COSEWIC
Assessment and Status Report

on the

Black Hills Mountainsnail
Oreohelix cooperi

in Canada

ENDANGERED
2021

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Production note:
COSEWIC would like to acknowledge Robert Forsyth for writing the status report on the Black Hills Mountainsnail, *Oreohelix cooperi*, in Canada. It was 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

Some supplementary information used in the assessment has been removed from this report and is available on request.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la Petite oréohélice (*Oreohelix cooperi*) au Canada.

Cover illustration/photo:
Black Hills Mountainsnail — R. Forsyth photograph, Cypress Hills Interprovincial Park, Alberta, 2018

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COSEWIC
Assessment Summary

Assessment Summary – April 2021

Common name
Black Hills Mountainsnail

Scientific name
Oreohelix cooperi

Status
Endangered

Reason for designation
Globally, this small (shell width about 1 cm) land snail is confined to four mountainous “sky islands” on the Great Plains of North America. In Canada, it occurs only in the Cypress Hills of Alberta and Saskatchewan. Known from this area since 1905, albeit under a different name, this species occurs on ridges, hilltops, cliffs, and slopes at or near the sand, silt, cobbles, and conglomerates of the Cypress Hills Formation. The snails are patchily distributed within these habitats. It is absent from the gently sloping southern exposure of the Cypress Hills and seldom occurs in the valley bottoms. This slow-moving species is susceptible to catastrophic wildfire, exacerbated by a build-up of fuels from fire suppression over the past century and drought associated with climate change. Introduced species, including ground-foraging Wild Turkey and a parasite, are a growing concern.

Occurrence
Alberta, Saskatchewan

Status history
Designated Endangered in May 2021.

COSEWIC
Executive Summary

Black Hills Mountainsnail
Oreohelix cooperi

Wildlife Species Description and Significance

Black Hills Mountainsnail is one of three species of its genus (*Oreohelix*) occurring in the Cypress Hills. It is clearly distinguished from the others within the genus by its smaller size and genetics. The shell of this species is about 1 cm in diameter, opaque, greyish-white or brown, and usually has one or two brown spiral bands, although sometimes bands are absent. The shell surface has irregular incremental wrinkles and striae. Very young snails have a flattened, keeled shell with coarse sculpture and scaly ridges.

Black Hills Mountainsnails, as do other terrestrial species of snail, perform important ecological roles: they consume and therefore aid in the decomposition of dead plant matter; they are important in cycling calcium through the ecosystem, making it available to other organisms; and they serve as hosts and food for a variety of other organisms.

As one of the few large-bodied molluscs in the Cypress Hills, Black Hills Mountainsnail is a molluscan representative of this unglaciated region's special fauna and flora. This species is scientifically important within the context of glaciation, relictual species, geographic disjunction, dispersal, and the significance of sky islands (isolated mountainous areas surrounded by entirely different lowland terrain) as generators of biodiversity.

Distribution

Black Hills Mountainsnail is restricted to four sky islands on the Great Plains of South Dakota, Wyoming, Montana, Alberta, and Saskatchewan. In Canada, this species occurs only on the western butte of the Cypress Hills (Alberta/Saskatchewan), where it is mostly associated with the Cypress Hills Formation, a variable stratum of gravel, sand, sandstone, and conglomerate rock. At some sites, snails occur down slope from the Cypress Hills Formation. In the Cypress Hills, it is likely that there are some connections between known sites, such as along slopes and ridgelines. It is absent from the central butte of the Cypress Hills. All known occurrences in Canada, except one, are within Cypress Hills Interprovincial Park (Alberta and West Block, Saskatchewan). In the Pleistocene, this species occurred east as far as Iowa and Illinois.

Habitat

Typical habitats of Black Hills Mountainsnail include steep slopes and cliffs, in areas with Cypress Hills Formation. They live in dry habitats such as under juniper, as well as under flattened, dead grass and cinquefoil shrubs at the margin of the plateau prairie and very thin vegetation on exposed hill tops. They are found in moister habitats as well, with abundant and varied understorey vegetation along and below cliffs in coniferous forests. A leaf litter layer is necessary. Snails grow larger and might be more common in these moister, cooler habitats, which are considered optimum for this species.

Biology

Black Hills Mountainsnail is a simultaneous hermaphrodite, with both male and female genitalia concurrent in each individual. This species, like all *Oreohelix*, is ovoviviparous, with eggs retained and then hatching within the parent. There is most likely one clutch of offspring per year. Growth likely occurs when snails are most active; snails are dormant during winter (hibernation) and summer (aestivation). In general, *Oreohelix* species are believed to mature in 1–3 years and possibly live for up to six years, with the average life span less than two years. Generation time for this species is estimated to be 2–3 years.

This species, like most land snails, has limited dispersal capacity. There is little evidence of dispersal away from the conglomerate, cobble, or silt layer of the Cypress Hills Formation.

This species is likely a generalist detritivore and herbivore and therefore has no specific plant requirements for food. Predation on it, likely by small mammals, has been seen. This species is frequently infected by an invasive European trematode.

Population Sizes and Trends

No information is available on population sizes and trend. Surveys to date have focused on detecting its presence. This species is somewhat gregarious, often occurring in tens to perhaps hundreds of individuals where it is found.

Threats and Limiting Factors

Limiting factors for land snails in general are their poor ability for dispersal and low tolerance for extreme changes in environmental conditions such as humidity and temperature. The most serious and plausible threat is catastrophic wildfire, exacerbated by a century of fire suppression and climate change. A very hot fire burning down to the mineral soil would be devastating, killing snails and destroying vegetation and the litter layer. Additional but low impact threats include tourism development, trampling by recreationalists and cattle, and the introduction of invasive species including ground-foraging birds and a European parasite, the latter of which affects the snail's reproduction.

Protection, Status and Ranks

No direct legal protection is currently afforded to this species in Canada or the USA. As all but one known site is within Cypress Hills Interprovincial Park, habitat is generally well-protected.

TECHNICAL SUMMARY

Oreohelix cooperi

Black Hills Mountainsnail

Petite oréohélice

Range of occurrence in Canada (province/territory/ocean): Alberta, Saskatchewan

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)	Possibly 2-3 yr
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	NA
Are there extreme fluctuations in number of mature individuals?	Unknown; possible because of trematode parasitism, preventing reproduction

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	277 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	88 km²
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. Possibly
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	5 (due to catastrophic wildfire)
Is there an [observed, inferred, or projected] decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] decline in number of subpopulations?	No
Is there an [observed, inferred, or projected] decline in number of "locations"*?	No
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, projected decline in area, extent, and quality of habitat
Are there extreme fluctuations in number of subpopulations?	NA or 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**
Entire population (probably not subdividable) restricted to the west butte of the Cypress Hills	Unknown
Total	Unknown

Quantitative Analysis

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

* See Definitions and Abbreviations on COSEWIC web site 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; assigned overall threat impact is High.

i. Threat 7. Natural system modifications (very high – medium impact)
ii. Threat 11. Climate change & severe weather (medium-low impact)
iii. Threat 1. Residential and commercial development (low impact)
iv. Threat 2. Agriculture and aquaculture (low impact)
v. Threat 6. Human intrusions & disturbance (low impact)
vi. Threat 8. Invasive & other problematic species & genes (low impact)
vii. Threat 4. Transportation & service corridors (negligible impact)
viii. Threat 10. Geological events (negligible impact)
ix. Threat 9. Pollution (unknown impact)

What additional limiting factors are relevant? Low capacity for dispersal, low resistance to severe changes in environmental conditions, ovoviparity

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	None likely. South Dakota (S3), Wyoming (S1), Montana (SNR)
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?[+]	Yes, with climate change and increased risk of wildfire
Are conditions for the source (i.e., outside) population deteriorating?[+]	Unknown
Is the Canadian population considered to be a sink?[+]	Unknown
Is rescue from outside populations likely?	Not likely

Data Sensitive Species

Is this a data sensitive species? The Molluscs SSC scored disturbance by observation as “moderate” (Data Sensitivity Matrix, O&P F8) but the level of detail included in this status report is not likely to increase the risk to the species.	Yes, possibly.

Status History

COSEWIC: Designated Endangered in May 2021.

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

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric codes:** B1ab(iii)+2ab(iii)
Reasons for designation: Globally, this small (shell width about 1 cm) land snail is confined to four mountainous “sky islands” on the Great Plains of North America. In Canada, it occurs only in the Cypress Hills of Alberta and Saskatchewan. Known from this area since 1905, albeit under a different name, this species occurs on ridges, hilltops, cliffs, and slopes at or near the sand, silt, cobbles, and conglomerates of the Cypress Hills Formation. The snails are patchily distributed within these habitats. It is absent from the gently sloping southern exposure of the Cypress Hills and seldom occurs in the valley bottoms. This slow-moving species is susceptible to catastrophic wildfire, exacerbated by a build-up of fuels from fire suppression over the past century and drought associated with climate change. Introduced species, including ground-foraging Wild Turkey and a parasite, are a growing concern.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. The number of mature individuals is unknown; therefore, there are 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 (277 km^2) and IAO (88 km^2) are both below the thresholds (<5,000 km^2 and 500 km^2, respectively), there are 5 locations based on increasing frequency and intensity of wildfires (a), and there is an observed and projected continuing decline in quality of habitat (b(iii)) caused by a variety of threats.
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 mature individuals is unknown. Meets Threatened D2. The number of locations (5) is below the typical threshold and the species is prone to the effects of human activities or 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
(2021)

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

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

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

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

Environment and Climate Change Canada
Canadian Wildlife Service

Environnement et Changement climatique Canada
Service canadien de la faune

Canada

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

COSEWIC Status Report

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2021

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Figure 2. Maps showing the probability of ignition and wildfire in Cypress Hills Interprovincial Park (Alberta), reproduced from O2 Planning + Design (2009). The village of Elkwater, adjacent to Elkwater Lake, has the highest ignitition probability (upper panel) from combined anthropogenic and natural causes. The fire would then move southeast (lower panel), due to prevailing winds and forest cover. 15

Figure 3. Five locations (thick grey ellipses) of Black Hills Mountainsnail (Oreohelix cooperi) based on fire as the most serious plausible threat. Occurrences of the snail (black dots), with the Cypress Hills Formation (orange area; from Glombick 2014), superimposed on wildfire threat zones (Figure 2 lower map). Using the park boundary as a guide, Figure 2 has been manually stretched to approximate the same map projection as the other layers.. 28

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Black Hills Mountainsnail (BHMS) can be classified as follows (classification by Bouchet *et al.* 2017):

Kingdom Animalia
 Phylum Mollusca
 Class Gastropoda
  Subclass Heterobranchia
   Cohort Tectipleura
    Subcohort Panpulmonata
     Superorder Eupulmonata
      Order Stylommatophora
       Suborder Helicina
        Superfamily Punctoidea
         Family Oreohelicidae
          Genus *Oreohelix*
           Species *Oreohelix cooperi* (W.G. Binney, 1858)

Common English name: Black Hills Mountainsnail

Common French name: Petite oréohélice (Agreed upon by Molluscs SSC in consultation with francophone taxonomic experts in both North America and Europe. No name was available in the SSC standard taxonomic references.)

This species was originally described by Binney (1858) based on material from the Black Hills, South Dakota. However, for some years prior to Pilsbry (1939), the species epithet *cooperi* had been wrongly used for members of the *Oreohelix subrudis* group in both Canada and the US (Pilsbry 1939; Frest and Johannes 2002). An example of this is the publication by Berry (1922), who wrongly referred to snails from Alberta and British Columbia (BC) locales in the Rocky Mountains as "*Oreohelix cooperi*" and "*Oreohelix cooperi limitaris*".

