COSEWIC
Assessment and Status Report

on the

Western Tiger Salamander
Ambystoma mavortium

Southern Mountain population
Prairie / Boreal population

in Canada

Southern Mountain population – ENDANGERED
Prairie / Boreal population – SPECIAL CONCERN
2012

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. 2001. COSEWIC assessment and status report on the tiger salamander *Ambystoma tigrinum* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 33 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Schock, D.M. 2001. COSEWIC assessment and status report on the tiger salamander *Ambystoma tigrinum* in Canada, *in* COSEWIC assessment and status report on the tiger salamander *Ambystoma tigrinum* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-33 pp.

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COSEWIC would like to acknowledge Arthur Whiting for writing the status report on the Western Tiger Salamander, *Ambystoma mavortium*, in Canada, prepared under contract with Environment Canada. This report was overseen and edited by Kristiina Ovaska, Co-chair of the COSEWIC Amphibians and Reptiles Specialist Subcommittee.

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Western Tiger Salamander — Photo by A. Whiting.

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COSEWIC
Assessment Summary

Assessment Summary – November 2012

Common name
Western Tiger Salamander - Southern Mountain population

Scientific name
Ambystoma mavortium

Status
Endangered

Reason for designation
This large salamander has a range restricted to southern British Columbia which mostly overlaps with populated and modified agricultural areas in the South Okanagan Valley. The species has suffered loss of available breeding habitat through wetland draining, contamination, and stocking with fish. Salamander habitats are fragmented by roads and urban and agricultural developments that continue to expand, resulting in disruption of migration routes, mortality through roadkill, and loss of upland habitat for terrestrial adults. Increased drought and lowering water tables, as well as introduced Bullfrogs, also threaten this species.

Occurrence
British Columbia

Status history
The Tiger Salamander (*Ambystoma tigrinum*) was originally assessed by COSEWIC in November 2001 as three separate populations: Great Lakes population (Extirpated), Prairie / Boreal population (Not at Risk), and Southern Mountain population (Endangered). In November 2012, Tiger Salamander was split into two separate species, Eastern Tiger Salamander (*Ambystoma tigrinum*) and Western Tiger Salamander (*Ambystoma mavortium*), each with two different populations that received separate designations. The Southern Mountain population of the Western Tiger Salamander was assessed as Endangered.

Assessment Summary – November 2012

Common name
Western Tiger Salamander - Prairie / Boreal population

Scientific name
Ambystoma mavortium

Status
Special Concern

Reason for designation
This large salamander remains widely distributed in the Prairie provinces, but it faces numerous threats from habitat loss and fragmentation, fish stocking, and emerging diseases, such as the *Ambystoma tigrinum* virus that can decimate local populations. Salamander habitats are becoming increasingly fragmented by agricultural and oil and gas developments and associated infrastructures and roads. The disruption of migration routes, mortality through roadkill, and deterioration and loss of breeding and upland habitat for terrestrial adults and juveniles lead to concern for the species in a large part of its Canadian range.

Occurrence
Alberta, Saskatchewan, Manitoba

Status history
The Tiger Salamander (*Ambystoma tigrinum*) was originally assessed by COSEWIC in November 2001 as three separate populations: Great Lakes population (Extirpated), Prairie / Boreal population (Not at Risk), and Southern Mountain population (Endangered). In November 2012, Tiger Salamander was split into two separate species, Eastern Tiger Salamander (*Ambystoma tigrinum*) and Western Tiger Salamander (*Ambystoma mavortium*), each with two different populations that received separate designations. The Prairie / Boreal population of the Western Tiger Salamander was assessed as Special Concern.

