> <ul style="list-style-type: none"> • Habitat requirements • Protection needs • Habitat degradation and loss
Necessary	Ongoing	Inventory and Monitoring	<p>2.4 Conduct yearly monitoring of current subpopulations (in conjunction with the ongoing yearly monitoring of Double-crested Cormorant nests and vegetation on Middle Island by Parks Canada), in addition to inventorying and monitoring habitat parameters at each site.</p>	<p>Knowledge gaps:</p> <ul style="list-style-type: none"> • Size and distribution of population unknown • Habitat degradation and loss
Beneficial	Ongoing	Inventory and Monitoring	<p>2.5 Survey suitable habitats to find any unknown subpopulations of Eastern Banded Tigersnail.</p>	<p>Knowledge gaps:</p> <ul style="list-style-type: none"> • Size and distribution of population unknown

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Beneficial	Ongoing	Inventory	<p>2.6 Engage volunteers (e.g., local naturalists, land stewards, experts) to undertake surveys in the search for this species to determine presence or absence.</p> <ul style="list-style-type: none"> • Include information on Eastern Banded Tigersnail in any ongoing bio-blitzes, or other citizen science initiatives. 	<p>Knowledge gaps:</p> <ul style="list-style-type: none"> • Size and distribution of population unknown

516 Objective 3: Assess and mitigate threats to all known sites in Ontario.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Ongoing	Protection, Management, Monitoring and Assessment	<p>3.1 Quantify and rate threats at each site to aid in identifying and prioritizing site-specific actions to reduce threats.</p> <ul style="list-style-type: none"> • When conducting snail surveys, gather detailed information on current conditions, human activities and land-uses (e.g., how many earthworms, how many people on the trail/day, soil salinity). 	<p>Threats:</p> <ul style="list-style-type: none"> • All known threats <p>Knowledge gaps:</p> <ul style="list-style-type: none"> • Extent of threats at different sites

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Ongoing	Protection, Management, Monitoring and Assessment	<p>3.2 Assess and implement actions that are needed to protect Eastern Banded Tigersnails from predation by, and competition from, non-native species.</p> <ul style="list-style-type: none"> • Investigate distribution and habitat use patterns of Eastern Banded Tigersnails in relation to exotic terrestrial molluscs and introduced predators. • Quantify threat impacts, such as competition for food and shelter, predation rates etc. • Investigate feasibility of reducing or controlling non-native species and introduced predators. 	<p>Threats:</p> <ul style="list-style-type: none"> • Competition with exotic gastropods • Predation by Wild Turkeys, Ring-necked Pheasants and Glass Snails <p>Knowledge gaps:</p> <ul style="list-style-type: none"> • Best management practices

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Ongoing	Protection, Management, Monitoring and Assessment, Communication	<p>3.3 Assess and implement actions needed to protect Eastern Banded Tigersnails from habitat degradation and loss as a result of ecosystem modification (due to fire, invasive plants, earthworms and Double-crested Cormorants).</p> <ul style="list-style-type: none"> • Ensure that any controlled burns are conducted in a way to minimize mortality of snails and allow for subpopulation recovery. • Quantify habitat changes induced by problematic species and determine physiological response limits. • Investigate feasibility of reducing or controlling these species in areas where control efforts are currently not in place. • Encourage citizens to prevent the accidental introduction of invasive species into new habitat. 	<p>Threats:</p> <ul style="list-style-type: none"> • Habitat degradation and loss due to ecosystem modification (Double-crested Cormorants, invasive plants, earthworms) • Fire <p>Knowledge gaps:</p> <ul style="list-style-type: none"> • Best management practices

