COSEWIC
Assessment and Status Report

on the

Shagreen
Inflectarius inflectus

in Canada


ENDANGERED
2019

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. 2019. COSEWIC assessment and status report on the Shagreen *Inflectarius inflectus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 51 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html).

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

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur L'escargot galuchat (*Inflectarius inflectus*) au Canada.

Cover illustration/photo:
Shagreen — Photo by Annegret Nicolai, Middle Island, 1 May 2013.

Catalogue No. CW69-14/790-2020E-PDF
ISBN 978-0-660-35191-9

COSEWIC
Assessment Summary

Assessment Summary – November 2019

Common name
Shagreen

Scientific name
Inflectarius inflectus

Status
Endangered

Reason for designation
This medium-sized terrestrial snail occurs in the Carolinian zone of southwestern Ontario, where it exists near the northern extremity of its global range. Historically, it was known from two sites in mainland Ontario and five islands in Lake Erie. It is currently known to persist only on two islands, where it inhabits rocky or open woods and can be found clustering under logs or rocks, and in leaf litter. Suitable Canadian habitat has experienced historical loss and degradation, and continuing habitat fragmentation is problematic for this species due to its low dispersal ability. The species is threatened by climate change (extreme temperatures, droughts, and flooding), prescribed burns, and invasive species.

Occurrence
Ontario

Status history
Designated Endangered in November 2019.

COSEWIC
Executive Summary

Shagreen
Inflectarius inflectus

Wildlife Species Description and Significance

Shagreen is a medium-sized land snail (adult shell width about 1 cm) with a shell that is imperforate (no hole in middle of shell where whorls come together), depressed, and yellow to brown in colour, with three tooth-like denticles in the shell opening. This species is part of the unique fauna of the Carolinian Forest in Canada and has significance for ecosystem functioning through nutrient cycling. The range edge population in Canada is important for the global conservation of this species.

Distribution

Shagreen's global distribution extends from southern Ontario, Michigan, and New York southward to Florida in the east and Texas in the west. In Canada, the species is still extant in Essex County on two Lake Erie islands: Middle and Pelee. The species appears to have been extirpated from southwestern Ontario mainland sites and two other islands in Lake Erie.

Habitat

Shagreen inhabits rocky or open woods and can be found clustered under logs, rocks, and in the leaf litter. The habitat at all sites is surrounded by unsuitable arable land or water. There is in total about 480 ha of protected habitat on Pelee and Middle islands.

Biology

Shagreen is an egg-laying land snail. Reproduction probably occurs in spring and late-summer. Hibernation extends from early October until April in temperate regions. Aestivation in summer may occur only during prolonged drought / heat waves. Sexual maturity may be reached at 1 year and individuals may live 2-3 years. The species may mainly feed on decaying wood or fungi in forest floor litter. Active dispersal for colonization of new areas is extremely slow, because the species stays confined to sheltering micro-habitat (logs, rocks). Passive dispersal by flooding of rivers or transportation by birds is possible but has not been documented. There is no evidence of transportation by humans.

Population Sizes and Trends

The species seems to be extirpated from six historical occurrences; the status at three additional sites is uncertain, because they are privately owned and were not searched. Measured density of the species may be extremely low, <0.1 mature individuals/m^2, because it lives in colonies under big logs. Total population size is unknown.

Threats and Limiting Factors

Low dispersal ability and low physiological resistance to fluctuating environmental factors such as temperature and humidity are limiting factors. The main threats for Shagreen are climate change (droughts, changes in frost regimes), prescribed burns, and habitat modifications due to invasive species such as earthworms which are destroying the leaf litter, and Double-crested Cormorants which are changing litter conditions.

Protection, Status and Ranks

Shagreen has no legal designations. It is ranked as globally secure and nationally secure in the US but critically imperilled in Canada and Ontario.

TECHNICAL SUMMARY

Inflectarius inflectus

Shagreen

Escargot galuchat

Range of occurrence in Canada: 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)	~2 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes (observed historical decline due to reduction in number of occupied sites; continuing decline inferred from continuing threats)
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations, whichever is longer up to a maximum of 100 years]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations, whichever is longer up to a maximum of 100 years] including both the past and the future.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. No b. Yes c. No
Are there extreme fluctuations in number of mature individuals?	Unknown

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	41 km^2
Index of area of occupancy (IAO) (Always report 2x2 grid value).	32 km^2

Is the population "severely fragmented" i.e., is >50% of its total area of occupancy is in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. Yes
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	1-6 (based on different threat combinations)
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes, historical decline
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes, historical decline
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes, historical decline
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Yes, historical decline
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes (historical habitat loss/degradation; projected continuing decline due to threats)
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Pelee Island (due to distance and dispersal barriers, there could be five subpopulations on Pelee Island)	Unknown
Middle Island	Unknown
Entire range	Unknown

Quantitative Analysis

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

* 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 (formal threats teleconference 26 October 2018) Overall threat impact: High-Low Threat 11: Climate Change and Extreme Weather (HIGH-LOW impact) Threat 9: Pollution (UNKNOWN impact) Threat 8: Invasive & other problematic species & genes (UNKNOWN impact) Threat 7: Natural system modifications (LOW impact) Threat 4: Transportation & service corridors (NEGLIGIBLE impact) Threat 6: Human intrusions & disturbance (NEGLIGIBLE impact) What additional limiting factors are relevant? Low dispersal or migration capacity, low resistance to fluctuating environmental conditions

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Pennsylvania (S2), Ohio (SNR), Michigan (SNR). Note: New York, Maryland, Wisconsin, and Iowa are not included in NatureServe ranking but there are records for these states.
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?*	Unknown but probably
Are conditions for the source population (i.e., outside) deteriorating?*	Unknown
Is the Canadian population considered to be a sink?*	Unknown
Is rescue from outside populations likely?	No

Data Sensitive Species

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

Status History

COSEWIC: Designated Endangered in November 2019.

*See https://www.canada.ca/en/environment-climate-change/services/committee-status-endangered-wildlife/wildlife-species-assessment-process-categories-guidelines/modifications-rescue-effect.html (Guidelines for modifying status assessment based on rescue effect)

Status and Reasons for Designation

Status:	**Alpha-numeric codes:**
Endangered	B1ab(iii)+2ab(iii)

Reasons for designation:
This medium-sized terrestrial snail occurs in the Carolinian zone of southwestern Ontario, where it exists near the northern extremity of its global range. Historically, it was known from two sites in mainland Ontario and five islands in Lake Erie. It is currently known to persist only on two islands, where it inhabits rocky or open woods and can be found clustering under logs or rocks, and in leaf litter. Suitable Canadian habitat has experienced historical loss and degradation, and continuing habitat fragmentation is problematic for this species due to its low dispersal ability. The species is threatened by climate change (extreme temperatures, droughts, and flooding), prescribed burns, and invasive species.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Insufficient data to reliably infer, project, or suspect population reduction.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1ab(iii)+2ab(iii). The EOO (41 km^2), and IAO (32 km^2) are both below the thresholds (<5,000 km^2 and <500 km^2, respectively), the number of locations ranges from 1 to 6, but most likely the population exists at 5 or fewer locations, and is experiencing a continuing projected decline in the extent and quality of habitat.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Number of mature individuals is unknown.
Criterion D (Very Small or Restricted Population): D1 is not applicable because the number of individuals is unknown. Threatened, D2, may be applicable because the number of locations ranges from 1 to 6, but most likely the population exists below or near the typical threshold (5 or fewer) and the species is prone to the effects of human activities and stochastic events and could become critically endangered or extirpated within one or two generations.
Criterion E (Quantitative Analysis): Not applicable. Analysis not conducted.

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 (2019)

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
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Canada

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

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TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

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

Common English name: Shagreen
Common French name: Escargot galuchat

Originally recognized as *Helix inflecta* by Say in 1821, the species was also assigned to the genus *Triodopsis* by Binney in 1878 and *Polygyra* by Pilsbry in 1900 (Pilsbry 1940). Pilsbry (1940) recognized the species as *Mesodon inflectus* in a new subgenus *Inflectarius* which is currently accepted as a genus by Turgeon *et al.* (1998).

There are 11 species in the genus *Inflectarius*, but *I. inflectus* is the only one with a range extending to Canada. One species of this genus, Magazine Mountain Shagreen (*I. magazinensis*), is endemic to the Magazine Mountains in Arkansas (Caldwell *et al.* 2014) and listed as Critically Endangered on the IUCN Red List (Mollusc Specialist Group 2000).

Morphological Description

Shagreen is a distinctive, medium-sized land snail with adult size 8-14 mm (measured as maximum shell breadth) with a cream-buff or yellow to brown coloured, imperforate (i.e., no hole in middle of shell where whorls come together), depressed shell (Pilsbry 1940). The shell surface is slightly striate (shallow grooves), with granules and a scaly periostracum (outer shell layer), which may be the reason for the common name. The scales appear like hairs in juveniles (Figure 1), but lose this appearance in adults. The lip at the shell opening (i.e., aperture, where the body retreats into the shell) is reflected, forming a gutter at its base. Three tooth-like denticles are visible in the aperture: one long, slightly curved tooth on the upper wall, a tooth at the basal lip, and a blunt, slightly receding tooth at the outer arc of the opening (see photo on front cover). The animal is dark grey (Figure 1), but rarely extends out of its shell.

Figure 1. Juvenile Shagreen (*Inflectarius inflectus*) on Middle Island, Point Pelee National Park, 15 September 2017. The scaly periostracum resembles short hairs and the shell is still perforate. (Photo by Tarra Degazio.)

Population Spatial Structure and Variability

Excluding the one occurrence where Shagreen is probably extirpated (North Harbour Island; Table 1), at least two subpopulations currently exist: Middle and Pelee islands in Lake Erie. Given distances and barriers to dispersal, more than one subpopulation could occur on Pelee Island; however, genetic differences are expected between the two islands because there is probably no gene flow and dispersal over open water (see **Dispersal and Migration**). The Middle Island subpopulation is separated by approximately 5 km of open water from the snails on Pelee 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).