COSEWIC
Executive Summary

Western Tiger Salamander
Ambystoma mavortium

Southern Mountain population
Prairie / Boreal population

Wildlife Species Description and Significance

Western Tiger Salamanders are among the largest salamanders in North America and are top predators in the largely fishless ponds and lakes where they occur. Terrestrial adults have a blotched, barred or reticulate pattern of yellow or off-white on a dark background. Genetic and morphological evidence indicates that the Western Tiger Salamander, consisting of several subspecies, is a separate species from the Eastern Tiger Salamander, *Ambystoma tigrinum*, with which it was previously combined as a single species. Much of the older literature does not necessarily distinguish the Western Tiger Salamander from the Eastern Tiger Salamander, as currently recognized.

Distribution

Western Tiger Salamanders have a wide distribution in arid interior regions of western North America. They occur along the border of the Prairie ecozone in Alberta, east to the Red River in Manitoba, south into western Minnesota and down to Texas, west along the border of Mexico and then north through Arizona and along the eastern slopes of the Rocky Mountains north to Alberta. There is a disjunct distribution in northern Oregon, Idaho and through Washington into the southern Okanagan region of British Columbia. Tiger salamanders in British Columbia are disjunct from populations in the remainder of Canada and occur in the Southern Mountain ecozone, whereas the remainder of the Canadian distribution occurs in the Prairie ecozone in Alberta, Saskatchewan and Manitoba. This distribution is likely the result of post-glacial expansion into Canada from at least two points on either side of the Rocky Mountains.

Habitat

Western Tiger Salamanders occupy a variety of open habitats, including grasslands, parkland, subalpine meadows, and semi-deserts. Key habitat features include sandy or friable (crumbly) soils surrounding semi-permanent to permanent water bodies lacking predatory fish. Terrestrial Western Tiger Salamanders burrow actively into soil or utilize small mammal burrows for refuges and over-wintering. Breeding habitats must hold water for the 3 to 7 months required to complete larval development. Populations of completely aquatic neotenic adults (animals that retain larval form after sexual maturity) are occasionally found in cool, fishless lakes.

Biology

Western Tiger Salamanders migrate to breeding sites in wetlands or lakes following spring rains soon after ice-off. Females lay eggs singly or in small clusters attached to twigs or stems of emergent plants below the water's surface. Juveniles migrate *en mass* from breeding sites into terrestrial habitats in late summer. Males may reach sexual maturity in their second year, while females mature a year or two later. Generation time is approximately 5 – 6 years.

Both larvae and adults are carnivorous and feed on a wide range of small prey. Western Tiger Salamanders do not fare well where predaceous fish have been introduced, or are naturally occurring, as all life stages are preyed upon.

Population Sizes and Trends

Population sizes and trends are poorly known, and numbers of adults may vary considerably among sites and years. There is an inferred decline in the number and size of populations in the Southern Mountain region in British Columbia, where continued habitat loss, habitat alteration, and introduced species threaten the persistence of populations.

Outside of British Columbia, little is known about the occurrences of Western Tiger Salamanders. Anecdotal reports suggest that the species persists over relatively wide areas of the prairie provinces. Mass mortalities, primarily due to disease and road kill, are reported sporadically in localized areas.

Threats and Limiting Factors

Tiger salamanders face the same pressures and threats as other amphibian species with separate requirements for terrestrial adults and aquatic larvae. Over much of the species' Canadian range, there are immense pressures from loss, degradation and fragmentation of habitat. In the Prairies, a change has occurred in land use from grazing and low-scale agriculture to large-scale farming and conversion of habitat to accommodate growing urban populations and expansion of oil and gas developments. Within the core area of the species' distribution in British Columbia, in the Okanagan Valley, there has been rapid habitat loss due to housing and vineyard developments with associated pollutant run-off. The introduced American Bullfrog poses an additional threat in this region. Increasing human populations and road densities have greatly increased the potential for road mortality during seasonal migrations between breeding sites and terrestrial overwintering and foraging habitats. Fish stocking for recreational fishing, aquaculture, and mosquito-control can have severe impacts on tiger salamander populations and continue to occur throughout the species' Canadian range. The emergence of infectious diseases, specifically the widespread *Ambystoma tigrinum* virus, can decimate local populations.