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Ongoing	Management, Assessment, Education, Communication, and Stewardship	<p>3.4 Assess and implement site-specific actions that are needed and appropriate to minimize damage to Eastern Banded Tigersnail habitat caused by human disturbances. This may include but not be limited to:</p> <ul style="list-style-type: none"> • restricting intensive recreational activities within known occupied habitat. • introducing signage and fencing to reduce trampling and re-directing trails. • monitoring trail development and the threat of trampling (if needed: deactivating and reclaiming any excessive trails. 	<p>Threats:</p> <ul style="list-style-type: none"> • Habitat loss and degradation, trampling <p>Knowledge gaps:</p> <ul style="list-style-type: none"> • Best management practices
Critical	Ongoing	Management, Protection	<p>3.5 Identify protect and/or create refuge areas for snails to move into in times of extreme temperatures and/or droughts.</p> <ul style="list-style-type: none"> • Explore options such as increasing the abundance and diversity (species and size) of downed logs in the habitat. 	<p>Threats:</p> <ul style="list-style-type: none"> • Climate change and severe weather

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Ongoing	Management, Protection	<p>3.6 Identify Eastern Banded Tigersnail habitats that are more vulnerable to threats from flooding, erosion, fire and development.</p> <ul style="list-style-type: none"> • Overlay spatial information that shows flood and erosion information, fire information and potential development information (residential, commercial, transportation and recreational) within Eastern Banded Tigersnail habitats. • Develop protection or rescue measures for these events. 	<p>Threats:</p> <ul style="list-style-type: none"> • Habitat loss and degradation due to flooding, erosion, fire, and development
Necessary	Ongoing	Management, Protection	<p>3.7 Identify habitat restoration and enhancement opportunities to increase and improve habitat availability.</p> <ul style="list-style-type: none"> • Encourage connectivity between habitats to allow dispersal. • Identify existing or ongoing programs which may be mutually beneficial (e.g., snake or salamander habitat restoration projects). 	<p>Threats:</p> <ul style="list-style-type: none"> • Habitat loss and degradation • Lack of connectivity between habitats

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Ongoing	Management, Protection	3.8 As knowledge gaps pertaining to habitat requirements are filled, re-evaluate management and protection actions.	Threats: <ul style="list-style-type: none"> • Habitat degradation and loss • Invasive and non-native species • Climate change/severe weather

517 Objective 4: Address knowledge gaps related to biology, habitat requirements and threats that may assist in recovery
518 efforts.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Short-term	Research	4.1 Engage the academic community to participate in researching knowledge gaps such as: <ul style="list-style-type: none"> • habitat requirements for feeding, nesting, shelter; • dispersal ability and home range size; • minimum population viability; • life history; • genetic diversity; and • threats. 	Knowledge gaps: <ul style="list-style-type: none"> • Any or all, such as: habitat requirements, dispersal ability, home range size, minimum population viability and genetics
Critical	Short-term	Research	4.2 Monitor Eastern Banded Tigersnail activity (through mark-recapture studies) to determine home range size and dispersal ability, which will allow for better estimates of the amount of habitat required for snail survival.	Knowledge Gaps: <ul style="list-style-type: none"> • Home range size and dispersal ability • Habitat requirements

DRAFT Recovery Strategy for the Eastern Banded Tigersnail in Ontario

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Short-term	Research	4.3 Conduct habitat assessments at known sites to better identify key habitat features that could predict presence/absence of snails and allow for greater understanding of habitat requirements of the species.	Knowledge Gaps: <ul style="list-style-type: none"> • Habitat requirements
Critical	Short-term	Research	4.4 Determine the degree Double-crested Cormorant colonies need to be managed to ensure persistence of snail subpopulations.	Threats: <ul style="list-style-type: none"> • Habitat degradation Knowledge gaps: <ul style="list-style-type: none"> • Tolerance to changes in ecosystem as a result of Double-crested Cormorant colonies
Critical	Short-term	Research	4.5 Research the direct impact of prescribed burns on subpopulations (mortality, demography, recolonization) and indirect impacts (physiological and population-level responses to habitat changes)	Threats: <ul style="list-style-type: none"> • Habitat disturbance Knowledge gaps: <ul style="list-style-type: none"> • Responses to management measures