For many years since Pilsbry (1939), *O. cooperi* had been thought to be a subspecies of Rocky Mountainsnail (*Oreohelix strigosa*). However, Weaver *et al.* (2006), who used mitochondrial DNA (partial sequences of the *COI* and *12S* genes) to investigate the phylogeny of mountainsnail species from the Black Hills and other mountainous areas in South Dakota, Wyoming, and Montana, concluded that *cooperi* is a full species, separate from *O. strigosa*. They did not include in their study specimens from the Cypress Hills, Canada.

Dall (1905) described *O. strigosa* var. *stantoni* based on small-shelled *Oreohelix* specimens collected from the Head of the Mountain, Cypress Hills (Assiniboia, now Alberta) in 1903. Pilsbry (1939) took this taxon to be a synonym of *O. strigosa cooperi*. This usage has been generally accepted since, although Mozley (1937) and CESCC (2016) treated *cooperi* as a full species, and Frest and Johannes (1991, 2002) speculated that *O. stantoni* was not *O. cooperi* but a species more closely related to *O. berryi* (Pilsbry, 1915). Recently, Dempsey (2017) and Nicolai and Forsyth (unpubl. data) confirmed that *O. stantoni* is a synonym of *O. cooperi* based on *COI* gene sequence data.

Species-level taxa in the genus *Oreohelix* are many and the majority of taxa are taxonomically not well known and others controversial. Another small-shelled *Oreohelix* species similar to BHMS is Pygmy Mountainsnail (*Oreohelix pygmaea* (Pilsbry, 1913)), which is known from northern Wyoming and central Montana (Pilsbry 1939). Although BHMS and *O. pygmaea* are difficult to distinguish morphologically and COI sequences of these species are very similar (Dempsey 2017), the two species were found to be genetically distinct monophyletic taxa (Chak 2007). Dempsey's results show that all small-shelled *Oreohelix* in his samples from Cypress Hills are BHMS, not any of the other similarly small *Oreohelix* spp.; that is, his partial COI sequences all matched published sequences for BHMS. Additionally, partial COI sequences of Nicolai and Forsyth (unpubl. data) also match published sequences for BHMS. The large- and small-shelled *Oreohelix* in the Cypress Hills are clearly separate species (Dempsey 2017; Dempsey *et al.* 2019a,b; Nicolai and Forsyth unpubl. data), with a 17.4–18.6% divergence in their COI sequences (Dempsey *et al.* 2019a). Dempsey *et al.* (2019a) found a minimum of 18 fixed differences in the ITS2 sequences between BHMS and *Oreohelix subrudis* (Subalpine Mountainsnail) in the Cypress Hills, with an average sequence divergence of 7.9%. There is a third genetic lineage in the Cypress Hills, not morphologically distinct from *O. subrudis*, which is referred to as *Oreohelix* sp. X (Dempsey 2017) or clade X (Dempsey *et al.* 2019b).

Alternative English common names for this species are Cooper's Rocky Mountainsnail (e.g., NatureServe 2021—not accurate as this species is not in the Rocky Mountains) and Cypress Hills Mountainsnail (CESCC 2016).

Morphological Description

BHMS (see cover image) is a relatively large land snail (adult diameter ca. 1 cm) but smaller than the other *Oreohelix* species in the Cypress Hills, *O. subrudis* (adult diameter ca. 1.5 cm; Dempsey *et al*. 2019b). The shell is opaque, greyish-white or brown with usually one or two darker, brown spiral bands; these bands are absent in some individuals, or additional bands might be present. The spire is conical and variable in height. The shell surface has irregular incremental wrinkles and striae. The aperture height of adults is equal to or slightly more than the shell width (in *O. subrudis*, more transversely oval). Very young snails have a flattened, keeled shell with coarse sculpture and scaly periostracal ridges. Subadult shells differ from adults by being flatter and with a spiral keel on the last whorl. The animal is more or less beige. The foot is rather short and not as slender as in many terrestrial snails.

Compared to BHMS from the Black Hills in the US, snails from the Cypress Hills are smaller (Dempsey 2017). Dempsey (2017) and field verification for this status report found that different BHMS vary in shell size, as previously noted by Anderson *et al.* (2007) for the

Black Hills. In Canada, shells are larger in diameter and taller in moister, more sheltered habitats (Dempsey 2017; field verification); in contrast, Anderson *et al.* (2007) found that in the Black Hills, mean shell sizes decreased with higher elevation and lower mean annual temperature and that size was unaffected by mean annual precipitation.

Population Spatial Structure and Variability

Known occurrences of BHMS in the Cypress Hills are scattered and the global range is restricted to just four sky islands (isolated mountainous areas surrounded by lowland terrain) on the Great Plains (see **Global Range**). However, very little genetic differentiation is known within sampled BHMS in the Cypress Hills (Dempsey 2017; Forsyth and Nicolai unpubl. data) and US populations (Weaver *et al.* 2006; Chak 2007; Dempsey 2017; Dempsey *et al.* 2020) based on mitochondrial DNA analyses.

Designatable Units

There is a single designatable unit in Canada, as the criteria for discreteness and significance for more than one designatable unit are not met. Based on *ITS2* gene sequence data, BHMS forms a monophyletic clade (Dempsey 2017). Although some occurrences of this species in the Cypress Hills are probably connected (e.g., along ridgelines, across slopes, and along cliffs), others may not be. Still, there is little reason to consider sites of BHMS as being disjunct from one another; the geographic distances among these occurrences are small. BHMS occurs within a single ecozone (Prairie) in Canada. There are no apparent local adaptations although variation in shell size and shape exists (Dempsey 2017; Forsyth and Nicolai unpubl. data) (see **Morphological Description**).

Special Significance

In general, terrestrial gastropods perform important ecological functions in the ecosystems where they live. Species that are largely detritivorous, such as BHMS, consume dead plant matter and therefore aid in its decomposition (Jennings and Barkham 1979). Land snails are also important in cycling calcium, which is needed by other animals at a higher trophic level for a variety of physiologic functions (Hotopp 2002). Terrestrial gastropods serve as intermediate hosts for other organisms, including mites (Schüpbach and Baur 2008, 2010), nematodes (Boag 1983), and trematodes (Dempsey 2017).

BHMS is one of just a few species of *Oreohelix* in Canada. BHMS has special significance as one of the two (or three if the two clades of *O. subrudis* are formalized as separate species; see Dempsey 2017) large-bodied land snails in the Cypress Hills. BHMS is often the dominant terrestrial gastropod species at some sites or shares this distinction with *O. subrudis*. It is a molluscan representative of this unglaciated region's special fauna and flora. This species is scientifically important within the context of glaciation, relictual species, geographic disjunction, dispersal, and the significance of sky islands as generators of biodiversity (McCormack *et al.* 2009). The Canadian population, in one of only three relatively small areas, may be important to the global status of BHMS (see

Global Range and **PROTECTION, STATUS AND RANKS**).

Black Hills Mountainsnail has no social-economic importance, is not a pest to agriculture or horticulture, and is unknown to most Canadians.

This species has not been selected to go through the formal Aboriginal Traditional Knowledge (ATK) gathering process, and no ATK is available (Davis pers. comm. 2018).

DISTRIBUTION

Global Range

Because there has been some past taxonomic uncertainty about BHMS, and because some populations have been erroneously excluded and other species erroneously included, the global range of this species is mostly incorrect in the literature. Previously, it was believed that BHMS was endemic to only a portion of the Black Hills; the range of this species was often under-reported in the literature (e.g., Anderson 2005). However, Pilsbry (1939) included records of *O. cooperi* that have not since been confirmed as this species and are, perhaps, beyond the likely range of this species as it is now known. Even recently, Weaver *et al.* (2006) erroneously included populations of another species as BHMS (Chak 2007).

From the molecular studies of Weaver *et al.* (2006) and Chak (2007) BHMS has been identified from the Black Hills (Pennington and Lawrence counties, South Dakota and Crook County, Wyoming), Bear Lodge Mountains (Crook County, Wyoming), and Judith Mountains (Fergus County, Montana; Figure 1). BHMS from Bighorn Mountains (Big Horn County) in Weaver *et al.* (2006) is actually *Oreohelix pygmaea*, with very similar *COI* sequences according to Chak (2007). In Canada, BHMS is known only from the Cypress Hills (Pilsbry 1939; Dempsey 2017; Dempsey *et al*. 2019b; Forsyth and Nicolai unpubl. data). Thus, BHMS is known from only four upland landforms (sky islands), eastern outposts of the Rocky Mountains, which are surrounded and separated from each other by the Great Plains. BHMS is unknown from, and not expected to be on, the surrounding Great Plains.

Pleistocene fossils from the loess of Iowa and Illinois were attributed to *O. cooperi* (Pilsbry 1939; Frest and Rhodes 1981; Frest and Dickson 1986), although originally described as *O. cooperi* form *iowaensis* Pilsbry, 1916. The disappearance of this species from the US Midwest was possibly caused by a changing climate during the Pleistocene (Frest and Rhodes 1981). Because BHMS has not lived in these states since the Pleistocene, these fossil occurrences are not considered part of the current global range of the species.

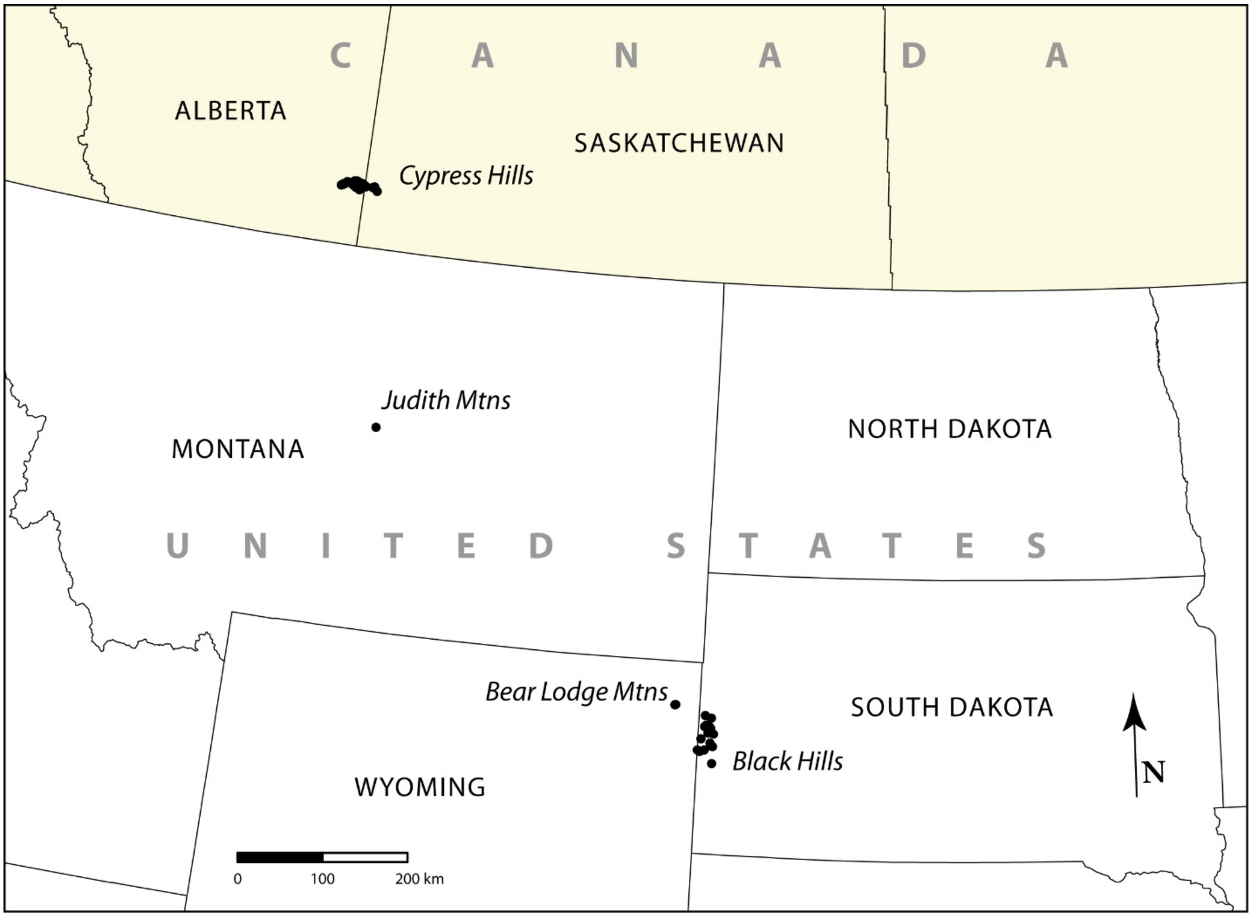

Figure 1. Global range of Black Hills Mountainsnail (*Oreohelix cooperi*; black dots = individual records), based on data from Weaver *et al*. (2006), Dempsey *et al.* (2019b), and Lepitzki, Forsyth, and Nicolai (unpubl. data). Records of this species from the Pleistocene are excluded. The record from Bighorn Mountains, Wyoming (Weaver *et al.* 2006) is excluded because it was *Oreohelix pygmaea* (see Chak 2007). (Map by R. Forsyth.)

