COSEWIC
Assessment and Status Report

on the

Great Basin Spadefoot
Spea intermontana

in Canada

THREATENED
2019

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Previous report(s):

COSEWIC 2007. COSEWIC assessment and update status report on the Great Basin Spadefoot *Spea intermontana* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 34 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

COSEWIC 2001. COSEWIC assessment and status report on the Great Basin Spadefoot *Spea intermontana* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. v + 21 pp.

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Great Basin Spadefoot from the Okanagan Valley, British Columbia; photo by Sara Ashpole.

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COSEWIC
Assessment Summary

Assessment Summary – November 2019

Common name
Great Basin Spadefoot

Scientific name
Spea intermontana

Status
Threatened

Reason for designation
This toad-like amphibian is one of a suite of grassland and open woodland species restricted to the arid southern interior of British Columbia. It prefers to breed in temporary waterbodies, and requires terrestrial habitats with loose, friable soils for refuge from freezing and drought. Frequent widespread droughts in this area result in highly variable breeding success and recruitment among years, causing populations to fluctuate greatly. Current population size likely exceeds 10,000 mature individuals, although robust estimates are lacking. Recent population trends are unknown, but a continuing decline in number of mature individuals is inferred and projected, based on threats from road mortality, pollution of breeding sites, reduction in water tables associated with increasingly severe and frequent droughts, and agriculture. The species is designated Threatened based on its restricted area of occupancy, extreme fluctuations in number of mature individuals, an inferred and projected decline in number of mature individuals, and an observed, inferred, and projected continuing decline in extent and quality of habitat.

Occurrence
British Columbia

Status history
Designated Special Concern in April 1998. Status re-examined and designated Threatened in November 2001, April 2007, and November 2019.

COSEWIC
Executive Summary

Great Basin Spadefoot
Spea intermontana

Wildlife Species Description and Significance

Great Basin Spadefoot, *Spea intermontana*, is one of two species of spadefoots (family Scaphiopodidae) that occur in Canada. Adults are small to medium-sized toad-like amphibians, about 40–65 mm long, and have a squat body and relatively short legs. Diagnostic features include a black, keratinous ridge (“spade”) on the sole of each hind foot used for burrowing and eyes with a vertical, lens-shaped pupil, indicative of good night vision. The species is part of a suite of grassland and open woodland species unique to the arid southern interior of British Columbia.

Distribution

Great Basin Spadefoot is widely distributed in arid grasslands in western North America and occupies the intermontane region between the Rocky Mountains and coastal ranges, extending from British Columbia southward to Arizona. In Canada, the species occurs in the Okanagan-Similkameen, Kettle, Granby, Thompson, and Nicola valleys, and in the South Cariboo region of interior British Columbia, where it reaches the northernmost limit of its distribution.

Habitat

Great Basin Spadefoot inhabits semi-arid grasslands, shrub-steppe, and open woodland habitats. It requires aquatic habitats for breeding and terrestrial habitats for foraging, hibernation, and aestivation. Breeding sites range from ephemeral pools to the wetted margins and shallow areas of lakes and deeper ponds, but sites that dry up each year are typically preferred. In the terrestrial habitat, loose, deep, and friable (crumbly) soils that allow for burrowing are important. Availability of rodent burrows or other crevices are important in areas with more compact soils. A landscape containing a mosaic of temporary and permanent water bodies with connecting terrestrial habitat is thought to be important for sustaining viable populations over the long term.

Biology

Like other anurans in the northern hemisphere, Great Basin Spadefoot has a biphasic life cycle, consisting of aquatic eggs and tadpoles, and terrestrial adults and juveniles. Mating and egg-laying take place in spring and early summer during wet periods. Timing and duration of the breeding season vary depending on the availability of water at breeding sites. Females usually lay 300–800 eggs in small clusters, attached to sticks, pebbles, or aquatic vegetation in shallow water. New World spadefoots have short developmental times, an adaptation that allows them to effectively exploit ephemeral pools. Under field conditions, Great Basin Spadefoot larvae typically take six to ten weeks for metamorphic development, but metamorphs can leave water after 28 days. Adults and juveniles forage for insects and other small invertebrates at night, mostly within 500 m of breeding sites. They cope with lack of water by burrowing underground during the day and remaining dormant through dry and cold periods. Spadefoots have a remarkable ability to survive long periods of inactivity in underground refuges and have a variety of physiological adaptations for living in an arid environment, including an ability to survive water loss of up to 48% of their body weight. Males attain sexual maturity in approximately two years, females in three years; individuals may live for over ten years. Generation time is about five to six years.

Population Sizes and Trends

The size of the Canadian population of Great Basin Spadefoot is unknown but probably consists of well over 10,000 mature individuals. Based on the distribution of occurrence records, the largest number of mature individuals, over 5000, is thought to be in the Okanagan region. Breeding success varies greatly among years, depending on the availability of water in breeding ponds during spring and early summer, and recruitment can be low to absent in dry years. The number of mature individuals is inferred to fluctuate more than 10-fold among years.

Historically, the Canadian population has undoubtedly experienced drastic habitat loss and concomitant population declines. Recent population trends are unknown due to lack of systematic surveys and long-term monitoring, but local declines have been noted, particularly in the Okanagan, following habitat loss and alteration. The species continues to persist across its historical range, and, because of increased survey efforts since 2000, the overall Canadian range and pattern of occupancy within this range are better understood. However, threats from various sources are ongoing and predicted to result in a population decline over the next 3-generation period.

Threats and Limiting Factors

The greatest threats to Great Basin Spadefoot are from road mortality, pollution of breeding sites, and a reduction in the water table associated with increasingly severe and frequent droughts that in turn influence breeding opportunities. Several other threats compound the impacts: urban expansion, land conversion into agriculture, free-range cattle that congregate in water bodies, recreational use of off-road vehicles, water withdrawal for human consumption and agriculture, and non-native species (including fish and, potentially, disease-causing organisms).

Great Basin Spadefoot is most at risk from road mortality in areas where roads are near breeding sites and intercept seasonal migration routes. Across the species' Canadian distribution, 80% of the range is within 500 m of a road. Road mortality has been documented from many localities, but the greatest problem areas are in the Okanagan Valley, where road densities and traffic volumes are the highest. Further increases in traffic volumes are expected in future, concomitant with increasing human population growth in these areas.

Seasonal ponds important for Great Basin Spadefoot are expected to continue to diminish and experience shorter hydroperiods as a result of climate change. The water table has dropped substantially in several areas of the species' Canadian range over the past few decades, and a decreasing trend in the number and hydroperiod of breeding ponds has been noted. Water levels are further projected to decrease as demand for water for agricultural and other human uses increases concomitant with climate change. Sensitivity of this species to climate change was ranked as “high” in a vulnerability assessment of British Columbia's wildlife species.

Protection, Status and Ranks

Great Basin Spadefoot was listed as Threatened under the federal *Species at Risk Act* in Canada in 2003. A recovery strategy that identifies Critical Habitat has been published, including a map of the geographical areas, list of attributes needed by the species, and list of examples of activities likely to destroy attributes within Critical Habitat boundaries. Great Basin Spadefoot is ranked as globally secure, nationally secure in the United States, and vulnerable in Canada. The species is on British Columbia's provincial Blue list of species at risk and has a subnational status of S3 (special concern, vulnerable to extirpation or extinction).

Most of the habitat suitable for Great Basin Spadefoot remains unprotected, although recent efforts have expanded conservation lands, including the establishment of 21 Wildlife Habitat Areas that target this species. The species is known from several provincial parks and conservation lands. Stewardship activities with private landowners have increased across the Okanagan over the past decade, providing voluntary protection for habitats on privately owned lands. Habitat restoration, including construction of breeding ponds, has been carried out at several sites. However, broader scale protection is needed to ensure long-term viability of subpopulations across the species' Canadian range.

TECHNICAL SUMMARY

Spea intermontana

Great Basin Spadefoot

Crapaud pied-bêche du Grand Bassin

Range of occurrence in Canada: British Columbia

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2011) is being used)	~5–6 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred and projected decline from habitat loss and ongoing threats
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Threat impact is Medium based on IUCN threats calculator results, suggesting a suspected and projected decline of 3 –30%
[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.	As above
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. Not clearly reversible b. Partially understood c. Not ceased
Are there extreme fluctuations in number of mature individuals?	Yes; number of mature individuals inferred to fluctuate >10-fold among years, due to frequent widespread droughts that result in highly variable breeding success and recruitment over time.

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	37,823 km² (calculated for records since 1985)
Index of area of occupancy (IAO) (Always report 2x2 grid value).	1,340 km² (calculated for records since 1985)
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. Unknown b. Probably, based on recorded movement distances

Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	>10 (based on either road mortality or drought-associated drying of breeding sites as the most plausible threats)
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?	Possible inferred and projected decline based on threats
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Possible inferred and projected decline based on threats
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Possible inferred and projected decline based on threats
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, observed, inferred, and projected decline in area and quality of habitat
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations" *?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Total	Well over 10,000 suspected but robust estimates are not available

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Not done due to lack of data

* 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, 24 April 2019

Threats with Medium - Low impacts:

i. Roads & railways
ii. Droughts
iii. Agricultural & forestry effluents

Threats with Low impacts:

iv. Housing & urban areas
v. Annual & perennial non-timber crops
vi. Livestock farming & ranching
vii. Recreational activities
viii. Dams & water management/use
ix. Invasive & other problematic species

Threats with Unknown impacts:

x. Fire & fire suppression
xi. Other ecosystem modifications
xii. Airborne pollutants
xiii. Habitat shifting & alteration
xiv. Temperature extremes

What additional limiting factors are relevant?

Habitat availability and connectivity are considered the main limiting factors for this species, which relies on sensitive and naturally rare seasonal grassland ponds for breeding.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Washington State: secure (S5)
Is immigration known or possible?	Possible but undocumented; no records exist from the immediate vicinity of the border on the US side
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	No
Are conditions deteriorating in Canada?*	Yes
Are conditions for the source (i.e., outside) population deteriorating?*	Unknown
Is the Canadian population considered to be a sink?*	No
Is rescue from outside populations likely?	Possible near the international border but of limited significance

Data Sensitive Species

Is this a data sensitive species?	No

* See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Status History

COSEWIC: Designated Special Concern in April 1998. Status re-examined and designated Threatened in November 2001, April 2007, and November 2019.

Status and Reasons for Designation:

Status: Threatened	**Alpha-numeric codes:** B2b(iii,v)c(iv)
Reasons for designation: This toad-like amphibian is one of a suite of grassland and open woodland species restricted to the arid southern interior of British Columbia. It prefers to breed in temporary waterbodies, and requires terrestrial habitats with loose, friable soils for refuge from freezing and drought. Frequent widespread droughts in this area result in highly variable breeding success and recruitment among years, causing populations to fluctuate greatly. Current population size likely exceeds 10,000 mature individuals, although robust estimates are lacking. Recent population trends are unknown, but a continuing decline in number of mature individuals is inferred and projected, based on threats from road mortality, pollution of breeding sites, reduction in water tables associated with increasingly severe and frequent droughts, and agriculture. The species is designated Threatened based on its restricted area of occupancy, extreme fluctuations in number of mature individuals, an inferred and projected decline in number of mature individuals, and an observed, inferred, and projected continuing decline in extent and quality of habitat.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Insufficient data to reliably infer, project, or suspect population reduction.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Threatened, B2b(iii,v)c(iv).The IAO of 1340 km² is below the threshold of 2,000 km², and the following sub-criteria apply: b) population is experiencing (iii) an observed, inferred, and projected continuing decline in extent and quality of habitat, and (v) an inferred and projected decline in number of mature individuals, and c) extreme fluctuations in (iv) number of mature individuals.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Number of mature individuals likely greatly exceeds thresholds.
Criterion D (Very Small or Restricted Population): Not applicable. Population is neither very small nor restricted.
Criterion E (Quantitative Analysis): Not applicable. Analysis not conducted.

PREFACE

Since the previous status report (COSEWIC 2007), surveys conducted in semi-arid habitats in British Columbia's interior have provided new distribution records and continued to clarify the area of occupancy of Great Basin Spadefoot in Canada. Both the known extent of occurrence and index of area of occupancy have expanded as a result of increased survey efforts. Four studies have provided new information on terrestrial movements and habitat use by the species (Garner 2012; Richardson and Oaten 2013; Grods 2017; Hales 2018). Road mortality and associated mitigation have been examined in two areas (lower South Okanagan: Crosby 2014; White Lake: Winton 2016; Butchard 2017). Research has been conducted on impacts of climate change (see Gerrick *et al*. 2014; Price and Daust 2016). The area of conservation lands that support spadefoot habitat has increased, particularly in the Okanagan, with the establishment of two new provincial parks and land acquisitions by conservation organizations. New provincial Wildlife Habitat Areas have been established in the Thompson and Okanagan areas. Restoration and habitat enhancement activities have increased in South Okanagan (Ashpole *et al.* 2018a), and Vernon and Kamloops areas (MFLNRO 2018; Okanagan Similkameen Stewardship Society 2018). Environmental DNA sampling has been used to help document pond occupancy (Hobbs and Vincer 2015). A federal recovery strategy has been prepared, and Critical Habitat under the *Species at Risk Act* has been delineated (ECCC 2017).

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS
(2019)

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

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

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

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

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

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

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Great Basin Spadefoot (Anura: Scaphiopodidae: *Spea intermontana*, Cope 1883) is one of four species of western North American spadefoots of the genus *Spea*; the other three species are Western Spadefoot (*S. hammondii*), Plains Spadefoot (*S. bombifrons*), and Mexican Spadefoot (*S. multiplicata*) (Crother 2012). Great Basin Spadefoot is one of two species of spadefoots that occur in Canada; Plains Spadefoot occurs in southern Alberta and Saskatchewan. For many years, *Spea* was widely considered a subgenus of *Scaphiopus* (Tanner 1939), but it is now recognized as a valid genus (Crother 2012). Garcia-Paris *et al.* (2003) examined phylogenetic relationships of North American and Eurasian spadefoots using mtDNA markers, and concluded that the North American and Eurasian members of the nominal family Pelobatidae were not monophyletic. They revived the family Scaphiopodidae for the North American genera (*Spea* and *Scaphiopus*) and retained the remaining genera found in Europe and Asia in the family Pelobatidae.

Cope (1883) described *Spea intermontana* as a subspecies of *S. hammondii* (Tanner 1939). Tanner (1939) considered *S. intermontana* as a species separate from *S. hammondii*, a treatment that is now accepted (Crother 2012). Reflecting changes in nomenclature, *Spea intermontana* is referred to as *Scaphiopus intermontanus* in much of the literature prior to 1990.

The French common name for the species is Crapaud pied-bêche du Grand Bassin (Green 2012). The n'syilxcən name for Great Basin Spadefoot is pəskʷaqs (Bezener pers. comm. 2019). Other Indigenous names for the species may exist in south-central British Columbia but were not available for this report.

Morphological Description

Great Basin Spadefoot is a small to medium-sized frog with adult body size (snout-vent length, SVL) ranging from 40 to 65 mm (Hallock 2005; Matsuda *et al*. 2006; Crosby 2014). Adults are grey-green with numerous dark brown or reddish tubercles and spots (Figure 1). The limbs are relatively short and the snout is blunt and angled slightly upwards. Similar to all members of the family, adults have a characteristic black, keratinous ridge (spade) on the sole of each hind foot. The eyes have a vertical, lens-shaped pupil, giving a "cat's-eye" appearance (see cover picture). A characteristic glandular bump, called a "boss", is between the eyes. Adult males are somewhat smaller than females, have a dark throat, and develop black nuptial pads on their inner three fingers during the breeding season (Hallock 2005; Matsuda *et al*. 2006).

A. adult

B. Keratinous ridge (spade) on hind foot

C. Tadpole partially buried in pond bottom substrate

D. First-year young

Figure 1. Photographs of Great Basin Spadefoot from British Columbia (photos by K. Ovaska).

The advertisement call of males is a repeated, low, grating “gwaah” (resembling snoring), audible to the human ear from more than 200 m away. The loud calls and continuous chorus create a strong “assembly call” typical of explosive breeders, i.e., amphibians that breed suddenly in response to environmental cues (Stebbins and Cohen 1995).

Egg masses consist of small (15–20 mm in diameter) grape-like clusters; 10–106 eggs/cluster were recorded in South Okanagan (Ashpole *et al*. 2014). Individual eggs are small (ca. 5 mm in diameter including the jelly layer) and loosely attached to each other. In dorsal view, tadpoles have a triangular-shaped head that appears distinct from the trunk (Figure 1). The closely set eyes are raised and nostrils are prominent. The tail fin is high and terminates where the tail joins the trunk. The colour is dark with metallic flecking. Total length of tadpoles just before metamorphosis is about 30–70 mm (Hallock 2005; Matsuda *et al*. 2006).

Population Spatial Structure and Variability

Crother (2012) noted that geographic variation of Great Basin Spadefoot remains poorly documented across its global range and that the nominal species may be a composite of two or more species with possible undescribed species within the southern portion of the species' distribution in the United States (Wiens and Titus 1991). The Canadian population is part of the largest clade.

The Canadian distribution of Great Basin Spadefoot occurs within six distinct habitat areas of British Columbia: Okanagan-Similkameen, Kettle, Granby[2], Nicola, Thompson, and South Cariboo (Figure 2; see **Canadian Distribution**). Movements of Great Basin Spadefoot among these habitat areas are probably minimal due to unsuitability of habitat in intervening areas. Within each geographic area, the population is further fragmented, reflecting both the natural distribution of grasslands and anthropogenic features. The delineated Critical Habitat for the species, as presented in the federal recovery strategy (ECCC 2017), shows numerous habitat polygons in each geographic area, which may reflect subpopulations at the landscape scale (see **Population Fragmentation**). The polygons include both core habitat and dispersal habitat where movements of Great Basin Spadefoot among polygons are deemed likely. However, it is unclear whether sufficient search effort has been conducted in intervening areas to confirm isolation of all polygons. Conversely, it is unclear whether all polygons, particularly smaller ones, continue to be inhabited by the species.