DRAFT Recovery Strategy for the Eastern Banded Tigersnail in Ontario

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Ongoing	Research	<p>4.6 Investigate the impact of climate change on Eastern Banded Tigersnail subpopulations.</p> <ul style="list-style-type: none"> • Research adaptive strategies to climate variation – including plasticity and evolvability of physiological responses combined with behavior. • Monitor snail performance (e.g., reproduction, feeding, dispersal) in relation to microclimatic variations within Eastern Banded Tigersnail habitat. • Investigate protection (through habitat enhancement and/or alteration) or rescue measures (e.g., captive breeding, population augmentation) for extreme events (e.g., droughts, flooding, fire). 	<p>Threats:</p> <ul style="list-style-type: none"> • Climate change, drought, storms, flooding <p>Knowledge gaps:</p> <ul style="list-style-type: none"> • Adaptability to climate variations • Effects of climate change and severe weather • Protection needs
Beneficial	Ongoing	Research	<p>4.7 Research impacts of non-native terrestrial gastropods and earthworms on Eastern Banded Tigersnail and its habitat.</p>	<p>Threats:</p> <ul style="list-style-type: none"> • Non-native species <p>Knowledge gaps:</p> <ul style="list-style-type: none"> • Habitat degradation, inter-specific competition
Necessary	Short-term	Research	<p>4.8 Research the effects of predation caused by introduced species, and estimate potential mortality for Eastern Banded Tigersnail as a result of predation.</p>	<p>Threats:</p> <ul style="list-style-type: none"> • Predation <p>Knowledge gaps:</p> <ul style="list-style-type: none"> • Mortality risk due to predation

DRAFT Recovery Strategy for the Eastern Banded Tigersnail in Ontario

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Beneficial	Short-term	Research	<p>4.9 Research the effects of pesticides (effluents from agriculture and gardens, and pesticides used to control invasive plants) on Eastern Banded Tigersnail.</p>	<p>Threats:</p> <ul style="list-style-type: none"> • Pesticides <p>Knowledge gaps:</p> <ul style="list-style-type: none"> • Physiological tolerance

519 **2.4 Area for consideration in developing a habitat regulation**

520 Under the ESA, a recovery strategy must include a recommendation to the Minister of
521 the Environment, Conservation and Parks on the area that should be considered in
522 developing a habitat regulation. A habitat regulation is a legal instrument that prescribes
523 an area that will be protected as the habitat of the species. The recommendation
524 provided below by the author will be one of many sources considered by the Minister
525 when developing the habitat regulation for this species.

526 The Eastern Banded Tigersnail has a very limited distribution in Ontario, with confirmed
527 extant subpopulations only found on two Lake Erie islands (Middle Island and Pelee
528 Island). Because of the extremely limited distribution (only a few locations on these
529 islands) along with a very low dispersal ability, it is recommended that a precautionary
530 approach be applied in defining habitat for Eastern Banded Tigersnails.

531 When overlaying Eastern Banded Tigersnail occurrences on vegetation maps
532 (Ecological Land Classification [ELC] by Lee *et al.* 1998) of Pelee Island and Middle
533 Island, an affinity for particular habitat types was shown (COSEWIC 2017). However,
534 what knowledge we have for current habitat use is based on a small number of
535 observations during seasonal annual surveys. How Eastern Banded Tigersnails use
536 particular habitat patches, in different seasons, for various biological functions such as
537 feeding and aestivation/hibernation, is unknown. With the lack of information on habitat
538 requirements, it is recommended that the regulated area include sufficient suitable
539 habitat to maintain specific life functions throughout different seasons. In general, snail
540 populations are typically made up of several hundred individuals heterogeneously
541 distributed over a habitat patch. Using a contiguous ecological area to define habitat
542 increases the probability that all habitat elements necessary for foraging, mating and
543 nesting, aestivating and hibernating are included. It is therefore recommended that all
544 entire Ecological Land Classification (ELC) ecosites polygons occupied by an extant
545 subpopulation of Eastern Banded Tigersnails be prescribed as habitat in a habitat
546 regulation.