Table 1. Collections of Shagreen (*Inflectarius inflectus*) from Ontario and verification of all sites during fieldwork in 2013-2018. See Abundance, Fluctuations and Trends for numbers observed during 2013-2018 surveys. No other Canadian collections are known and these are curated by the Carnegie Museum (CMNH), and by R.G. Forsyth (RGF and ANiD). Record numbers from the Natural Heritage Information Centre of Ontario (NHIC) refer to specimens in personal collections.

County/Island	Site	First Record	Last record	Collectors or literature	Occurrence status based on 2013-2018 surveys
North Harbour Island		1915	1915	B. Walker, C. Goodrich, G.H. Clapp (CMNH81267)	No access. Natural habitat not available. Status uncertain but probably extirpated.
Middle Sister Island		1916	1916	Goodrich (1916)	Historical, extirpated
East Sister Island		1915	1915	B. Walker, C. Goodrich, G.H. Clapp (CMNH81264)	Historical, extirpated
Middle Island		1915, B. Walker, C. Goodrich, G.H. Clapp (CMNH81268)	2017	T. Dobbie, T. Degazio (2013: M.J. Oldham BIOUG15234-B10, -B11)	Extant
Pelee Island (first record in 1919 by C. Goodrich without locality, CMNH81559)	Winery Woods (WW)	1995, M.J. Oldham (NHIC168439206)	2013	A. Nicolai, M.J. Oldham (ANiD014)	Extant
	Richard & Beryl Ivey Property (RBIP), NCC	2010, M.J. Oldham, S.R. Brinker	2013	A. Nicolai, M. Oldham (ANiD015)	Extant
	Stone Road Alvar (SRA) – NCC	1994, M.J. Oldham, B. Porchuk (NHIC168439208)	2017	A. Nicolai (2013: NHIC 170498623, ANiD010)	Extant
	Stone Road Alvar (SRA) – ONature	2010	2010	M.J. Oldham, S.R. Brinker (NHIC170017456)	Extant
	Florian Diamante Nature Reserve (FDNR), NCC	2013 A.G. Harris, R. Foster (BIOUG09921-A02, -A04)	2018	A. Nicolai, V. Briand	Extant
	Gibwood (GW), NCC	2013	2013	A. Nicolai, M. Oldham (NHIC170498624, ANiD008)	Extant
	Sheridan Point (SP)	1995, M.J. Oldham, B. Porchuk (NHIC168439207)	2017	A. Nicolai (RGF # not assigned yet)	Extant
	Lighthouse Point (LP), Verbeek Savannah	1995	1995	M.J. Oldham (NHIC168439209)	Historical, extirpated

County/Island	Site	First Record	Last record	Collectors or literature	Occurrence status based on 2013-2018 surveys
	Fish Point (FP)	1994	1994	M.J. Oldham (NHIC168439211)	Historical, extirpated
	Girl Guide Camp Woods	1994	1994	M.J. Oldham, B. Porchuk (NHIC 53816, 53817)	Uncertain; no access
	Campground	1995	1995	M.J. Oldham (NHIC168439210)	Uncertain; no access
Essex Co.	Point Pelee National Park	No date	No date	COSEWIC (2014a)	Historical, extirpated
	Oxley	No date	No date	COSEWIC (2014a)	Historical, extirpated

A genetic study by A. Nicolai of barcodes is in progress at the Biodiversity Institute of Ontario (BIO, Guelph, Ontario). DNA barcoding uses 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 Middle and Pelee islands in 2013 (two from Middle Island and two from the Florian Diamante Nature Reserve [FDNR] on Pelee Island) and processed at BIO 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 intra-island similarities in COI gene sequences for the two specimens from Pelee Island and the two from Middle Island are very high (similarity > 99.9%), but that the inter-island dissimilarity is 12.66 ± 0.01%. All specimens from Pelee Island were assigned to one BIN in the Barcode of Life Database (BOLD; Ratnasingham and Hebert 2007): ACL2322, while specimens from Middle Island were assigned to another BIN: ACP8279 . These preliminary results show a substantial genetic distance between the subpopulations on Pelee and Middle islands. Similarly, COI sequences obtained from different subpopulations in Tennessee, Alabama, North Carolina, and Georgia showed a high within-species variation and high morphological variability within and between species of the genus *Inflectarius* (Perez *et al.* 2014). For this genus, COI is not useful in distinguishing species given that a 12% difference is typically sufficient to distinguish genera and *I. inflectus* is not monophyletic.

Designatable Units

Designatable units (DUs) of a species are recognized if there is both discreteness and evolutionary significance; however, neither are found for Shagreen. Specifically, there is a lack of sufficient evidence of genetic distinctiveness which could also be evolutionarily significant. While the 5 km of water body between Middle and Pelee islands probably prevents gene flow (see **Dispersal and Migration**) and the preliminary barcoding placed the specimens from the two islands in different BINs, this level of genetic dissimilarity appears to be common for this genus (see **Population Spatial Structure and Variability**; Perez *et al.* 2014). In addition, both islands occur in the Great Lake Plains COSEWIC National Ecological Area and there is no evidence of local adaptation caused by this natural disjunction. A single DU is therefore recognized in Canada.

Special Significance

In Canada, Shagreen was historically and is currently confined to the Carolinian Forest Region, near the northern limit of its global range. As shown by Fraser (2000), range-edge populations can have significance for genetic diversity, long-term survival, and evolution of the species, and provide opportunities for human recreation activities (e.g., recreational wildlife observations, in this case, snail watching).

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

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

DISTRIBUTION

Global Range

Shagreen is distributed across eastern North America. The northern limit is southern Ontario, Michigan, and New York. The east-west distribution in the US is from Pennsylvania to Kansas in the north and from Florida to Texas in the south (Figure 2). Robertson and Blakeslee (1948) cite two records from New York where they noticed it being very rare. A record from 2007, Nassau Co. (CMNH 86221) and one from 1901, Hamilton Co. (CMNH 81260) in the Carnegie Museum prove the existence of Shagreen in New York State. Furthermore, the Carnegie Museum also has a record for Maryland, Anne Arundel Co. from 1981 (CMNH81129). Additionally, there is one undated record in the National Museum of Natural History for Iowa without an exact site reference (USNM 132978) and one for Wisconsin (USNM 27695). New York, Maryland, Wisconsin, and Iowa are not included in the distribution according to NatureServe (2019). The Carnegie Museum has also an undated record from the Bahamas (CMNH 62.739). See **Non-Legal Status and Ranks** for the detailed list of US states where the species was known to occur.

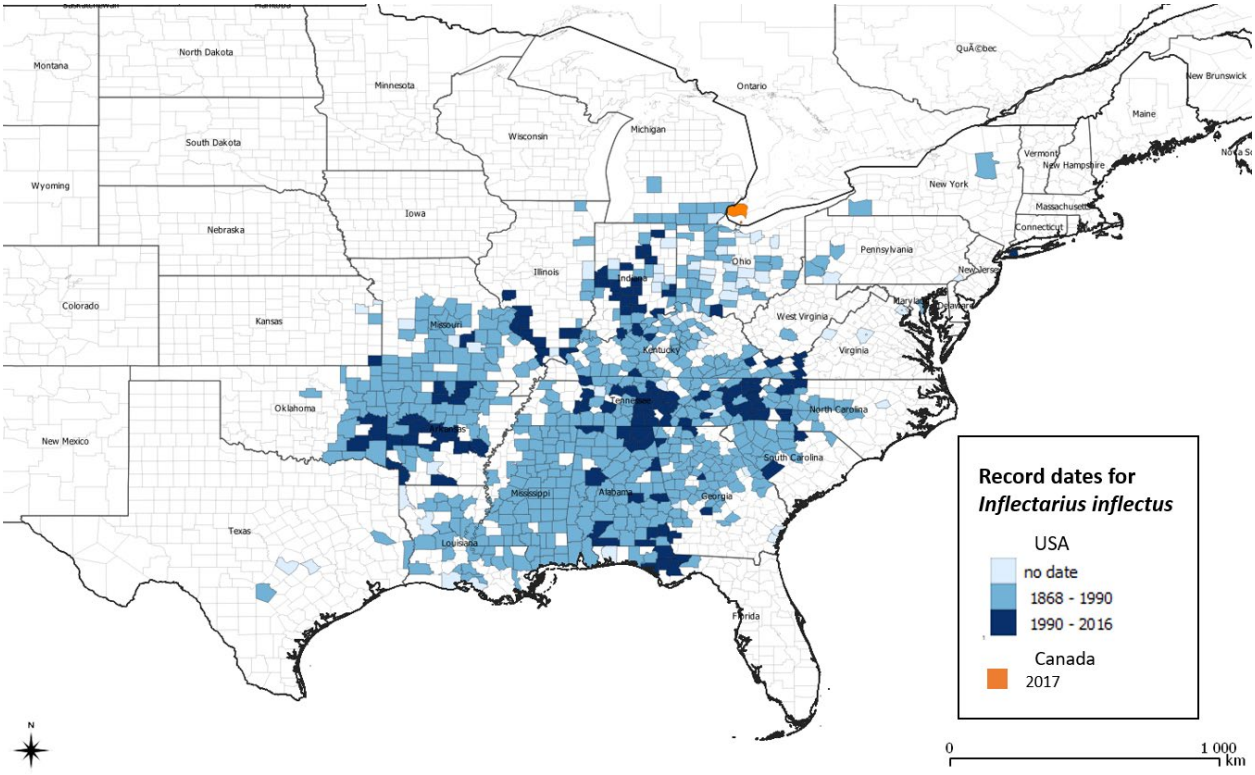

Figure 2. Global distribution of Shagreen (*Inflectarius inflectus*). Canadian county in orange (refer to Figure 3 for exact possible distribution) and US counties in variations of blue following the date of the record (from no date and 1868 to 2016). Note that the species does not occur in the entire county. Occurrences per county are based on the most recent records in collections (see Collections Examined) and literature (Robertson and Blakeslee 1948; Hodges 2016).