Protection, Status, and Ranks

The Southern Mountain population of the Western Tiger Salamander in British Columbia is listed federally as Endangered and is on Schedule 1 under the *Species at Risk Act*. Approximately 16% of breeding sites of this population are within protected areas, and an additional 27% receive some protection through voluntary stewardship efforts; the majority of the sites, however, are on unprotected private lands.

Tiger salamanders in Alberta, Saskatchewan and Manitoba, as the Prairie / Boreal population, were previously assessed by COSEWIC as Not at Risk, but this assessment included Eastern Tiger Salamanders in Manitoba. There is no specific protection for tiger salamander habitat, but there are records of tiger salamanders from various parks and protected areas.

TECHNICAL SUMMARY - Southern Mountain population

Ambystoma mavortium
Western Tiger Salamander — Salamandre tigrée de l'Ouest
Southern Mountain population — Population des montagnes du Sud
Range of occurrence in Canada: British Columbia

Demographic Information

Generation time Calculated based on estimated survival rates of adults in US populations (see **Biology**).	Approximately 5 - 6 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? Inferred decline based on habitat trends, including spread of previously stocked fish through watersheds, illegal stocking, continued stocking programs, and other habitat loss from residential and agricultural development	Yes
Estimated percent of continuing decline in total number of mature individuals	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
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	Unknown
Are there extreme fluctuations in number of mature individuals? Inferred from life history and information on large multi-annual fluctuations in abundance in other parts of the species' range for subspecies *A. m. nebulosum* and for *A. tigrinum* in USA. Females may forgo breeding for several years if conditions are unsuitable, resulting in multi-year pulses in breeding activity, followed by similar pulses in recruitment of young into the adult population. This pattern results in extreme fluctuations in adult population size over longer time spans (see **Population Sizes and Trends**). Given that there can be a complete failure of reproduction in drought years and that multi-year droughts associated with pond-drying appear to be and are predicted to become more frequent in the arid environments inhabited by the salamanders, fluctuations in salamander population size are expected occur simultaneously over large areas.	Yes

Extent and Occupancy Information

Estimated extent of occurrence Calculated using the minimum polygon method, which includes mountainous areas in the northwest that provide unsuitable habitat. BC Conservation Data Centre gives the EO as 2208 km^2, using the alpha convex polygon method. Both estimates are an increase from <1500 km^2 since the previous assessment due to greater search effort.	5054 km^2
Index of area of occupancy (IAO) Lower value is based on a 2×2 km grid cells placed over known breeding occurrences (58 cells). Higher value includes grid cells placed on all occurrences, including those unlikely to represent breeding sites (116 cells). AO in the previous status report was given as 150 km^2, but IAO was not calculated (see **Distribution**).	232 - 464 km^2
Is the total population severely fragmented? All known breeding sites are within 1 km of a roadway and within habitat that continues to be modified and fragmented (see **Threats and Limiting Factors**). Average nearest distance between populations/breeding sites is 5.2 km. Limited information suggests breeding populations are small and fluctuate among years, in response to weather patterns. Populations at most known breeding sites probably have low viability based on severity of threats.	Yes
Number of locations American Bullfrogs may limit the number of locations in the Okanagan Valley to **one;** fish introduction and habitat loss and fragmentation are the greatest threats to remaining sites in Kettle River Valley and Grand Forks and would affect each site individually, resulting in approximately 13 additional locations.	Approximately 14
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Probably not
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy? Inferred and projected decline due to fish introductions and spread and to habitat loss	Unknown but possible
Is there an [observed, inferred or projected] continuing decline in number of populations? Projected decline based on habitat trends	Unknown but likely
Is there an [observed, inferred, or projected] continuing decline in number of locations? Introduced fish could reduce the number of locations	Unknown
Is there a continuing decline in the quality of habitat? Observed and projected: Encroachment of roadways and human settlements and intensification of agriculture within EO	Yes
Are there extreme fluctuations in number of populations?	Probably not
Are there extreme fluctuations in number of locations?	Probably not
Are there extreme fluctuations in extent of occurrence?	Probably not
Are there extreme fluctuations in index of area of occupancy?	Probably not