547 The habitat in which the species is found has substantial leaf litter, decaying logs, and
548 humus-rich soil, all of which provide moist microhabitat sites for hibernation, aestivation
549 and egg-laying. A buffer around the ELC ecosite polygon will help maintain the
550 important microhabitat properties required by the Eastern Banded Tigersnail. Therefore,
551 it is further recommended that a buffer of 50 m be added to the ELC ecosite polygons to
552 account for the dispersal of snails into neighbouring habitat, to reduce edge effects, and
553 to maintain important microhabitat properties. Without an understanding of how Eastern
554 Banded Tigersnails use different habitat patches at different times of year, the
555 importance of neighbouring habitat remains unclear. A 50 m buffer of suitable habitat
556 around the ELC ecosites polygons takes into account the furthest net dispersal distance
557 measured (32 m) in similar sized terrestrial snail species (Edworthy *et al.* 2012), along
558 with ensuring the protection of habitat that may be used by snails at different times of
559 year. Habitat known to be unsuitable (e.g., roads, lakes) for Eastern Banded Tigersnails
560 should be excluded from this buffer. Farmland is in general unsuitable habitat for the

561 snail, but agricultural effluents and herbicides have been shown to alter snail population
562 dynamics by affecting reproduction (Druart et al. 2011) and increasing mortality
563 (Koprivnikar and Walker 2011). Transforming farmland into a filtering buffer, like
564 hedgerows, grass strips, and poly-cultures without chemical inputs, around the ELC
565 ecosite polygon could help reduce the impacts of effluents and herbicides used in
566 nearby habitats on Eastern Banded Tigersnails.

567 Information on the spatial limits of habitat used by Eastern Banded Tigersnails is
568 lacking. When new information on home range size, dispersal ability and key habitat
569 features critical for supporting the species lifecycle become available, the area
570 prescribed as habitat should be revised and updated.

571 **Glossary**

572 Aestivation: A period of deep and prolonged sleep, or torpor, that occurs in the summer
573 or dry season in response to heat and drought.

574 Committee on the Status of Endangered Wildlife in Canada (COSEWIC): The
575 committee established under section 14 of the Species at Risk Act that is
576 responsible for assessing and classifying species at risk in Canada.

577 Committee on the Status of Species at Risk in Ontario (COSSARO): The committee
578 established under section 3 of the *Endangered Species Act, 2007* that is
579 responsible for assessing and classifying species at risk in Ontario.

580 Conservation status rank: A rank assigned to a species or ecological community that
581 primarily conveys the degree of rarity of the species or community at the global
582 (G), national (N) or subnational (S) level. These ranks, termed G-rank, N-rank
583 and S-rank, are not legal designations. Ranks are determined by NatureServe
584 and, in the case of Ontario's S-rank, by Ontario's Natural Heritage Information
585 Centre. The conservation status of a species or ecosystem is designated by a
586 number from 1 to 5, preceded by the letter G, N or S reflecting the appropriate
587 geographic scale of the assessment. The numbers mean the following:

- 588 1 = critically imperilled
- 589 2 = imperilled
- 590 3 = vulnerable
- 591 4 = apparently secure
- 592 5 = secure
- 593 NR = not yet ranked

594 *Endangered Species Act, 2007* (ESA): The provincial legislation that provides protection
595 to species at risk in Ontario.

596 *Species at Risk Act* (SARA): The federal legislation that provides protection to species
597 at risk in Canada. This act establishes Schedule 1 as the legal list of wildlife
598 species at risk. Schedules 2 and 3 contain lists of species that at the time the Act
599 came into force needed to be reassessed. After species on Schedule 2 and 3 are
600 reassessed and found to be at risk, they undergo the SARA listing process to be
601 included in Schedule 1.

602 Species at Risk in Ontario (SARO) List: The regulation made under section 7 of the
603 *Endangered Species Act, 2007* that provides the official status classification of
604 species at risk in Ontario. This list was first published in 2004 as a policy and
605 became a regulation in 2008.