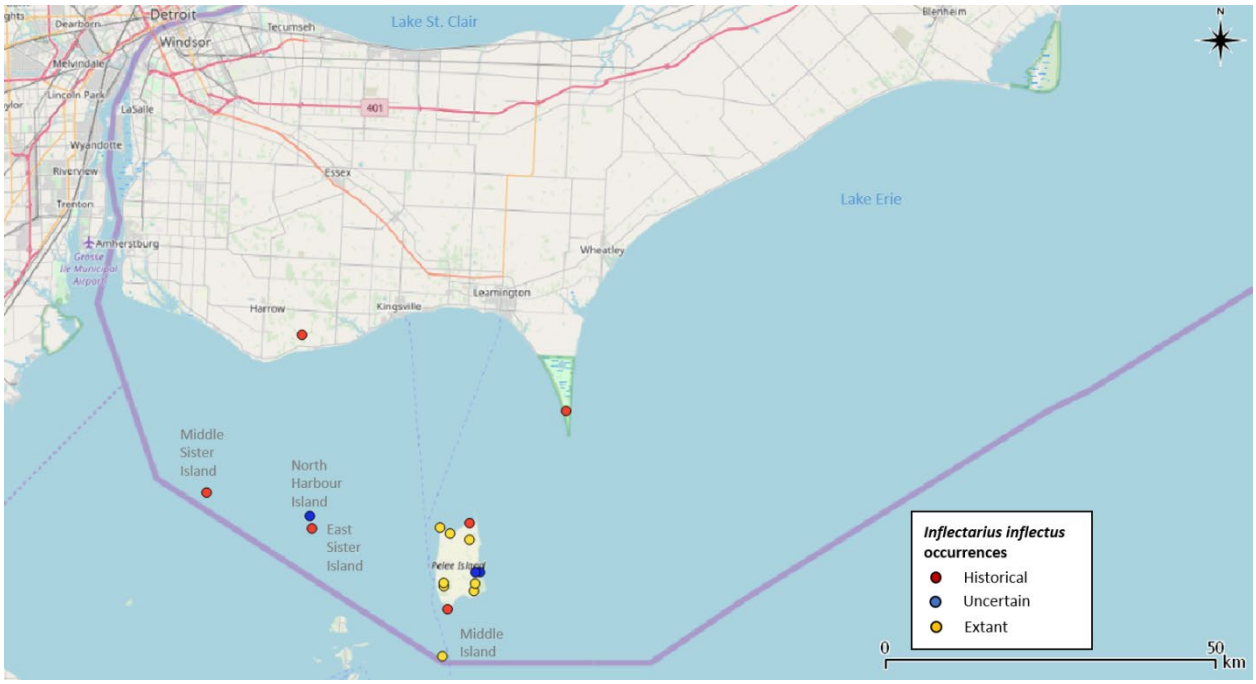

Figure 3. Canadian distribution of Shagreen (*Inflectarius inflectus*) in Ontario based on records compiled for this report. "Uncertain" means the presence of the species is unknown, because habitat was not accessible (private land). "Extant" means that shells or live individuals have been found in the site within the last 20 years, whereas "Historical" means that only records older than 20 years exist and recent surveys could not confirm the species' presence with shells or live individuals.

Canadian Range

Shagreen is historically known in mainland southwestern Ontario (two sites near Leamington) and from five Lake Erie islands (Table 1, Figure 3). The current range in Ontario includes only two islands, Middle and Pelee. The presence of the species on the privately owned North Harbour Island is uncertain, because access was not granted for field verification. However, habitat seems unsuitable as the island is no longer forested.

On Pelee Island the species has been recorded from seven sites in five areas within the last 20 years:

1. Ontario Nature and Nature Conservancy of Canada (NCC) properties on Stone Road Alvar (SRA),
2. Richard & Beryl Ivey Property (RBIP) of NCC and Winery Woods (WW),
3. Florian Diamante Nature Reserve (FDNR) of NCC,
4. Gibwood (GW) of NCC,
5. Sheridan Point.

The presence of the snail at two more sites on Pelee Island is uncertain (Table 1). They are privately owned and have not been surveyed for snails.

Extent of Occurrence and Area of Occupancy

The current extent of occurrence (EOO), based on records within the last 20 years (Table 1), is 41 km^2. Including historical records, the EOO is 884 km^2. Historical and current EOO, as measured by the minimum convex polygon method on central points of each site, encompass mainly water (Lake Erie) and unsuitable land. The EOO has declined by about 95% within the last 100 years.

Using 2 km x 2 km grid cells, IAO is currently 8 grid cells (32 km^2). If all historical records are included, the IAO is 15 grid cells (60 km^2). There has been a decline in IAO of about 47% within the last 100 years.

Search Effort

Shagreen is a species that lives mostly hidden and clustered under logs. However, empty shells remain on the forest floor for some time after the animals have died (>3 years, Říhová *et al.* 2018) and may indicate its presence.

Notable historical surveys that mention Shagreen include those conducted by John Oughton between about 1930 and 1940 (Oughton 1948), by Grimm between 1970 and the mid-1990s (Grimm 1996), and by Nekola (2003, 2010). Oughton did not find it himself, but cited Goodrich's record (Goodrich 1916). Grimm mainly collected in eastern Ontario but his collection included specimens sent to him by others, including those collected by M.J. Oldham (see next paragraph) up to around 2000. Both Grimm's wet (stored in alcohol) and dry (mostly shells) collection now at the Canadian Museum of Nature have been examined by R.G. Forsyth (R. Forsyth pers. comm. 2019). Nekola's collection is not accessible.

Surveys between 1992 and 2012 were general land snail searches rather than targeted for Shagreen. There are 2,349 geo-referenced collection records from searches by M.J. Oldham between 1992 and 2012. Oldham focused on conservation areas, parks, and other areas of interest, mostly in southeastern Ontario and sent his collection since about 2006 for identification and curation to R.G. Forsyth (R. Forsyth pers. comm. 2019). 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. Since 2014 Parks Canada Agency has surveyed seven plots (2x2 m) on Middle Island in spring and late summer for snails, mainly endangered species.

During the 2013–2018 general gastropod surveys in remnant natural habitats and protected areas in southwest Ontario, 135 localities were searched (in some localities several sites with different habitats were searched) with a total effort of 557 person-hours (Table 2). 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 Biodiversity Institute of Ontario and 200 shell samples of

about 40 species, currently being curated by R. Forsyth. During the 2013 surveys, all historically intact and accessible known sites were visited and voucher specimens deposited at the Biodiversity Institute of Ontario (Table 1). The surveys in 2015-2018 were targeted at species of conservation concern, including Shagreen; therefore, fewer vouchers were collected and deposited.

Table 2. Summary of general gastropod survey sites in southwestern Ontario in 2003-2018. Methods used allow for detection of all sizes of snails and slugs. Observers were Jane Bowles (JMB), Tammy Dobbie (TD1), Tarra Degazio (TD2), Robert Foster (RFF), Allan Harris (AGH), Annegret Nicolai (AN), Michael Oldham (MJO), Robert Forsyth (RGF), Hiroko Udaka (HU), Litza Coello (LC), Dwayne Lepitzki (DL), Suzanne Dufour (SD), Ron Gould (RG), Kara Layton (KL), Mykola Mykow (MM), Paul Catling (PC). CA – Conservation Area, NCC – Nature Conservancy of Canada, TTLT – Thames Talbot Land Trust. (NAD83, 17T or 18T/N UTM). In addition and since 2014, Parks Canada Agency has yearly examined seven 2x2 m plots on Middle Island.

Site	Effort (person-hours)	Observers	Date(s) 2013	Date(s) 2014	Date(s) 2015	Date(s) 2016	Date(s) 2017	Date (s) 2018	I. i. records
Black Oak Heritage Forest, south part, Windsor	14	AN, JMB, MJO	May 3, July 28, Aug 27-28, Sep 5						No
Former industrial area south of Black Oak Heritage Forest, Windsor	3	MJO	Sep 5						No
Black Oak Heritage Forest, north part, Windsor	4	AN, MJO,	Apr 29						No
Devonwood Conservation Area, Windsor	6	AN, MJO, DL, SD, RGF	April 29		Aug 22				No
Springgarden Road Park, Windsor	2	AN, MJO	April 29						No
Ojibway Park, Windsor	5	AN, MJO, JMB	Apr 29, May 3						No
Malden Park, Windsor	2	AN, JMB	May 3						No
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	38	RFF, AN, MJO; AN, TD1, TD2, RG, RGF, 1 park staff, 1 student	May 1; Aug 29		Aug 13		Aug 28		Alive
East Sister Island Provincial Park, Lake Erie	16.5	TD1, RFF, AGH, AN, MJO, RGF, RG, 2 park staff	Apr 30		Aug 13				No
Middle Sister Island, Lake Erie	3.5	TD1, RFF, AGH, AN, MJO	Apr 30						No