Genetic studies to elucidate subpopulation structure of the Canadian population have been initiated, but geographic coverage is still incomplete. Russello and Hollatz (2011) presented preliminary data on population structure among northern and southern portions of the Canadian distribution based on five microsatellite markers. They sampled a total of 86 individuals from three ponds in the Cariboo, one pond in the Thompson Okanagan, and four ponds in the South Okanagan Region (samples were grouped by administrative districts). They found significant differences between most pair-wise comparisons between ponds and also when data for individuals were pooled by the above regional designations. Bayesian Cluster Analysis revealed two distinct clusters with South Okanagan separating from the remainder of the Canadian range. The authors emphasized the preliminary nature of the results due to small sample size and uneven geographic coverage. They pointed out a need for additional microsatellite markers to increase robustness of the results and for mitochondrial DNA sequence data, which would help document possible deep genetic divisions in the population and elucidate evolutionarily significant units.

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[2] Granby is a tributary of Kettle, joining it just north of the international border, and Great Basin Spadefoot habitat in these two areas might be connected through the USA.

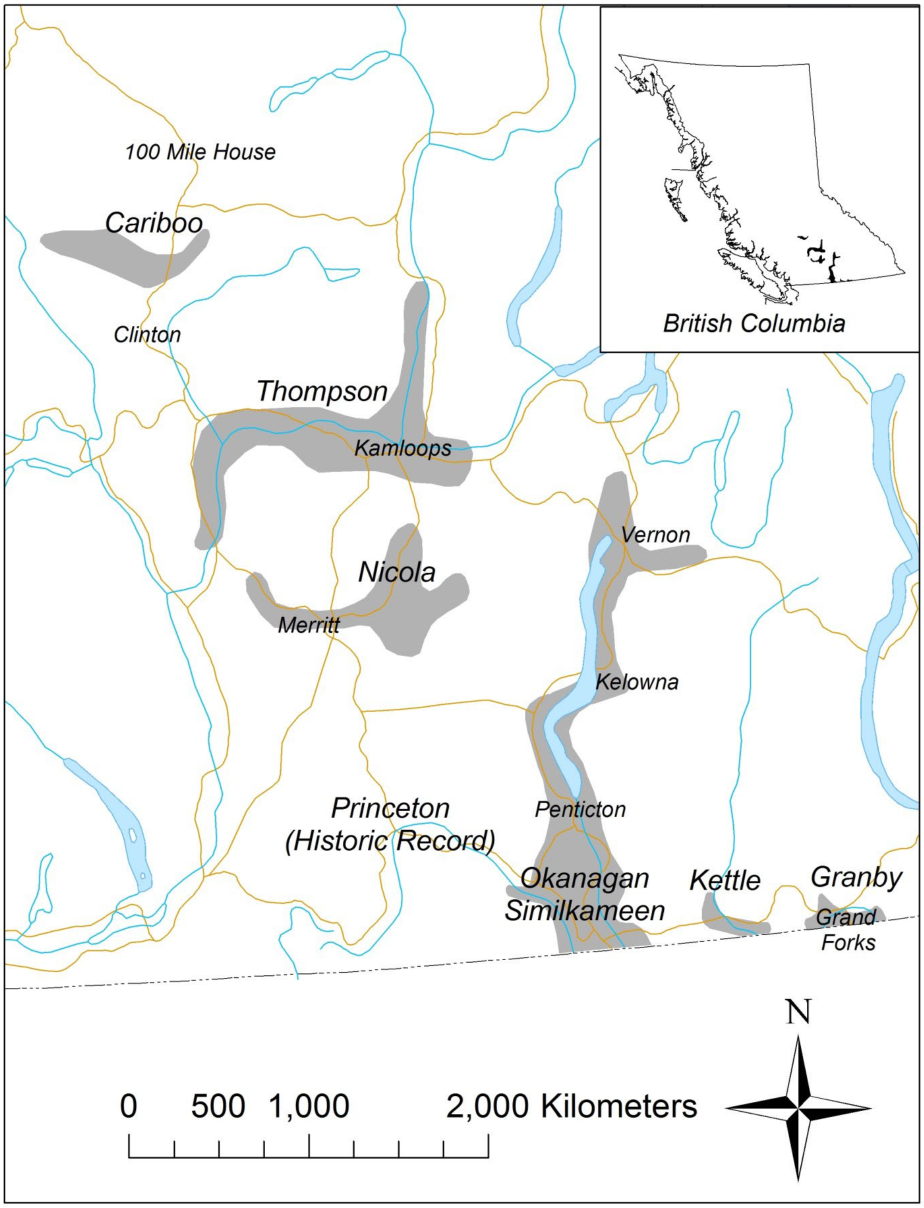

Figure 2. Overview of Canadian distribution of Great Basin Spadefoot outlining major habitat areas. Map from the provincial recovery plan (Figure 4 in Southern Interior Reptile and Amphibian Working Group 2017).

Designatable Units

One designatable unit is proposed. Great Basin Spadefoot occurs mainly within the Intermountain Amphibian and Reptile Faunal Province but extends northward into the Cordillera Faunal Province (Figure 3b in Appendix F5 in COSEWIC 2019). The population probably expanded northward from a single southern refuge after the Pleistocene glaciations (O'Connor and Green 2016). The species occurs in six geographically distinct habitat areas, isolated from one another by largely unsuitable habitat (Figure 2). However, there is no evidence of adaptations that would satisfy the criteria of significance as per

COSEWIC (2019) guidelines for designatable units. While the species occupies wooded habitats at the northern extremity of its distribution rather than grasslands as farther south, the difference is not sufficient to treat spadefoots in the Cariboo habitat area as a separate designatable unit.

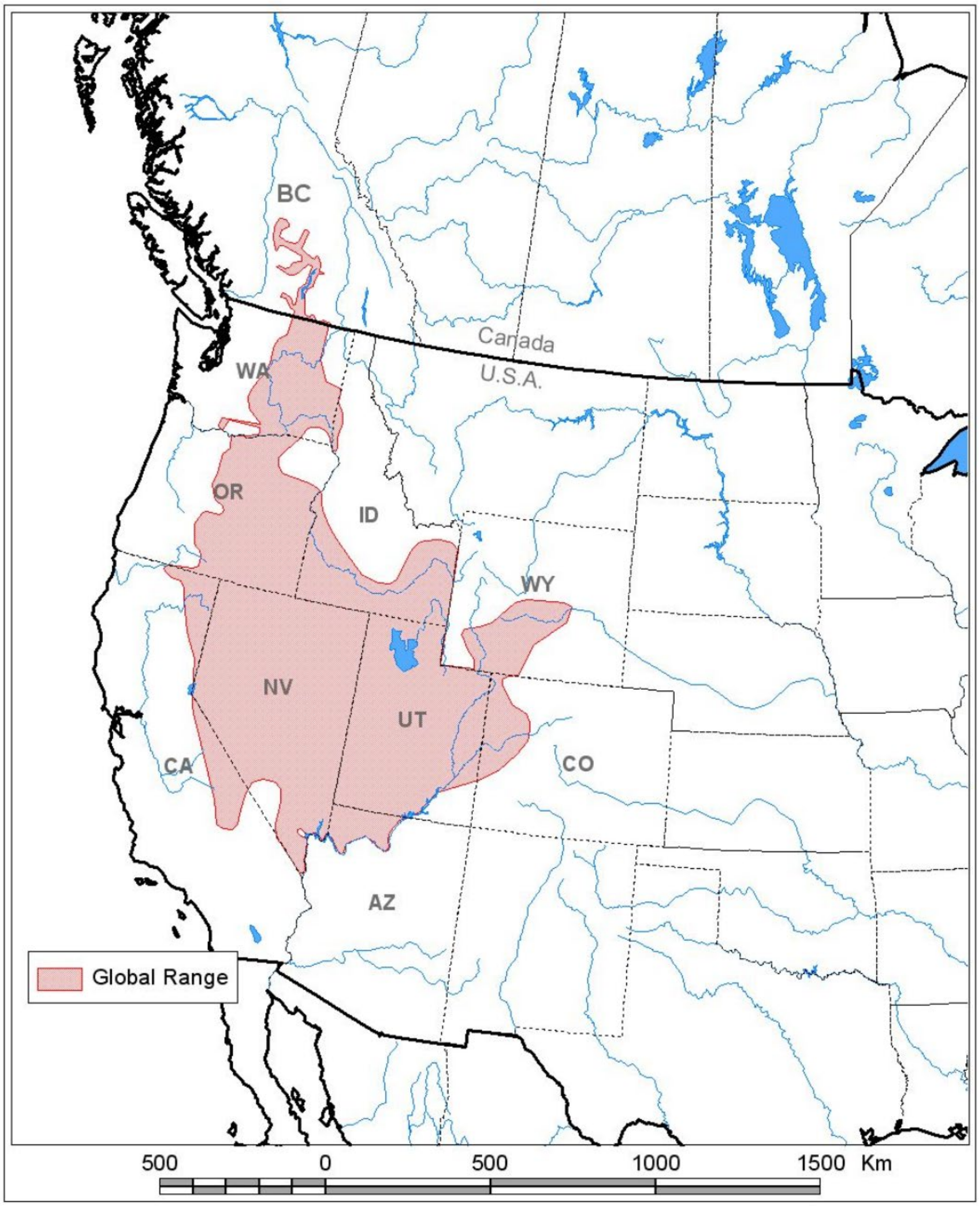

Figure 3. Global distribution of *Spea intermontana*. Map reproduced from COSEWIC (2007) and originally produced by Ophiuchus Consulting and printed courtesy of Mike Sarell.

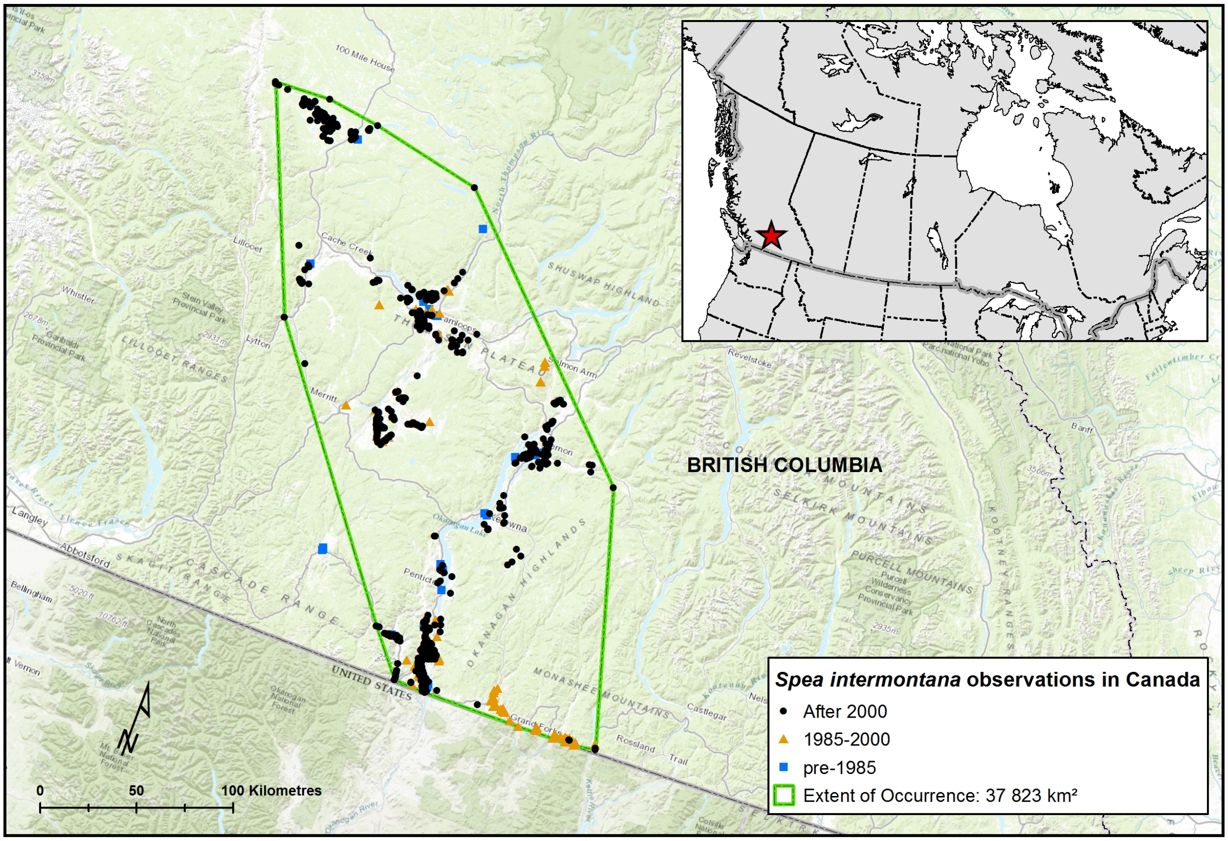

Figure 4. Canadian distribution of Great Basin Spadefoot based on records compiled for this report, showing records from three periods. Map produced by Rosana Soares and Sydney Allen (COSEWIC Secretariat) in July 2018. Extent of occurrence (EOO) polygon for 1985–2016 is shown.

Special Significance

Great Basin Spadefoot belongs to a suite of grassland and open woodland species restricted to the arid southern interior of British Columbia. Examples of other organisms typical of these ecosystems that occur nowhere else in Canada include Pygmy Short-horned Lizard (*Phrynosoma douglassi* – now extirpated), Night Snake (*Hypsiglena torquata*), Western Rattlesnake (*Crotalus oreganus*), Gray Flycatcher (*Empidonax wrightii*), Sage Thrasher (*Oreoscoptes montanus*), Pallid Bat (*Antrozous pallidus*), Showy Phlox (*Phlox speciosa*), and Lyall's Mariposa Lily (*Calochortus lyallii*).

Consultations in nine Indigenous communities in south-central British Columbia suggest that although not used for food or medicinal purposes, spadefoots are considered beneficial as they provide food for other animals, such as turtles (Markey and Ross 2005). They are recognized as an integral part of the ecosystem, and there is an awareness of their distribution and habits.

DISTRIBUTION

Global Range

Great Basin Spadefoot is widely distributed in arid grasslands in western North America and occupies the intermontane region between the Rocky Mountains and coastal ranges (Hallock 2005; Matsuda *et al*. 2006). Its range extends north from the Colorado River in Arizona to south-central British Columbia, west to the Sierra Nevada and Cascade ranges, and east to the Rocky Mountain divide (Figure 3). Less than 5% of the species' global distribution is in Canada.

Canadian Range

In Canada, Great Basin Spadefoot occurs in arid areas of south-central British Columbia (Figure 4). The species is found in the Okanagan-Similkameen, Kettle, Granby, Thompson, and Nicola valleys, and in the south Cariboo region, where the species reaches the northernmost limit of its distribution. It occurs primarily in the Bunchgrass, Ponderosa Pine, and Interior Douglas-fir biogeoclimatic zones (see Meidinger and Pojar 1991 and MFLNRO 2018 for descriptions).

Surveys since 2000 have resulted in observations of Great Basin Spadefoot across much of the species' historical distribution in British Columbia (Table 1, Figure 4). A notable exception is near Princeton in the Similkameen Valley, where the species' presence is indicated only by two historical records (1952, 1955). The validity of these records could not be confirmed (Dyer pers. comm. 2019), but potentially suitable habitat exists in the general area. Only a few recent records exist from the southeast in the Kettle and Granby valleys, probably reflecting lack of recent survey efforts (Table 1). Recent surveys have greatly expanded knowledge of the northern distribution of the species, which extends to just south of 100 Mile House in the Cariboo region, where the species is more widely distributed than previously thought (Table 1).

Table 1. Summary of amphibian surveys within the Canadian distribution of Great Basin Spadefoot by region.