Number of Mature Individuals (in each population)

Population	N Mature Individuals
No accurate estimates are available	BC CDC estimates 2500 - 10,000 adults
Total	2500 – 10,000 adults

Quantitative Analysis

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

Threats (actual or imminent, to populations or habitats)

Habitat loss and fragmentation from agricultural and residential development; roadkill; introduced fish; spread of introduced Bullfrogs; agricultural contaminants, emerging infectious diseases

Rescue Effect (immigration from outside Canada)

Status of outside population:

Ambystoma mavortium: S3, state monitor in Washington, and S5 in Idaho (no known population within immigration distance)

Is immigration known or possible?	Possible but unlikely
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	No
Is rescue from outside populations likely?	No

Status History

COSEWIC: The Tiger Salamander (*Ambystoma tigrinum*) was originally assessed by COSEWIC in November 2001 as three separate populations: Great Lakes population (Extirpated), Prairie / Boreal population (Not at Risk), and Southern Mountain population (Endangered). In November 2012, Tiger Salamander was split into two separate species, Eastern Tiger Salamander (*Ambystoma tigrinum*) and Western Tiger Salamander (*Ambystoma mavortium*), each with two different populations that received separate designations. The Southern Mountain population of the Western Tiger Salamander was assessed as Endangered.

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Endangered	B1ab(ii,iii,v)c(iv)+2ab(ii,iii,v)c(iv)

Reasons for designation:

This large salamander has a range restricted to southern British Columbia, which mostly overlaps with populated and modified agricultural areas in the South Okanagan Valley. The species has suffered loss of available breeding habitat through wetland draining, contamination, and stocking with fish. Salamander habitats are fragmented by roads and urban and agricultural developments that continue to expand, resulting in disruption of migration routes, mortality through roadkill, and loss of upland habitat for terrestrial adults. Increased drought and lowering water tables, as well as introduced Bullfrogs, also threaten this species.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable; inferred decline in population size, but its magnitude is unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): B1 and B2 apply as EO and IAO are below (or in the case of EO near) thresholds for endangered; the population is severely fragmented (subcriterion a), and there is an observed decline in habitat quantity and quality (biii) and an inferred decline in area of occupancy and population size (bii, v); c(iv) applies as the population is likely to undergo extreme fluctuations.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable; there is a decline but its magnitude and population size are unknown.
Criterion D (Very Small or Restricted Total Population): Not applicable; population size is unknown; the number of locations and IAO exceed guidelines for Threatened under D2.
Criterion E (Quantitative Analysis): Not applicable; not enough data are available for analysis.

TECHNICAL SUMMARY - Prairie / Boreal population

Ambystoma mavortium
Western Tiger Salamander — Salamandre tigrée de l'Ouest
Prairie / Boreal population — Population boréale et des Prairies
Range of occurrence in Canada: Alberta, Saskatchewan, Manitoba

Demographic Information

Generation time Calculated based on estimated survival rates of adults in US populations (see **Biology**).	Approximately 5 - 6 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? Inferred decline due to continued stocking of fish, loss of habitat, and emerging infectious diseases	Likely: Alberta Possible: Saskatchewan Unknown: Manitoba
Estimated percent of continuing decline in total number of mature individuals	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
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	Unknown
Are there extreme fluctuations in number of mature individuals? Inferred from life history and information on large multi-annual fluctuations in abundance in other parts of the species' range for subspecies *A. m. nebulosum* and for *A. tigrinum* in USA. Females may forgo breeding for several years if conditions are unsuitable, resulting in multi-year pulses in breeding activity, followed by similar pulses in recruitment of young into the adult population. This pattern results in extreme fluctuations in adult population size over longer time-spans. (see **Population Sizes and Trends**). Fluctuations may be driven by climate and multi-year periods of droughts. However, because the range of this population is large, the fluctuations may not be synchronous.	Possibly