Site	Effort (person-hours)	Observers	Date(s) 2013	Date(s) 2014	Date(s) 2015	Date(s) 2016	Date(s) 2017	Date (s) 2018	I. i. records
Lighthouse Point Provincial Nature Reserve, Pelee Island (2 sites)	10	RFF, AN, MJO; AN, RGF	May 1; Aug 25		Aug 12	01 Sep	Aug 14		No
Sheridan Point, Pelee Island	1	AN					Aug 14		Shells
Erie Sand and Gravel NCC parcel, Pelee Island	4.5	AN, MJO, AGH, RGF	May 2		Aug 12				No
Middle Point Woods – north part, NCC, Pelee Island	5.5	AGH, RFF, MJO, AN, RGF	May 2; Aug 25		Aug 14	03 Sep	Aug 17		No
Middle Point Woods – south part, NCC, Pelee Island	8	RFF, AGH, AN, RGF	May 1, 2; Aug 26	Aug 3		03 Sep	Aug 17		No
Middle Point Woods – Novatney, NCC, Pelee Island	3	AN, MJO, RGF	May 2			03 Sep	Aug 17		No
Gibwood Property, NCC, Pelee Island	3	AN, MJO	May 2				Aug 14		Alive
Florian Diamante Nature Reserve, NCC, Pelee Island	11	AGH, RFF, AN, RGF	May 2	Aug 2	Aug 11, 12	02 Sep	Aug 14		Alive
Richard and Beryl Ivey Nature Reserve, NCC, Pelee Island	8	RFF, AGH, AN, RGF	May 1	Aug 2	Aug 12	02 Sep	Aug 16		Shells
Winery property, Pelee Island	6.5	RFF, AGH, AN, MJO, RGF	May 2	Aug 2		31 Aug	Aug 16		Alive
Porchuk Property, NCC, Pelee Island	8	AN, MJO, RGF, AN	May 2			01 Sep	Aug 15		Alive
Fish Point Provincial Nature Reserve, Pelee Island	21	RFF, AGH, AN, RGF	May 1	Aug 3	Aug 11	02 Sep	Aug 16	**Aug 5-6**	No
Fleck Property, Pelee Island	2	RFF, AN	May 2				Aug 15		No
Essex Region Conservation Authority Stone Road Alvar, Pelee Island	5	AGH, AN, RGF	May 2		Aug 11		Aug 16		No
Ontario Nature Stone Road Alvar, Pelee Island	9	AGH; AN, MM, RGF	May 2; Aug 27		Aug 11		Aug 16	**Aug 7-9**	No
NCC Stone Road Alvar, Pelee Island	4	RGF, AN			Aug 11		Aug 16		No
Cohen Shaughnessy Property, NCC, Pelee Island	4.5	AGH; AN, MM	May 2; Aug 27	Aug 3			Aug 15		No
Krestel Parcel, NCC, Pelee Island	5	AGH, AN, RGF	May 1	Aug 3	Aug 11		Aug 15	**Aug 6**	No
Finley Parcel, NCC, Pelee Island	1	AN		Aug 4					No
Fronzier Parcel, NCC, Pelee Island	1	AN, RGF			Aug 12				No
Point Pelee National Park (6 sites)	30	AGH, AN, MJO, RFF, RGF, TD2	Apr 28, 29			30 Aug	Aug 11	**May 11**	No

Site	Effort (person-hours)	Observers	Date(s) 2013	Date(s) 2014	Date(s) 2015	Date(s) 2016	Date(s) 2017	Date (s) 2018	l. i. records
Oxley Swamp, NCC	4	AN, HU	May 20				Aug 12		No
Cedar Creek CA	4	RFF, AGH	April 29				Aug 13		No
Kopegaron Woods CA	5	RFF, AGH, AN, MJO	Apr 29, 30				Aug 12		No
Two Creeks CA	3	MJO	May 18				Aug 13		No
Andrew Murray O'Neil Memorial Woods	1	AN					Aug 13		No
Canard River CA	2	AN, MJO	April 29						No
Canard River Scout Camp (former)	3	AN, RGF				29 Aug			No
For the Birds (East of Gore Rd, Road 13)	1	AN, RGF				29 Aug			No
Maidstone CA	2	RFF, AGH	April 29						No
Rondeau Provincial Park	6.5	MJO, JMB; AGH	May 17; Sep 4						No
Wheatley Provincial Park	3	AN					Aug 12		No
Sinclair's Bush	2	MJO, JMB	May 17						No
Thames Grove CA	1	AN, JMB	May 3						No
Moraviantown First Nation (2 sites)	9	AN, JMB	June 7						No
John E. Pearce Provincial Park	2	MJO	May 15						No
Newport Forest, TTLT	3	AN; AN, HU	April 21; Sep 01						No
Wardsville Woods TTLT	1	JMB	May 17						No
Backus Woods, NCC, Norfolk Co	6	MJO; AGH	May 15; Sep 2				Aug 9		No
Lake Erie Farms, NCC, Norfolk Co	2	AN					Aug 9		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	7	JMB, MJO; AGH; AN, LC, RGF	May 16, Aug 3; Sep 22			28 Aug			No
Tremblay Beach CA	1	AN, RGF				29 Aug			No
Ruscom Shores CA	1	AN, RGF				29 Aug			No

Site	Effort (person-hours)	Observers	Date(s) 2013	Date(s) 2014	Date(s) 2015	Date(s) 2016	Date(s) 2017	Date (s) 2018	l. i. records
Killaly Meadows, London	1	AN	May 4						No
Lambton United Church Camp	2	AGH	Aug 3						No
Highland Glen CA	1	AGH	Aug 3						No
Joany's Woods TTLT	1	AN, JMB	April 1					**Aug 44**	No
Port Franks	2	AGH	Aug 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	4	AN, LC, RGF	Sep 22			28 Aug			No
Brigden Crown Game Reserve (3 sites)	5	AN, LC, RGF	Sep 22			28 Aug			No
Wawanosh CA	1	AN, RGF				28 Aug			No
Moore Wildlife Refuge CA	2	AN, LC	Sep 22						No
Perch Creek CA	2	AN, LC	Sep 21						No
Floodway CA	2	AN, LC	Sep 21						No
Petrolia CA	1	AN, LC	Sep 22						No
Rouge Park, Scarborough	4	AN	Sep 14, 15						No
High Park, Grenadier Pond, Toronto	1	MM	Sep 22						No
Clements Property, Buttenwood, Alvinston	5	MJO, RGF, AN			Aug 14, Sep 1		Aug 11		No
A.W. Campbell CA, Alvinston	2	AN					Aug 10		No
Grape Fern Woods, SCRCA Shetland	1	EC					Sep 7		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

Site	Effort (person-hours)	Observers	Date(s) 2013	Date(s) 2014	Date(s) 2015	Date(s) 2016	Date(s) 2017	Date (s) 2018	I. i. records
Cape Croker Park	1	AN			Aug 31				No
Elora Gorges CA	3	AN, KL, 1 student		Aug 5					No
Speed River Trail, Guelph	3	AN, KL, 1 student		Aug 5					No
Gorba Trail, Guelph	3	AN, KL, 1 student		Aug 5					No
Arboretum Guelph	1	AN		Aug 5					No
Bruce Peninsula National Park (11 sites)	11	AN		Jul 21, 22, 23					No
Rare, Charitable Research Area, Cambridge	4	AN, RGF			Aug 16				No
Dundas Valley CA, Hamilton	4	AN					Aug 7		No
Tiffany Falls CA, Hamilton	1	AN					Aug 7		No
Royal Botanical Garden, Cootes Sanctuary, Hamilton	5	AN					Aug 8		No
Port Bruce Provincial Park	1	AN, VB						Aug 10	No
Norfolk CA	1	AN, VB						Aug 11	No
Port Dover, Silver Lake	2	AN, VB						Aug 11	No
Port Dover, Lynn River Valley Trail (3 sites)	2	AN, VB						Aug 11	No
North Cayuga Slough Forest (3 sites)	2	AN, VB						Aug 11	No
Byng Island CA	1	AN, VB						Aug 11	No
Rock Point Provincial Park	1	AN, VB						Aug 11	No
Long Beach CA	1	AN, VB						Aug 11	No
Gord Harry Conservation Trail	2	AN, VB						Aug12	No
Wainfleet Bog CA	1	AN, VB						Aug 12	No
E.C. Brown CA	1	AN, VB						Aug 12	No
Mud Lake CA (2 sites)	1	AN, VB						Aug 12	No
Point Abino Woods (NCC, 2 sites)	2	AN, VB						Aug 12	No
Humberstone CA	1	AN, VB						Aug 12	No
Stevensville Conservation Park	1	AN, VB						Aug 12	No
St. John’s CA (2 sites)	1	AN, VB						Aug 12	No
Short Hills Natural Area (NCC)	2	AN, VB						Aug 12	No

Site	Effort (person-hours)	Observers	Date(s) 2013	Date(s) 2014	Date(s) 2015	Date(s) 2016	Date(s) 2017	Date (s) 2018	I. i. records
Short Hills Provincial Park	1	AN, VB						Aug 12	No
Brant CA (3 sites)	2	AN, VB						Aug 15	No
Vanderwater CA (3 sites)	4	AN, VB						Aug 13	No
MRCA Authority Land (Moneymore Road, Thomasburg)	2	AN, VB						Aug 13	No
MRCA Authority Land (Colonization Road, Thomasburg)	2	AN, VB						Aug 13	No
MRCA Authority Land (Rapids Road, Thomasburg)	1	AN, VB						Aug 13	No
Geoheritage Walking Trail (Eganville)	2	AN, VB						Aug 14	No
C44 (Egan Line, Eganville)	1	AN, VB						Aug 14	No
C42 (Brehm Road, Eganville)	1	AN, VB						Aug 14	No
C62 (Tramore Road, Eganville)	1	AN, VB						Aug 14	No
Ottawa/Gatineau (14 sites)	40	AN, RGF, PC				Aug 23-26, Sep 6-7			No
North Stormont	2	RGF				Sep 6			No
Papineau MRC: Plaisance	8	AN, RGF				Aug 24			No
Metcalfe (near Ottawa)	6	AN, PC, RGF				Aug 25			No
Edwardsburgh/Cardinal	2	RGF				Sep 6			No
Casselman	2	RGF				Sep 7			No
Morris Island CA	3	AN, RGF				Aug 23			No

HABITAT

Habitat Requirements

Hubricht (1985) did not define a preferred habitat for Shagreen in the US. The species seemed to be common and was found in a great variety of habitats ranging from natural woods to roadsides and urban areas. In Tennessee, Shagreen was mainly found in nature parks and less often in urban areas (Hodges 2016). Shagreen is always confined to wood logs and rocks or within the leaf litter, a microhabitat preserved in nature parks. However, when these microhabitats are not present, trash and waste may be used as habitat (Hubricht 1985).