606 **List of abbreviations**

- 607 COSEWIC: Committee on the Status of Endangered Wildlife in Canada
608 COSSARO: Committee on the Status of Species at Risk in Ontario
609 ELC: Ecological Land Classification
610 ERCA: Essex Region Conservation Authority
611 ESA: Ontario's *Endangered Species Act, 2007*
612 ISBN: International Standard Book Number
613 MECP: Ministry of the Environment, Conservation and Parks
614 NCC: Nature Conservancy of Canada
615 SARA: Canada's *Species at Risk Act*
616 SARO List: Species at Risk in Ontario List

617 **References**

- 618 Ahlstrom, E.H. 1930. Mollusks collected in Bass Island region, Lake Erie. *Nautilus*
619 44:44-48.
- 620 Ansart, A., and P. Vernon. 2003. Cold hardiness in molluscs. *Acta Oecologica* 24:95-
621 102.
- 622 Augspurger, C.K. 2013. Reconstructing patterns of temperature, phenology, and frost
623 damage over 124 years: spring damage risk is increasing. *Ecology* 94:41-50.
- 624 Barker, G.M. 2001. *The Biology of Terrestrial Molluscs*. CABI Publishing, New York.
625 558 pp.
- 626 Baur, A., and B. Baur. 1990a. Are roads barriers to dispersal in the land snail *Arianta*
627 *arbustorum*? *Canadian Journal of Zoology* 68:613-617.
- 628 Baur, B., and A. Baur. 1990b. Experimental evidence for intra- and interspecific
629 competition in two species of rock-dwelling land snails. *Journal of Animal Ecology*
630 59: 301-315.
- 631 Bellido, A. 1987. Field Experiment about direct effect of a heathland prescribed fire on
632 microarthropod community. *Revue d'Ecologie et de Biologie du Sol* 24:603-633.
- 633 Blinn, W.C. 1963. Ecology of the land snails *Mesodon thyroideus* and *Allogona profunda*.
634 *Ecology* 44:498-505.
- 635 Boutin, C., T. Dobbie, D. Carpenter, and C.E. Hebert. 2011. Effects of Double-crested
636 Cormorants (*Phalacrocorax auritus* Less.) on island vegetation, seedbank, and
637 soil chemistry: Evaluating island restoration potential. *Restoration Ecology*
638 19(6):720-727.
- 639 Burch, J.B., and T.A. Pearce. 1990. Terrestrial gastropods. Pp. 201-309, in D. L. Dindal
640 (ed.). *Soil Biology Guide*. John Wiley and Sons, New York.
- 641 Campbell, S.P., J.L. Frair, J.P. Gibbs and R. Rundell, 2014. Coexistence of the
642 endangered, endemic Chittenango Ovate Amber Snail (*Novisuccinea*
643 *chittenangoensis*) and a non-native competitor. *Biological Invasions* 17(2):711-
644 723.
- 645 Catling, P.M., G. Mitrow, and A. Ward. 2015. Major invasive alien plants of natural
646 habitats in Canada. 12. Garlic Mustard, *Alliaria officinale*: *Alliaria petiolata* (M.
647 Bieberstein) Cavara & Grande. *CBA/ABC Bulletin* 48(2):51-60.
- 648 CESCC (Canadian Endangered Species Conservation Council). 2016. *Wild Species*
649 2015: The General Status of Species in Canada. National General Status
650 Working Group: 128 pp.
- 651 Clapp, G.H. 1916. Notes on the land shells of the islands at the western end of Lake
652 Erie and description of new varieties. *Annals of the Carnegie Museum* 10:532-
653 540.