Region or area	Year(s)	Search Effort	Great Basin Spadefoot found	Source
South Okanagan	~	86 sites	56 sites	St. John (1993)
South Okanagan	2003 - 2006	108 ponds and additional river channels (multiple survey methods)	43 ponds (498 occurrences; 27 ponds with breeding)	Ashpole *et al*. (2018a)
South Okanagan (First Nations lands)	2004?	Not available	Species found	Sarell and Alcock (2004)
South Okanagan (First Nations lands)	2005?	Not available	Species found	Rebellato (2005)
South Okanagan	2010 - 2012	52 km of road surveys (657 survey hours)/Incidental auditory recordings	1894 alive, 1648 dead	Crosby (2014)
South Okanagan - White Lake	2015	Road surveys / 10 ponds surveyed	115 captures	Winton (2015)

Region or area	Year(s)	Search Effort	Great Basin Spadefoot found	Source
South Okanagan - White Lake	2016	Road surveys / 10 ponds surveyed	97 captures	Winton (2016)
South Okanagan - White Lake	2017	12 km of road surveys / 2-10 ponds surveyed	5 alive, 21 dead; 3 ponds and 2 ditches with metamorphs	Butchard (2017)
South Okanagan	2007 - 2018	30 - 56 ponds (multiple survey methods)	31 ponds (13 existing & 18 restored ponds)	Ashpole *et al*. (2018b); Ashpole unpubl. data
South Okanagan	2014	22 ponds (eDNA surveys)	2 ponds (eDNA detected in water samples)	Hobbs and Vincer (2015)
Central Okanagan (Kelowna)	2005	24 ponds	3 ponds	Tarangle and Yelland (2005)
North Okanagan (Vernon Military Camp)	1999 - 2005	39 ponds	10 ponds	Sarell (2006)
North Okanagan (Outskirts City of Vernon)	2017	6 ponds (eDNA)	Species not detected	Arner pers. comm (2019)
Thompson	1994	38 sites	24 sites	Leupin *et al*. (1994)
Thompson (Lac Bios Provincial Park)	2005	50 ponds	3 ponds	Simpson (2005)
Thompson (Lac Bios Provincial Park)	2012-2013	65 ponds (multiple methods); research on movements	Breeding success in 3 ponds 2012; zero in 2013; 32 individuals radio-tracked	Richardson and Oaten (2013)
Thompson (10 km from Kamloops)	2013-2014	18 ponds (11 anthropogenic) surveyed and selected non-randomly for habitat use study	Breeding in 10 ponds; telemetry conducted with 33 adults	Hales (2018)
Nicola	2011 - 2015	214 wetlands (1580 person-hours) and nighttime road surveys in 54 UTM grid cells (each 10 km x 10 km)	16.7% of 54 UTM grid cells: 9 ponds; 117 observations at roadside listening posts; 48 sightings on roads; all above in Upper Nicola	Ovaska *et al*. (2016)
South Cariboo	2006	17 sites (each with 1 - 2 ponds)	11 sites	Verkerk *et al*. (2006)
South Cariboo	2006 - 2008, 2014	670 auditory surveys at 650 ponds	unknown	Packham pers. com. (2018)
South Cariboo	2007	202 sites (330 auditory surveys)	45 sites	Nicolson and Packham (2008)
South Cariboo	2008	361 sites (255 auditory surveys)	54 sites (15%; 44 new sites)	Kline and Packham (2009)
South Cariboo	2009	68 sites (101 auditory surveys)	8	Crosby and Packham (2010)
South Cariboo	2012	Research study on movements & habitat use	19 individuals radio-tracked	Garner (2012)

Extent of Occurrence and Area of Occupancy

Distribution records were obtained from British Columbia Conservation Data Centre (BC CDC) and from the Canadian Wildlife Service; the latter source consisted of background data associated with the description of Critical Habitat (ECCC 2017). BC CDC records consisted of (a) data from records in their database and (b) data extracted from the provincial Species Inventory (SPI) database; both data sets were compiled in 2018 by Jocelyn Garner under contract for BC CDC. Data from the Canadian Wildlife Service included (a) compilation of records from available sources by Biolinx Environmental Research Ltd. in 2015, (b) Ajax Mine terrestrial wildlife surveys in 2015, (c) surveys by Dustin Oaten in 2012 and 2013 and (d) incidental records from 2016. Sensitive data from First Nations lands were excluded from the submission. After the removal of duplicate localities (with same coordinates and year), records with missing dates, and records with missing or obviously erroneous coordinates, the dataset consisted of 3867 records with unique coordinates. These records were used to create distribution maps and to calculate the extent of occurrence (EOO) and index of area of occupancy (IAO; Figure 4).

EOO was calculated using the minimum convex polygon method for records since 2000, corresponding approximately to the past three generations. IAO was calculated by placing a grid across the EOO and counting the number of 2 x 2 km cells with recent (since 2000) records of the species. For comparison, both the EOO and IAO were also calculated for the period 1985–2000. Comparisons between the two periods should be treated with caution because lack of systematic surveys across the species' range, including revisits to historical sites, may result in an underestimation of current values. Conversely, better knowledge of the distribution in some areas, especially in the northern portion of the species' range, gained through increased survey efforts in recent years, could mask actual changes (increase or decrease). The EOO and IAO were also calculated for all records since 1985, because this value may most accurately reflect the current distribution in light of survey effort biases described above.

Calculated values for EOO are 20,563 km² for 1985–2000 and 37,738 km² for 2001–2016, showing an 83.5% increase. The increase reflects expanded survey effort rather than an increase in the range, as the northern portion of the range, in particular, had received little survey effort in past. Using all records from the period 1985–2016, the EOO is 37,823 km². The EOO in the previous status report was reported as 30,770 km² (COSEWIC 2007).

Calculated values for IAO were 272 km² for records from 1985–2000 and 1,164 km² for 2001–2016, showing a 328% increase, a result of increased survey effort. Using all records from the period 1985–2016, the IAO is 1,340 km². The IAO in the previous status report was reported as 619 and 864 km², using two different methods (COSEWIC 2007).

Search Effort

Search effort across the species' Canadian range remains consistently focused on the South Okanagan region, but efforts in the south Cariboo and Thompson-Nicola regions have expanded over the past decade (Table 1). Total search effort is difficult to quantify, as negative data (i.e., number of localities where the species was not found) are available for only a portion of the surveys. Areas lacking recent records might reflect either low search effort or true absence. No new information was available for this report about Great Basin Spadefoot occurrence on First Nations' lands.

Search effort since the previous status report (COSEWIC 2007) included the following: in the South Okanagan, from 2007 to 2018, Ashpole *et al*. (2018a) and Ashpole (unpubl. data) continued annual surveys of 30 to 56 lowland ponds, of which 21 were newly constructed or enhanced wetlands; 31 ponds, including 18 constructed or enhanced ponds, contained Great Basin Spadefoots. Efforts to document movement hotspots and establish roadkill mitigation increased in the lower river valley of South Okanagan (before and after impact study in 2010 to 2012, Crosby 2014) and in the upper plateaus around White Lake (Winton 2015, 2016; Butchard 2017). Similarly, greater efforts to identify potential Wildlife Habitat Areas were expended in 2014 using environmental DNA sampling (Hobbs and Vincer 2015). Minimal new search effort has been expended in the central and north Okanagan areas. In the Thompson-Nicola region, efforts by Ovaska *et al*. (2016) from 2011 to 2015 in the Nicola Valley and by Richardson and Oaten (2013) in 2012 and 2013 within the Lac du Bois Protected Area increased records for the species in wetlands and along roads. In the south Cariboo region, from 2006 to 2009 and in 2014, Packham and colleagues conducted approximately 670 auditory surveys at 650 ponds (Packham pers. comm. 2018). However, the inventory of potential breeding ponds is incomplete, and there are numerous additional ponds in the area west of 70 Mile House that may support this species (Packham pers. comm. 2019).

HABITAT

Habitat Requirements

Great Basin Spadefoot inhabits semi-arid grasslands and open forests. In British Columbia, the species occurs in grasslands, shrub–steppe, and open Ponderosa Pine (*Pinus ponderosa*) and Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) forests (Matsuda *et al*. 2006). It has been recorded from valley floors to about 1230 m[3] asl (Southern Interior Reptile and Amphibian Working Group 2017). In the south Okanagan, St. John (1993) found most breeding sites to be below 600 m.

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[3] Three records reported by Leupin *et al*. (1994) from up to 1800 m asl east of Enderby appear to be erroneous (O. Dyer per. comm. 2019).

Great Basin Spadefoot requires aquatic habitats for breeding and terrestrial habitats for foraging, hibernation, and aestivation (summer dormancy or inactivity). These habitats must be suitably connected (i.e., within movement ability of the spadefoots and permeable habitat with no insurmountable barriers) to allow for seasonal movements. A landscape containing a mosaic of temporary and permanent water bodies and connecting terrestrial habitat is thought to be important for sustaining viable populations over the long term (Southern Interior Reptile and Amphibian Working Group 2017).

Great Basin Spadefoot is able to use a variety of breeding sites ranging from ephemeral pools to wetted margins and shallow water areas of lakes and deeper ponds, but sites that fill with water and dry up each year seem to be preferred (Hallock 2005; Sarell 2004) (see Figure 5 for examples of breeding sites). Water in breeding sites must be present in spring/early summer and last long enough for larval development to take place. In British Columbia water must be present for approximately six weeks from April to mid-July. Breeding sites often, but not always, contain abundant emergent and riparian vegetation (Leupin *et al*. 1994). Great Basin Spadefoot readily uses human-made spawning sites and has been recorded from dug-out ponds, ditches, and plastic pools in various parts of their range in British Columbia (K. Ovaska unpubl. data 2011–2015; Ashpole *et al*. 2014; Hales 2018). This opportunistic behaviour underscores their plasticity in breeding site use and their success in predictably variable environments, where breeding opportunities are sporadically available both spatially and across years.

In contrast to breeding site use, less is known of specific habitat requirements of metamorphs, which is important information contributing towards the assessment of breeding success and persistence of subpopulations. Metamorphs are susceptible to desiccation because of their small size and have been found under plywood cover-objects along pond edges (Hales 2018) and in cracks of mud in dried-up breeding pond basins (Ovaska unpubl. data 2011–2015). In enclosure experiments in the Kamloops area, metamorphs selected moist areas with cover-objects, while daytime retreats of adults followed with telemetry in the natural environment were not associated with soil moisture or specific microhabitat features (Hales 2018).

Figure 5. Examples of Great Basin Spadefoot breeding sites in ephemeral and semi-permanent water bodies with varying water levels. South Okanagan: top 4 panels (photos by S. Ashpole); Upper Nicola: bottom 4 panels (photos by K. Ovaska).

The Recovery Strategy (ECCC 2017) listed the following features for Great Basin Spadefoot's breeding habitats:

Vernal pools (seasonal and temporary water bodies):

- shallow areas less than 1 m deep, required for development of eggs and tadpoles
- emergent vegetation (e.g., grasses, sedges, rushes), sticks, rocks, or other debris, required to provide egg attachment surfaces
- algae, aquatic vegetation, and other organic matter, required as food for tadpoles
- dry areas that become wet under the right conditions, identified at any time by: depressions with bare mud, sedges, rushes, or other hydrophilic plants

Permanent water bodies (lakes, ponds, marshes, springs, sluggish streams, and seasonally wetted margins):

- shallow areas less than 1 m deep, required for development of eggs and tadpoles
- emergent vegetation (e.g., grasses, sedges, rushes), sticks, rocks, or other debris, required to provide egg attachment surfaces
- algae, aquatic vegetation, and other organic matter, required as food for tadpoles
- optimally, an absence of predatory fish (sport fish, goldfish (*Carassius auratus*), and fish used for mosquito control or other purposes)

Great Basin Spadefoot shelters underground from unfavourable conditions and requires terrestrial habitat year-round (Hallock 2005; Matsuda *et al*. 2006). Loose, deep, and friable (crumbly) soils that facilitate burrowing are important (Sarell 2004; Ashpole 2018a) (see **BIOLOGY**: **Terrestrial Activity and Hibernation**).

The Recovery Strategy (ECCC 2017) listed the following features for Great Basin Spadefoot's terrestrial habitats:

Grassland, shrub-steppe, open forest:

- friable soils that permit burrowing (e.g., clay loam, fine gravel, clay, sandy soils), existing burrows (may include firmer soils), or naturally occurring holes or crevices
- small vertebrate and invertebrate prey (e.g., earthworms, ants, beetles, flies, grasshoppers, etc.)
- active-season refuges: self-made burrows, rodent burrows (ground squirrel, pocket gopher), surface cover objects such as flat rocks and coarse woody debris
- overwintering refuges: self-made burrows, rodent burrows, crevices, or soil mounds that are sufficiently deep to permit access to frost-free areas (40–145 cm below surface)

Habitat Trends

Grasslands are naturally rare in British Columbia, covering less than 1% of the land area of the province (0.74 million ha; Wikeem and Wikeem 2004). These ecosystems have been reduced drastically since European settlement, especially in productive and biologically rich valley bottom habitats, and continue to be lost and fragmented due to expanding urban development, agriculture, and other land uses (Lea 2008). Fire suppression, invasive species, livestock grazing, intensive recreation, and other human-mediated activities further continue to degrade and diminish these habitats (reviewed in Gayton 2016).

In the South Okanagan and Similkameen valleys, 48% of the land base consists of grasslands and associated wooded habitats that are now considered sensitive, most of which are under private ownership with limited options for conservation and restoration (reviewed in Gayton 2016). Sensitive ecosystems particularly pertinent to Great Basin Spadefoot include wetlands that the frogs require for breeding. Historically, wetland loss has been tremendous in the arid interior of British Columbia (Lea 2008). Gayton (2016), citing BC Ministry of Environment statistics, stated "it is estimated that the Okanagan river valley has lost 85 percent of its wetland and riparian habitat since the advent of European settlement, due to land conversion, channelization and infill."

The southern interior valleys of British Columbia are among the most desirable areas for people to live, and the human population in the Okanagan-Similkameen and Thompson-Nicola regional census districts has increased dramatically since the 1980s (BC Stats 2018). While the rate of increase appears to have peaked in the late 1990s, the human population within the most productive parts of the Great Basin Spadefoot's range is expected to continue to grow well into the future, with greatest increases in the central Okanagan (BC Stats 2018). In contrast, the human population growth rate appears to have stabilized within the northern limits of the species' distribution in the Cariboo region and shows a decreasing trend in the Kootenay Boundary region, where it overlaps with only a small portion of the species' range in the Kettle and Granby valleys. Concomitant with human population growth, there is increased pressure for land conversion and modification for housing, farming, resource extraction, and recreational uses which may not be compatible with the habitat requirements of Great Basin Spadefoot. Infilling of ponds, including depressions that hold water for brief periods, may be considered wasted space by landowners, and modification of surrounding terrestrial habitats by irrigation or other human uses is particularly damaging. Increased road networks and traffic volumes associated with an expanding human population (see Gayton 2016 for a review) elevate the risk of road mortality and can lead to isolation of subpopulations of Great Basin Spadefoot.

Asong *et al.* (2018) analyzed historical trends in drought patterns from 1950 to 2013 at a broad, Canada-wide scale and found that southern Canada has experienced a significant drying trend during this period, although considerable variation existed in the data. The authors pointed out that the drying trend was particularly pronounced in the Prairie regions; the figures provided show a similar trend for the arid southern interior of British Columbia.

Historical drought patterns at a finer scale across the Great Basin Spadefoot's range have not been analyzed in detail, but there is evidence of a drop in the water table in parts of the species' range over the past decades (Cohen 2004; Coelho 2015). Since 2015, the province has provided an annual drought summary for different regions across the province (British Columbia Drought Information Portal 2019). The southern interior regions have experienced "dry" to "extremely dry" conditions for various periods in summer in each year except 2016, when precipitation patterns were rated as "normal". The year 2015 was the driest on record across much of the province, including the southern interior regions, with a low snow pack and early start to the drought season. The drought season in 2017 was also one of the worst on record, but the season started later and extended into fall.

Climatic conditions largely responsible for shaping and maintaining grasslands include droughts, wind, long periods of cold, and a lack of moderating influences of maritime air masses (Wikeem and Wikeem 2004). The pattern of these processes is likely to alter under climate change scenarios. In general, temperatures are predicted to rise, winters to become wetter, and summers to become drier, but the magnitude of the changes will vary considerably across British Columbia (reviewed in Price and Daust 2016). By 2050 the Thompson-Okanagan region, which overlaps with most of the Great Basin Spadefoot's range, is predicted to experience a pronounced increase in temperature and a decrease in precipitation in summer, and a decrease in snowpack (Price and Daust 2016). By 2050 the mean annual Change in Mean Annual Temperature is expected to increase by 2.54–2.84°C throughout the species' range and the annual moisture deficit by >56.68 mm throughout 99.7% of the species' range, in relation to values for 1961–1990s (Atikian *et al*. 2019). The moisture deficit is in the highest category across Canada.

Over the long term (by 2080s), arid ecosystems in British Columbia's interior are expected to expand in extent based on shifting climate envelopes (summarized in Price and Daust 2016); conifer encroachment into open and semi-open ecosystems as a result of fire suppression may counteract this trend. Of particular concern for Great Basin Spadefoot is the continued loss of wetland habitats, which is predicted from increased summer droughts and reduced surface runoff that largely feeds seasonal pools used as breeding sites (Bunnell *et al*. 2010; Coelho 2015). Coelho (2015) examined pond persistence in the Lac du Bois grasslands in the Thompson region using remote sensing technology and found a decline of 63% in number of ponds from 1992 to 2012 within the study area of eight 100 km^2 areas sampled. Declines were linked to increased air temperature and potential evapotranspiration during the 20-year period. A field sampling of a small number of ponds indicated that seasonal ponds rely almost entirely on surface runoff, including spring snow melt, and are therefore extremely vulnerable to drying up as the climate continues to warm (Coelho 2015).

Increased demand for water for human uses, associated with an expanding human population, is likely to compound effects of climate change on amphibian breeding sites. Cohen (2004) examined interactions of climate change scenarios with water management in the Okanagan region and concluded that climate change is likely to result in "reduced water supply, increased water demand, and an increased frequency of high-risk years in which high demand and low supply occur concurrently." In addition to effects on Great

Basin Spadefoot habitat, there is much uncertainty regarding how changes in temperature and precipitation regimes will interact with epidemic diseases and outbreaks of chytrid fungi and other pathogens that have plagued amphibian populations worldwide.

BIOLOGY

The natural history of Great Basin Spadefoot is poorly known, in part due to its unique adaptations to life in arid environments. The following account focuses on information from studies in British Columbia whenever available, supplemented with anecdotal observations and by studies in the United States on this and related species of spadefoots. Extrapolations to Great Basin Spadefoot in British Columbia, however, should be considered with caution, as habitats and conditions at the northern limits of their range differ from those farther south.