As determined by the search effort shown above, in Canada, Shagreen lives in rocky or open woods (including Common Hackberry *Celtis occidentalis* woods), open deciduous woods, and a wooded alvar with Chinquapin Oak (*Quercus muehlenbergii*). These habitats are defined based on Ecological Land Classification (Lee *et al.* 1998) maps from Middle (North - South Environmental Inc. 2004) and Pelee (maps provided by NCC for their two properties: ELC_FDNR 2014-131660 and Ivey_ELC_21Feb08-2183, ELC_Gibwood 2011-22419, ELC_Stone_Road_Alvar-53743) islands.

Habitat Trends

Climate change

The climate on Lake Erie islands and the adjacent mainland 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 (Parks Canada 2008), with waves immersing large parts of the south side of the island. Vegetation and the litter layer on the ground are affected. In 2019, flooding was observed on Middle Island while on Pelee Island, SRA flooded and Sheridan Point was partially underwater (A. Nicolai pers. obs.)

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

- Average winter temperatures will increase by 3.3°C in southwestern Ontario (from -3.8°C in 1960-1990 to -0.5°C in 2015-2045). Mean temperature close to 0°C increases the chances of increased frequency of freeze-thaw cycles in fall/winter (Nicolai and Ansart 2017) and more spring frosts (Augspurger 2013).
- 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; both beneficial and adverse effects may ensue, but the overall effects are difficult to predict. Additionally, anthropogenic activity influences microhabitat structure although the link between habitat choice and physiology is poorly understood (Deutsch *et al.* 2008).

Land management

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

Habitat connections among all four of the bedrock islands were re-established by restoring former fields adjacent to forested areas to forest and wetland on Pelee Island by NCC (NCC 2008), but all habitat patches are still unconnected at the micro-scale suitable for gastropods because the intervening restored land consists of former fields (now thickets), which still pose a barrier (e.g., in RBIP). Colonization or exchanges between habitats on distant properties on Pelee Island is even more difficult because of barriers between the protected areas. Ditches as well as paved and unpaved roads or tracks as narrow as 3 m with both high and low traffic densities are barriers to snail dispersal (Baur and Baur 1990a; Wirth *et al.* 1999). Disturbed habitats such as cultivated or grazed fields and small cultured woodlots between fields do not seem to act as movement corridors, because no native snails or slugs were found in such sites on Pelee Island in 2013-2018. NCC controls invasive plants by mechanical removal or periodically with chemicals (NCC 2008). Herbicide use is still restricted to study plots (study in progress by NCC; no results currently available). Logging and grazing are forbidden, while hunting is still allowed on almost all NCC properties. Access for the public is possible on one biking and walking trail that goes through the savanna in the Florian Diamante Nature Reserve and on the Richard and Beryl Ivey Property.

The Pelee Island Winery has restored red cedar savanna, which is accessible by the public (NCC 2008). Sheridan Point is a small historic site with an old dock surrounded by trees in the immediate vicinity of a private woodlot and an old quarry.

Prescribed fire is planned in late summer 2019 on the Stone Road Alvar owned by Ontario Nature but is only applied to grassy areas in the savanna, which is not preferred Shagreen habitat. Access for the public is possible on walking trails that go through Ontario Nature properties of Stone Road Alvar.

Middle Island, added to Point Pelee National Park in 2000 (Parks Canada 2010), has been uninhabited since the 1980s, but disturbance by a former runway 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 rapid increase in nesting Double-crested Cormorants (*Phalacrocorax auritus*; Parks Canada 2008). 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). Parks Canada has been implementing management strategies to restore the ecological integrity of Middle Island and protect at-risk species since 2008. The management plan includes the culling of adult breeding cormorants on the island, the use of deterrents, and nest removals. Results from research and monitoring show that overall cormorant nest density on the island has been reduced by 55% since management began, resulting in conservation gains. The loss of healthy forest canopy cover has been halted and the analysis of LIDAR imagery shows an increase in forest canopy of 16% from 2010 to 2016 (Parks Canada unpubl. data). Monitoring also shows an increase in the cover of native herbaceous plant species, increases in at-risk species populations and an overall improvement in tree health indices since active management began in 2008. However, with cormorant nest densities still at 115 nests/ha as of 2017, negative impacts of cormorant nesting remain apparent on the island, with the proliferation and spread of invasive, exotic plant species fuelled by ongoing disturbance and increased nutrients being a primary concern (Dobbie pers. comm. 2018/2019).

BIOLOGY

Little information is available about the biology of Shagreen. General aspects of terrestrial snail biology are provided by the review of Barker (2001). Some information from other Polygyridae is available. However, this information could give misleading conclusions about the capacity of Shagreen to survive or to adjust to specific conditions, because Polygyridae include common species that are not of conservation concern and others, such as Flat Bladetooth (*Patera appressa*) that are strongly synanthropic (associated with human activity), perhaps invasive (Grimm *et al.* 2010).

Life Cycle and Reproduction

Shagreen is an air-breathing (pulmonate), terrestrial snail that is a simultaneous hermaphrodite (possesses both male and female reproductive organs) and lays eggs (Pilsbry 1940). In general, both members of a mating pair exchange sperm and produce eggs. In another polygyrid snail, Whitelip Snail (*Neohelix albolabris*), self-fertilization can occur if mating probability is extremely low, resulting in very low reproductive success (McCracken and Brussard 2008). Usually, the frequency of such inbreeding is very low in most populations (McCracken and Brussard 2008). In most snail species, larger individuals lay more eggs than smaller ones (Heller 2001). In temperate regions, reproduction usually occurs in spring and late summer and egg clutches are deposited in shallow holes excavated in moist soil (Barker 2001). Clutch size for Shagreen is unknown.

Most gastropods are crepuscular or nocturnal, and sympatric species often have different activity patterns (Asami 1993). During 2013-2018 surveys, most observed snail species were mainly active in morning hours or after rain. However, Shagreen was only observed under logs, not moving. The hibernation period probably extends from early October until mid-April; the exact timing is expected to vary depending on conditions in particular years. Typical hibernation sites in other species are shallow depressions in the forest floor covered with leaf litter or soil at depths of 5 to 10 cm (Pearce and Örstan 2006).

Aestivation in various species of snails occurs occasionally during periods of prolonged heat and drought in temperate regions (Nicolai *et al.* 2011). During aestivation, snails usually remain inactive in moist microhabitats, such as in soil, under leaf litter, and under logs. During these longer periods of inactivity, hibernation and aestivation, the snails cover their shell opening with a slightly calcified epiphragm. Polygyridae in aestivation and hibernation with epiphragms were observed during 2013-2018 surveys in August and November, respectively.

In general and in other species, growth occurs only during periods of activity (spring to fall; Nicolai 2010; Nicolai *et al*. 2010; Charrier *et al.* 2013). The adult shell size (~10 mm in width) could be reached after 1 year with sexual maturity being reached at the same time, as has been observed in other species of the same size (Nicolai pers. obs.). Shagreen may live 2-3 years. The estimated generation time is somewhere between the age at sexual maturity and longevity, probably 2 years.

Physiology and Adaptability

Physiological responses to environmental factors and their plasticity and adaptability have not been studied intensively in Polygyridae. Details of diet and feeding behaviour are unknown. Shagreen may, like other litter dwelling species, such as Broad-banded Forestsnail (*Allogona profunda*; COSEWIC 2014b), Eastern Banded Tigersnail (*Anguispira kochi kochi*; COSEWIC 2017), or Striped Whitelip (*Webbhelix multilineata*; COSEWIC 2018) eat decaying plants (everywhere in the leaf litter) or microfungi on the log on which the snails are found.

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

Snails in regions with prolonged periods of drought and heat generally aestivate in buffered refuges and seal their shell aperture to avoid evaporation (Barker 2001; Pearce and Örstan 2006). In temperate regions, many species only aestivate in extreme summer conditions for a short period and have developed biochemical stress reactions that protect cellular architecture and processes (such as membrane fluidity, osmoregulation, and enzyme activity) and hence maintain survival mechanisms (Nicolai *et al.* 2011). Unusually long, hot, and dry periods with unusual timing can increase mortality, e.g., up to 70% in Roman Snail (*Helix pomatia*) right after arousal from hibernation (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). Within the same family, species have evolved different strategies which may be disadvantageous to some species under climate change and human-caused microhabitat degradation (Nicolai and Ansart 2017). Mortality during hibernation is usually around 40% in some species and drives population dynamics (Peake 1978; Cain 1983).

Usually, snails in temperate regions hibernate in buffered microsites which are additionally insulated by snow (Nicolai *et al.* 2011). Burch and Pearce (1990) suggest refuges with buffered environmental conditions, such as temperature and humidity, may be the most important factor limiting terrestrial snail abundance.

Dispersal and Migration

Active movement distances of Shagreen are unknown. While other Polygyridae have been observed moving between 120 and 220 cm per day within a home range of 80 to 800 m^2 (Pearce 1990), Shagreen was never observed actively moving during fieldwork in 2013-2018. Therefore, dispersal might be even less than 32.2 m over 3 years as observed in the Oregon Forestsnail (*Allogona townsendiana*; Edworthy *et al.* 2012). Eggs and immature stages are not known to be dispersed by wind. However, some snails can survive short periods in water, in hypoxia (Nicolai and Ansart 2017), and the passage through bird intestines (Wada *et al.* 2012). Other snails have been found to be dispersed by bird migration (Kawakami *et al.* 2008) or, especially in riparian populations, by rafting on floating objects (Vagvolgyi 1975) or by fish (Altaba 2015). The likelihood of aerial or aquatic transport of Shagreen is unknown, but is probably small.