Canadian Range

In Canada BHMS is restricted to the Cypress Hills, which are roughly 280 km north of the nearest US occurrences of this species in the Judith Mountains (Figure 1). The Canadian population is within the Prairies ecozone and the Cypress Uplands ecoregion (Ecological Stratification Working Group 1995).

Within the Cypress Hills complex, this species is known almost entirely from areas within Cypress Hills Interprovincial Park (CHIP), in the Alberta and the West Block portion of the park in Saskatchewan. The exception is that one of the sites reported by Dempsey (2017) as being within the park is several hundred metres outside the park. Several other sites are <200 m from a park boundary, and it is anticipated that more occurrences of BHMS exist outside the park, particularly on its northern and eastern limits.

Prior to Pilsbry (1939), reports of *O. cooperi* (and infraspecific taxa) in the literature from elsewhere in Canada, for example, Dall (1905; "Lake of the Woods to … the Rockies …") and Berry (1922; "various places in BC and Waterton, Alberta") are based on an earlier misuse of the name (see **Name and Classification**), or are simply wrong (as in the case of Dall's claim that *Oreohelix* occur east of Saskatchewan).

BHMS is only known in Canada from the western butte of the Cypress Hills (Dempsey 2017; 2018 field verification), that part of the hills west of "the gap" (Gap Creek). During the last glacial maximum, the western butte was an unglaciated nunatak, 90 m high and with an area of 311 km^2 (Newsome and Dix 1968; Westgate 1968). The western butte is characterized by a broad, flat plateau, with steep escarpments on the north and west. BHMS has not been found on the centre butte (see **Search Effort**), which is lower than the western butte. Dempsey (2017) suggested that the Milk River Ridge and the Porcupine Hills, two higher land forms in south and southwestern Alberta, should be surveyed for BHMS. However, the Porcupine Hills are contiguous with the Rocky Mountain Foothills, where only *O. subrudis* have been found and a survey of terrestrial snails along the Milk River (Forsyth and Lepitzki 2015) did not find BHMS, so the presence of BHMS in these areas seems unlikely (see Search Effort). The eastern butte of the Cypress Hills, as well as Eagle Butte, also might harbour occurrences of this species (see **Search Effort**).

The Cypress Hills Formation, of Oligocene age (Glombick 2014), is a stratigraphic unit composed of water-worn gravels and cobbles, marl, and silt (McConnell 1886; Williams and Dyer 1930). Calcification of these materials by groundwater has formed conspicuous sandstone or conglomerate bedrock outcroppings or cliffs at the surface with little lateral extent (Kupsch and Vonhof 1967). Although Dempsey (2017) noted the association of BHMS with conglomerate outcroppings, BHMS was also found to be associated with the other non-consolidated materials of this formation during field verification for this report (see **Habitat Requirements**). BHMS has been found on silty and cobbly ridges, hilltops, and slopes where the Cypress Hills Formation was largely eroded away and along conglomerate cliffs and sand/silt/cobble cliffs. The Cypress Hills Formation is restricted to the Cypress Hills (Glombick 2014) and does not extend west to Eagle Butte (Glombick 2014). Dempsey (2017) noted that nearly all his conglomerate sites had BHMS. In the Alberta portion of the park areas with conglomerate outcroppings amount to ca. 30 ha in total (Alberta Parks 2011).

BHMS generally does not occur on the top of the main plateau areas, except peripherally. This species does not occur on the gently sloping southern exposure of the Cypress Hills, and it mostly does not occur in the valley bottoms, such as along Battle Creek, which were glaciated or were glacial melt-water channels (Newsome and Dix 1968). BHMS is known to occur at elevations between 1178 and 1450 m (Dempsey *et al.* 2019a; field verification for this report). The presence of this species at these elevations, however, might be correlated to the elevation of the Cypress Hills Formation. The differences in the impermeability of the various strata of the Cypress Hills concentrates groundwater at certain layers (Kupsch and Vonhof 1967), which may also account for the distribution of BHMS at certain parts of the slope and with this geological feature.

Thus, in the Cypress Hills, the BHMS is remarkably restricted (or almost so) to a specific stratum layer, and elevation, although some downhill dispersal seems apparent (see **Dispersal and Migration**). Colonies of snails generally do not extend far from the Cypress Hills Formation, and overall, occurrences seem patchily distributed (Forsyth pers. obs.). In the Cypress Hills, surveys have found BHMS at one place but not at another just tens of metres away; the "absence" of BHMS in a small area might not mean that it is absent from the larger area. However, restricted or patchy distributions are quite common among species of *Oreohelix,* and some taxa are believed to occur in very small areas; for example, Unita Mountainsnail (*Oreohelix eurekensis uinta* Brooks, 1939) is known from an area of only ca. 0.03 ha (Oliver and Bosworth 2000).

Recent occurrences of BMHS in the Cypress Hills include those from 2006 forward and historical occurrences are all prior to 2006. Historical records (i.e., museum collections 1903–1960) have insufficient data to locate the sites with certainty. Recent occurrences include an incidental collection of shells from 2006, as well as those found during targeted searches (2009, 2014–2018) for *Oreohelix* species by Lepitzki *et al.* (2009), Lepitzki and Forsyth (2018), field verification for this status report, and Dempsey (2017; Dempsey *et al.* 2019a,b).

Currently, BHMS is known from approximately 30 separate recent sites (some very close observations have been grouped). This number does not exclude the possibility that some sites/occurrences might be, or probably are, connected. A single population is suggested to contain all Canadian occurrences of BHMS.

No information is available on temporal changes or trends in the distribution, number of subpopulations, or number of locations of BHMS, as the species has only been rediscovered in Canada in the last decade. The precise geopositions of historical records are uncertain, which makes comparisons impossible, or at best, difficult. The Head of the Mountain (the highest, westernmost part of the main plateau) is important because it is the type locality of the synonymous *O. stantoni* and because Russell (1951) last collected the species there in the 1930s. Lepitzki and Forsyth tried twice (2009 and 2017) to find BHMS at the Head of the Mountain but were unsuccessful. However, they did notice evidence of a forest fire in the area. During field verification for this report, it was successfully found at the Head of the Mountain in 2018, in association with the Cypress Hills Formation (and Dempsey [2017] also found it there). Whether BHMS has undergone a contraction in distribution or is less common, perhaps caused by fire, at the Head of the Mountain since Russell's time (or earlier) is unknown. C.D. Bird collected *O. stantoni* along Hwy 48 (now 41) south of the unincorporated community of Elkwater in 1960 but the precise geoposition of this record is indeterminable now. Dempsey surveyed a number of spots along this road but did not find the species, and again, whether this is the result of a loss of a BHMS site is unknown.

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EOO) of Black Hills Mountainsnail in Canada is 277 km^2, as measured by the minimum convex polygon method to encompass all recent occurrences (i.e., 2006–2018). Excluded were historical occurrences, for which no precise geopositional data are available. Based on the premise that EOO might include additional sites throughout the entire upland extent of the western butte of Cypress Hills, EOO could potentially be larger (perhaps as much as ca. 510 km^2) if all upland areas of the west butte are included.

The discrete index of area of occupancy (IAO) is 88 km^2 (22 grid cells of 2 × 2 km), based on recent occurrence data only and excluding historical occurrences. However, based on potential unknown occurrences in possibly suitable habitat (i.e., ridgelines, cliffs, and steep slopes above ca. 1100 m), IAO could be larger. Calculation of continuous IAO might be possible if grid cells between known sites are interpolated using, for example, elevation, slope, or presence of the Cypress Hills Formation. Due to the possibly linear nature of habitat and occurrences, IAO may not be very accurate in representing the true area occupied by BHMS in the Cypress Hills.

Search Effort

Shells of BHMS are relatively thick-walled and, as expected in calcium-rich soils seem to persist, perhaps for years (Pearce 2008; Říhová *et al.* 2018). They are relatively large and often easily detected. Living snails, however, can be more difficult to find but dead shells retaining colour and periostracum are indicative of colonies of living snails (Říhová *et al.* 2018).

Prior to 2009, search effort for this species was minimal. All of these records consist of incidental collections of shells by various collectors. Nearly all of these records are decades-old, from 1903 to 1960, but there is one collection from the West Block of Saskatchewan by M.J. Oldham in 2006. Russell (1951) gave the impression that he had made more than just a few collections of terrestrial gastropods in the Cypress Hills, but few materials have been found in Canadian museum collections and none collected after 1948 (Forsyth pers. obs.). Indiscriminate, general searches for terrestrial snails might largely overlook BHMS. Conversely, narrow targeting of just one type of habitat (e.g., only well-formed conglomerate cliffs) might overlook BHMS in other habitats. There have now been several surveys targeting mountainsnails in the Cypress Hills since 2009. In all surveys, the focus was on detecting the presence of the species at sites or to collect material for molecular and parasitological study.

The first targeted survey for Black Hills Mountainsnail occurred in August 2009 by Lepitzki and Forsyth (2009), who searched 18 sites (some within 100 m or less of each other) within the Alberta portion of the CHIP and located this species at seven sites. At that time, the association with the Cypress Hills Formation was unknown, so their searches were not as well focused for this species. Summary of sites and findings: Alberta, in park (*n* = 18): present (7), not detected (11); Saskatchewan, West Block (*n* = 0): Saskatchewan, Centre Block (*n* = 0).

Dempsey (2017) and colleagues sampled 41 sites for *Oreohelix* spp. in CHIP and found BHMS at 13 sites (or 11 if some sites are combined). The focus was on habitats with conglomerate cliffs. Summary of sites and findings: Alberta, in park (*n* = 33): present (9), not detected (24); Alberta, outside park (*n* = 1): present (1); Saskatchewan, West Block (*n* = 4): present (3), not detected (1); Saskatchewan, Centre Block (*n* = 3): present (0), absent (3).

Lepitzki and Forsyth (2018) surveyed 20 sites in August 2017, which included revisits of most of their 2009 BHMS sites and several sites new to them, including in the West Block, Saskatchewan. Summary of sites and findings: Alberta, in park (*n* = 16): present (9), not detected (7); Saskatchewan, West Block (*n* = 4): present (2), not detected (2); Saskatchewan, Centre Block (*n* = 0).