Extent and Occupancy Information

Estimated extent of occurrence Last assessment reported a value of 500,000 km^2	567,436 km^2
Index of area of occupancy (IAO) Based on a 2×2 km grid placed over known occurrences; underestimates true IAO, as additional undocumented occurrences are likely. Without adequate distribution data, it is unclear if populations exist between known occurrences. Last assessment reported a value of 50,000 km^2 for AO, but IAO was not calculated (see **Distribution**).	2,388 km^2, probably larger
Is the total population severely fragmented?	Unknown

Number of locations Based on threat of introduced fish or habitat destruction affecting one site at a time.	> 500
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Unlikely
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy? Lack of recent information from SK and MB	Unknown
Is there an [observed, inferred or projected] continuing decline in number of populations? Inferred decline possible based on widespread stocking of trout throughout the Prairies and loss of wetlands due to increasing urbanization and intensive agriculture.	Possibly in southern Alberta and Saskatchewan, but otherwise unknown
Is there an [observed, inferred, or projected] continuing decline in number of locations? Inferred decline is possible based on widespread stocking of trout throughout the Prairies and loss of wetlands due to increasing urbanization and intensive agriculture.	Unknown
Is there an [observed, inferred or projected] continuing decline in [area, extent and/or quality] of habitat? Observed and projected decline in habitat quantity and quality from widespread stocking of trout and land use change in the Prairies	Yes: Alberta Yes: Saskatchewan Likely: Manitoba
Are there extreme fluctuations in number of populations?	Probably not
Are there extreme fluctuations in number of locations?	Probably not
Are there extreme fluctuations in extent of occurrence?	Probably not
Are there extreme fluctuations in index of area of occupancy?	Probably not

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Total	Unknown

Quantitative Analysis

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

Threats (actual or imminent, to populations or habitats)

Habitat loss and fragmentation mainly from agricultural and oil and gas developments; roadkill; introduced fish; agricultural contaminants; emerging infectious diseases

Rescue Effect (immigration from outside Canada)

Status of outside population: Western Tiger Salamander is SNR in North Dakota and Minnesota, S5 in Idaho, and S4 in Montana	
Is immigration known or possible?	Possible across Prairie provinces
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	Unknown

Status History

COSEWIC: The Tiger Salamander (*Ambystoma tigrinum)* was originally assessed by COSEWIC in November 2001 as three separate populations: Great Lakes population (Extirpated), Prairie / Boreal population (Not at Risk), and Southern Mountain population (Endangered). In November 2012, Tiger Salamander was split into two separate species, Eastern Tiger Salamander (*Ambystoma tigrinum*) and Western Tiger Salamander (*Ambystoma mavortium*), each with two different populations that received separate designations. The Prairie / Boreal population of the Western Tiger Salamander was assessed as Special Concern.

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric code:** Not applicable
Reasons for designation: This large salamander remains widely distributed in the Prairie provinces, but it faces numerous threats from habitat loss and fragmentation, fish stocking, and emerging diseases, such as the *Ambystoma tigrinum* virus that can decimate local populations. Salamander habitats are becoming increasingly fragmented by agricultural and oil and gas developments and associated infrastructures and roads. The disruption of migration routes, mortality through roadkill, and deterioration and loss of breeding and upland habitat for terrestrial adults and juveniles lead to concern for the species in a large part of its Canadian range.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable; no information exists on population trends.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable as both EO and IAO are above threshold values.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable; population size and trends are unknown.
Criterion D (Very Small or Restricted Total Population): Not applicable; population sizes are unknown but likely much greater than threshold values; the number of locations and IAO exceed guidelines for Threatened under D2.
Criterion E (Quantitative Analysis): Not applicable; not enough information is available.