In Ontario, the likelihood of dispersal from the US is nonexistent given the snails' poor dispersal capabilities (see **Population Spatial Structure and Variability** and/or **Rescue Effect**). A potential northern expansion of the peripheral Canadian population of Shagreen could be largely negated by historical and current habitat loss and degradation, important factors to consider for range peripheral species under climate warming (Gibson *et al.* 2009). Because Shagreen is not actively searching for fresh plant material as food, it is unlikely that it would be transported by human activity, for example with horticultural or agricultural products, and then be introduced to new areas (Robinson 1999; Robinson and Slapcinsky 2005).

Interspecific Interactions

Trematodes (Barger and Hnida 2008; Barger 2011) and free swimming or attached flagellates were observed in other Polygyridae (Current 2007). Parasitic mites are also common in snails in general (A. Nicolai pers. obs.) with prevalence ranging from 46 to 78% within infested populations (Baur and Baur 2005). Depending on the mite species, infestations can cause high mortality, reproductive perturbations, and reduced cold hardiness in some snail species (Baur and Baur 2005). Nematodes can also infect a snail population and increase mortality rate among juveniles (Morand *et al.* 2004). In snails reared in the laboratory, thus in a confined space, nematodes can cause extremely high mortality (Örstan 2006), although nematodes were not efficient in controlling pest gastropods in an urban green space (i.e., open space, Fredon Inc. unpubl. data).

Predation can be a source of mortality for land snails. Potential predators have been reviewed by Jordan and Black (2012): "Gastropods are an important food source to a vast number of species, including salamanders, frogs, toads, turtles, snakes, lizards, birds, shrews, voles, moles, rats, mice, chipmunks, and squirrels. Invertebrate predators of

terrestrial mollusks include sciomyzid fly larvae, firefly larvae, parasitic wasp larvae, carabid and staphylinid beetles, ants, spiders, and harvestmen." Among carnivorous gastropods Draparnaud's Glass Snail (*Oxychilus draparnaudi*) includes forest snails in its diet, especially Striped Whitelip, Bristled Slitmouth (*Stenotrema barbatum*), and Tigersnail (*Anguispira alternata*) (often observed in the same sites, Örstan 2006). Garlic Glass Snail (*Oxychilus alliarius*), an invasive predatory snail on Hawaii, is negatively affecting native Hawaiian land snails (Curry *et al.* 2016). Draparnaud's Glass Snail and Cellar Glass Snail (*Oxychilus cellarius*) were observed on Lake Erie islands and on the mainland of southwestern Ontario during 2013-2018 surveys. Introduced predators or an increase in abundance of native predators due to ecological disturbance can increase mortality due to predation.

Competition for food with other terrestrial gastropods, including exotic species, is a possibility for native Polygyridae in southwestern Ontario, but has not been documented. Introduced exotic gastropods, such as Grove Snail (*Cepaea nemoralis*) and various species of slugs, mainly Grey Fieldslug (*Deroceras reticulatum*) or Dusky Arion (*Arion fuscus/subfuscus*), present in many natural areas in Ontario, might be in direct competition for food as these species mainly eat decaying plant material or fungi.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

The objective of fieldwork in 2017 was to increase search effort, to measure abundance and demography, and to better understand the distribution and ecology of the species. The method used was a visual search under logs and in the leaf litter on a wandering transect across different habitats within each site. In addition, 2x2 m plots (in total 35 plots) were established in different habitat types in all historically occupied sites on Pelee Island to measure abundance and record exotic species (Table 3). Size was measured as the maximal shell breadth. Five plots were surveyed for Shagreen on Middle Island, but size was not measured due to time constraints.

Table 3. Abundance of Shagreen (*Inflectarius inflectus*) in 2x2m plots in different habitat types in 2017 on Pelee and Middle islands and presence of exotic gastropod species. Random transects at each site also were searched for Shagreen.

Locality	Site	Field verification in 2017	*Inflectarius inflectus* total abundance	Exotic gastropod species
Middle Island		3 plots	7 juveniles, 2 adults	*Oxychilus cellarius*
Pelee Island	Winery Woods	1 plot		
	Stone Road Alvar – Porchuk, NCC	3 plots	2 juveniles	
	Stone Road Alvar – Shaughnessy, NCC	2 plots		

Locality	Site	Field verification in 2017	*Inflectarius inflectus* total abundance	Exotic gastropod species
	Stone Road Alvar – Krestel, NCC	1 plot		
	Stone Road Alvar – Finley, NCC	1 plot		
	Stone Road Alvar – ON Nature	3 plots		*Deroceras reticulatum*
	Florian Diamante, NCC	6 plots		*Deroceras reticulatum*
	Gibwood, NCC	2 plots		
	Richard & Beryl Ivey, NCC	4 plots		*Deroceras reticulatum* *Arion fasciatus*
	Lighthouse Point	3 plots		*Deroceras reticulatum*
	Fish Point	5 plots		*Cepaea nemoralis* *Deroceras reticulatum*
	Sheridan Point	1 plot		*Deroceras reticulatum*

Abundance, Fluctuations and Trends

Size distribution could not be analyzed in 2017, because only two individuals were found alive on NCC SRA property on Pelee Island (juveniles of 4 and 6 mm); however, the presence of juveniles indicates reproduction is occurring. On Middle Island, the Parks Canada search team found seven juveniles and two adults.

The species' densities in different habitats could not be estimated in 2017, because only a few individuals were observed (n = 11). In 2013 and 2014 the species was found in clusters of 10-20 individuals under one to two logs per site. In 2013, 21 and 44 live individuals were collected from the FDNR site and Middle Island, respectively. In the GW site about 10 individuals were observed under one log. In 2018, three individuals (one juvenile) were recorded in the FDNR site. This great heterogeneity in distribution of the species makes it difficult to estimate population size. However, given the scarcity of the species, a maximum density of < 0.1 adults/m^2 (2 adults in 5 plots of 4 m^2 each on Middle Island in 2017) could be expected. Assuming this density is evenly distributed over the entire protected natural area on Pelee and Middle islands where the species has been recorded within the last 20 years (Table 1), the estimated maximum number of mature individuals in the Canadian population in protected areas is 480,100; however, this number must be viewed with extreme caution due the patchy, clumped distribution of the snail and its preferred habitat and the assumption of equal snail density over the entire protected area. This maximum estimate was derived by multiplying snail density by the following sizes of the various protected areas: on Pelee Island FDNR: 184 ha, RBIP: 51 ha, GW: 14 ha, SRA – Ontario Nature and NCC properties: 179 ha, WW: 33.6, and Middle Island: 18.5 ha; total 480 ha of protected area. The number of individuals on private land (Winery Woods, Sheridan Point) is unknown because Shagreen was not found on the plots (Table 3); therefore, snail densities could not be calculated. Essentially, the size of the Canadian population is unknown.

Rescue Effect

Although snails have some capacity for passive dispersal (see **Dispersal and Migration**), rescue from outside Canada is unlikely due to barriers and population disjunction. The closest US subpopulations in Ohio and Michigan are separated by large water bodies, such as Lake Erie and the Detroit River. The closest confirmed record for Shagreen in iNaturalist (iNaturalist 2019) is from Kelley's Island, Ohio, about 6 km south of Middle Island across Lake Erie.

THREATS AND LIMITING FACTORS

Threats

Direct threats facing Shagreen were assessed, organized, and based on the IUCN-CMP (World Conservation Union-Conservation Measures Partnership) unified threats classification system (Master *et al.* 2012) using definitions in Salafsky *et al.* (2008). Threats are defined as the proximate activities or process that directly and negatively affect the population. Results of the impact, scope, severity, and timing of threats are presented in tabular form in Appendix 1. The threats calculation included the extant subpopulations on Middle and Pelee islands, including all sites with live snails and sites with potential habitat where empty shells were observed in 2013-2018 (Table 1). The mainland subpopulations 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). 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.

<u>Threat 11: Climate change & severe weather – HIGH TO LOW IMPACT</u>

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

Threat 11.2: Droughts, and Threat 11.3: Temperature extremes (HIGH TO 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). McDermid *et al.*'s (2015) study, which is at a finer spatial scale, also suggests summer precipitation is likely to decline in the Lake Erie basin while winter precipitation is likely to increase. 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%, unpublished data). However, medium-sized snails are less susceptible to freezing than bigger snails, but still rely on snow cover and temperature-buffered micro-habitat shelters (Ansart *et al.* 2014). Droughts can cause high mortality in some species depending on the presence of shelter (e.g., 75% in *H. pomatia*, Nicolai *et al.* 2011). Even though Shagreen seems to be a habitat generallist (Hubricht 1985), it relies heavily on logs and rocks for its entire life cycle and is therefore mainly found in natural areas (Hodges 2016) where micro-habitat structure is complex.

Threat 11.4: Storms and flooding (LOW IMPACT)

Storms were identified as a predominant natural disturbance on Middle Island (Parks Canada 2008), immersing the south side of the island. During fieldwork in 2013-2018 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. With increased precipitation due to climate change, flooding can also affect other islands that earlier harboured subpopulations. Elevation (above sea level) on Pelee Island ranges from 175 m (~1 km north of the ferry dock along the western edge of the island) to 183 m (near Gibwood) with the lake level being 173 m (Natural Resources Canada 2019). The threat should also be considered when considering the potential of recolonization.