Life Cycle and Reproduction

Like other northern anurans, Great Basin Spadefoot has a biphasic life cycle, consisting of aquatic eggs and tadpoles and terrestrial adults and juveniles. The timing of egg-laying and larval development varies geographically and with local conditions in particular years. In British Columbia, egg-laying typically occurs from April to June (Matsuda *et al*. 2006). Timing of metamorphosis varies with conditions, but metamorphs usually leave breeding sites from end of June to mid-July. In the Okanagan, adults begin to emerge from hibernation in early to mid-April and move quickly to breeding ponds where males begin to call (St. John 1993; Leupin *et al*. 1994). At any given site, length of the breeding season, as measured by presence of calling males, can vary from one month to less than a week; sites occupied earlier in the season had calling spadefoots longer than those occupied later in summer (St. John 1993). Females typically lay 300–800 eggs in small clusters, attached to sticks, pebbles, or aquatic vegetation in shallow water (Stebbins 1951; Leonard *et al*. 1993); cluster sizes of 10–110 eggs have been reported from South Okanagan (Ashpole *et al*. 2014).

North American spadefoots have the shortest developmental time of all anurans (Buchholtz and Hayes 2002), an adaptation that allows them to effectively exploit ephemeral pools. Under field conditions, Great Basin Spadefoot larvae typically take six to ten weeks for metamorphic development (Nussbaum *et al*. 1983; Green and Campbell 1984; Ashpole *et al*. 2014), but metamorphs can leave water after only 28 days (Brown 1989). Larval developmental time varies depending on water temperature and other environmental conditions (Nussbaum *et al*. 1983; Brown 1989). In addition to temperature, environmental factors shown to accelerate development in spadefoot species include reduction in water volume and/or food availability (Boorse and Denver 2003). If a pond begins to dry up, older tadpoles can accelerate metamorphosis to some extent but at the expense of body size. Small body size may be disadvantageous, as small individuals lose water more rapidly than larger ones (e.g., Newman and Dunham 1994: Couch's Spadefoot, *Scaphiopus couchii*). In contrast, O'Regan *et al*. (2014) found no effect of combined pool warming and drying on body size of Great Basin Spadefoot in enclosure experiments in the

Okanagan; while metamorphosis was accelerated by 15–17 days in warmer water, there was little difference in body size at metamorphosis between metamorphs reared in treatments with different water temperatures.

Great Basin Spadefoot males become sexually mature at about 40 mm SVL and females at about 45 mm SVL; they can reach this size in their second or third year of life (Nussbaum *et al*. 1983; Green and Campbell 1984). Females may not breed each year if conditions are unsuitable (Leupin *et al*. 1994), but no information on the frequency of breeding is available. The maximum longevity of this species is unknown, but Couch's Spadefoot can live 11 to 13 years (Tinsley and Tocque 1995). Annual survivorship is expected to be relatively low for larvae and metamorphs when compared to adults. The generation time is probably 5–6 years; the previously reported lower value of three years (COSEWIC 2007) is probably an underestimate, corresponding to the age at sexual maturity. The generation time is between age at maturity and life expectancy or lifespan of individuals; annual survivorship patterns that would allow for estimating generation time with accuracy are not available.

Terrestrial Activity and Hibernation

Spadefoots cope with lack of water in their semi-arid habitats by burrowing underground and remaining dormant through dry and cold periods. They emerge when a combination of warm weather and wet soil (either the result of rainfall or snowmelt) provides suitable conditions for survival above ground. Emergence usually, but not always, occurs during or after rainfall (Wright and Wright 1949).

Great Basin Spadefoot forage at night, especially during rain or when humidity is high, and shelter underground during the day, thereby minimizing water loss (Hallock 2005; Matsuda *et al*. 2006). Svihla (1953) described diurnal retreats of Great Basin Spadefoot around breeding ponds in central Washington. Adults dug backward away from the pond in sand, leaving tracks and "pretzel-shaped ridges" marking their temporary burrows. Svihla also found many individuals burrowed under flat rocks about 30 cm^2, within 0.6 to 6 m from the breeding pond. In British Columbia, day-time refuges are mainly shallow, self-constructed burrows, but the frogs also shelter in rodent burrows, other existing crevices, and occasionally under surface cover-objects (Sarell 2004; Garner 2012; Richardson and Oaten 2013; Hales 2018). Small mammal burrows and other crevices may be important in areas with heavier substrates (Hales 2018). Garner (2012) found that Great Basin Spadefoot burrows were often in bare ground in open rather than vegetated microsites, while Hales (2018) found no differences in soil moisture or vegetation features around refuge sites and available microsites in the immediate vicinity (within 5 m).

Availability of suitable substrates for burrowing is important. In laboratory experiments, adults of Eastern Spadefoot (*Scaphiopus holbrookii*) burrowed most easily in sand and were unable to burrow in sod; recently metamorphosed juveniles were unable to burrow in gravel and sod (Jansen *et al*. 2001). In enclosure experiments, juveniles of Great Basin Spadefoot were able to burrow into sandy clay loam, fine gravel, sand, and Brown Chernozemic soils prevalent in the grassland habitats, but tended to prefer sandy clay loam and gravel over clay and sand (Oaten 2003). They showed no preferences for substrates with pre-existing holes (Oaten 2003). Also in enclosure experiments, metamorphs preferentially sheltered under cover-objects on moist soil rather than in self-dug burrows in either dry or moist soil (Hales 2018).

Great Basin Spadefoot burrows deeply into the substrate for hibernation or use rodent burrows, but little specific information is available. At the northern part of the species' range, overwintering burrows occurred at 40–145 cm depth near 70 Mile House (n = 3; Garner 2012), and at a mean depth of 54 cm with a maximum depth of 1.5 m near Kamloops (n = 12; Richardson and Oaten 2013; Oaten pers. comm. 2014). In Kelowna, overwintering depths ranged from 63–90 cm in October (n = 5; Grods 2017). Some spadefoot species can obtain enough energy in as few as seven feedings (New Mexico Spadefoot, *Spea multiplicata*) or even just one feeding (*Scaphiopus couchii*) to survive a year of dormancy (Dimmit and Ruibal 1980), but similar data are not available for Great Basin Spadefoot. Couch's Spadefoot and Western Spadefoot (*Spea hammondii*) can remain dormant for two or more years while waiting for suitable foraging and breeding conditions (Seymour 1973), but it is unknown how long Great Basin Spadefoot can survive dormant underground.

Dispersal and Migration

Great Basin Spadefoot undertake seasonal migrations between terrestrial foraging and hibernation habitats, and aquatic breeding sites. In British Columbia, four studies have investigated terrestrial movements of the species using radio-telemetry: Garner (2012) near 70 Mile House at the northern limits of the species' distribution; Richardson and Oaten (2013) and Hales (2018) near Kamloops, and Grods (2017) in Kelowna. Most seasonal movements of tracked individuals were within 500 m of breeding ponds (Garner 2012: mean distance = 100 m, 95% confidence interval = 85.3–111.7 m, maximum distance = 371 m, n = 19; Richardson and Oaten 2013: < 500 m for 66% of 32 individuals; Hales 2018: mean distance = 233 m, SD = 150 m, n = 33; Grods: mean maximum distance = 285 for females, 183 for males; maximum distance = 570 m, n = 17 adults). However, in the Richardson and Oaten (2013) study, ten individuals made longer movements (750–2350 m) away from their breeding sites. These longer movements may have represented dispersal among wetlands or forays into more distant foraging areas by non-breeding individuals.

Observations by Richardson and Oaten (2013) remain the only records of longer distance movements, and whether such movements are a frequent occurrence in other areas is unknown. No information exists on movements of juveniles, which are difficult to track due to their small body size, but juveniles may be more prone to disperse to new areas than adults, as reported for other anurans (e.g., Berven and Grudzien 1990; Funk *et al*. 2005). Funk *et al*. (2005) suggested that relatively long-distance dispersal by juveniles is an important, often underestimated life history feature that accentuates habitat fragmentation as a serious threat to the persistence of amphibian populations. The recovery strategy noted that Great Basin Spadefoot may use a relatively broad range of habitats when moving among ponds and travel relatively rapidly across the landscape on suitable wet nights (ECCC 2017), as has been documented for other amphibians (Marsh and Trenham 2001). In fragmented landscapes, such as the Okanagan Valley, dispersal movements of Great Basin Spadefoot are curtailed by insurmountable barriers to movements, including highways, urban areas dominated by buildings and pavement, fast-flowing rivers, cliffs, and blocky talus (Hammerson 2005).

Physiology

Spadefoots have a variety of physiological adaptations for living in an arid environment, including the ability to survive water loss of up to 48% of their body weight, compared to a tolerance of only 31% of species in the genus *Rana* (now *Lithobates*) (Nussbaum *et al*. 1983). While permeability of the amphibian integument is often considered a detriment to life in an arid environment, it does allow spadefoots to absorb water directly from the soil while burrowed (Ruibal *et al*. 1969). This is accomplished by accumulating urea in the blood plasma, thus reducing the water potential of body fluids to allow absorption of water through the skin (Ruibal *et al*. 1969).

Water quality is often highly variable in the small ponds used by spadefoots. Brown (1967) found that eggs of Western Spadefoot near hatching could withstand temperatures of up to 39 or 40°C, but freshly laid eggs died at 37°C. Leupin *et al*. (1994) reported that 24-hour water temperature fluctuations between 33 and 12˚C in small breeding ponds of Great Basin Spadefoot in British Columbia had no apparent effect on tadpole survival. Great Basin Spadefoot has been recorded at breeding sites with pH between 7.2 and 10.4 (Utah: Hovingh *et al*. 1985; British Columbia: Leupin *et al*. 1993; Ovaska *et al*. 2014; Hales 2018). Anecdotal evidence suggests that it may be intolerant of pH levels above 10, which are commonly recorded in many ponds within its Canadian range (Low pers. comm. cited *in* COSEWIC 2007). Breeding ponds in ranching and agricultural areas of British Columbia may have high levels of nitrates and dissolved organic matter (Ovaska *et al*. 2014: nitrate concentrations of 2.4–11.5 mg/l and specific conductivity of 1,367–6,078 µS/cm for five Great Basin Spadefoot breeding ponds; Hales 2018: specific conductivity of 109–20,525 µS/cm in ten Great Basin Spadefoot breeding ponds north of Kamloops). The plasma osmolarity of Western Spadefoot tadpoles was consistently higher than that of American Bullfrog (*Lithobates catesbeianus*) tadpoles, an apparent adaptation to osmotic concentrations found in drying pools (Funkhouser 1977).

Interspecific Interactions

Great Basin Spadefoot is a generalized feeder, and metamorphosed individuals prey on a wide variety of invertebrates, including earthworms, ants, beetles, crickets, grasshoppers, and flies (Nussbaum *et al*. 1983; Sarell pers. comm. cited in COSEWIC 2007). Tadpoles are voracious scavengers on algae, aquatic plants, dead fish, and even their own feces (Green and Campbell 1984).

In South Okanagan, cannibalism among Great Basin Spadefoot tadpoles was frequently observed in ponds where densities were high (Ashpole unpubl. data). A specialized carnivorous morph with enlarged head and modified feeding apparatus has been described for tadpoles of Plains Spadefoot (*Spea bombifrons*; Bragg 1956, 1964) and New Mexico Spadefoot (*Spea multiplicata*: Pfennig 1990) but has not been documented for Great Basin Spadefoot to date.

Predators of adults include Western Garter Snake (*Thamnophis elegans*), Great Basin Gophersnake (*Pituophis catenifer deserticola*), Great Blue Heron (*Ardea herodias*; Ashpole unpubl. data), Burrowing Owl (*Athene cunicularia*; Leupin *et al*. 1994), and likely larger predators, such as Coyote (*Canis latrans*; Leonard *et al*. 1993; Leupin *et al*. 1994). Adults have noxious skin secretions that appear to deter some predators (Stebbins and Cohen 1995; Matsuda *et al*. 2006). Tadpoles are preyed on by ducks, Killdeer (*Charadrius vociferus*), Carp (*Cyprinus* sp.; Ashpole unpubl. data) and corvids, which have been seen feeding on larvae in a drying pond (Leupin *et al*. 1994).

Competition between Great Basin Spadefoot and Pacific Treefrog (*Pseudacris regilla*; Leupin *et al*. 1994) and Western Toad (*Anaxyrus boreas*; Bishop pers. comm. cited *in* COSEWIC 2007) has been suspected based largely on the complementary pattern of breeding site occupancy in some areas.

Adaptability

Great Basin Spadefoot is adapted to the variable rainfall patterns and breeding pond persistence in its arid habitats. It is able to use a variety of open and semi-open habitats and breeds opportunistically in a wide range of aquatic habitats, including very small pools and artificial ponds (Leupin *et al*. 1994; Sarell 2004; Ashpole *et al*. 2014; Ashpole *et al.* 2018b; Hales 2018). Rapid colonization of artificial habitats suggests that adults are not philopatric to their natal sites and/or that individuals are flexible in their selection of breeding ponds from year to year. These characteristics contribute to the species' ability to persist in human-modified landscapes (Ashpole *et al*. 2018b), provided that key features of both the aquatic and terrestrial habitat are retained or restored. However, breeding success and contribution of recruits from artificial ponds to the breeding population are poorly understood. Seasonal migrations to and from breeding sites and reliance on naturally scarce water bodies for breeding increase the vulnerability of the species in fragmented landscapes. NatureServe (2018) characterizes the species' intrinsic vulnerability as "moderately vulnerable" and its environmental specificity as "very narrow to narrow".

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Surveys targeting Great Basin Spadefoot have focused on determining site occupancy and distribution patterns, rather than obtaining an estimate of abundance (see **Search Effort**). As a result, very little information is available on population sizes, fluctuations, and trends. Typical of many pond-breeding amphibians, Great Basin Spadefoot populations fluctuate greatly from year to year, reflecting recruitment success from previous years and variable mortality, posing further complications for assessing trends. A small number of studies have conducted repeated surveys of the same sites over multiple years (e.g., South Okanagan: Ashpole unpubl. data; Upper Nicola: Ovaska *et al*. 2016), but longer-term monitoring is required to accurately depict trends. Survey methods have included visual encounter surveys of ponds during the breeding period and/or frog call surveys from standardized listening stations along roads.

Abundance

The size of the Canadian population is unknown. BC CDC (2018), citing information in the previous COSEWIC (2007) status report, suggested a population size of over 10,000 mature individuals but noted that year-to-year fluctuations may periodically result in a much reduced population size. The Okanagan region is presumed to have the largest number of mature individuals, over 5000. Considering that the known EOO and IAO have increased substantially since the preparation of the previous status report, it is plausible that the Canadian population greatly exceeds 10,000 mature individuals.

Fluctuations and Trends

<u>Population Trends:</u>

Globally, NatureServe (2018) reported that the species is relatively stable (< 10% decline) over the short term. Over the long term, the EOO of the global population is also deemed relatively stable with probably < 25% decline in “population size, area of occurrence, and number/condition of occurrences.”

Historically, the Canadian population has undoubtedly experienced drastic habitat losses and concomitant declines (see **Habitat Trends**). Recent population trends are unknown due to lack of systematic surveys and long-term monitoring, although local declines have been noted, particularly in the Okanagan, following habitat loss and alteration (see below for examples). The species continues to persist across its historical range. However, threats from various sources are ongoing across the species’ Canadian distribution (see **Threats**) and are projected to result in 3–30% population decline from threats operating over the next 10-year period (Medium threat impact). The values in the threats calculator are based on expert opinion, as robust quantitative data are lacking.

Case studies from the South Okanagan Valley show local declines. Ashpole and coworkers repeatedly surveyed 108 wetlands from 2003 to 2006, and a subsample of 30 to 40 lowland valley sites annually up to 2018; they also conducted additional surveys of river channels from Osoyoos to Oliver in 2003–2006 (Ashpole *et al*. 2018b). Forty-three ponds contained spadefoots, but breeding was observed in only about half of them. Observations of eggs, tadpoles, or metamorphs in high densities (> 1000 individuals) were found on seven survey occasions. Population fluctuations and declines were observed in connection with changes in seasonal flooding, water management, infilling, and for unknown reasons, as described below (Ashpole unpubl. data).

In four productive ephemeral wetlands and throughout the grassland in the north end floodplain of Osoyoos Lake, reproductive efforts by spadefoots failed in two years with heavy spring floods (2010, 2018), possibly due to access by predatory fish into the ponds. In extreme drought years (2015, 2016, 2017), ephemeral wetlands, flooded fields, and ditches along the river channel drained rapidly due to water withdrawal that, in some cases, occurred before spadefoot tadpoles had metamorphosed. A change from overhead to drip irrigation systems throughout the mid-2000s has resulted in less water and a failure of inundation in up to 11 previously productive spadefoot breeding sites, depending on the year (S. Ashpole unpubl. data).

From 2003 to 2018, partial and complete infilling of breeding sites has been observed in six private ponds, a significant number considering that the total number of available breeding ponds in the lower valley south of Penticton is approximately 31. Compared to an observation of a large population of breeding spadefoots (the reported value of 1000 is most likely an approximation) in the Osoyoos sewage lagoons in the early 1990s (St. John 1993), annual surveys from 2003 to 2017 have detected only a handful of calling males (Ashpole *et al*. 2018a and unpubl. data). The reason for the apparent decline at this site is unknown, but loss of associated upland habitat due to significant housing development may be a contributing factor.