In 2018, field verification for this status report was undertaken. Because of the recent work of previous years (2009–2017), the focus of this fieldwork was to locate new sites. Altogether, 31 sites were surveyed in Alberta and Saskatchewan, including the Centre Block. Eight new sites were located within the Alberta portion of the park. A better understanding of the association of this species to geological features resulted in more predictability in locating new occurrences, and not only in habitats with conglomerate cliffs. Whereas the presence of conglomerate cliffs is easily noticeable, at other sites, the formation is less obvious and finding snails more difficult. Summary of sites and findings: Alberta, in park (*n* = 17): present (8), not detected (9); Saskatchewan, West Block (*n* = 4): present (0), not detected (4); Saskatchewan, Centre Block (*n* = 10): present (0), absent (10).

The searches by Dempsey (2017) and for field verification in 2018 in the Centre Block of CHIP are probably sufficient to reasonably conclude that BHMS is not there (although *O. subrudis* was found).

In the surveys of Forsyth, Lepitzki, and Nicolai, snails were searched for using the usual method of meandering through potentially suitable habitat, looking for evidence of dead shells, and looking under grasses, other vegetation, stones, or dead wood for live snails. The presence of living snails was often signaled by the presence of dead shells, often in quantity. Presumably, Dempsey and colleagues used similar methods.

In areas outside of the known geographic range of BHMS, search effort is variable depending on the area, but the Rocky Mountain Foothills, Rocky Mountains proper, and the cordillera west in BC are all quite well searched for large-bodied terrestrial snails (e.g., COSEWIC status report on Banded Tigersnail (*Anguispira kochi*): COSEWIC 2017). These areas have *Oreohelix subrudis* (in Alberta; Pilsbry 1939; Dempsey 2017; Lepitzki and Forsyth unpubl. data) and *O. strigosa* (BC) (Pilsbry 1939; Forsyth 2004; Lepitzki, Forsyth, *et al.* unpubl. data). Neither BHMS nor any other *Oreohelix* resembling BHMS have ever been found in any of these areas. There are several higher-elevation areas in Alberta and Saskatchewan prairies that have had no or little search effort to date. These include the east butte of the hills in Saskatchewan, and the privately owned Eagle Butte, a highland area (to ca. 1340 m) that is separated (<10 km) from the main western butte by the valley of Bullshead Creek (the Cypress Hills Formation does not extend to that butte; Glombick 2014). Other areas, speculated by Dempsey (2017) as possibly having BHMS, are the Porcupine Hills and the Milk River Ridge. However, Forsyth and Lepitzki (2015) did not find BHMS along the Milk River in Writing-on-Stone Provincial Park, which flows through the Milk River Ridge.

HABITAT

Habitat Requirements

Dempsey (2017) characterized the habitat of BHMS as dry, shrubby slopes and thought that one of his sites, a cool, shaded, pine-forested slope, was unusual. He noted that snails were most abundant beneath Creeping Juniper (*Juniperus horizontalis*). Drier sites on slopes and along ridges were similarly thought to be the predominant habitat type after the 2009 and 2017 fieldwork of Lepitzki and Forsyth, who found BHMS also under juniper, as well as under flattened, dead grass and cinquefoil (*Potentilla* sp.) shrubs at the margin of the plateau prairie and very thin vegetation on exposed hill tops. They also found BHMS in aspen groves on hillsides and, at one site, in a spruce forest with abundant and varied understorey vegetation. However, during field verification in 2018 BHMS was found at several sites along slopes with cooler, moisture conditions and forested with pine or spruce. In the Black Hills, US, the largest colonies of BHMS are said to occur in pine forests, often with a developed understorey, according to Frest and Johannes (2002).

Dempsey (2017) reported that this species was most abundant in decaying plant matter and beneath juniper stems, but a wider variety of microhabitats are occupied. BHMS was observed under dead wood, in needle and leaf litter, under flattened, dead grass, and on undersides of stones (Lepitzki and Forsyth 2009, 2018; 2018 field verification). In general, the litter layer is important for land snails (Meadows 2002; Anderson 2005); the litter layer varies from sparse and shallow (but with coarse woody debris providing shelter) to rather deep in Cypress Hills (Forsyth pers. obs.).

Slope and aspect varied immensely among the BHMS field verification sites in 2018. These abiotic characteristics influence moisture (important for snails, see **Physiology and Adaptability**), and in turn the type and amount of vegetation. In August 2018 at sites in the Alberta portion of the park (*n* = 7), soil humidity and soil temperature were 0–9.2% and 13.5–21.7 °C, respectively. Some vegetation seems necessary, as no snails were found on bare earth or rock, but the type of vegetation did not appear important. At the moister, more sheltered sites, the flora was more varied, as to be expected, and snails were generally more numerous and larger, suggesting optimum habitat. More exposed sites with fewer trees, shrubs, and forbs had snails of smaller adult size which suggest less optimal habitat.

At most BHMS sites, the conspicuous stratum of the Cypress Hills Formation was evident (see **Canadian Range**). At all but one of the 2018 BHMS sites, the soil pH was slightly basic (6.22 and 7.60–8.01). The high calcium availability in these habitats is possibly important to this species (see **Physiology and Adaptability**). However, not all sites searched in 2018 with this formation were occupied by BHMS, nor were all base-rich sites. However, the prairie plateau, where BHMS is almost entirely absent is also base-rich (based on one sample), so there would seem to be factors involved other than only calcium availability. In the Black Hills, Frest and Johannes (2002) found this species at sites on calcareous soils.

Habitat Trends

The climate of the Cypress Hills is undergoing change. Between 1950 and 2010, the mean annual temperature in the Cypress Hills has increased by >2°C (Alberta Climate Records 2018). Mean summer temperatures in the Cypress Hills have increased by 1.1–1.3°C in the same period, mean spring temperatures by 1.3–1.4°C, and fall temperatures by 0.8–1.1°C. A change in mean winter temperatures is most dramatic, with increases of 5.3–6.1°C since 1950 (Alberta Climate Records 2018). The Prairie Climate Centre (2017) has used 12 global climate models and different emission scenarios to predict change in temperature and precipitation for 2051–2080 relative to 1976–2005 levels. Using the RCP 8.5 emission scenario (highest representative concentration pathway scenario in terms of greenhouse gas emissions), mean monthly temperatures are projected to increase by a minimum of 2.1–3°C (April–May) to a maximum of 4.1–5°C (July–September, December). Thus, the climate already has changed in the Cypress Hills over the last six decades or more and is projected to continue to change in the future. Changes to average and extreme temperatures, along with increased risk of prolonged or more frequent droughts (O2 Planning + Design 2009), likely will affect the quality and availability of habitat and microhabitats. Drier habitats might become intolerable for this species and optimum habitats might be reduced.

With climate change, forests in the Cypress Hills are becoming more vulnerable to insects and pathogens (Alberta Parks 2011), including Mountain Pine Beetle (*Dendroctonus ponderosae*) and Dwarf Mistletoe (*Arceuthobium americanum*); Spruce Budworm (*Choristoneura fumiferana*) is another important forest pest.

The risk of catastrophic fire in the Cypress Hills is very high due to aging forests and increases in fuel loads caused by insect damage, pathogens, and blowdowns (Alberta Parks 2011). The probability of fire from combined anthropogenic sources and lightning is high, with very high risk around Elkwater and on the plateau area (O2 Planning + Design 2009; Figure 2). Strauss (2001) predicted that “the next large fire within the Cypress Hills is likely to be catastrophic, causing unpredictable impacts to the forest and grassland ecosystems”. A fire in the grasslands would quickly move into forested habitats due to wind (O2 Planning + Design 2009). The landscape-level fire in 1885 originated in Manyberries (ca. 30 km southwest, on the prairie) and spread to the park to become a crown fire (Forsite 2021).

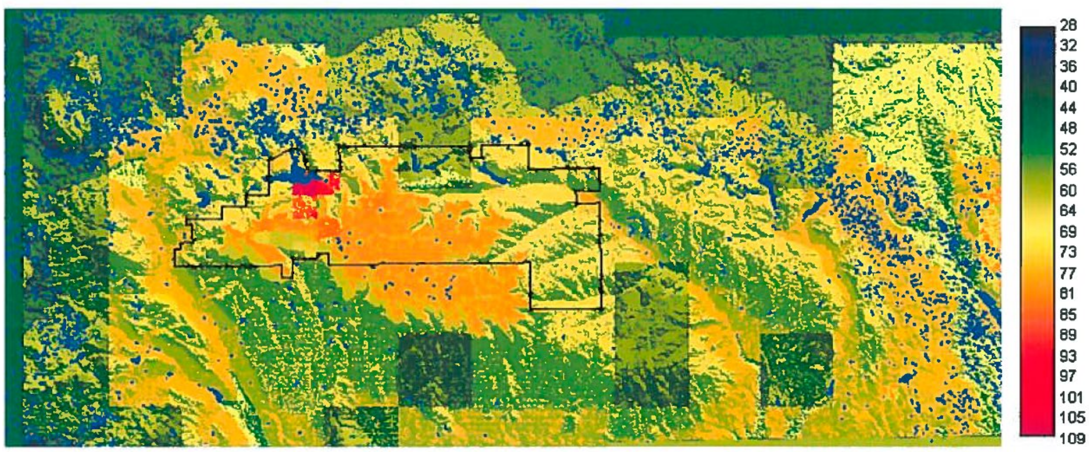

Figure A.4. Probability of ignition model from combined lightning and anthropogenic sources of ignition.

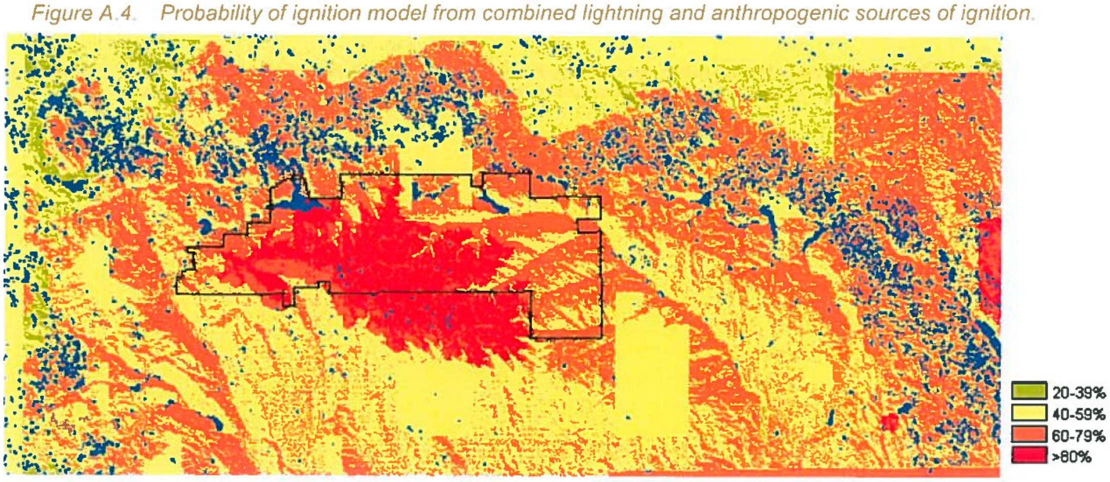

Figure A.5. Wildfire threat zones based strictly on values from the probability of ignition model.

Figure 2. Maps showing the probability of ignition and wildfire in Cypress Hills Interprovincial Park (Alberta), reproduced from O2 Planning + Design (2009). The village of Elkwater, adjacent to Elkwater Lake, has the highest ignition probability (upper panel) from combined anthropogenic and natural causes. The fire would then move southeast (lower panel), due to prevailing winds and forest cover.