- 654 COSEWIC. 2017. COSEWIC assessment and status report on the Eastern Banded
655 Tigersnail *Anguispira kochi kochi* and the Western Banded Tigersnail *Anguispira*
656 *kochi occidentalis* in Canada. Committee on the Status of Endangered Wildlife in
657 Canada. Ottawa. xv + 82 pp.
- 658 Dobbie, T., and J. Kehoe. 2008. Point Pelee National Park of Canada. Middle Island
659 Conservation Plan 2008-2012. Parks Canada, Leamington, Ontario. 44 pp.
- 660 Drouin, M., R. Bradley, and L. Lapointe. 2016. Linkage between exotic earthworms,
661 understory vegetation and soil properties in sugar maple forests. *Forest Ecology*
662 *and Management* 364:113-121.
- 663 Druart, C., M. Millet, R. Scheifler, O. Delhomme, and A. de Vaufleury. 2011. Glyphosate
664 and glufosinate-based herbicides: fate in soil, transfer to, and effects on land
665 snails. *Journal of Soil Sediments* 11:1373-1384.
- 666 Edworthy, A.B., K.M.M. Steensma, H.M. Zandberg, and P.L. Lilley. 2012. Dispersal,
667 home-range size, and habitat use of an endangered land snail, the Oregon
668 forestsnail (*Allogona townsendiana*). *Canadian Journal of Zoology* 90(7):875-
669 884.
- 670 Forsyth, R.G., P. Catling, B. Kostiuk, S. McKay-Kuja, A. Kuja. 2016. Pre-settlement
671 Snail Fauna on the Sandbanks Baymouth Bar, Lake Ontario, Compared with
672 Nearby Contemporary Faunas. *Canadian Field-Naturalist* 130(2):152-157.
- 673 Goodrich, C. 1916. A trip to the islands in Lake Erie. *Annals of the Carnegie Museum*
674 10:527-531.
- 675 Grimm, F.W., R.G. Forsyth, F.W. Schueler, and A. Karstad. 2010. Identifying Land
676 Snails and Slugs in Canada: Introduced Species and Native Genera. Canadian
677 Food Inspection Agency, Ottawa, Ontario. 168 pp.
- 678 Guillaumet, A., B.S. Dorr, G. Wang, and T.J. Doyle. 2014. The cumulative effects of
679 management on the population dynamics of the Double-crested Cormorant
680 *Phalacrocorax auritus* in the Great Lakes. *IBIS* 156:141-152.
- 681 Hotopp, K.P. 2002. Land snails and soil calcium in central Appalachian mountain forest.
682 *Southeastern Naturalist* 1(1):27-44.
- 683 Hubricht, L. 1985. The distributions of the native land mollusks of the Eastern United
684 States. *Fieldiana Zoology* 24:47-171.
- 685 Kawakami, K., S. Wada, and S. Chiba. 2008. Possible dispersal of land snails by birds.
686 *Ornithological Science* 7:167-171.
- 687 Kimura, K., and S. Chiba. 2010. Interspecific interference competition alters habitat use
688 patterns in two species of land snails. *Evolutionary Ecology* 24:815-825.
- 689 Knapp, E.E., B.L. Estes, and C.N. Skinner. 2009. Ecological effects of prescribed fire
690 season: A literature review and synthesis for managers. USDA General
691 Technical Report. Albany, California. 80 pp.