<u>Extreme Fluctuations:</u>

Breeding populations of Great Basin Spadefoot can vary substantially from year to year depending on water table levels, temperature, and rainfall. For example, in the Kamloops area, Thompson Valley, little breeding was observed in 2003 and 2004, whereas breeding was confirmed at numerous sites in 2005 (Larsen pers. comm. cited *in* COSEWIC 2007). In the Vernon area, North Okanagan, breeding attempts and success in ten ponds were highly variable from 1999 to 2005, depending on the availability of surface water (Sarell 2006). All ponds contained water during the breeding period in 1999, but only two ponds did so in dry years, with only one pond producing metamorphs in 2015. In the Upper Nicola area, two sections of roads each with ten listening posts, 0.8 km apart, were surveyed repeatedly during wet nights each spring and early summer for five years (2011 to 2015; Ovaska *et al*. 2016). The number of stations with calling by Great Basin Spadefoot varied among the years and ranged from 12 stations in 2011 to 7 in 2015. The number of stations with a full chorus, indicating an abundance of calling males, was the greatest during the particularly wet spring of 2011 and lowest in 2014 (7 versus 2 stations with full chorus, respectively).

Pond-breeding amphibian populations often fluctuate greatly on multi-year basis to the extent that discerning population trends can be exceedingly difficult (Pechmann and Wilbur 1994). Pechmann and Wilbur (1994) provided examples of fluctuations of an order of magnitude for several anurans breeding in temporary ponds (e.g., *Rana sylvatica*, *R. temporaria*, *Arthroleptis poecilonotus*), but long-term monitoring required to demonstrate the magnitude of such fluctuations is lacking for most species (with several notable exceptions below).

Population fluctuations can be expected to be pronounced for amphibians inhabiting arid areas, where the availability of ephemeral breeding sites varies greatly from year to year and results in highly variable recruitment. The previous status report (COSEWIC 2007) considered fluctuations of the Great Basin Spadefoot population as extreme (i.e., fluctuations of an order of magnitude or greater), based on qualitative information and the life history of this and related species.

Recruitment rates of Great Basin Spadefoot vary greatly among years, ranging from high output of young in wet years to complete reproductive failure in dry years, and are expected to affect the size of the breeding population in subsequent years. Individual spadefoots live multiple years, and adult longevity will buffer against recruitment fluctuations to some degree. However, several consecutive dry years are not uncommon, such as occurred within Great Basin Spadefoot's range in British Columbia during the first decade of the 21st century, and would depress adult numbers and further amplify fluctuations. Lack of water during the breeding period as a result of droughts or reduced snow melt can affect large areas simultaneously. For Great Basin Spadefoot, human activities, including water withdrawal, and more frequent summer droughts predicted under climate change would further accentuate natural fluctuations, reducing available water and inhibiting or preventing movements among remaining waterbodies (see **Threats**).

IUCN Red List Guidelines (2019) recognize two diagnostic pathways to apply the criterion of extreme fluctuations: "(i) interpreting population trajectories based on an index of abundance; and (ii) using life history characteristics or habitat biology of the taxon" (IUCN 2019). The guidelines are clear that direct observation of successive increases and decreases of the taxon under consideration is not required to infer extreme fluctuations, and in lieu of such data, inference of fluctuations can be based on "studies of functionally similar taxa" (IUCN 2019). To that end, several studies are germane, and are offered below in support of the inference of 'extreme fluctuations' in Great Basin Spadefoot in Canada.

In a study of eight ponds over nine years, Greenberg and Tanner (2005) found >10-fold variation in adult numbers of Eastern Spadefoot (*Scaphiopus holbrookii*) at individual ponds. Recruitment of young occurred in only four years, and only four ponds produced metamorphs, although breeding took place in all but one of the ponds. In some ponds intervals between breeding events exceeded adult longevity. Only ponds with large numbers (>175) of breeding adults produced substantial recruitment, and captures of breeding adults and juvenile recruitment showed "dramatic differences" both among years and among ponds. The authors inferred that half of the breeding sites acted as reproductive sinks (i.e., produced no recruits to the population), while the remaining breeding sites acted as sources of recruits in some but not all years. Great Basin Spadefoot populations may experience similar source-sink population dynamics, as the two species inhabit similar predictably variable environments and show opportunistic breeding strategies.

Berven and Grudzien (1990) found 3- to 20-fold variation in breeding population sizes of *Rana sylvatica* over 6 yrs in five ponds in Virginia, largely due to annual variation in recruitment, which ranged up to four orders of magnitude and included many complete recruitment failures.

In Russia, Bannikov (1948) found in a multi-pond study of temporary pond dwelling anurans *Rana temporaria* and *Bufo vulgaris* that drought and cold winters resulted in a 97% decrease in the adult *Rana* population between 1936 and 1939, and a subsequent 44-fold increase by 1942. Other amphibians breeding in temporary ponds in the area showed similar fluctuations, and *Bufo vulgaris* disappeared completely from some localities. In contrast, the species that inhabited deeper ponds and lakes, including *Rana ridibunda* and *R. esculenta*, were apparently buffered from the climatic variation and did not show population fluctuations over that same period (Bannikov 1948).

Population Fragmentation

Habitats of Great Basin Spadefoot are naturally fragmented, and the fragmentation is exacerbated by human developments and barriers to movement (see **Habitat Trends**). However, whether the Canadian population is severely fragmented (i.e., > 50% of population is in fragments too small for long-term viability) cannot be assessed with any degree of confidence with available information. Considerations include defining habitat fragments at a biologically meaningful scale and qualitatively assessing the long-term viability of subpopulations in these habitat patches. Both are particularly challenging for Great Basin Spadefoot, which occurs in metapopulations (series of loosely interconnected groups) in a predictably variable environment, where the availability of breeding sites varies both spatially across the landscape and among years.

Clusters of occurrences of Great Basin Spadefoot may be used as a proxy to represent subpopulations in habitat patches. ECCC (2017) used a distance of 500 m around observations to define core Critical Habitat polygons, merging those with overlapping buffer zones. Additional dispersal habitat was identified by connecting core habitat polygons that were within 2,400 m of other polygons; the distances were based on documented movement distances of spadefoots in British Columbia (see **Movements and Dispersal**). This method resulted in a total of 252 core habitat polygons and 111 polygons joined by potential dispersal habitat (calculated from Figures 1–17 in the recovery strategy; ECCC 2017). The latter clusters could be interpreted to represent subpopulations. Most of the above clusters (42 of 111) are within the Okanagan-Similkameen area, where habitat loss and modification have been the greatest, followed by the Thompson (36), Cariboo (12), Nicola (11), Kettle (6), and Granby (4) regions; the areas of polygons ranged from 78 ha around single records to 1000s of ha with the largest polygons located in the Okanagan. The protection provided by the Critical Habitat designation is currently implemented only on federal lands; therefore, subpopulations within the polygons continue to be under threat from various sources, but even rudimentary information on their viability is lacking. BC CDC (2018) has mapped 102 occurrences using somewhat different separation distances from the Critical Habitat mapping (1 km and 5 km in unsuitable and suitable habitat, respectively, following NatureServe's general recommendations for spadefoots; Hammerson 2005) and reported that the number of occurrences with good viability is unknown.

The previous status report (COSEWIC 2007) assessed the Canadian population as severely fragmented, based on general habitat fragmentation, habitat requirements, and movement abilities of the species. While these considerations still apply, a more rigorous assessment of the degree of population fragmentation is not possible at present. The persistence of the species across its Canadian range and the many newly discovered occurrences argue against the applicability of severe fragmentation.

Rescue Effect

While there might be some interchange of individuals near the Canada - United States border, rescue from south of the border is unlikely to be significant due to the relatively low dispersal ability of Great Basin Spadefoot, coupled with habitat fragmentation. In Washington State, there are scattered records of the species from Okanogan, Ferry, and Stevens counties that abut the Canadian border, but no records exist from the immediate vicinity of the border (Washington Herp Atlas 2018; records up to 2016). The search effort near the border is unknown. The majority of records from the state are from extensive shrub and grasslands farther south. The northern populations in Washington State are potentially contiguous with the Okanagan-Similkameen and Kettle-Granby populations in British Columbia, and some movement northward is possible. However, modification and fragmentation of the habitat in the valley bottom areas, especially on the Canadian side, would restrict dispersal. As a consequence, although it is possible for some individuals to cross from the United States into Canada, these immigrants would likely have little significance at the population level and actual rescue is unlikely.

THREATS AND LIMITING FACTORS

Threats

The IUCN Threats Calculator was applied to Great Basin Spadefoot in April 2019 by a panel of experts. The process consists of assessing impacts for each of 11 main categories of threats and their subcategories, based on the scope (proportion of the population exposed to the threat over the next 10-year period), severity (proportion of the segment of the population exposed to the threat predicted to decrease within the next 10 years or 3 generations, whichever is longer), and timing of each threat. The overall threat impact is calculated taking into account the separate impacts of all threat categories and can be adjusted by the panel. For Great Basin Spadefoot, the overall threat impact was assessed as “Medium”[4], based on three medium and five to eight low level threats (Appendix 2). The greatest threats were deemed to be from road mortality (Transportation & service corridors), agricultural and forestry effluents (Pollution), and reduction in water table associated with droughts (Climate change & severe weather) affecting the availability of breeding sites. Other threats individually scored as low compound the impacts of the main threats. The applicable threats are discussed below in an approximate, perceived order of importance. The narrative is adapted from the comments in the threats calculator and accounts in the provincial recovery strategy (Southern Interior Reptile and Amphibian Working Group 2017).

Transportation & service corridors (Category 4.0) - threat impact Medium – Low

Impacts on Great Basin Spadefoot accrue from habitat loss and fragmentation associated with the construction of new roads and road mortality on both new and existing roads. Great Basin Spadefoot is most at risk where roads are near breeding sites and intersect seasonal migration routes. The frogs may also use paved road surfaces for thermoregulation and hydration (Crosby 2014), thereby increasing the time spent on roads, and as a result, mortality risk. Based on a review of a large number of studies, Charry and Jones (2009) determined that traffic volume and road location in relation to movement patterns of wildlife are the primary determinants of mortality risk for a variety of species and groups; they found that for amphibians the onset of risk occurred at 120 vehicles/day and increased dramatically thereafter.

In the southern interior of British Columbia, major roads with high traffic volumes (thousands of vehicles/day) tend to follow valley bottoms, where they intercept Great Basin Spadefoot habitats (Appendix 3). However, lower traffic volumes on secondary roads may also be problematic during peak migration periods. Road densities and traffic volumes vary greatly across the species’ range, with the greatest problem areas in the Okanagan Valley (Appendix 4). Further increases are expected concomitant with increasing human population growth (see **Habitat Trends**). In the Okanagan, annual daily traffic volumes along Highway 97 and 97A have increased over 20% from 2004 to 2017, based on traffic data from two monitoring points: Okanagan Falls south of Penticton and Armstrong north of Vernon (Appendix 4). In the northern portions of the species’ range, traffic volumes and road densities are lower. For example, in the Nicola uplands, Ovaska *et al*. (2016) sporadically encountered concentrations of Great Basin Spadefoot on sections of paved secondary roads during the breeding period, but traffic volumes were low (few or no vehicles encountered during road surveys), and little roadkill of this species was documented. Across the species’ Canadian range, 80% of the range is within 500 m of roads and almost all is within 3 km of roads (analysis with Hectares BC for Southern Interior Reptile and Amphibian Working Group 2017). For this reason, the scope of the threat was scored as Large (31–70% of the population exposed to this threat).

[4] The overall impact was reduced from the calculated threat impact of “High-Medium” to “Medium” because there is high uncertainty about the three greatest threats, all of which were thought to be closer to the lower end of range of the assigned severity scores.

Brehme *et al*. (2018) developed a numerical scoring system to assess the relative road mortality risk for California amphibian and reptile species. The system is based on space use and life history as reported in the literature and excludes exposure. The road mortality risk for Great Basin Spadefoot was assessed as "medium" on a scale that ranged from "very high" to "very low". The ranking was on par with that of Northwestern Salamander (*Ambystoma gracile*) and slightly below that of Western Toad. Contributing factors were fragmentation of terrestrial habitat, seasonal migrations, and distance of 670 m, which is considered to include 95% of movements of the population at a particular site. The authors noted that specific circumstances, including road types and densities, may elevate or reduce the risk to particular species or populations.

Road mortality has been recorded from many areas across Great Basin Spadefoot's Canadian range (Leupin *et al*. 1994; Sarell 2004; Crosby 2014; Winton pers. comm. 2018) but has been rarely quantified. In South Okanagan, Crosby (2014) found that Great Basin Spadefoot represented 87.4% of all amphibians and 46.5% of amphibian roadkill encountered along 52 km of paved roads surveyed, including 31 km on Highway 97, over a 2-year period. Roadkill peaked in May when adults were migrating to breeding ponds and again from the end of June to mid-July when metamorphs were dispersing from these sites. An underpass and associated drift fencing specifically designed to facilitate amphibian road crossing were installed at Highway 31 and helped reduce, but not eliminate, roadkill at this site (Crosby 2014). However, road mortality within most of the species' range remains undocumented and unmitigated.

The available information suggests that roadkill is variable across the species' range and is expected to be locally significant. Road mortality of adult females, in particular, during the spring migration to breeding ponds is expected to reduce reproductive output and number of recruits from the ponds, but population effects remain unstudied. Therefore, a wide range (Moderate–Slight; 30–1% population decline within the scope) was used for the severity rating associated with this threat.

<u>Climate change & severe weather (Category 11) - threat impact Medium - Low</u>

The threat to Great Basin Spadefoot accrues mainly from increased frequency and duration of droughts and associated reduction in the number of breeding ponds as predicted under climate change scenarios, which has already been documented in some areas. Direct effects of droughts on survivorship are of lesser concern because Great Basin Spadefoot is able to withstand long periods of inactivity in underground refuges. Increased temperature fluctuations associated with climate change are a contributing factor to reduction in breeding ponds that may become significant over the long term (Gerick *et al*. 2014).

While grassland ecosystems are predicted to expand in British Columbia's interior over the long term, seasonal ponds important for Great Basin Spadefoot are expected to continue to diminish and experience shorter hydroperiods as a result of climate change (see **Habitat Trends**). The water table has dropped substantially within the species' Canadian range over the past few decades (Cohen 2004; Coelho 2015). A decreasing trend in the number of Great Basin Spadefoot breeding ponds was noted in several areas of the Okanagan during a period of long drought that ended circa 2013; however, this trend may have been reversed in subsequent wetter years (Dyer pers. comm. 2014, 2019). A similar trend was noted during drought years in the Cariboo region (Packham pers. comm. 2014). The level of reduction in water supply is predicted to be modest during the 2020s but will become more severe during the 2050s and 2080s (Cohen 2004). The scope of this threat has considerable uncertainty over the next 10-year period and was scored as Large–Restricted (11–70% of the population exposed to this threat).

Spadefoots are fairly tolerant of a wide range of environmental conditions, but Griffis-Kyle (2016) noted that desert-adapted amphibians may be particularly susceptible to climate change effects because they may already live near their physiological tolerances. The global distribution of Great Basin Spadefoot extends farther south in the United States, where temperatures are routinely much higher than in British Columbia. However, sublethal effects may occur sooner than might be expected even at the northern limits of the species' distribution. Gerrick *et al*. (2014) found that this species exists close to its thermal safety margin (calculated as degrees between habitat temperature during summer and thermal performance optima) in British Columbia and that the safety margin can erode rapidly, at a rate of 0.5 °C/decade, as climate warming proceeds. They found that 82% of the current distribution of the species is expected to be in thermally limiting environments by the 2080s; in some lower elevation habitats in the southern portion of its range in British Columbia, the species might already have little or no thermal safety margin. However, the analysis did not take into account the burrowing behaviour of spadefoots and their use of below-ground refuges, which are likely to shield them from temperature extremes.

The actual mechanisms of climate change impacts on Great Basin Spadefoot are complex and include interactions among temperature, rate of pond drying, and survivorship (O'Regan *et al*. 2014). Based on enclosure experiments, O'Regan *et al*. (2014) found that pond warming and drying combined act antagonistically on early growth, reducing negative impacts expected from each factor alone. In the threats calculator, the severity of this threat category was scored as Moderate–Slight (30–1% population decline within the scope). While severity might be extreme in some areas in highly fragmented habitats where the species breeds mainly in shallow water bodies, subpopulations in areas with multiple wetlands with different depths within migration distances are expected to be more resilient. However, as ephemeral breeding habitats decrease with climate change, the species will be increasingly dependent on permanent breeding habitats that support predators such as fish and turtles, resulting in higher tadpole mortality and reduced breeding success. A wide range was used to capture the uncertainty reflecting differences in the habitat quality and speed of change.

Climate change vulnerability assessments applied to Great Basin Spadefoot have ranged from highly vulnerable to relatively resilient depending on the indices used. Results of different trait-based indices are discussed below:

1) Price and Daust (2016) evaluated the vulnerability of 63 species of British Columbia vertebrates of conservation concern or of particular ecological importance, including 15 species of amphibians, using a simplified climate change vulnerability framework created for an application to British Columbia wildlife. The approach focuses on exposure at a coarse scale, sensitivity, and adaptive capacity, but, unlike the NatureServe Climate Change Vulnerability Index, it does not require detailed spatial information on distributions or exposure. The following features are assessed under the BC framework: species' sensitivity to changes in habitat and the abiotic and biotic environment related to climate change, sensitivity to non-climate stressors that combine with climate to create cumulative effects, and adaptive capacity. Unlike other systems, the BC framework takes into account the dependency of a species on specific fine-scale ecosystems under the sensitivity rating. The ratings are not combined into a single score or rating, but the individual ranks are intended as red flags for any factor warranting concern. For Great Basin Spadefoot, climate change sensitivity was rated as High, non-climate stressors as Moderate–High, and adaptive capacity as Moderate–Poor. All these factors suggest high vulnerability to climate change. The only other amphibian with a "High" climate change sensitivity rating was the Coeur d'Alene Salamander (*Plethodon idahoensis*).