PREFACE

Technically this is a new report as it considers the Western (formerly Barred) Tiger Salamander, *Ambystoma mavortium*, alone for the first time. The species was previously assessed by COSEWIC (2001) as a subspecies within a polytypic species formerly known as the Tiger Salamander, *Ambystoma tigrinum*. Of the subspecies formerly recognized as Tiger Salamanders within Canada, the Eastern Tiger Salamander and the Western Tiger Salamander (which includes the subspecies Gray Tiger Salamander and Blotched Tiger Salamander) are now recognized as distinct species (Crother 2012).

A recovery strategy for the Southern Mountain population has been prepared (Southern Interior Reptile and Amphibian Recovery Team. 2008). This strategy describes strategies for protecting habitat, filling in data gaps on population processes, habitat use, and life history, and building support for habitat protection among stakeholders and the public. Steps towards protecting habitat according to the recovery strategy targets have been initiated.

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
(2012)

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 Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

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

COSEWIC Status Report

on the

Western Tiger Salamander
Ambystoma mavortium

Southern Mountain population
Prairie / Boreal population

in Canada

2012

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

The Western (formerly Barred) Tiger Salamander, *Ambystoma mavortium* (Family Ambystomatidae or Mole Salamanders) was first described by Baird in 1850 (Gehlbach 1967). Subsequently, it was considered part of the taxon *A. tigrinum*, a polytypic species with a geographic range spanning much of North America (Bishop 1943; Gehlbach 1967). Based on molecular, phylogenetic (Shaffer and McKnight 1996), and morphological evidence (Irschick and Shaffer 1997), the western form was recently elevated to a species status and is now known as *A. mavortium* (Crother 2012). It is separated from the eastern form, now known as the Eastern Tiger Salamander, *Ambystoma tigrinum*. The Red River in Manitoba acts as an approximate dividing line between the two species in Canada. Older literature does not generally distinguish between the Western Tiger Salamander, *A. mavortium,* and the Eastern Tiger Salamander, *A. tigrinum*.

The Western Tiger Salamander currently includes 5 subspecies (Crother 2012).The validity of these subspecies has been questioned (Jones and Collins 1992; Shaffer and McKnight 1996; Storfer *et al.* 2004) and requires a detailed, range-wide analysis. Much of the range of the two northern subspecies is recently colonized (< 18,000 years) (Shaffer and McKnight 1996). The Gray Tiger Salamander, *A. m. diaboli*, occurs in the prairies of Manitoba and Saskatchewan (Figure 1, 2) and according to distribution maps in Stebbins (1985) might also occur in east-central Alberta, but this has not been confirmed (Russell and Bauer 2000). The other subspecies in Canada is the Blotched Tiger Salamander, *A. m. melanostictum* (Figure 3), which occurs in south-central Saskatchewan and westward in central and southern Alberta and as a disjunct population in the Southern Mountain region of British Columbia (Figure 1).