Threat 7: Natural system modifications – LOW IMPACT

Threat 7.1: Fire & fire suppression (LOW IMPACT)

Prescribed fire has become an important management tool for prairie and forest conservation in North America (Gottesfeld 1994; Williams 2000), particularly to limit the invasion of exotic species (Brooks and Lusk 2008) and to promote growth and reproduction of native prairie species (Towne and Owensby 1984). Burning directly and indirectly affects survival of ground nesting animals, litter dwelling organisms, and soil invertebrates, including snails (Nekola 2002). Fire reduces and modifies organic substrates and residues, which are sources of nutrients and buffer and shelter 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 and the Essex Regional Conservation Authority (ERCA) in 1993, 1997, 1999, and 2005 (NCC 2008). There are plans by Ontario Nature for burns of the alvar in late summer 2019 to enhance snake habitat and control invasive grasses on the Stone Road Alvar. 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 prescribed burn will take place on 11 ha of the Ontario Nature property where soil-litter depth ranges

between 4 and 17 cm. The burn block consists of a mosaic of cool season grasses, alvar-specific vegetation, tall grass prairie vegetation, and woody shrubs. Standing hardwoods and shrubs such as Common Hackberry (*Celtis occidentalis*), Common Prickly Ash (*Zanthoxylum americanum*), sumac (*Rhus* sp.), mulberry (*Morus* sp.), Chinquapin Oak, and Blue Ash (*Fraxinus quadrangulata*) are scattered across the entire burn area, but canopy closure is less than 10%. Some Eastern Red Cedars (*Juniperus virginiana*) are located in the northern part of the burn block. No live snails or shells of Shagreen were found in the Stone Road Alvar during fieldwork in 2013-2018. However, the threat should be considered despite the lack of recent observations.

Threat 7.3: Other ecosystem modifications (UNKNOWN IMPACT)

There are several highly invasive plants in southern Ontario, including Garlic Mustard (*Alliaria petiolata*), found on Pelee and Middle islands. This plant was observed displacing native vegetation and altering soil nutrient cycles, thereby slowing restoration (Catling *et al.* 2015). Although a positive impact of an invasive plant on the diversity of common land snails has been documented in western Pennsylvania (Utz *et al.* 2018), invasive plants can also lead to a decrease in endangered snail abundance, as shown in Europe (Stoll *et al.* 2012). Stoll *et al.* (2012) found that the impact is size-dependent: abundance of small species (<5 mm shell size) increased whereas larger species (>5 mm) decreased.

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). While direct evidence of effects of exotic earthworms on terrestrial gastropods is lacking, Norden (2010) and Forsyth *et al.* (2016) suggested that invasive earthworms could indirectly alter terrestrial snail communities. Earthworms, such as the Asian genus *Amynthas* that removes the surface leaf litter (Qiu and Turner 2017), where snails live, would be a particular threat (see also Dobson 2017 and Lee 2017 for photographs of the effects of exotic earthworms on soil duff layers). Other indirect effects could result from earthworms feeding on forest plant seeds (Cassin and Kotanen 2016) or altering plant-fungi mutualisms (Paudel *et al.* 2016) thereby affecting understorey vegetation composition (Drouin *et al.* 2016) and potentially reducing available food plants. This change in forest floor structure profoundly affects plant and litter-dwelling invertebrate communities (Addison 2009; Dobson and Blossey 2015) as well as bird abundance and nesting success (Loss *et al.* 2012). Invasive earthworms are present on the north shore of Lake Erie (Evers *et al.* 2012) and on Pelee Island (Reynolds 2011) as well as elsewhere in Ontario (Reynolds 2014). The Asian genus *Amynthas* is present in Essex County (Reynolds 2014).

Double-crested Cormorant nesting colonies have increased dramatically on Lake Erie islands since the early 1980s, especially on Middle Sister, East Sister, and Middle islands (COSEWIC 2017). When Middle Island became part of Point Pelee National Park in 2000, the number of cormorant nests had increased to 5,202 and the island was showing signs of forest canopy loss. Since 2008 Parks Canada has been actively managing Double-crested Cormorant nesting density on Middle Island (Thorndyke and Dobbie 2013), and vegetation has recovered. High nest densities are still found on the other islands. Cormorants may be

the reason for the extirpation of Shagreen from East and Middle Sister islands and have been identified as a threat to Eastern Banded Tigersnail (COSEWIC 2017) through the 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).

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

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

Competition with exotic terrestrial gastropods is also a potential threat (Whitson 2005; Grimm *et al.* 2010) through aggression (Kimura and Chiba 2010), density effects, and/or food competition (Baur and Baur 1990b). Exotic gastropods can compete for resources and shelter with the remaining native species. Dusky Arion, Grey Fieldslug, and Grove Snail are widespread in southern Ontario. Carnivorous snails, such as Draparnaud's Glass Snail and Cellar Glass Snail, found on Lake Erie islands and mainland of southwestern Ontario during 2013-2017 surveys, may directly affect native species (Mahlfeld 2000).

Wild Turkeys (*Meleagris gallopavo*) and Ring-necked Pheasants (*Phasianus colchicus*) were introduced to some places in Ontario for hunting. Both bird species are omnivorous and include snails in their diet (Sandilands 2005). The impacts on snail populations are unknown, but they are a potential additional source of predation and were recently listed as ongoing threats to the Endangered Striped Whitelip (COSEWIC 2018), Eastern Banded Tigersnail (COSEWIC 2017), Broad-banded Forestsnail (COSEWIC 2014b), and the Endangered Small-mouthed Salamander (*Ambystoma texanum*; COSEWIC 2014c). However, Shagreen hides under logs and in rock piles, areas not easily accessed by these birds, which reduces the potential impact of this threat.

Threat 9: Pollution – UNKNOWN IMPACT

Threat 9.1: Domestic and urban waste water (NEGLIGIBLE IMPACT)

Air and water borne pollution (e.g., heavy metals and road salt) in close proximity to roads is a threat to land snails (Viard *et al.* 2004), because heavy metals in the soil and plants are accumulated in tissues (Notten *et al.* 2005) and decrease food consumption, growth, and fecundity (Laskowski and Hopkin 1996).

Threat 9.3: Agriculture and forestry effluents (UNKNOWN IMPACT)

The impacts of pesticides on terrestrial gastropods are poorly known. Population level impacts of herbicides on terrestrial snails and slugs were not detected in agricultural (Roy *et al.* 2003) or forested (Hawkins *et al.* 1997a) landscapes, but laboratory studies have shown that exposure to some herbicides increases mortality of an aquatic snail species infected with parasitic trematode cercariae (Koprivnikar and Walker 2011) and could affect reproduction in terrestrial snails (Druart *et al.* 2011). Neonicotinoid insecticides are increasingly used as a coating on soy bean and maize seeds (Douglas and Tooker 2015)

and were not harmful to Grey Fieldslug but were to mollusc-predating arthropods (Douglas *et al.* 2015). It is currently unknown how these pesticides act on native gastropod species. The close proximity of agricultural land to wooded areas in southern Ontario may also expose snails to pesticide drift.

Threat 4: Transportation & service corridors – NEGLIGIBLE IMPACT

Threat 4.1: Roads and railroads (NEGLIGIBLE IMPACT)

Woodlots are separated by roads and ditches in Ontario. Paved roads or tracks as narrow as 3 m with high or low traffic densities may fragment snail populations (Wirth *et al.* 1999), because snails tend not to cross roads (Baur and Baur 1990a). Reck and van der Reer (2015) cite a study by Martin and Roweck (1988) who documented local extinctions in a population of Rotund Disc (*Discus rotundatus*) in Germany after the original habitat became unsuitable and roads acted as barriers for movement. Road mortality has also been recognized as a threat for wildlife in other protected areas, such as Point Pelee National Park (Parks Canada 2007). However, Shagreen is not likely to be affected by road mortality as individuals rarely move away from under logs.

Threat 6: Human intrusions & disturbance – NEGLIGIBLE IMPACT

Threat 6.1: Recreational activities (NEGLIGIBLE 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. Stone Road Alvar is a prominent site in Pelee Island ecotourism. The site attracts substantial numbers of birders, photographers, tourists, ecologists, and researchers. A short loop trail is close to the road. Large parts of Stone Road Alvar are not accessible due to high vegetation density and absence of trails. Visitor numbers are lower at NCC properties on Pelee Island. Hunting is allowed on all NCC properties. Visitation of Middle Island is allowed except for during an annual closure from 1 March to 1 September to protect the colonial water bird colony during nesting season. While trampling is not a threat in this species because it lives under logs, displacement of logs and rocks or disturbance of leaf litter can alter micro-habitat conditions of the species.

Threat 6.3: Work & other activities (NEGLIGIBLE IMPACT)

Vegetation and species-at-risk monitoring (including snails) will continue to occur on Middle and Pelee islands. Snails will not be collected, but they could be affected by trampling and modifying micro-habitat conditions in small areas of each site.

Cumulative Effects

Logging, mining, agriculture, recreation, and the establishment of second growth forest are activities that are generally known to increase the abundance of invasive plants (Calinger *et al.* 2015). There is a quarry on Pelee Island and landowners do cut trees on their land. Climate change and forest disturbance may also facilitate the spread of introduced species in Canada with largely unknown and untracked, but potentially serious impacts, on native gastropod faunas.

Limiting Factors

In Canada, Shagreen exists near the northern limit of its distribution and northward expansion is probably limited by harsh winters, human-caused habitat fragmentation and loss (Gibson *et al.* 2009), and physical barriers (i.e., extensive bodies of water). Low dispersal ability and low physiological resistance to a fluctuating environment (e.g., temperature and humidity) restrict gene flow among subpopulations. At the micro-habitat 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

Considering all sites where Shagreen has been observed since 2010 (Table 1, Figure 3) and the various threats, there are between one and six locations with the minimum corresponding to combining the two known currently occupied islands, Middle and Pelee. The most serious and plausible threats are climate change and prescribed burns with the unknown impact threat from Double-crested Cormorants being confined to Middle Island. Because the threat of increasing frequency of droughts and temperature extremes could affect each island differently, each could be one location; however, flooding could also affect both islands simultaneously. If drought or temperature extremes act differently in different areas of Pelee Island, each block of protected area could be considered single locations: Sheridan Point, GW, RBIP/WW, FDNR, and SRA (Table 1, Figure 3: five locations). An additional threat confined to SRA is prescribed fire.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Shagreen is not protected by any legislation, regulations, customs, or conditions. It is not listed on the IUCN Red List (IUCN 2017), under the US *Endangered Species Act* (USFWS 2017), or under any provincial acts. It is not listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2017).