2) Friggens *et al*. (2018), using the System for Assessing Vulnerability of Species to Climate Change (SAVS; Bagne *et al*. 2011), assessed climate change vulnerability for a range of fish and wildlife species within the intermountain region of the western USA. They concluded that Great Basin Spadefoot is relatively resilient because it uses a variety of vegetation communities but pointed out that loss of wetland breeding sites due to changes in precipitation and evaporation rates is of concern. The document identified effects on water resources to be the most pronounced and earliest potential impacts.

3) Three groups of University of Toronto Master class students independently applied the IUCN/NatureServe climate vulnerability index, which incorporates exposure, sensitivity, and adaptability, to Great Basin Spadefoot in Canada (Abdulhafiz *et al*. 2019; Abdurahman *et al*. 2019; Atikian *et al*. 2019). The analyses of all groups resulted in a score of Highly Vulnerable, the second highest category. Two other approaches tested by the student groups also indicated vulnerability (SAVs and Montane Amphibian Vulnerability Assessment, developed by the students; Abdurahman *et al*. 2019; Atikian *et al*. 2019), but a third, Fodden *et al*.'s (2013) trait-based assessment, which is similar to the NatureServe method but differs in the suite of traits used and their scoring method, resulted in a Low vulnerability rating (Abdulhafiz *et al*. 2019).

Pollution (Category 9) - threat impact Medium-Low

This threat accrues mainly from agricultural effluents contaminating breeding sites, with smaller contributions from other sources of pollution. While airborne pollution from pesticides at higher elevation lakes is increasing in British Columbia, water sampling data from high elevation ponds in South Okanagan do not support airborne pollutants as an impending threat (Bishop *et al*. 2010).

Agricultural contamination from herbicides, pesticides, and fertilizers, as well as spraying for mosquito control, applies mainly to the Okanagan. The scope was scored as Large-Restricted (11–70% of the population exposed to this threat), reflecting the extent of agricultural areas. The use of pesticides to combat both new and well known agricultural pests will likely continue. An example of emerging, potentially serious orchard pests is Spotted-wing Drosophila (*Drosophila suzukii*), a fruit fly that was first identified in British Columbia in 2009 and is now widespread in fruit growing areas in British Columbia (Pest Alert Bulletin 2019). In the last 10 years, agriculture in the Okanagan has experienced a significant influx of pesticides with new classifications (>100), while many previously used pesticides are no longer used or registered (Y. Herbison pers. comm. 2019). The effects of these "new" pesticides on wetland fauna are poorly known.

Field evidence for declines of Great Basin Spadefoot in agricultural areas is lacking; however, some information suggests negative impacts, though source-sink population dynamics is a confounding factor. In South Okanagan orchards, Bishop *et al*. (2010) detected low concentrations of 17 chemicals in amphibian breeding sites; both organic and treated orchards had contaminants. Great Basin Spadefoot hatching success was highly variable: 0–92% in sprayed orchards; 48–98.6% in organic orchards; 51–95.5% at reference sites. Atrazine, total nitrate, and chlorpyrifos accounted for 79% and 80% of variation in hatching success in 2005 and 2006, respectively. A dose response study examined exposure of developing Great Basin Spadefoot embryos to environmentally relevant levels of endosulfan, diazinon, and azinphosmethyl. The study found increased tadpole mortality, deformity, and other sublethal effects (de Jong Westman *et al*. 2010).

Widespread applications of mosquito control agents, such as *Bacillus thuringiensis var. israelensis* (Bti) (Vectobac®), to prevent establishment and spread of West Nile virus is a developing issue if implemented within the species' distribution. Effects of Bti on amphibians are poorly understood, but sublethal effects have been reported under experimental conditions for other species (*Rana temporaria*; Allgeier *et al*. 2018). Additional pollutants for consideration include application of magnesium chloride (MgCl) to desiccate gravel road surfaces for dust abatement during road maintenance. Impacts on spadefoot metamorphs crossing roads are unknown, but likely serious as documented for other amphibians (e.g., metamorphs of Long-toed Salamander, *Ambystoma macrodactylum*, leaving a breeding pond died by the thousands trying to cross a recently treated road in the Cariboo region; Packham pers. comm. 2019). This is an emerging threat that is becoming more widespread and requires research.

A wide range for severity (Moderate-Slight; 30–1% population decline within the scope) was applied to reflect uncertainty about the combined effects of various contaminant sources. Great Basin Spadefoot eggs and tadpoles are most vulnerable to pollution effects in breeding ponds; in contrast, little is known about impacts from terrestrial exposure or cumulative impacts affecting the population. However, cumulative impacts from agricultural contaminants have been well documented in other amphibian species (see examples in Relyea 2005).

Residential & commercial development (Category 1) - threat impact Low

The human population across much of Great Basin Spadefoot's range continues to expand (see **Habitat Trends**); this increase is associated with land conversion to residential developments. The increases are most likely to be focused around existing population centres, especially in central Okanagan, where the population is projected to continue to increase at a relatively rapid rate, and around Kamloops in the Thompson-Nicola region. In the Okanagan, draining of ponds is expected to be minimal due to regulations, but a loss of upland foraging and hibernation habitat and of dispersal habitat may occur (Dyer pers. comm. 2019). In contrast, little residential development is expected in the northern portion of the species' range in the Cariboo region, where most Great Basin Spadefoot habitat is on provincial crown land (Packham pers. comm. 2014).

The scope across the species' range was assessed as Small (1–10% of the population exposed to this threat). In general, subpopulations are expected to disappear if breeding ponds are infilled or sink habitats (i.e., sites where Great Basin Spadefoot breeds but which result in little or no recruitment) are created. Subpopulations may persist within low density developments or continue migrating across developed areas. However, where land conversion does occur, impacts are permanent, and the severity was assessed as Serious (31–70% population decline within the scope).

Agriculture & aquaculture (Category 2) - threat impact Low

The threat to Great Basin Spadefoot accrues from a combination of land conversion to annual non-timber crops and from livestock farming and ranching. Loss of breeding and associated terrestrial habitats from land conversion into agricultural uses is largely historical (see **Habitat Trends**). However, some new conversion of lands into croplands or pasture is expected to occur within the next 10-year period. Furthermore, free-range cattle in some areas (in particular, the Thompson-Nicola and Cariboo regions) continue to alter Great Basin Spadefoot habitats. In the Okanagan, conversion of land into vineyards, orchards, and other agricultural uses has led to loss of breeding habitat in the past, but the rate of these types of developments has slowed since the early 2000s; intensification and redevelopment of existing agricultural sites continues. Irrigation is a primary driver of agricultural development and degrades habitat for spadefoots where turf replaces friable substrates where spadefoots can burrow (also see Natural system modifications).

Livestock can have both adverse and beneficial effects on Great Basin Spadefoots, but negative effects are most likely of overriding importance. Grazing may be beneficial by retaining the ecosystem at an early stage of ecological succession (Cragg 2007) and maintaining vernal pool hydrology (Pyke and Marty 2005). In semi-arid grasslands, cattle tend to concentrate wherever there is available water. Negative effects on Great Basin Spadefoot include trampling of eggs, tadpoles, riparian vegetation, and shallow water areas at breeding sites. Where improperly managed, “the combination of grazing, browsing, trampling, urination, and defecation has the potential to damage amphibian habitat, which includes upland areas, the riparian zone, and aquatic habitat” (Cragg 2007). Heavy grazing also indirectly affects the composition of plant communities and can increase the prevalence of invasive plant species in and around wetlands, based on a study in grasslands near Kamloops (Jones *et al*. 2011). However, the impact of such changes on spadefoots is unknown.

The scope was assessed as Pervasive (71–100% of the population exposed to this threat), largely reflecting the prevalence of free-range cattle in Great Basin Spadefoot habitats across much of the species’ Canadian range. The severity of impacts depends on stocking density and duration of grazing season, and effects are expected to be more damaging in drought years. Threat impact was assessed as Slight (1–10 % population decline within the scope), although local impacts on subpopulations in areas affected by agricultural land conversions and/or overstocking of livestock can be substantial.

Human intrusions & disturbance (Category 6) - threat impact Low

The threat to Great Basin Spadefoot accrues from recreational activities. The main source is intensive use of off-road vehicles, particularly when it occurs in wetlands, which seem to attract some types of recreational users (“mudboggers”). Off-road vehicle use occurs sporadically throughout the Canadian range of the species but is expected to be more frequent near human population centres; Southern Interior Reptile and Amphibian Working Group (2017) reported several such incidents. Scope was deemed to be at the lower end of Small, with just over 1% of the Canadian population exposed to this threat.

The impact on Great Basin Spadefoot is from breeding habitat destruction and mortality of eggs and young at these sites. In addition, tyre ruts can trap tadpoles, isolating them from the remainder of the wetland and causing die-offs when the ruts dry up. In terrestrial habitat, off-road vehicles can potentially result in soil compaction and burrow collapse. The severity was rated as Moderate–Slight (30–1% population decline within the scope), reflecting uncertainty about the intensity, timing, and frequency of activities, which in turn influence magnitude of the impact. While there is much uncertainty in average impact across the species' range, it can be locally severe.

Natural system modifications (Category 7) - threat impact Low

This threat to Great Basin Spadefoot accrues mainly from dams and water management/use. Fire and fire suppression and other ecosystem modifications, consisting of habitat alteration by invasive plants and conifer encroachment, were both scored as Unknown for scope and severity; these potential threats were not included in the calculated impact rating, but may be important.

The assessment of this threat is intended to address human use or diversion of water apart from climate change effects to avoid double-scoring, but the two are intertwined and difficult to tease apart. Concomitant with human population growth, water use is predicted to increase, especially in the more arid southern parts of Great Basin Spadefoot's range in the Okanagan and Thompson-Nicola regions, and may result in drying of seasonal breeding ponds or shortening of the hydroperiod. In the Okanagan watershed, almost half of the region's extensive cropland is irrigated (Cohen 2004). Cohen (2004) noted that with a longer growing season and warmer summers, water demand is expected to increase per hectare on agricultural lands and per capita on residential lands. The scope was deemed to be Small (1–10% of the population exposed to this threat) over the next 10 years, reflecting the scores for residential and agricultural developments, but it is likely to increase as climate change continues and demands for water increase.

Impacts on Great Basin Spadefoot are from water withdrawal for human uses, including irrigation and consumption, and alteration of natural hydrological patterns, such as ditching and channelization of water courses. A mitigating factor is that water withdrawal usually occurs later in the season after breeding by spadefoots has been completed. Unauthorized dam removals are ongoing and could result in breeding site destruction (Dyer pers. comm. 2018). In addition, sink habitats may be created by making ponds permanent or creating new ponds in unsuitable landscape contexts. Severity was scored as Serious–Moderate (70–11% population decline within the scope); the wide range reflects uncertainty about average impacts under the range of water management practices that are used.

Invasive & other problematic species & genes (Category 8) - threat impact Low

Non-native fish and diseases, particularly chytridiomycosis, caused by *Batrachochytrium dendrobatidis* (Bd), pose widespread threats to Great Basin Spadefoot. Introduced American Bullfrog (*Lithobates catesbeianus*) is a potential threat in the Okanagan. In addition to ecosystem effects (scored under Natural system modifications: Other Impacts), invasive plants may directly reduce opportunities for burrowing.

No disease outbreaks in Great Basin Spadefoot populations have been documented in British Columbia, but epidemic disease remains a serious threat to all amphibian populations. Bd is widespread in amphibians across British Columbia (Govindarajulu *et al*. 2013). In 2008, 14.3% of 35 Great Basin Spadefoot tadpoles in the Okanagan tested positive for Bd (Richardson *et al*. 2014). Great Basin Spadefoot may be protected from water-borne epidemic diseases to some degree due to its terrestrial habits and extensive use of small seasonal ponds where disease transmission may be reduced.

In permanent water bodies, introduced sport fish (e.g., bass, *Micropterus sp.*) represent a widespread threat to aquatic-breeding amphibian populations through predation (reviewed in Wind 2005). Sport fish and non-native fish for mosquito control (e.g., carp sp. (*Carassius* sp.)) or other purposes continue to be introduced to Great Basin Spadefoot habitats and to larger water bodies from where they can spread and consume eggs and tadpoles (Ashpole *et al*. 2018a). In the lower South Okanagan valley, three sites with Goldfish (*Carassius auratus*) have been restored to spadefoot breeding sites by removal of the fish. In permanent wetlands where Asian Carp (*Cyprinus carpio*) or sport fish were introduced or gained access to ephemeral wetlands through flooding, egg and tadpole survival of Great Basin Spadefoot was significantly impaired and likely completely eliminated (Ashpole *et al*. 2018a).

American Bullfrog poses a localized threat in seven sites in South Okanagan. Eradication efforts have been conducted since the early 2000s and have been largely successful (Lukey 2017); these efforts resulted in the removal of 11,102 individuals (all life stages combined). American Bullfrog has not been detected since 2011 using standard survey methods (including automated recording devices) (S. Ashpole unpubl. data). However, recent surveys detected evidence of the species' eDNA in two water samples from a site where it was presumed eradicated (Govindarajulu pers. comm. 2018); repeat sampling the following year yielded no positive results (Arner pers. comm. 2018).

The scope of this threat was scored as Pervasive (71–100% of the population exposed to this threat), mainly reflecting a combination of threats from epidemic disease and introduced fish. There is much uncertainty about the severity of the impact from all sources. Severity was scored as Slight (1–10% population decline within the scope), based mainly on threat from introduced fish. The severity of impact from epidemic disease could not be predicted at this time.

Limiting Factors

The persistence of spadefoot populations in particular areas depends on the availability of suitable breeding sites, which are naturally in short supply and unpredictable in space and time, and surrounding upland habitat, coupled with appropriate weather conditions and chance events (Greenberg and Tanner 2005). In California, causes of population declines of Western Spadefoot were best explained by local habitat destruction, rather than by other hypotheses tested (e.g., pesticide drift, UVB-radiation, climate change), and the number of occupied breeding sites was reduced in areas surrounded by urban or agricultural developments within a 5-km radius (Davidson *et al*. 2002). At the northern extremity of the species' distribution in British Columbia, long, cold winters and short summers may limit population growth, but habitat availability and connectivity are most likely the main factors limiting distribution across the Canadian range of the species.

Number of Locations

The most plausible threats to Great Basin Spadefoot are from loss and alteration of breeding sites associated with droughts and reduced snow melt, exacerbated by increased human water use, and from road mortality. While droughts would be region-wide in spatial extent, site-specific conditions would probably determine the significance of impacts and the level of threat. It is not possible to calculate the number of locations for this threat, but it is most certainly greater than ten. For road mortality as a threat, the number of locations is also greater than ten.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Great Basin Spadefoot was listed as Threatened under the federal *Species at Risk Act* in Canada in 2003. A recovery strategy has been published, containing Critical Habitat identification (ECCC 2017). The Critical Habitat description includes a map of the geographical areas included, list of attributes needed by the species, and list of examples of activities likely to destroy attributes within Critical Habitat boundaries. The *Species at Risk Act* requires protection of important habitats, including designated Critical Habitat and residences for threatened and endangered species on federal lands, and provides provisions for their protection on other lands through the safety net clause. The British Columbia *Wildlife Act* prohibits collection, possession, and trade of all native vertebrates, including amphibians; however, this law has limited effectiveness in protecting Great Basin Spadefoot because of challenges in enforcement and because it does not cover habitat damage. A provincial *Species at Risk Act* is under preparation in British Columbia. The new provincial *Water Sustainability Act*, which was brought into force in 2016, regulates management, diversion, and use of water resources and provides protection for water bodies, including temporary wetlands (BC Government 2019).

Non-Legal Status and Ranks

NatureServe (2018) ranks Great Basin Spadefoot as globally secure (G5; last reviewed in 2016) and nationally secure (N5; last reviewed in 1996) in the United States and vulnerable (N3; last reviewed in 2017) in Canada. In the United States, the sub-national status is as follows: Arizona (S3-vulnerable), California (SNR-not ranked), Colorado (S3), Idaho (S4-apparently secure), Nevada (S4), Oregon (S5-secure), Utah (S5), Washington (S5), Wyoming (S3). The subnational status in British Columbia is S3. The species is on the British Columbia Conservation Data Centre Blue List. The General Status rank of the species in Canada follows that of BC Conservation Data Centre (N3, S3). COSEWIC assessed the species as Threatened in 2001 and the status was reconfirmed in 2007 and 2019.

A provincial recovery plan (Southern Interior Reptile and Amphibian Working Group 2017) and federal recovery strategy addition to this plan, along with associated identified Critical Habitat (ECCC 2017), has been approved, which, if fully implemented, will help protect Great Basin Spadefoot and its habitats. The goal of the recovery plan is to maintain or increase abundance of Great Basin Spadefoot in each geographic area where it occurs and to ensure connectivity within these areas. Efforts have been made to achieve primary recovery objectives that aim to secure core habitats, to maintain or increase connectivity through wetland restoration, and to address knowledge gaps on distribution (see **Search Effort**). Primary knowledge gaps identified, but yet to be addressed, include clarification of distribution in less studied areas, characteristics of dispersal habitats, population density and dynamics across the landscape, and impacts of priority threats. The effectiveness of recovery actions also remains largely unknown.