Although Doerr and Santín (2016) found that during the last three decades the severity and area burned in the western US has declined overall due to fire suppression (contrary to the impression held by the public), Pechony and Shindell (2010: 2) project dramatic increases in fire trends in western North America and conclude that "future projections indicate an impending shift to a temperature-driven global fire regime in the 21st century, creating an unprecedentedly fire-prone environment". Wildfire has, indeed, been historically more prevalent in the Cypress Hills. Free-roaming bison were eliminated in the hills by 1883 and grassy fuel loads increased as a result (Alberta Parks 2011). In 1885, a major (high severity) fire burned through almost the entire forested area of the Cypress Hills and 95% of the Lodgepole Pine (*Pinus contorta* var. *latifolia*) forest (Strauss 2001; Henderson *et al.* 2002). A second fire burned through the area in 1889 (Strauss 2001). Fuel load in forests of the Cypress Hills has since increased to dangerously high levels (Henderson *et al*. 2002), as fire suppression since the 1890s has eliminated frequent, low severity fires that would have reduced the fuel load (Strauss 2001). Fire suppression began in 1909 (O2 Planning + Design 2009). Since then, only two large fires (>200 ha) have burned: 434 ha (in 1919) and 607 ha (in 1934; O2 Planning + Design 2009).

To address the risk of potential catastrophic wildfire, management plans to renew older forests have been initiated. This generally involves cutting older trees to allow for forest regeneration. Areas where forests have been cut are visible in satellite/aerial imagery; these areas show a network of tracks and a pattern of cut strips within the forest. It is unknown if BHMS are in such areas, but this pattern of patchy cutting would be expected to be beneficial to maintaining snails by providing refuges in uncut areas (similar to patchy prescribed burns; Gaines *et al.* 2011). Prescribed burning and chemical spraying are being considered (Chu pers. comm. 2018).

American Bison (*Bison bison bison*) was a keystone species on the Canadian Prairies, and their grazing and soil disturbance were ecologically important to the development and maintenance of the prairies (Campbell *et al.* 1994; COSEWIC 2013). BHMS has co-existed with grazers in the Cypress Hills for millennia, but since the 1880s domestic cattle have replaced bison on the prairies and have a similar ecological effect (Tastad 2013). Cattle graze rangelands within both Alberta and Saskatchewan parts of the park, with ca. 4000 head grazing in the park annually between June and October (Hegel *et al.* 2009). Livestock grazing, part of the "cultural heritage" of the Cypress Hills, is a vegetation management tool in the park (Saskatchewan Parks 2005), unlikely ever to cease (Lockerbie pers. comm. 2019), and managed grazing of livestock continues to be part of park management plans (Alberta Parks 2011).

BIOLOGY

Although there is some information available on the biology of BHMS (Anderson *et al.* 2007; Dempsey 2017) and related *Oreohelix* species, knowledge is incomplete. However, general information on terrestrial snails might apply to some aspects of the biology of BHMS.

Life Cycle and Reproduction

The majority of terrestrial pulmonates are simultaneous hermaphrodites, with male and female genitalia apparently developing concurrently in each individual (Heller 2001). This includes *Oreohelix* species, which have both male and female parts of the hermaphroditic reproductive system (Pilsbry 1939; Webb 1951). Cross-fertilization is common in terrestrial pulmonates (Jordaens *et al.* 2007) and the exchange of gametes is reciprocal (Webb 1951), but observations by Webb (1951) indicate that copulation is non-reciprocal in the genus *Oreohelix*, meaning that only one partner receives gametes (one partner acts as a "male", the other, a "female"). It is unknown whether BHMS is capable of self-fertilization, such as reported as a "last resort" in normally crossing species (Heller 2001; McCracken and Brussard 2008).

Like all other species of *Oreohelix*, BHMS are ovoviviparous (Anderson *et al.* 2007), with eggs retained and hatching within the reproductive system of the parent. At "birth", *Oreohelix* exit the adults as fully developed, albeit small, snails. In the Black Hills, Anderson *et al.* (2007) found the brood size to vary from 1 to 11 (average 3.3) and to be more prevalent in late spring (May) and late summer/early autumn (September-October). They hypothesized that there is one clutch per year and that "… copulation normally occurs from late May to July as conditions allow. It appears that broods then grow opportunistically and are then retained over winter and released in late spring" (Anderson *et al.* 2007:136). At higher elevations, offspring are as numerous as (but smaller than) at lower elevations (Anderson *et al.* 2007).

Growth in land snails likely occurs during times of greatest activity; thus, for BHMS, most growth is likely in the spring prior to aestivation and in the fall prior to hibernation. Longevity in BHMS is unknown and there is some conflicting information about the lifespan of BHMS. Beetle (1987) supposed that *O. subrudis* die after reproduction, but the basis of this is unknown. In general, *Oreohelix* species are believed to mature in 1–3 years and possibly live for up to six years, with the average life span less than two years (Frest and Johannes 1991, 2002; later authors cite these durations as for BHMS, apparently in error). In captivity, *O. subrudis* was found to attain large size in three years (Beetle 1987). Both adults and juveniles were found in August 2018 (during drought and aestivation), which suggests that young may take at least one year to mature. Much of the lifespan of long-lived snails is spent hibernating or aestivating in some species (Cameron 2016). The generation time of BHMS is possibly two to three years.

Physiology and Adaptability

Oreohelix species are detritivores and herbivores. An analysis of faecal matter of another species of *Oreohelix* found that leaf litter (dead plant material) was the main food of choice and that live plants constitute a small part of the diet (Bernard and Wilson 2016), and it is expected that BHMS is the same.

Snails require calcium to build shells and perform other physiological functions (Peake 1978). *Oreohelix* are generally thought of as being calciphilic, and although some calcifuge species are known (Frest and Johannes 2002), BHMS has been found primarily on base-rich soils, suggesting it is a calciphilic species (see **Habitat**).

Excessive heat and drought is a major problem for land snails in general, but BHMS seems well adapted to survive these conditions. In general, relatively pale, opaque and rather thick-walled shells, such as in *Oreohelix* spp., are adaptations to dry conditions and high solar radiation (Yom-Tov 1971; Cameron 2016). Terrestrial snails are especially vulnerable to water loss through the skin and by mucus secretion needed for locomotion (Cameron 2016). In August 2018, when soil humidity was 0–9.2% (mostly on the low end of the range) and soil temperature was 18–21°C, BHMS were aestivating. During aestivation, the aperture is sealed by a membrane of dried mucus (the epiphragm) and the shell may be glued by dried mucus to a hard substrate such as a rock or piece of dead wood. Although some xeric-adapted species of snails climb the stems of vegetation to take advantage of cooling air currents (Yom-Tov 1971), this has not been observed for BHMS. According to Frest and Johannes (1991), *Oreohelix* spp. are commonly most active from April to June and September to November. Thus, BHMS are likely quite seasonal in their activity levels. Clearly, in other seasons, humidity could be much higher and temperatures considerably cooler, although data and observations of BHMS at other times of the year are lacking. BHMS might have some resistance to freezing (Frest and Johannes 2002), but hibernation is expected.

Ovoviviparity (see **Life Cycle and Reproduction**) is thought to be an adaptation to environmental conditions that are unfavourable for the development of eggs and tiny young. Eggs hatch within the parent and hatching can be delayed, minimizing the negative effects of drought and predation (Baur 1994; Heller 2001).

Dispersal and Migration

The dispersal of relatively immobile terrestrial snails has garnered considerable interest, although little is known about *Oreohelix* species. Both abiotic and biotic means of long-distance dispersal of land snails are possible (Dörge *et al.* 1999). Four examples are strong winds such as tornadoes, transport by ungulates (Fischer *et al.* 1996), being carried by birds on feathers and feet, and being eaten and passing through the gut (Simonová *et al.* 2016). Although dispersal must have happened in the history of BHMS for it to populate the Cypress Hills and other parts of its range, dispersal between these sky islands must have been extremely rare. Conditions might not be the same now as they were in the past (Dörge *et al.* 1999) to allow for the passive dispersal of BHMS between disjunct parts of the species' range.

The ability of snails to disperse on their own is not large and is severely limited by their physiology as well as periods of hibernation and aestivation. In land snails, active dispersal by means of crawling is generally <1 m to tens of metres in a year depending on the species (e.g., Baur and Baur 1993, 2006). *Oreohelix* spp. appear generally slow-moving relative to other species of snail (Forsyth pers. obs.). In Wyoming, a mark and recapture study found that unspecified species of mountainsnails moved 2.6 m/year on average (Tronstad 2016). Among terrestrial snails, dispersal of individuals is generally restricted by the availability of suitable habitats as well as food (Cook 2001). Baur and Baur (1992) found that in Copse Snail (*Arianta arbustorum*) dispersal along linear habitats, such as along a slope that is bounded by unfavourable habitats, was less than in two-dimension habitats, such as a meadow. The mostly linear nature of the exposed Cypress Hills Formation might pose a similar limitation for the dispersal of BHMS.

At sites with BHMS, there was little evidence in 2018 of dispersal away from the conglomerate, cobble, or silt layer of the Cypress Hills Formation, although in places, BHMS colonies extend farther down slope by a few hundred metres, which suggests past passive dispersal by rolling (Baur *et al.* 1997) or perhaps by other means such as water.

In Canada, BHMS likely is not severely fragmented. Although some habitat patches might be separated from other habitat patches by large distances, it is likely that there are some connections between known sites, such as along slopes and ridgelines. Moreover, nothing is known about the viability of any of the known occurrences of BHMS in Cypress Hills.

Interspecific Interactions

BHMS is likely a generalist detritivore and herbivore and therefore has no specific plant requirements for food. Competition for food and other resources (e.g., shelter) with *O. subrudis* and other terrestrial gastropods is unknown. As *Oreohelix* spp. are the only large-bodied land snails in the Cypress Hills (Forsyth, Lepitzki, and Nicolai unpubl. data), it seems that competition with gastropods, if it exists, might be between these species and only where they co-occur. There are few introduced gastropod species (and none large) in the Cypress Hills (Forsyth, Lepitzki, and Nicolai unpubl. data), and none are known from the habitats with BHMS, that would either compete with or prey on BHMS.

Evidence of predation (broken shells), likely by small mammals, was seen in 2018 (Forsyth pers. obs.) although the predators are unknown. Possible (and expected) predators to land snails in general might include small mammals, birds (see also **Threat 8** <u>Invasive and other problematic species and genes</u>), and insects such as various fly larvae and carabid beetles (Barker 2004).

The invasive, central European trematode *Dicrocoelium dendriticum*, a liver fluke of ungulates, was previously undetected or rare in the Cypress Hills prior to 1990 (Goater and Colwell 2007; Beck 2015) (see **Threat 8.1**). It was first introduced in North America in 1931 and spread north and west over the following decades (Goater and Colwell 2007). Snails are obligate first intermediate hosts of *D. dendriticum*, and in the Cypress Hills this includes the species of *Oreohelix* (Dempsey *et al.* 2019a). Dempsey *et al*. (2019a) found that infection was seasonally variable; in June, the prevalence of infection in BHMS peaked at and exceeded 15% although there was no statistically significant difference (P = 0.243) in prevalence among months (May through September). At two sites, the average prevalence of infection was 9% (n = 300 snails; 6.7 and 11.3%, P = 0.755; Dempsey *et al.* 2019a). Although only two sites with BHMS were included in Dempsey *et al.* (2019a), Dempsey (pers. comm. 2019) noticed infected snails elsewhere and believes that the snails throughout the park are likely equally infected. The average prevalence of infection in *O. subrudis* and *Oreohelix* sp. (two sites and 300 snails of each species) were both 10.3% (no significant difference in overall prevalence between sites for samples pooled across species and months, $P = 0.415$; Dempsey *et al.* 2019a). Snails infected with larval *D. dentriticum* do not reproduce, likely due to a significant drain on host energy reserves (Dempsey *et al.* 2019a).