- 692 Koprivnikar, J., and P.A. Walker. 2011. Effects of the herbicide Atrazine's metabolites
693 on host snail mortality and production of trematode cercariae. *Journal of*
694 *Parasitology* 97(5):822-827.
- 695 Meadows, D.W. 2002. The effects of roads and trails on movement of the Odgen Rocky
696 Mountain snail (*Oreohelix peripherica wasatchnesis*). *Western North American*
697 *Naturalist* 62:377-380.
- 698 NatureServe. 2018. NatureServe Explorer: An online encyclopedia of life [web
699 application]. Version 7.1. NatureServe, Arlington, Virginia. Available
700 <http://explorer.natureserve.org>. (Accessed: November 5, 2018).
- 701 NCC (Nature Conservancy of Canada). 2008. Management Guidelines: Pelee Island
702 Alvars. NCC – Southwestern Ontario Region, London, Ontario. 43 pp.
- 703 Nekola, J.C. 2002. Effects of fire management on the richness and abundance of
704 central North American grassland land snail faunas. *Animal Biodiversity and*
705 *Conservation* 25(2):53-66.
- 706 Nicolai, A., J. Filser, R. Lenz, C. Bertrand, and M. Charrier. 2011. Adjustment of
707 metabolite composition in the haemolymph to seasonal variations in the land
708 snail *Helix pomatia*. *Journal of Comparative Physiology B* 181:457-466.
- 709 Nicolai, A., P. Vernon, R. Lenz, J. Le Lannic, V. Briand, and M. Charrier. 2013. Well
710 wrapped eggs: Effects of egg shell structure on heat resistance and hatchling
711 mass in the invasive land snail *Cornu aspersum*. *Journal of Experimental*
712 *Zoology A* 319:63-73.
- 713 Nicolai, A., and A. Ansart. 2017. Conservation at a slow pace: Terrestrial gastropods
714 facing fast changing climate. *Conservation Physiology* 5(1):007, doi:
715 10.1093/conphys/cox007.
- 716 Norden, A.W. 2010. Invasive earthworms: a threat to eastern North American forest
717 snails? *Tentacle* 18:29-30.
- 718 North – South Environmental Inc. 2004. Vegetation Communities and Significant
719 Vascular Plant Species of Middle Island, Lake Erie. Research Report of Point
720 Pelee National Park of Canada. 97 pp.
- 721 Ontario Parks. 2005. Fish Point and Lighthouse Point. Park Management Plan of
722 Wheatley Provincial Park, Wheatley, Ontario. 27 pp.
- 723 Pearce, T.A. 1990. Spooling and line technique for tracing field movements of terrestrial
724 snails. *Walkerana* 4(12):307-316.
- 725 Pilsbry, H.A. 1948. Land Mollusca of North America (North of Mexico). Volume 2, Part
726 2. Academy of Natural Sciences of Philadelphia, Monograph 3:i-xxvii + 521-1113.
- 727 Qiu, J., and M.G. Turner. 2017. Effects of non-native Asian earthworm invasion on
728 temperate forest and prairie soils in the Midwestern US. *Biological Invasions*
729 19:73-88.

- 730 Sandilands, A. 2005. Birds of Ontario. Birds of Ontario: Habitat Requirements, Limiting
731 Factors, and Status. Volume 1. Nonpasserines: Waterfowl through Cranes.
732 University of British Columbia Press. Vancouver, British Columbia. 365 pp.
- 733 Thorndyke, R., and T. Dobbie. 2013. Point Pelee National Park of Canada. Report on
734 research and monitoring for year 5 (2012) of the Middle Island Conservation
735 Plan. Parks Canada, Leamington, Ontario. 34 pp.
- 736 Vagvolgyi, J. 1975. Body size, aerial dispersal, and origin of pacific land snail fauna.
737 Systematic Zoology 24:465-488.
- 738 Varrin, R., J. Bowman, and P.A. Gray. 2007. The known and potential effects of climate
739 change on biodiversity in Ontario's terrestrial ecosystems: Case studies and
740 recommendations for adaptation. Climate Change Research Report CCRR-09.
741 Ontario Ministry of Natural Resources and Forestry. Queen's Printer for Ontario,
742 Toronto. 47. 1379 pp.
- 743 Viard, B., F. Pihan, S. Promeyrat, and S.J-C. Pihan. 2004. Integrated assessment of
744 heavy metal (Pb, Zn, Cd) highway pollution: bioaccumulation in soil,
745 Graminaceae and land snails. Chemosphere 55:1349-1359.
- 746 Wäreborn, I. 1979. Reproduction of two species of land snails in relation to calcium salts
747 in the foerna layer. Malacologia 18:177-180.
- 748 Whitson, M. 2005. *Cepaea nemoralis* (Gastropoda, Helicidae): The invited invader.
749 Journal of the Kentucky Academy of Science 66:82-88.
- 750 Wirth, T., P. Oggier, and B. Baur. 1999. Effect of road width on dispersal and population
751 genetic structure in the land snail *Helicella itala*. Journal of Nature Conservation
752 8:23-29.

753 **Personal communications**

- 754 Forsyth, R.G. 2017-2018. Meetings with A. Nicolai. August-September 2017 and 2018.
755 Taxonomist. Research Associate. New Brunswick Museum, St. John, New
756 Brunswick.
- 757 Horrigan, E. 2018. Email correspondence to A. Nicolai. September 2018. Ecologist.
758 Prescribed Burn Project Manager. Ontario Nature, Toronto, Ontario.