Habitat Protection and Ownership

Most of the habitat suitable for Great Basin Spadefoot remains unprotected, although recent efforts have expanded conservation lands within the species' distribution, including the establishment of Wildlife Habitat Areas (WHAs) that target this species. General Management Measures, intended to protect the species, apply within WHAs (Sarell 2004). WHAs do not directly protect land but are a management tool intended to reduce impacts from select industrial activities; cattle grazing is permitted in at least some of these areas. At a broad scale, the ecosections (Demarchi 2011) with greatest protection within the species' distribution are in South Okanagan (8–12% of the land base under some type of protection); the level of protection within the remainder of the species' Canadian range is lower (4–8% protected; see Appendix 5 for an overview of the locations of parks and other conservation lands with respect to the species' range). Several large First Nations' reserves overlap Great Basin Spadefoot habitats across the species' Canadian distribution, including productive valley bottom habitats. Surveys for the species have been conducted on a number of these lands, but the data were not available for this report.

In the south Cariboo region, all recent records and the majority of ponds that provide potential habitat for Great Basin Spadefoot are on provincial crown lands that are under grazing licences. In 2010, 14 Wildlife Habitat Areas totalling 942 ha were approved and designated to conserve Critical Habitat of the species in the 100 Mile House district (BC Ministry of Environment 2018).

In the Thompson-Nicola region, the Lac du Bois Grasslands Protected Area (15,712 ha) near Kamloops is occupied by Great Basin Spadefoot; this protected area was expanded in 2008 when the Nature Conservancy of Canada (2018) purchased 948 ha of land adjacent to the park. Wetland construction and restoration in the Kamloops area was carried out in 2007–2010 at four ponds, and at least one of the ponds has been successfully colonized by Great Basin Spadefoot (BC Wildlife Federation 2018). In 2008, three Wildlife Habitat Areas totalling 84.3 ha were approved and designated to conserve Critical Habitat for the species in this region (BC Ministry of Environment 2018).

In the Okanagan, including valley bottom and upland areas, conservation lands constitute approximately 10.4%, dedicated open spaces 1.8%, resource lands 69.6%, agriculture and crown leases 6.3%, privately owned lands 8.5%, and Indian Reserves 3.1% of the landscape, listed in the order of conservation/management opportunities (values from Table 12 in Caslys Consulting 2013). Resource lands include crown lands, community watersheds, and municipal lands zoned for forestry or grazing, while conservation lands include parks and various protected lands (but exclude Wildlife Habitat Areas established since 2013). Privately owned lands dominate in the most productive valley bottom habitats where much of the biodiversity of the region is concentrated, while the resource lands are mostly in the surrounding uplands.

In the Okanagan, Haynes Lease Ecological Reserve (ER#100) provides 100 ha of secure habitat for part of the large subpopulation of Great Basin Spadefoot breeding and foraging in the marsh and shrub steppe habitats at the north end of Osoyoos Lake. The adjacent South Okanagan Wildlife Management Area (SOWMA) provides additional habitat for that population but at a lower level of protection. In 2017, three Wildlife Habitat Areas totalling 122.2 ha were added to the SOWMA complex. The Nature Conservancy of Canada and private conservation groups have added to the protected areas adjacent to SOWMA and actively enhance and manage lands for the protection of Great Basin Spadefoot.

Two provincial parks with suitable habitat for the species were established in 2001 in the Okanagan: White Lake Grasslands Protected Area (3,741 ha), which is contiguous with other protected areas around Vaseux Lake, and South Okanagan Grasslands Protected Area (9,364 ha). A Wildlife Habitat Area protecting 20.1 ha was established in 2011 in the White Lake complex. The Sage and Sparrow Conservation Area acquisitions by the Nature Conservancy of Canada in 2012, 2014, and 2015 protects an additional 1,390 hectares of land adjacent to South Okanagan Grassland Protected Area (Nature Conservancy Canada 2018). Since 2009, the Okanagan River Restoration Initiative and Okanagan Nation Alliance have been re-establishing meandering oxbows and constructed wetlands, enhancing habitat for Great Basin Spadefoot (Okanagan Nation Alliance 2018).

Stewardship activities with private landowners have increased across the Okanagan over the past decade. Stewardship collaborations by the South Okanagan Similkameen Conservation Program (50 organizations since 2000) and the Okanagan Similkameen Stewardship Society (2178 ha since 1992; formerly TLC ((The Land Conservancy of BC)) obtain voluntary stewardship agreements with private landowners to retain spadefoot habitat for the benefit of smaller subpopulations (Okanagan Similkameen Stewardship Society 2018). Between 2006 and 2017, 33 wetlands have been enhanced or constructed specifically for spadefoots, with successful metamorphosis occurring in 13 of 21 annually surveyed constructed ponds (Okanagan Similkameen Stewardship Society 2018; Ashpole *et al*. 2018b). However, many wetlands on private land remain unprotected and without stewardship commitment.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Kristiina Ovaska, MSc, PhD: Dr. Ovaska's academic experience includes graduate work (Acadia University; University of Victoria) and two post-doctoral studies on amphibian population biology and ecology (McGill University; University of British Columbia). Presently, she is ecologist with and partner of Biolinx Environmental Research Ltd. (Sidney, B.C.), scientific advisor to Habitat Acquisition Trust (Victoria), and research associate at Royal British Columbia Museum. She is co-chair of COSEWIC Amphibians & Reptiles Specialist Subcommittee and of IUCN Amphibian Specialist Group - Canada. She has studied behaviour and ecology of amphibians in western North America, Central America, and the West Indies for over 20 years. Dr. Ovaska is the report writer of the previous (2007) COSEWIC status report on Great Basin Spadefoot, and she co-authored the draft federal recovery strategy for this species, including Critical Habitat description. From 2011 to 2015, she led a 5-year community-based amphibian monitoring program in south-central British Columbia with Great Basin Spadefoot as a focal species. The study included pond surveys, frog call surveys along designated routes, habitat assessment, and working with landowners on threat mitigation and stewardship.

Sara Ashpole, PhD: Dr. Ashpole's academic experiences include graduate studies on amphibian and reptile multi-stressor landscape ecology (University of Waterloo, Ontario). Presently, she is assistant professor of Environmental Studies at the St. Lawrence University (New York state) and adjunct professor advising graduate students at the University of Waterloo. She is a member of the COSEWIC Amphibians & Reptiles Specialist Subcommittee (SSC), member of the Southern Interior Reptile and Amphibian Recovery Team and, together with Kristiina Ovaska, co-chair of IUCN Amphibian Specialist Group - Canada. Since 1999, Dr. Ashpole's research has been collaborative with non-government organizations, government, First Nation peoples, and private landowners examining cumulative impacts to amphibian, reptile, and turtle populations in the Great Lakes (Ontario) and the South Okanagan Valley (British Columbia). Projects with the Great Basin Spadefoot as a focal species include long-term amphibian population monitoring, wetland restoration and rehabilitation, road ecology, alien vertebrate species mitigation, agricultural eco-toxicology, and ongoing landowner stewardship, community outreach, and education.

COLLECTIONS EXAMINED

No collections were examined. Distribution records were obtained from the British Columbia Conservation Data Centre and from Canadian Wildlife Service, as compiled for the Critical Habitat delineation.

Appendix 1. Projected changes in temperature (temp), precipitation (ppt), and other factors associated with climate change in different regions of British Columbia by 2050. Coloured cells represent regions with large expected change. Reformatted from Table 5 in Price and Daust 2016 (BC's Climate Change Vulnerability report). Great Basin Spadefoot occurs in the Thompson – Okanagan and southern portion of the Cariboo region.

Region	Temp summer*	Temp winter*	Ppt summer*	Ppt winter*	Snow winter*	Snow spring*	Fire	Wind	Beetles
Coast	1.5	1.3	-16	6	-28	-52	up	up	up
Thompson - Okanagan	2.1	1.5	-9	7	-11	-55	up		
Kootenay	2	1.7	-6	8	-5	-48	up		
Cariboo	1.6	1.8	-7	7	-8	-54			
Omineca	1.5	1.9	1	9	2	-54			
Northeast	1.4	2.2	4	11	7	-57			up
Skeena	1.5	1.9	2	9	-6	-56		up	up
* Projected percentage change from baseline (1961 – 1990) to 2050s (2040 – 2069) for regions in BC. Projected changes continue to increase past 2050.									

Appendix 2. Threats calculator spreadsheet for Great Basin Spadefoot (*Spea intermontana*).

Species or Ecosystem Scientific Name	Great Basin Spadefoot (*Spea intermontana*)		
Element ID		**Elcode**	
Date (Ctrl + ";" for today's date):	4/24/2019		
Assessor(s):	Purnima Govindarajulu, Orville Dyer, Nick Cairns, Lindsay Anderson, Lea Randall, Jocelyn Campbell, Jared Maida, Jamie Leathem, Dave Fraser, Tom Herman, Kristiina Ovaska, Sarah Ashpole.		
References:	2019 COSEWIC draft status report; 2017 Recovery Strategy		

Overall Threat Impact Calculation:

Threat Impact		Level 1 Threat Impact Counts: high range	Level 1 Threat Impact Counts: low range
A	Very High	0	0
B	High	0	0
C	Medium	3	0
D	Low	5	8
	Calculated Overall Threat Impact:	High	Medium

Assigned Overall Threat Impact:	**C = Medium**
Impact Adjustment Reasons:	Reduced from calculated threat impact of High-Medium to Medium because there is high uncertainty about the three greatest threats, all of which were thought to be closer to the lower end of range of the assigned severity scores. The species continues to persist across its Canadian range, including the Okanagan, but population trends have not been monitored adequately to detect local declines.
Overall Threat Comments:	Generation time 5 years, 3 generations = 15 years. Threats are unevenly distributed across the species' Canadian range, and most declines are expected to occur in the southern portion in the Okanagan, where pressures from human activities are the greatest.

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development	D	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1.1	Housing & urban areas	D	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	CARIBOO: Majority (90+%) of spadefoot habitat is on Crown land and residential development is not an issue for this species. THOMPSON-NICOLA: There is much new development around Kamloops, especially around the perimeter of the city, which may have significant effect on spadefoots but on a small scale. OKANAGAN: Low probability of current wetlands getting filled in over the next 10 years, but there is more uncertainty about trends in upland and dispersal habitat. Scope includes both wetland and upland habitats and is thought to be closer to the 1% end of the "Small" range. Severity: In general, populations are expected to disappear if water bodies are destroyed or sink habitats are created, but spadefoots may persist within low density developments or continue migrating across these areas.
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	OKANAGAN: There is potential for recreational areas along the shoreline, golf courses etc., but the scope is <1%. We have considered the Oliver Mtn off-road vehicle site in section 6.1.
2	Agriculture & aquaculture	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	The two threats act in different areas and so are additive; however, because livestock ranching is the prevalent activity, its severity rating is used in the roll-up
2.1	Annual & perennial non-timber crops	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	CARIBOO: The majority of the species' range is on Crown land and not agricultural land. However, some conversion of land into turf fields has taken place recently and is possible in the future. THOMPSON-NICOLA: Not a big issue but some conversion of habitat to fields or pastures may occur. As of 2019, new vineyards planned in the Merritt area. OKANAGAN: Conversion of land into vineyards, orchards & other agricultural uses has led to the loss of breeding habitat in the past, but development has slowed since the early 2000s; intensification and redevelopment of existing agricultural sites continues. In addition to habitat loss and degradation, accidental mortality can increase in existing agricultural areas that spadefoots continue to use for travel routes or other purposes: Irrigation system control pits (10 to 12/10-acre farm) can act as deadly pitfall traps on irrigated lands (Ashpole pers. comm. 2012). Irrigation is a prime driver for agricultural development and degrades habitat (also see Dams and Water management in 7.2).

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.2	Wood & pulp plantations						Christmas tree farms were considered but no new farms are anticipated in the next 10 years. If there are new farms, the scope is likely negligible.
2.3	Livestock farming & ranching	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	CARIBOO: All of the Cariboo spadefoot range is subject to livestock grazing but General Wildlife Measures apply within the established WHAs that theoretically reduce the threats. On a positive note, some of the historical dugouts created years ago for water source for livestock are providing some of the more secure breeding habitats for spadefoots during droughts. THOMPSON/NICOLA: scope 71%+ (J. Surgenor pers. comm. 2011). OKANAGAN: Scope pervasive; cattle are even at higher elevations (71-100%) (O. Dyer pers. comm. 2011). Severity: Livestock can have both adverse and beneficial effects, but adverse effects are of overriding importance, especially in shallow water bodies. Severity of impacts depends on stocking density and duration of grazing season, and effects are expected to be more damaging in drought years. Livestock grazing can impact grassland species presence and composition and reduce the amount of bare ground available to spadefoots (ecosystem effects are included under 7.3). Research should be conducted to determine livestock stocking rates that are compatible with the maintenance of suitable spadefoot retreat habitats. In addition to habitat alteration, there are examples of accidental mortality of spadefoots due to trampling by cattle (telemetered adult in burrow stepped on & killed; trampling of eggs in water; egg masses separated; tadpoles stuck in foot prints), but much uncertainty exists about population effects.
2.4	Marine & freshwater aquaculture		Negligible	Negligible (<1%)	Extreme - Serious (31-100%)	High (Continuing)	A few cases of fish farming in ponds known in the Okanagan but the practice does not appear to be increasing. Probably not a big issue for this species that favours temporary wetlands, unless the ponds are made permanent. A few fish aquaculture sites exist in the Okanagan.
3	Energy production & mining		Negligible	Negligible (<1%)	Extreme - Serious (31-100%)	High (Continuing)	
3.1	Oil & gas drilling						
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Extreme - Serious (31-100%)	High (Continuing)	Proposed Ajax mine project was rejected by both federal and provincial governments in 2018, but this may be appealed. There is NewGold (copper/gold) mine in Kamloops area.
3.3	Renewable energy						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
4	Transportation & service corridors	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	
4.1	Roads & railroads	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	This threat includes the construction of new roads and mortality caused by traffic on existing, moderately busy roads. Across the species' BC range, 80% of the range is within 500 m of roads and almost all is within 3 km from roads (Hectares BC). CARIBOO: Wildlife underpasses have been placed on some sections of MOTI HWY 97 upgrades, but none are within known spadefoot distribution. OKANAGAN: Scope is pervasive (71-100%). Crosby (2014) found re: HWY 97 twinning near Oliver that this species represented 87.4% of the amphibians found on the roadways; 46.5% of the amphibians found on road were dead (most were adults; metamorphs constituted a small proportion); mortality continued to occur at a lower level after mitigation. Roadkill is highly variable across the species' range and can be significant at local sites, but population effects have been seldom, if ever, documented. Therefore, a wide range is included in the severity rating, for which there is much uncertainty. There is no evidence of declines or case studies of populations near busy roads, but the species seems to persist; immigration from adjacent areas is a possibility. Impact of metamorph roadkill to population declines is unstudied. The group thought that the upper limit for severity might be near the lower end of the range for "Moderate" (i.e., possibly just over 10%).
4.2	Utility & service lines		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.3	Logging & wood harvesting		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Scope is <1% and is mostly due to logging in the Cariboo region, where majority (90+%) of spadefoot habitat is on Crown forestry land. Salvage harvesting associated Mountain Pine beetle, in particular, was extensive up to 2014 and may continue but is possibly mostly done. In the Cariboo, spadefoots are found at forest edges but don't spend much time in forest, reducing scope for this threat. THOMPSON-NICOLA and OKANAGAN: Salvage harvesting occurs in higher elevations, but scope is negligible. Severity: Impacts are mostly from disturbing wetland breeding habitats and spadefoots there during logging activities. In the Cariboo, existing wildlife measures allow forest harvesting to occur during any season of the year, but within WHAs it should be restricted to winter harvest to prevent spadefoot mortality from surface harvesting activities (R. Packham pers. comm. 2014). Over the long term, some effects of tree removal may be positive, as they reduce encroachment of forest into grasslands (see Natural System Modifications).
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	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 - Slight (1-30%)	High (Continuing)	Includes mudbogging and other intensive uses of off-road vehicles for recreation, which occurs sporadically and locally across the entire range; it is more likely to occur near human population concentrations. Scope is Small (towards lower end of range). There is much uncertainty about here and how often this occurs; examples exist from the Okanagan (mudbogging at known breeding sites) and Kamloops (now restored breeding habitat) areas. Severity: Impacts are from direct mortality and habitat degradation at breeding sites; effects on burrowed spadefoots in terrestrial habitat are unknown (1 case of radio-tracked burrowed spadefoot apparently killed). Habitat degradation includes compressing the loose sandy soils that spadefoots need for burrowing and altering shallow breeding sites to create sink habitats (effects similar to cattle trampling). This potential impact is likely very localized but may be a severe threat at impacted sites. A wide severity range was used because the type of impact depends on the number of vehicles and frequency and timing of disturbance at particular sites, resulting in much uncertainty in the average impact across the species' range.
6.2	War, civil unrest & military exercises		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	The species occurs in the Vernon military area; known breeding sites are currently in a no-go zone.
6.3	Work & other activities						
7	Natural system modifications	D	Low	Small (1-10%)	Serious - Moderate (11-70%)	High (Continuing)	
7.1	Fire & fire suppression		Unknown	Unknown	Unknown	High (Continuing)	Spadefoots might survive fires burrowed underground, unless the fire is very hot. Over the long term, fire suppression may result in encroachment of forest into grassland and open woodland habitats, but conifer encroachment is not an issue at the moment.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.2	Dams & water management/use	D	Low	Small (1-10%)	Serious - Moderate (11-70%)	High (Continuing)	This threat category deals only with human use or diversion of water, not climate change effects, although the two interact and one exacerbates the other. CARIBOO: Drying of ponds has taken place in recent years, but the drought is believed to be from climate effects rather than from irrigation or domestic use (see Climate change 11.2). OKANAGAN: Mostly related to people drawing water with scope Small and close to 1%. Water withdrawal usually occurs after breeding by spadefoots has been completed. Unauthorized dam removal is ongoing and could result in breeding site destruction. Severity: Impacts are from water withdrawal for irrigation, which is a prime driver in agricultural areas, or for other purposes, as well as from alteration of natural water regimes. These range from draining ponds to altering natural patterns of wetland persistence, hydroperiods, and water levels. Sink habitats may be created by making ponds permanent or creating them in unsuitable landscape contexts. Converting habitat into turf and accidental mortality associated with irrigation structures are dealt with under Agriculture (2.1). Severity range is used because the average impact across the scope is uncertain given the different type of threats included in this category.
7.3	Other ecosystem modifications		Unknown	Unknown	Unknown	High (Continuing)	Free-range livestock poses a threat through ecosystem changes associated with intensive grazing, which alters the composition of the plant community and grass species and facilitates the spread of invasive plants. Invasive plants degrade habitat for spadefoots through ecosystem effects, such as the replacement of native vegetation with introduced species with different life forms and various effects on substrates and soils. Conifer encroachment on grasslands is not considered a problem over the next 10 years but may become one over the long term.
8	Invasive & other problematic species & genes	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.1	Invasive non-native/alien species	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Non-native fish and disease organisms, particularly Bd, pose widespread potential threats, and bullfrogs are a potential threat in the Okanagan. Diseases: No disease outbreaks are known to affect the BC spadefoots, but epidemic disease must now be considered a serious threat to all amphibian populations; hence the scope is pervasive (following practice for other species assessments). The fungus is widespread in amphibians across BC and also occurs in South Okanagan (Govindarajulu *et al*. 2013; Richardson *et al*. 2014). In 2008, 14.3% of 35 Spadefoot tadpoles tested in B.C. tested positive for Bd (Richardson *et al.* 2014), but whether this leads to mortality is unknown (P. Govindarajulu, pers. comm. 2014). *Ranavirus* has been found in other spadefoot species (*Spea bombifrons* in Kansas). Sport fish or other fish for mosquito control or other purposes continue to be introduced to spadefoot habitats or to larger water bodies from where they can spread. Spadefoots are somewhat protected from fish because of their extensive use of shallow temporary water bodies; scope would be less based on fish only. OKANAGAN: Spread of non-native fish has been extensive in the South Okanagan (M. Herborg 2012). Small breeding wetland are usually fishless, but most ponds that can support fish will eventually get fish. BC Ministry is no longer planning to stock some ponds that may become habitable in the future, but most are high-elevation sites and may not help spadefoots. Fish introduction is also conducted for mosquito control purposes (bulletin put out by the Health Ministry suggested introducing fish into ponds for mosquito control in response to West Nile virus). Bullfrog threat has reduced dramatically due to eradication efforts. Severity: Much uncertainty; scored slight based mainly on threat from fish, which suggests that severity is >1% (known effects, e.g., local disappearances after Goldfish introduction). Severity of potential threat from disease (no outbreaks recorded yet) is hard to predict; spadefoots may be protected to some degree by spending much time in the terrestrial habitats and extensively using temporary habitats; disease transmission may be more of an issue if forced to use permanent waters, e.g., by droughts, but there is no evidence.
8.2	Problematic native species						Trout stocking of ponds with species native to BC (but not necessarily to the areas in question) are discussed under non-native species under 8.1.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.3	Introduced genetic material						
9	Pollution	CD	Medium - Low	Large - Restricted (11-70%)	Moderate - Slight (1-30%)	High (Continuing)	
9.1	Household sewage & urban waste water		Negligible	Negligible (<1%)	Unknown	High (Continuing)	A large historical breeding population was in sewage lagoon (Osoyoos), but this population seems to be in decline (note: original estimates of this population size were an approximation). Impacts are unknown. Road surfactants: Additional consideration is application of magnesium chloride to desiccate gravel road surfaces for dust abatement during road maintenance, which can lead to mortality of migrating spadefoots throughout the species' range.
9.2	Industrial & military effluents		Negligible	Negligible (<1%)	Unknown	High (Continuing)	Ajax mine proposal application was rejected at both federal and provincial levels, but this decision may be appealed in the future).