Snails are also intermediate hosts for the larvae of *Protostrongylus*, a genus of nematode that is also parasitic in the lungs of ungulates (Boag 1983 and references therein). Boag (1983) found that non-*Oreohelix* species of snails were attracted to the dried faeces of Bighorn Sheep (*Ovis canadensis*), although not to fresh faeces. If a similar attraction occurs in BHMS, the susceptibility for BHMS to become infected might be heightened. A photograph of *O. subrudis* on fresh deer pellets in CHIP was taken in 2009 (Lepitzki unpubl. data).

Although there are no observations of mites on BHMS, in general mites are known to parasitize terrestrial snails, living within the mantle cavities of their hosts. Mites are known to cause increased mortality, decreased reproductive output, and decreased activity (Schüpbach and Baur 2008, 2010).

The invasive Rain Beetle (*Pterostichus melanarius*) is now by far the dominant invertebrate ground predator in the park, and it is known to feed on snails and slugs, but its effect on BHMS and other terrestrial snails is unknown (Goater pers. comm. 2019).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Surveys for BMHS have been focused on detecting the presence of the species.

Abundance

No information is available on the total number of individuals of all ages or the number of mature individuals of BHMS in Canada. This species is rather gregarious; where it occurs, it often occurs in the tens or perhaps hundreds (it’s difficult to find every individual, especially juveniles). However, in 2018 live snails appeared to be more abundant in cooler, moister habitats than in hotter, drier places.

Fluctuations and Trends

Nothing is known about fluctuations and the population trend of BHMS in Canada.

Rescue Effect

Although land snails have some limited capacity for dispersal (see **Dispersal and Migration**) and immigrants would likely be adapted to survive in Canada, rescue from the USA is extremely unlikely because of the great distance between suitable sky islands in the Great Plains (see **Global Range**).

THREATS AND LIMITING FACTORS

Threats

Direct threats facing BHMS were assessed, organized, and based on the IUCN-CMP (World Conservation Union-Conservation Measures Partnership) unified threats classification system (Master *et al.* 2012) based on Salafsky *et al.* (2008). Threats are defined as the proximate activities or processes 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 overall assigned threat impact is High. The numbers associated with the threats listed below correspond to the IUCN threat numbers and the threat calculator completed for this species. Threats are arranged from highest to lowest impact; see comments in Appendix 1 for negligible impact threats and those not scored.

<u>1. Residential and commercial development (low impact, small scope, moderate severity, high timing)</u>

1.1 Housing and urban areas (not scored; see Appendix 1 for comments).

1.3 Tourism and recreation areas (low impact, small scope, moderate severity, high timing).

While campgrounds and other non-trail facilities exist in the park, these are for the most part not in areas with BHMS. The exception is one campsite, where BHMS are found within a few metres of tent pads. The Alberta portion of the park is more developed than Saskatchewan's West Block, which is a wilderness area with minimal facilities, although it does include two rustic campgrounds and an equestrian centre. The Alberta park management plan seeks to ensure that park staff are knowledgeable about species at risk and take these into consideration when implementing development or activities (Alberta Parks 2011). Parking might be expanded at the Spring Creek Ski Trail shelter building but is on the grassland plateau (Berndt pers. comm. 2018); while it is unknown whether snails occur in that area (no surveys have been done in that area), given the placement on the plateau, it seems unlikely. A new trail plan for the Alberta park was under development in 2019, and development of trails would undergo an environmental review and the negative effects to the species would be mitigated as much as possible (Lockerbie pers. comm. 2019).

The threat from park facilities such as campgrounds would be potential expansions to facilities. See also 6.1 Recreational activities.

<u>2. Agriculture and aquaculture (low impact, restricted scope, moderate severity, high timing)</u>

2.1 Annual & perennial non-timber crops (not scored; see Appendix 1 for comments).

2.3 Livestock farming or ranching (low impact, restricted scope, moderate severity, high timing).

There is little chance that grazing in the park will be discontinued (Lockerbie pers. comm. 2019). Grazing might have little direct threat to BHMS in CHIP, although livestock trampling is known to have serious negative effects on terrestrial molluscs (Denmead *et al.* 2015). In the study of Denmead *et al.* (2015), even low frequency trampling had severe effect on communities of land snails, reducing both the abundance and species richness caused by the loss of leaf litter. However, most sites with BHMS are in areas (cliffs, steep slopes, and hilltops/ridgelines) that are un- or little-affected by grazing, which seems more likely to occur on plateau prairies. In 2018, Forsyth and Nicolai found a forested slope at the east end of the park in Saskatchewan where very recent severe trampling of vegetation and soil/woody debris disturbance were clearly evident; however, no BHMS were found in this area. Disturbance of occupied habitat seems possible in some areas. However, in the headwater areas of Battle and Beaver creeks, Goater and Dempsey observed sites often severely trampled by cattle (Goater pers. comm. 2019; Dempsey pers. comm. 2019).

<u>6. Human intrusions and disturbance (low impact, small scope, moderate severity, high timing)</u>

6.1 Recreational activities (low impact, small scope, moderate severity, high timing).

Non-consumptive recreation in protected areas, such as provincial parks, is increasingly found to negatively affect biodiversity, with “considerable negative effects” on gastropods (Larson *et al.* 2016). There were more than 250,000 visits annually to the park (O2 Planning + Design 1990); however, most visitations are within the Elkwater area or in the Centre Block (the latter outside of the range of BHMS). Trails, however, are attractive draws for visitors and their use will continue to grow as people seek outdoor experiences in the park and new trails are built. Annual visitation has grown from 250,000 to well over 300,000 (Cypress Hills Destination Areas Inc. nd).

Low-lying trails in the park are generally not in BHMS habitat, but some trails do traverse known BHMS sites. Although uneven ground and dense vegetation may act as a deterrent to off-trail use, in general, trails through natural habitat are widened with use and shortcuts are created over time, degrading habitat. Trails that follow ridgelines might be a concern, as these are in areas that are often prone to erosion and disturbance. The majority of sites with BHMS are on steep slopes, near cliffs, or in areas without recreational trails. However, there is a well-developed network of trails, especially in the Alberta portion of the park. Hiking, horseback riding, and mountain biking are allowed, although the type of activity allowed on individual trails varies. Horses and bicycles are likely to cause greater damage to trails, causing erosion and potentially trampling. The management plan for the Alberta park recognizes areas of sensitivity, such as trails on slopes prone to erosion, and puts limits on recreation activities in such areas (Alberta Parks 2011).

Mountain biking has gained interest in the park and is actively advertised on the park's website (Cypress Hills Destination Area 2018). Maps of trails are available online (e.g., Trail Forks 2018).

Some of the trails go through BHMS habitat and sites, while others might cross through BHMS habitat. At one site in the West Block, BHMS are within the immediate area of trails and a lookout. Photographs taken by smart phones with GPS technology show in Google Earth and Google Maps that people are walking into BHMS habitat to take photographs. Another site is probably more protected because the slope is very steep. A new trail plan for the Alberta park is currently under development in which several new trails will be proposed (Berndt pers. comm. 2018).

In August (in three years: 2009, 2017, and 2018) no snails were seen crossing paths or generally out in the open, but it is likely that snails are more active at other times of the year. In BC in a forest recreation site, *O. strigosa* was found to be active in May, crawling in the open, including on informal paths, but at other times of the year snails were not active (Forsyth unpubl. data).

Although Baur and Baur (1992) observed that a 0.3 m wide trail did not affect the movement of *A. arbustorum*, it is a somewhat larger snail and probably more agile than is BHMS (Forsyth pers. obs.).

Aside from the obvious effects of trampling and degradation of adjacent habitats, trails, paths, and roads create barriers for snails. For example, Meadows (2002) found that under laboratory tests Ogden Rocky Mountainsnail (*Oreohelix peripherica wasatchensis* (Binney, 1886)) avoided surfaces without leaf litter and that dry litter was chosen over no litter. Ultimately, this might lead to fragmentation of subpopulations (Meadows 2002).

6.3 Work and other activities (negligible impact, scope, and severity; high timing; see Appendix 1 for comments).

<u>7. Natural system modifications (Very High-Medium impact, pervasive to large scope, extreme to moderate severity, high timing)</u>

7.1 Fire and fire suppression (very high to medium impact, pervasive to large scope, extreme to moderate severity, high timing).

For many years fire has been suppressed in Cypress Hills Park, which has led to a heavy fuel load and an extreme risk of catastrophic wildfire. Fires that burn down to the mineral soil and destroy vegetation and litter are of particular concern for terrestrial snails, which might otherwise survive if buried in the duff. In habitats with *Oreohelix* that have been burned, such as a prescribed burn in Waterton Lakes National Park and a roadside fire along Kootenay Lake (BC), massive snail (*Oreohelix*) mortality has been observed; at the Kootenay Lake site, which was burned in 1996 or 1997, live snails were again seen 15 years later although it is unsure if they were as abundant as they were previously (Forsyth pers. obs.). In Yellowstone National Park, Beetle (1997) found that snail diversity, including *Oreohelix*, was reduced or snails entirely extirpated after a burn depending on the severity and the elimination of the leaf litter. In grasslands in central North America, species richness of terrestrial snails was reduced by roughly 30% on sites burned within 15 years (Nekola 2002). The same study found a reduction of 50–90% in abundance of snails (Nekola 2002).

Because they are ovoviviparous, *Oreohelix* may be slower at recovering after a fire than oviparous land snails (Gaines *et al.* 2011).

From historical precedents, it is possible that fire can burn across the whole of the Cypress Hills. The recent Kenow wildfire (30 August–3 October 2017), which started in BC west of Waterton Lakes National Park, Alberta, burned a total of 35,000 ha (= 350 km^2; Parks Canada 2021). BHMS obviously did survive the major fires of the 1880s (and earlier), but how well this species might fare is unknown if a catastrophic fire were to occur today. There are also no data on the distribution or abundance of BHMS prior to these massive fire events in the 1880s. For snails to survive fires, unburned or only lightly burned patches are needed (Gaines *et al.* 2011); intense fires burning the leaf litter down to the mineral earth are especially destructive (Beetle 1997), but fires often burn spottily, so some portion of the population might survive even a major fire. Fire also increases the potential for erosion and the ability of soils to absorb and retain moisture (McNabb and Swanson 1990; Certini 2005).

Fire suppression, using prescribed burns, will be used in Alberta, although there are no definite plans (Lockerbie pers. comm. 2019). In Saskatchewan, prescribed burns might be used following tree cutting but the details and certainty of these measures are not available until after plans have been completed (Chu pers. comm. 2018). The recently finalized management plan for the Saskatchewan portion of CHIP does state that management considerations should be in place to reduce fuel and wildfire hazard for protecting known and suitable habitats of BHMS (Forsite 2021). Snails may survive prescribed burning if the burns allow for refuges for recolonizing burned areas (Severn 2005).

7.3 Other ecosystem modifications (low impact, restricted to small scope, slight severity, high timing).

No commercial logging is allowed in the park (Alberta Parks 2011), but some cutting is allowed to manage vegetation with the purpose of renewing older forests, reducing fuel loads, and managing forest pests (Alberta Parks 2011). “Fire smarting” is a program of cutting forest to regenerate over-age trees. Fire smarting is underway, with trees being cut and thinned on the plateau, close to road edges, and around the Elkwater townsite (O2

Planning + Design 2009; Lockerbie pers. comm. 2019). Cutting of trees is expected to be restricted and carefully planned (and could increase to combat forest encroachment onto prairies). With the identification of BHMS as a species of concern, it should be expected that consideration will be given to it when undertaking ecosystem modifications (Lockerbie pers. comm. 2019), so the severity is scored as slight. In the West Block, Saskatchewan Parks has ideas to harvest some old forest areas to renew the ecosystem (Chu pers. comm. 2018). The management plan for the Saskatchewan portion of CHIP has been finalized and fire smarting has occurred in some places in the Centre Block (Forsite 2021), which is outside the known range of BHMS.