Non-Legal Status and Ranks

NatureServe (2019) provides the following ranks for Shagreen for the US and Canada:

- Global Rank: G5 – secure (last reviewed 2 Dec 2009)
- National Rank (US): N5 – secure (last reviewed 8 Oct 2002)
- National Rank (Canada): N1 – Critically imperilled (last reviewed 10 Aug 2017; same rank in CESCC 2016)

Subnational Ranks (S-ranks) as provided by NatureServe (2019) for the US and by CESCC (2016) for Canada are as follows:

- SNR: Alabama, Florida, Georgia, Illinois, Indiana, Kansas, Louisiana, Michigan, Mississippi, Missouri, Ohio, Oklahoma, Texas
- S5: Arkansas, Kentucky, North Carolina, Tennessee
- S3: Virginia
- S2: Pennsylvania, West Virginia
- S1: Ontario (NatureServe 2019 ranks it as S1S2)

NatureServe (2019) did not rank the occurrences of this species in New York, Maryland, Iowa, and Wisconsin.

Habitat Protection and Ownership

Ownership of currently occupied habitat in Ontario is shown in Table 1. Sites owned by Parks Canada, Nature Conservancy Canada, and Ontario Nature are protected areas. Winery Woods belongs to the Pelee Island Winery. Management plans for these areas were reviewed in **Habitat Trends**. Sheridan Point included the public edge of a larger forested area that is private.

ACKNOWLEDGEMENTS

Many thanks to Robert Forsyth who assisted with fieldwork, identification, databasing, and curation of Ontario specimens, and who provided useful information. The Nature Conservancy of Canada granted 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. Ontario Parks is thanked for providing a collecting permit, vegetation maps, and permission to access provincial parks and protected areas. Thanks to Ron Gould for assisting in fieldwork. 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. Thanks are extended to Northern Bioscience Inc. for assisting with field surveys in 2013. 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.

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- Canadian Wildlife Service:
  - Ontario Region (13 March 2018)

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

- Parks:
  - Parks Canada (many times in 2013-2018)
  - Ontario Parks (many times in 2013-2018)

- Provincial / territorial representatives:
  - ON (8 December 2017)

- Conservation Data Centres or Natural Heritage Information Centres:
  - ON: Natural Heritage Information Centre (many times in 2013-2018)

- COSEWIC Secretariat:
  - ATK (7 June 2017, 8 December 2017)

- Conservation organizations:
  - NCC (many times in 2013-2017)
  - ON Nature (9 December 2016)
  - ERCA (9 December 2016)

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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 Ph.D. from the University of Bremen in Germany and from the University Rennes 1 in France. Her research involves investigating eco-physiological questions in terrestrial snails, specifically about the impact of climate change and resource availability on the physiology and reproduction in endangered and invasive species. She has very specific knowledge about the biology, anatomy, physiology, and ecology of terrestrial gastropods. In Germany she developed a captive-breeding program for the protected *Helix pomatia* and in France she was coauthor of the National Action Plan for the conservation of *Tyrrhenaria ceratina* in Corsica. In the Sinclair lab at Western University, Ontario, she investigated the overwintering strategy of the invasive species *Cepaea nemoralis*. Since 2012 she has been surveying terrestrial gastropods in Ontario and participating in the "barcoding of life" project at the University of Guelph. She became a member of the mollusc subcommittee of COSEWIC in 2014.

COLLECTIONS EXAMINED

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

- NatureServe Central Databases (accessed through GBIF data portal, http://data.gbif.org/datasets/resource/607) doi:10.15468/lysaex

and US records :

- Museum of Comparative Zoology, Harvard University (2016): Museum of Comparative Zoology, Harvard University. Dataset/Occurrence. http://digir.mcz.harvard.edu/ipt/resource?r=mczbase doi:10.15468/p5rupv, doi:10.15468/p5rupv doi:10.15468/p5rupv
- Field Museum: Field Museum of Natural History (Zoology) Invertebrate Collection doi:10.15468/6q5vuc
- Florida Museum of Natural History: UF Invertebrate Zoology doi:10.15468/sm6qo6
- Bailey-Matthews National Shell Museum (BMSM) doi:10.15468/49s45k
- Sam Noble Oklahoma Museum of Natural History: Recent Invertebrates Specimens doi:10.15468/glxcep

- SysTax: SysTax - Zoological Collections doi:10.15468/zyqkbl
- Queensland Museum: Queensland Museum provider for OZCAM doi:10.15468/lotsye
- North Carolina Museum of Natural Sciences Invertebrates Collection doi:10.15468/jzqd4x
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Appendix I. Threats calculator for Shagreen (*Inflectarius inflectus*).

Species or Ecosystem Scientific Name	*Inflectarius inflectus* (Shagreen)
Date (Ctrl + ";" for today's date):	10/26/2018
Assessor(s):	Threats teleconference participants included: Joe Carney (SSC Co-chair), Jill Crosthwaite (Nature Conservancy of Canada), Christina Davy (Ontario Ministry of Natural Resources and Forestry), Tammy Dobbie (Parks Canada), Robert Forsyth (SSC), Dwayne Lepitzki (facilitator, responsible Co-chair), Bev McBride (observer), Kelly McNichols-O'Rourke (SSC), Annegret Nicolai (status report writer), Marie-Éve Paquet (observer), Elizabeth Shapiro (Canadian Wildlife Service Ontario Region), Daelyn Woolnough (SSC)
References:	Draft threats assessment provided with draft status report

Overall Threat Impact Calculation Help:

	Threat Impact	**Level 1 Threat Impact Counts: 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:		
	Overall Threat Comments	Large range in the overall threat impact is a consequence of the uncertainty for scores of severity for climate change. Generation time is around 2 years; therefore time frame for severity and timing is 10 years. Historically known at 2 southern Ontario mainland sites (including Point Pelee National Park [PPNP]) and 5 Lake Erie Islands (Table 1; Figure 3). Recent surveys suggest now confined to 7 sites in 5 natural areas on Pelee Island (Suppl. Info 6) and on Middle Island (part of PPNP). Not found at Fish Point since 1994. Access was not granted to survey North Harbour Island, but there is no suitable habitat. There are no subpopulation estimates to help refine scores for scope (but see 7.1 and 11.4). Draft threats calculator included only the sites where shells or live individuals have been observed since 2013: Middle and Pelee (Winery Woods, RBIP, Stone Road Alvar, FDNR, Gibwood, Sheridan Point) islands.	

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						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
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						
3.2	Mining & quarrying						Sheridan Point has a historical quarry. The currently active quarry is on the northeast end of Pelee Island, but not accessible, because it is private.
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)	Road kill not considered a threat due to microhabitat preferences.
4.2	Utility & service lines						
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use						
5.1	Hunting & collecting terrestrial animals						Few individuals from Middle and Pelee Island have been collected in 2013-2016 for genetic analyses. No further collections are anticipated in next 10 years.
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting						Historical threat but not happening now and not expected to increase.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Restricted (11-30%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	While trampling is not a threat in this species (due to its microhabitat preferences), displacement of logs and rocks or disturbance of leaf litter can alter micro-habitat conditions of the species.
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 this species and other species like salamanders (using logs as microhabitat) are ongoing.
7	Natural system modifications	D	Low	Small (1-10%)	Moderate (11-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
7.1	Fire & fire suppression	D	Low	Small (1-10%)	Moderate (11-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Prescribed burns will happen in alvar habitat in 2019, where the species was last seen in 2010. If the species is still extant and assuming a homogeneous distribution over Stone Road Alvar, the burn may affect <10% of the Canadian population with a presumed death of 75% of individuals in this area, although the reduction over 10 years will only be moderate.
7.2	Dams & water management/use						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.3	Other ecosystem modifications		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Invasive plants (such as Garlic Mustard) are found on Pelee and Middle islands. 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. Cutting of non-native trees to control for exotic species (on Pelee Island) and to protect Red Mulberry (on Middle Island) has unknown effects, but could be positive if the logs provide suitable micro-habitat. The progressive loss of Ash trees in forests on Middle and Pelee Island changes local climate and microclimate conditions in the species' habitat.
8	Invasive & other problematic species & genes		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
8.1	Invasive non-native/alien species/diseases		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Introduced Wild Turkeys and Ring-necked Pheasants on Pelee Island could consume snails, potentially NOT the species of interest. Carnivorous introduced snails are found on Middle Island and could be a threat too. Invasive slugs are found on Pelee Island; however, it is not known if these are competing with the species.
8.2	Problematic native species/diseases						Raccoons are becoming more and more abundant. However, it is unknown if they are a threat to land snails.
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						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9	Pollution		Unknown	Pervasive - Large (31-100%)	Unknown	High - Moderate	
9.1	Domestic & urban waste water		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	The threat from pollution from roads is negligible, because there is no heavy traffic on Pelee Island.
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents		Unknown	Pervasive - Large (31-100%)	Unknown	High - Moderate	NCC restores fields in adjacent properties. Light use of herbicides on NCC properties, in the past and probably in the future to control invasive species. On Middle Island glyphosate will be used to control invasive understorey plants. Population level impacts of Glyphosate not detected in agriculture or forested landscapes but have been found in lab studies. Neonicotinoids used in soy bean culture may have an effect on snails.
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						
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. Medium-sized snails less susceptible to freezing.
11.4	Storms & flooding	D	Low	Small (1-10%)	Serious - Slight (1-70%)	High (Continuing)	Storms on Middle Island cause flooding and could lead to high mortality.
11.5	Other impacts						
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).							