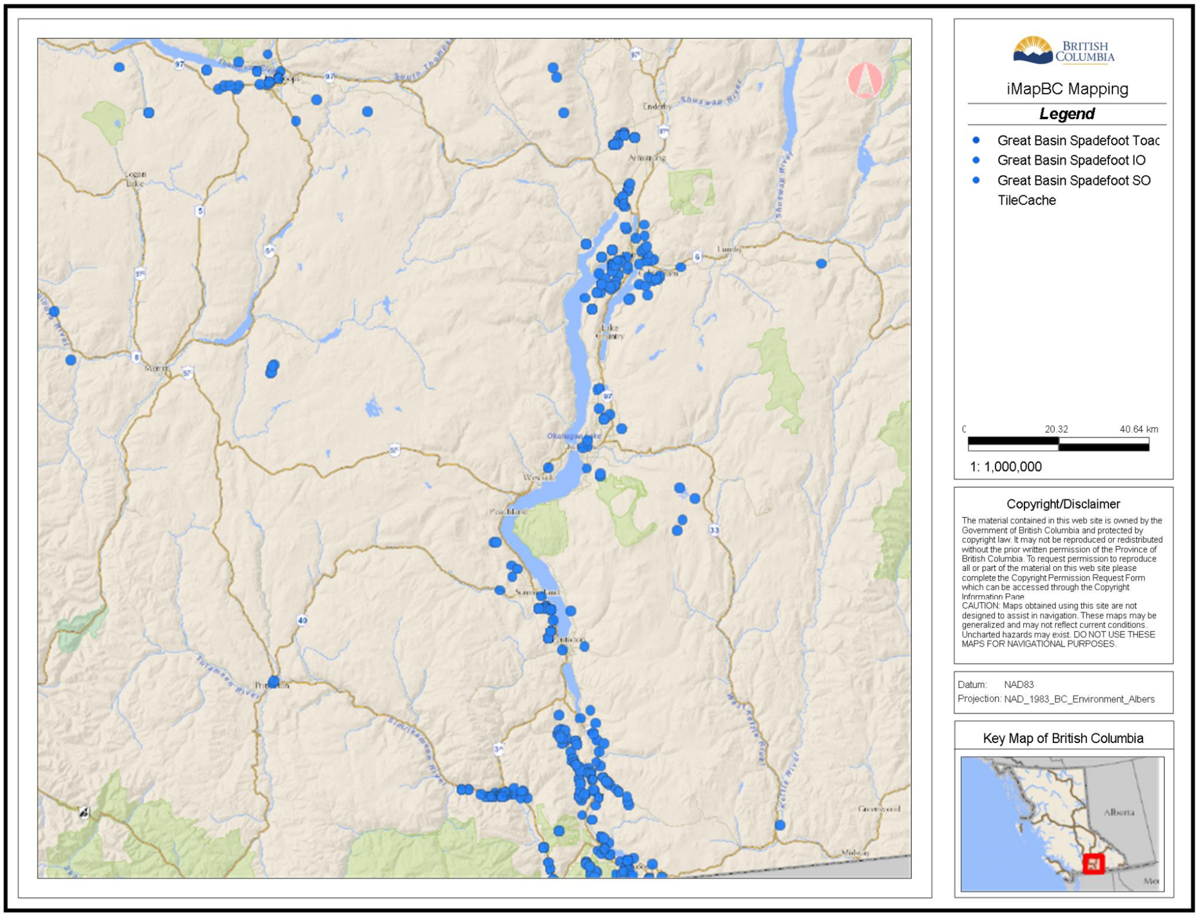
Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.3	Agricultural & forestry effluents	CD	Medium - Low	Large - Restricted (11-70%)	Moderate - Slight (1-30%)	High (Continuing)	This threat Includes herbicides, pesticides, and fertilizers, as well as spraying for mosquito control and applies mostly to the Okanagan. Herbicides are also used in forestry, but most likely not in spadefoot habitats. Agricultural: Bishop *et al.* (2010) detected low concentrations of 17 chemicals in amphibian breeding sites at orchards in the South Okanagan; both organic and treated orchards had contaminants. Spadefoot hatching success was variable: 0-92% in sprayed orchards; 48-98.6% in organic orchards; 51-95.5% at reference sites. Atrazine alone and atrazine, total nitrate, and chlorpyrifos accounted for ~80% of the variation in hatching success. Field evidence for declines in agricultural areas is lacking, but data are crude, and source-sink population dynamics confuse the picture. Nonlethal impacts of a variety of pollutants on amphibians are well documented. Tadpoles are affected, but there is uncertainty about population effects; where adults are exposed to pesticides in fields, there could be cumulative effects. Mosquito control: Widespread insecticide applications (i.e., Vectobac, Malathion) as part of mosquito control programs to control spread of the West Nile virus is a developing issue. Scope reflects the area of lands under agriculture (existing and projected). Severity: The group discussed severity at length; a range was used to reflect uncertainty; the upper value would be at lower end of moderate (just over 10%), but there are no data. After the conference call (May 2019), Christine Bishop was asked expert opinion on the scoring; she generally agreed with assessment but suggested that the severity might be closer to the moderate end of 1-30% decline range, when contaminants are considered cumulatively.
9.4	Garbage & solid waste						
9.5	Air-borne pollutants		Unknown	Unknown	Unknown	High (Continuing)	Airborne pollution is increasing in BC and might even be getting into the higher elevation lakes (confirmed by the MOE pesticide people)
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11	Climate change & severe weather	CD	Medium - Low	Large - Restricted (11-70%)	Moderate - Slight (1-30%)	High (Continuing)	The greatest impacts are from droughts, discussed under 11.2, and the effects are already happening. Price and Daust (2016) evaluated sensitivity of Great Basin Spadefoot to climate change as High, non-climate stressors as Moderate - High, and adaptive capacity as Moderate - Poor. All these factors suggest high vulnerability to climate change. USDA (Friggens *et al.* 2018) concluded that the species might be resilient because it uses a variety of vegetation communities but pointed out that loss of wetland breeding sites due to changes in precipitation and evaporation rates is of concern.
11.1	Habitat shifting & alteration		Not Calculated (outside assessment timeframe)	Unknown	Unknown	Low (Possibly in the long term, >10 yrs)	
11.2	Droughts	CD	Medium - Low	Large - Restricted (11-70%)	Moderate - Slight (1-30%)	High (Continuing)	The water table has dropped substantially within the species' Canadian range over the past few decades (Cohen 2004; Coelho 2015), and a decreasing trend in Great Basin Spadefoot breeding ponds has been noted in several areas of the Okanagan (Dyer pers. comm. 2014) and Cariboo regions (Packham pers. comm. 2014). A decrease in the water table is likely to either eliminate temporary shallow water bodies or shorten their hydro-period and accentuate effects of periodic droughts. Changes are already happening but will become a greater issue over the long term (>10 years). The reductions in water supply are predicted to be modest during the 2020s, but would become more severe during the 2050s and 2080s (Cohen 2004). Over the past decade, a significant number of small wetlands across the species' range in BC have gone dry or almost dry. A decreasing trend in the number of Great Basin Spadefoot breeding ponds was noted in several areas of the Okanagan during a period of long drought that ended circa 2013 (Dyer pers. comm. 2019); however, this trend may have been reversed in the subsequent wetter years. Scope: Although all areas of the range are affected, not all habitats are affected equally (permanent water bodies are least affected), hence scope has uncertainty and less than pervasive); Severity - Might be extreme in shallow water bodies in cases where drought continues for several years, but many areas have multiple wetlands with different depths within migration distance of spadefoots. A wide range is used for severity to capture this uncertainty.

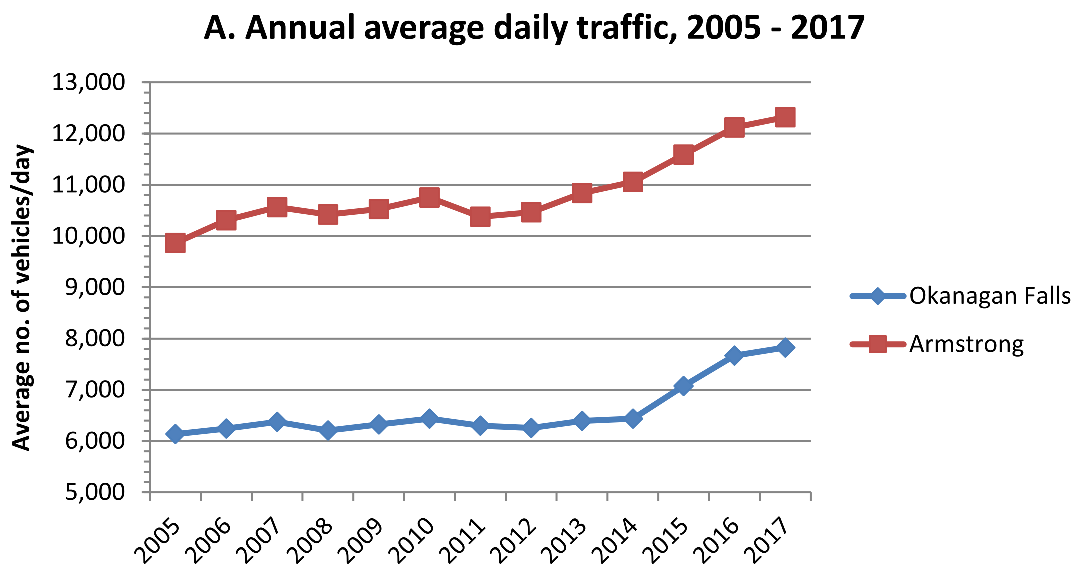
Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.3	Temperature extremes		Unknown	Unknown	Unknown	Moderate (Possibly in the short term, < 10 yrs)	Spadefoots are fairly tolerant and occur much farther south, where temperatures are routinely much higher than in BC. A study with Northern Red-legged Frog (*Rana aurora*), Great Basin Spadefoot, and Pacific Treefrog as model organisms indicates that all these species have thermal safety margins in BC of 3.2–3.8 °C, based on current maximum summer temperatures, but that the margins will rapidly erode at a rate of 0.5 °C per decade with climate change, leading to a high proportion of each species' range experiencing temperatures above optimal by the 2080s (Gerick *et al*. 2014). Spadefoots in some lower elevation habitats in the southern portion of their range might already have little or no thermal safety margins (Fig 2 in Gerick *et al*. 2014). Actual mechanisms of impacts are complex and include interactions among temperature, rate of pond drying, and survival - some effects of increased temperature are positive (O'Regan *et al*. 2014). Susceptibility to some diseases may be increase at higher temperatures, but there is much uncertainty (these interactions should be under Introduced and Other Problematic Species).
11.4	Storms & flooding						Extreme flooding events are predicted to increase. Impacts on the species may be beneficial through pond creation. However, flood control measures may have negative impacts. Also, flooding events may facilitate spread of introduced fish.

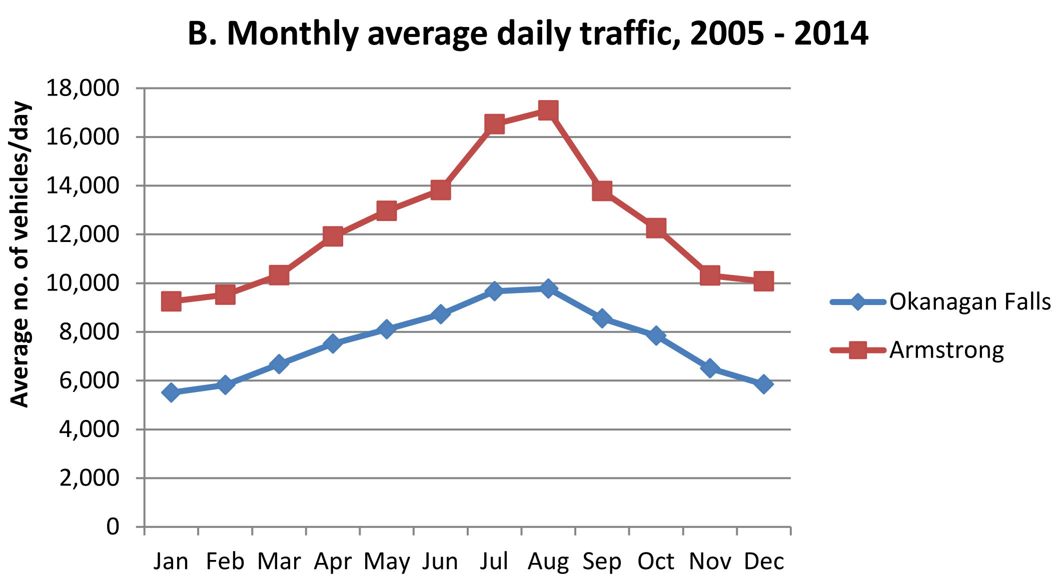
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).

Appendix 3. Map showing major roads within Great Basin Spadefoot's Canadian range. The roads tend to follow valley bottoms where most productive habitats are located. Map produced using data layers in BC CDC iMap (2018; note: distribution records for the species are as depicted in iMAP, hence differences from more complete dataset used in figures in this report).



Appendix 4. Trends in annual traffic volumes at two traffic monitoring points in the Okanagan Valley. Graphs produced from statistics from BC Ministry of Transportation and Infrastructure – Traffic Data Program (MOTI 2018). Armstrong P-24-1NS – NY: Route 97A, 4.0 km north of the north access to Armstrong; Okanagan Falls P-26-2NS - NY: Route 97, 7.7 km east of Kaleden Junction, south of Okanagan Falls.





Appendix 5. Parks and other conservation lands within the Canadian distribution of Great Basin Spadefoot and its vicinity. Map produced using data layers in BC CDC iMap (2018 note: distribution records for the species are as depicted in iMAP, hence differences from more complete dataset in figures in this report).