Clear cuts are detrimental to land snails, reducing both number of total snails and species (Hylander *et al.* 2004). None of the BHMS sites were in areas that had been recently cut; and no cut areas were searched for snails before or after cutting. It is unknown where cutting would be done, or if it would be on steep slopes where many of the BHMS sites are located.

After clear-cutting (and fires), snails are especially prone to desiccation changes in habitat with the loss of vegetative cover (Hylander *et al.* 2004; Ray and Bergey 2014).

<u>8. Invasive and other problematic species and genes (Low impact, small scope, extreme severity, high timing)</u>

8.1 Invasive and other problematic species and genes (Low impact, small scope, extreme severity, high timing).

Trematodes and other parasites are known to cause sterility in their snail hosts (Jordaens *et al.* 2007; Faro *et al.* 2013). Dempsey (2017) found that less than 1% of *Oreohelix* snails infected with *Dicrocoelium dendriticum* had eggs *in utero.* At two sites, 9% (*n* = 300 snails) of BHMS were infected, and most likely, the prevalence of snails infected elsewhere in the park is the same (Dempsey *et al.* 2019; Dempsey pers. comm. 2019). With infected snails not able to reproduce, the effective population size is reduced.

Ruffed Grouse (*Bonasa umbellus*) and Wild Turkey (*Meleagris gallopavo*) were introduced into CHIP in 1922 and 1962, respectively (Alberta Parks 2011) and have established substantial populations in both Alberta and Saskatchewan portions of the park (Fraser pers. comm. 2021). Both bird species eat snails. Elsewhere, insects and snails comprise about 10% of the year-round diet of turkeys (Korschegn 1967) and snails can be an important source of calcium for egg laying by turkeys (McRoberts *et al.* 2020).

<u>10. Geological events (Negligible impact and scope, serious to moderate severity, high timing)</u>

10.3. Avalanches/landslides (Negligible impact and scope, serious to moderate severity, high timing; see Appendix 1 for comments).

11. Climate change and severe weather (medium to low impact, pervasive scope, moderate to slight severity, high timing)

Using the framework proposed by Foden *et al.* (2013) for assessing the vulnerability of species to climate change, BHMS will be exposed to climate change (droughts, temperature extremes, and reduced snow cover) and has traits (only those applicable are listed using the numbered bullets in Foden *et al.* 2013) that suggest:

Sensitivity

a. Specialized habitat (apparent association with Cypress Hills Formation)
b. Environmental tolerances are likely to be exceeded (prolonged drought)
c. Dependence on environmental triggers that are likely to be disrupted (breeding, hatching of young)
e. Rarity (geographically restricted range)

Low Adaptive Capacity

f. Poor dispersal ability (little potential for long-distance dispersal; little availability for areas to disperse to)
g. Poor evolvability (BHMS might have low genetic diversity).

11.1 Habitat shifting and alteration; 11.2 Droughts; 11.3 Temperature extremes.

The effects of rapid anthropogenic climate change on terrestrial gastropods are poorly known. Nicolai and Ansart (2017) classified climate-change threats for terrestrial gastropods into four categories: (1) winter temperature and snow cover, (2) drought and high temperature, (3) extreme events, and (4) habitat loss and fragmentation.

(1) Winter temperature and snow cover. Snow cover provides insulation, which if absent, may allow snails to be exposed to greater variability in winter temperature and freeze-thaw cycles. A changing climate might affect the duration and timing of hibernation and stress snails. The effects of changes in hibernation cycles, however, are mostly unknown and might be unexpected. For example, in Brown Gardensnail (*Cornu aspersum*), longer periods of hibernation have been linked to increased reproductive activity (Bonnefoy-Claudet and Deray 1984, cited by Gomot de Vaufleury 2001); therefore, reduced hibernation might cause a decrease in reproductive productivity.

(2) Drought and high temperature. Drought and unusually hot weather require snails to extend their periods of aestivation. This change in the duration and timing of aestivation might stress snails if droughts are earlier, later, or more sustained than usual by reducing the periods of activity needed for reproduction and growth. There may be other physiological limits to more prolonged aestivation as well. For example, increased levels of urea (as a by-product of protein metabolism) in the tissues of aestivating *Oreohelix* spp. have been linked to increases in mortality (Rees and Hand 1993).

(3) Extreme events. Climate change might contribute to extreme events, such as fire and landslides (see 7.1 Fire and fire suppression and 10.3. Avalanches/landslides).

(4) Habitat loss and fragmentation. Climate change is likely to reduce suitable habitats by eliminating those that are marginally suitable. The rapidity of the changes, if any, and the capacity for this species to shift with habitat are unknown, but the hottest, driest, or coldest sites might no longer be suitable for BHMS. Some studies have suggested that snails might shift their distribution upward to higher elevations as climate warms (e.g., Baur and Baur 2013; Pearce and Paustian 2013) and that the area occupied will be thus reduced (Müller *et al.* 2009). However, the Cypress Hills are not sufficiently high for this to be feasible. BHMS is already narrowly restricted in elevation, with nowhere up to go. More likely, snails at higher, more exposed sites might be at greater risk of increased winter freezing and summer drought and heat.

Limiting Factors

In general, land snails have poor ability for dispersal and low tolerance for extreme changes in environmental conditions such as humidity and temperature. Ovoviparity may also slow snail recovery after a fire (Gaines *et al.* 2011).

Number of Locations

A large-scale catastrophic wildfire, the most serious and plausible threat (very high–medium threat impact; Appendix 1), could burn the whole of the Cypress Hills and the entire range of BMHS (see **Threats**), but more realistically only parts would burn. The number of locations in such a scenario might be as few as five, based on the probability of ignition and wildfire (Figure 2), the underlying Cypress Hills Formation, known occurrences of BHMS, wind direction, and local terrain (Figure 3); some of the effects of the medium–low impact threat of climate change (Appendix 1) would also increase the threat and intensity of wildfire. One location is near the village of Elkwater (small central circle near Elkwater Lake, Figure 3). A few occurrences of the snail are adjacent to the village; fire suppression to protect people and property would be extreme near the village. Little human infrastructure and few facilities exist in the other BHMS locations. A second location would be at the western edge of the park, Head of the Mountain (evidence of previous fires still visible, see **Canadian Range**), extending northeast to Horseshoe Canyon, the origin of the 1889 fire (Forsite 2021). The central part of the park, still in the highest wildfire threat zone (Figure 2, lower panel), would be a third location while the occurrences to the north and east would be a fourth. The occurrences in the West Block, Saskatchewan, would be the fifth.

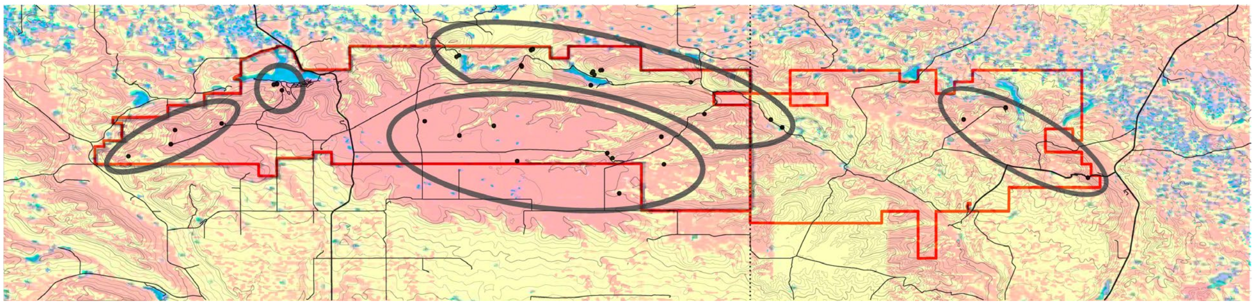

Figure 3. Five locations (thick grey ellipses) of Black Hills Mountainsnail (*Oreohelix cooperi*) based on fire as the most serious plausible threat. Occurrences of the snail (black dots), with the Cypress Hills Formation (orange area; from Glombick 2014), superimposed on wildfire threat zones (Figure 2 lower map). Using the park boundary as a guide, Figure 2 has been manually stretched to approximate the same map projection as the other layers.

Other threats (such as trails, other recreational facilities, and from livestock; all low impact threats: Appendix 1) are restricted to some but probably not all BHMS sites and may have varying impact at various sites; with just these threats considered, the number of locations would be much higher. Alternatively, there could be a single location due to invasive species (the parasite and ground-foraging birds) that are found throughout the park. However, this threat would not rapidly affect all individuals within the park simultaneously and the threat impact is currently low (Appendix 1) therefore this threat is not the most serious and plausible which is used to determine the number of locations.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Black Hills Mountainsnail has no direct legal protection in Canada, Alberta, or Saskatchewan under federal and provincial acts, except that all occurrences, but for one, are in CHIP. In Alberta, some protection is afforded to this species by the *Provincial Park Act* (Alberta), which prohibits or restricts some land use and removal of natural resources. In Saskatchewan some protection is also, presumably, indirectly afforded to BHMS by *The Parks Act* (Saskatchewan).

In the USA it is not protected under the *US Endangered Species Act*, although petitions for its listing have been received (US FWS 2018). It is not listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2018).

Non-Legal Status and Ranks

The global and national ranks for Black Hills Mountainsnail are:

- Global rank: G3 (vulnerable), last reviewed 16 December 2019 but information included is erroneous (e.g., states there is a “population in the eastern Canadian Rockies in Cypress Hills Interprovincial Park”) and other recent information is missing (NatureServe 2021).
- US National rank: N2N3 (Imperilled-Vulnerable; NatureServe 2021).
- Canadian National rank: N1N2 (CESCC 2016, as *O. stantoni*; NNR according to NatureServe 2021).

The subnational ranks are as follows:

In Canada (CESCC 2016, as *O. stantoni*):

- Alberta: S1S2 (CESCC 2016; Critically Imperilled-Imperilled also by NatureServe 2021).
- Saskatchewan: SU (undetermined; CESCC 2016). SNR (not ranked; NatureServe 2021). There is no reason why the ranks for Alberta and Saskatchewan should not be equivalent.

In the USA (NatureServe 2021):

- Illinois: SX (presumed extirpated), but this and the next are natural extirpations.
- Iowa: SX.
- Kansas: SNR, but the evidence for occurrence in this state is lacking.
- South Dakota: S3 (vulnerable).
- Wyoming: S1 (critically imperilled).
- Montana: not included (although comments suggest it is in the Judith Mountains in Montana).

BHMS is not included on the IUCN Red List of Threatened Species (IUCN 2018).

BHMS was not identified as a species of conservation importance in the 2011 management plan for CHIP by Alberta (Alberta Parks 2011) but is discussed in the recently finalized CHIP management plan for Saskatchewan (Forsite 2021).

Habitat Protection and Ownership

Presently, all known modern occurrences, except one, of BHMS in Canada are within CHIP. One site is outside of the park boundary and presumably on private land (in Alberta). Potentially, more sites exist on private lands (see **Canadian Range**).

Some protection to habitat is given by the *Provincial Park Act* (Alberta) and *The Parks Act* (Saskatchewan).

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- Mark Wayland, Canadian Wildlife Service, Environment and Climate Change Canada / Government of Canada. October 2018.

Museums:

- Dr. Jochen Gerber, Collections Manager, Invertebrate Collection, Field Museum of Natural History, Chicago, Illinois. October 2018.
- See also **COLLECTIONS EXAMINED**.

Parks:

- Dr. Shelley Pruss, Adjunct professor, Department of Renewable Resources, University of Alberta, Species conservation specialist, Natural resources conservation branch, Parks Canada, Government of Canada c/o Elk Island National Park, 1-54401 Range Road 203, Fort Saskatchewan Alberta. October 2018.
- Darwyn Berndt, Resource Management Coordinator, Parks Cypress Management Area, Alberta Environment and Parks, Box 12, Elkwater, Alberta. December 2018.

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Others:

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Robert Forsyth has been studying terrestrial molluscs of Canada since 1990, with particular emphasis on the biogeography of the Canadian fauna and non-native species. He is the author or co-author of two books, including “Land Snails of British Columbia” (2004), and over 30 peer-reviewed papers on the molluscs of Canada. He has done fieldwork in all provinces and two of the three territories, and since 2009, he has been studying the terrestrial molluscs of the Cypress Hills. He was a member of the Molluscs Species Specialist Subcommittee of COSEWIC (2000–2020) and served one term as Co-chair. He has co-written four previous COSEWIC status reports and written one status appraisal summary.

COLLECTIONS EXAMINED

- Canadian Museum of Nature, Gatineau, Quebec (collections examined).
- Field Museum of Natural History, Chicago, Illinois (photographs of collections examined).
- Royal British Columbia Museum, Victoria, British Columbia (collections examined).
- Royal Ontario Museum, Toronto, Ontario (collections examined).
- Santa Barbara Museum of Natural History, Santa Barbara, California (online database).
- National Museum of Natural History, Washington, DC (online database).

Appendix 1. Threats calculator spreadsheet for Black Hills Mountainsnail (*Oreohelix cooperi*).

Species Name	Black Hills Mountainsnail *Oreohelix cooperi*			
Date:	8/13/2019			
Assessor(s):	Robert Forsyth (report writer, SSC member), Dwayne Lepitzki (responsible Co-chair and facilitator), Joe Carney (Co-chair), Yeen Ten Hwang (CWS Prairie Region), Suzanne Dufour (SSC member), Glen Jamieson (SSC member), Cameron Lockerbie (Alberta Parks), Jenny Burgess (Alberta Parks), Zach Dempsey (University of Lethbridge), Bev McBride (COSEWIC Secretariat).			
References:	draft calculator prepared by report writer R. Forsyth to accompany the draft COSEWIC report; thesis and publications by Z. Dempsey also were sources; teleconference 13 August 2019			
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	1	0
	B	High	0	0
	C	Medium	1	1
	D	Low	4	5
Calculated Overall Threat Impact:			Very High	High
Assigned Overall Threat Impact:			**B = High**	
Impact Adjustment Reasons:			Threats overlap spatially.	
Overall Threat Comments			Generation time 2-3 years; therefore, timeframe for severity and timing also 10 years; confined to Cypress Hills, mostly within the Elkwater and West Block boundaries of the interprovincial Park (AB and SK), and associated with a specific geological formation; ~ 30 known occurrences; no population estimates and no population trends.	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	
1.1	Housing & urban areas						Most development is within Elkwater townsite. While Elkwater, first laid out in 1913 (Alberta Parks 2011), is within the park and BHMS is nearby, no known BHMS sites are found within areas developed for housing and associated uses.
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	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	One site is in/near a campground. Until now, the species has survived in close proximity to the campground despite maintenance, but it is a walk-in, more "rustic" site. No expansion of this campsite is expected in the next 10 years, but renewal is probable. A new trail plan for the Alberta portion of the park is now under development. Development of trails would go through environmental review and negative effects to the species would try to be mitigated.
2	Agriculture & aquaculture	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	
2.1	Annual & perennial non-timber crops						Haying for controlling invasive plant species is occasionally done on the plateau and in valley bottoms, but not likely to be in areas with snails and blades are a minimum of 3 inches (~7.5 cm) above the ground (Lockerbie pers. comm. 2019).
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	There is little chance that cattle grazing in the park will be discontinued (3000-4000 head plus calves); the threat is larger in SK. Snails on cliffs and very steep slope are unlikely to be as affected by grazing cattle. However, in areas, heavy trampling has been noticed.
2.4	Marine & freshwater aquaculture						
3	Energy production & mining						
3.1	Oil & gas drilling						No oil/gas exploration permitted within the park.
3.2	Mining & quarrying						No mining. Small-scale quarrying for roadworks is possible.
3.3	Renewable energy						No plans for wind or solar farms.
4	Transportation & service corridors		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
4.1	Roads & railroads		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	One highway (Hwy 41) and several paved and loose-surface roads, as well as many tracks are within the park. As the species is not overly mobile, road mortality is probably negligible. Roads as barriers to dispersal and gene flow is very long-term and continuing as long as the roads are there. There has been ongoing discussion to widen Hwy 41 to a double-lane highway, but this seems unlikely to affect any known sites with the snail. Roads, like trails, are potentially barriers for snails and conceivably cause direct mortality (but not observed). Some BHMS sites are within ca. 10 m of a main road but the effect, if any, is probably negligible, but most sites are far from roads and where roads are unlikely to ever be built. Snails were not seen on roads, and no mortality observed, by Forsyth and co-investigators in three years, but at all times snails were not active. None of the sites where BHMS occur are transected by roadways.
4.2	Utility & service lines						No (only in the Elkwater townsite, where there are no snails). There is a possibility for a water line to the ski hill (unknown if snails there), but with no definite plans. Some maintenance of existing lines and pole replacement, but outside of snail habitat.
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use						
5.1	Hunting & collecting terrestrial animals						Any future lethal collecting of snails will require a scientific permit. Shells might be collected by tourists/park users, with negligible impact.
5.2	Gathering terrestrial plants						Non-commercial mushroom collecting occurs but snails haven't been observed on mushrooms.
5.3	Logging & wood harvesting						No commercial logging operations in park (see 7.1, 7.3 instead).
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.1	Recreational activities	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	One site is in/near a campground (1/30 known occurrences). Until now, the species has survived in close proximity to the campground, but it is a walk-in, more "rustic" site. Trails for hiking, mountain biking, and horseback riding, and campsites could result in trampling of snails, but scope is small because of the steep slopes, cliffs, and relative remoteness of most occurrences of this species to popular recreational areas. Trail use and braiding is expected to increase. Almost no ATV use in park; occasional use with permit.
6.2	War, civil unrest & military exercises						
6.3	Work & other activities		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	The park continues to receive interest in research on other species. Possible activities such as further research on this species and other flora and fauna in the park could affect it, but this is unlikely to be a major threat.
7	Natural system modifications	AC	Very High - Medium	Pervasive - Large (31-100%)	Extreme - Moderate (11-100%)	High (Continuing)	
7.1	Fire & fire suppression	AC	Very High - Medium	Pervasive - Large (31-100%)	Extreme - Moderate (11-100%)	High (Continuing)	There is a strong possibility of a catastrophic, hot-burning fire at any time in the future until fuel loads are reduced. It is likely that a major, catastrophic fire will burn hotter and with more damage to the forest floor habitats of BHMS than might have occurred historically. Wildfire might be capable of burning the entire Cypress Hills, the entire Canadian range of the snail. However, fires often burn spottily, so some portion of the population could survive even in the case of a major fire. There is active fire suppression and human activities are restricted during times of high fire danger. Fire suppression using prescribed burns might eventually be used (no definite plans).
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	D	Low	Restricted - Small (1-30%)	Slight (1-10%)	High (Continuing)	Fire smarting (thinning, removal of understorey brush) is underway now, cutting trees on plateau, close to road edges, and around the Elkwater townsite. Cutting of trees is expected to be restricted and carefully planned (and could increase to combat forest encroachment onto prairies). With the identification of BHMS as a species of concern, it should be expected that consideration will be given to it when undertaking ecosystem modifications, so the severity is marked as slight. Patchy cutting could be beneficial to the snail but cutting may not be in areas with snails. Invasive plants also are a threat to the snail's habitat but the severity is uncertain.
8	Invasive & other problematic species & genes	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	*Dicrocelium dendriticum* was introduced prior to 1980s (Dempsey *et al*. 2019a); *Oreohelix* spp. are a first intermediate host, then an ant, before the definitive host (cattle, Moose, Elk, deer); prevalence in BHMS = 9% at two examined sites but infection is likely to be throughout the park (observed at other sites and with other species of *Oreohelix*; Dempsey *et al*. 2019a; pers. comm. 2019); no differences in prevalence among examined occurrences (i.e., no apparent "hot-spots"). Infected snails do not reproduce not due to parasites' ingestion of reproductive structures but due to drain in snail energy reserves. If no reproduction, severity should be extreme within the scope. The invasive beetle, *Pterostichus melanarius,* is now by far the dominant invertebrate ground predator in the park, and it is known to feed on snails and slugs. Its effect on *O. cooperi* and other terrestrial snails is unknown (Goater pers. comm. 2019). Ruffed Grouse and Wild Turkey introduced in 1922 and 1962, respectively (Alberta Parks 2011), found throughout the park (Fraser pers. comm. 2021), known to eat snails, would have a scope of pervasive, severity of unknown, and timing of high.
8.2	Problematic native species/diseases						
8.3	Introduced genetic material						
8.4	Problematic species/diseases of unknown origin						
8.5	Viral/prion-induced diseases						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.6	Diseases of unknown cause						
9	Pollution		Unknown	Small (1-10%)	Unknown	High (Continuing)	
9.1	Domestic & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents		Unknown	Small (1-10%)	Unknown	High (Continuing)	Spot spraying for control of invasive weeds is underway, but uses lower toxicity agents.
9.4	Garbage & solid waste						
9.5	Air-borne pollutants						
9.6	Excess energy						
10	Geological events		Negligible	Negligible (<1%)	Serious - Moderate (11-70%)	High (Continuing)	
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides		Negligible	Negligible (<1%)	Serious - Moderate (11-70%)	High (Continuing)	With abrupt and very steep slopes and escarpments, landslides are expected to be naturally occurring events in the Cypress Hills although post-fire, landslides might be more prone to occur. Landslides and slumping usually occur after snowmelt and heavy rains. In 1967, 1.5 million m^3 of earth moved at the big Police Point Slump and today is still slowly moving (Alberta Parks 2011). There is an approximately 300 m section of escarpment south of Battle Creek where a large slide has occurred (not visited; unknown whether BHMS occurs there but visible from the road and in satellite imagery), which can demonstrate that larger-scale slides are possible. At several BHMS sites, there is some instability and small-scale erosion, which presumably always has occurred within habitats occupied by this species. Nevertheless, there is potential for large slumps and landslides if conditions are right. Rapid warming and melting in the spring might contribute to increased rapidity of super-saturated soils and potentially increased changes of soil, and it is noteworthy that cementation of the Cypress Hills Formation is surficial, does not extend laterally (Kupsch and Vonhof 1967), and could contribute to instability. A drying climate might not increase the chance of landslides. Avalanches are not a factor.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11	Climate change & severe weather	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Excessive heat and drought is a major problem for land snails in general, but BHMS seems well adapted to survive these conditions.
11.1	Habitat shifting & alteration		Unknown	Unknown	Unknown	High (Continuing)	Not sure how habitats would change (although woody encroachment into prairie has been observed) or if snails could keep pace with the changes in the next 10 years. Continuing and increasing threat with climate change.
11.2	Droughts	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Would likely affect all areas, but severity might differ depending on the site. The driest sites now would be most affected and the severity score assumes that up to about 1/3 of the occurrences (or population) may be in the very driest sites, with most individuals in more optimum (wetter) sites but still prone to the effects of drought. Continuing and increasing threat. Could create conditions that increase risk of fire.
11.3	Temperature extremes	CD	Medium - Low	Restricted (11-30%)	Moderate - Slight (1-30%)	High (Continuing)	Sheltered occurrences, such as at bases of cliffs, are assumed to provide some shelter from temperature extremes (more chance of snow build-up and shelter from winds or heat) so scope is scored lower than drought to reflect that maybe about 1/3 of the occurrences are in the most exposed, hot/cold sites. Continuing and increasing threat.
11.4	Storms & flooding						
11.5	Other impacts						
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).							