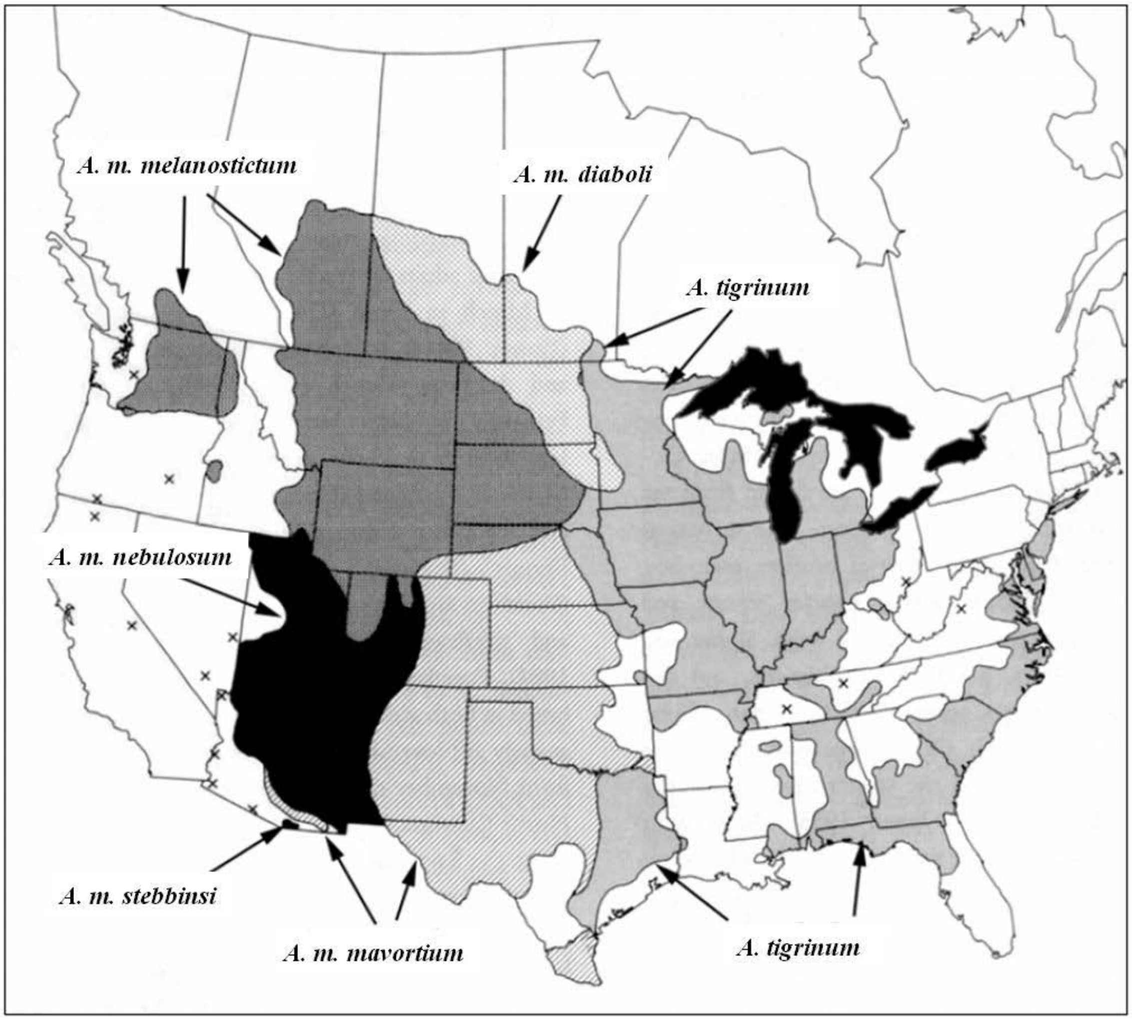

Figure 1. North American distribution of the Western Tiger Salamander (*Ambystoma mavortium*) with its subspecies, and the Eastern Tiger Salamander (*Ambystoma tigrinum*). Figure adapted from Schock (2001) and Petranka (1998).

Figure 2. Gray Tiger Salamander, *Ambystoma mavortium diaboli*; typical colouration of adult salamanders: older salamanders may show regression of dark markings (right) compared to younger individuals (left) (photos by A. Didiuk).

Figure 3. Blotched Tiger Salamander, *Ambystoma mavortium melanostictum,* from Alberta; typical colouration. Upper left – recently metamorphosed juvenile (with slight evidence of gills lower left). Upper right - Mottling on belly of a terrestrial adult from Alberta; Lower right: large pedomorphic (neotenic) individual from Tyrell Lake compared to smaller larvae. Photos by A. Whiting.

The English common name Barred Tiger Salamander for *A. mavortium* has been replaced recently by Western Tiger Salamander, so avoiding confusion arising from using Barred Tiger Salamander for both the species and one of its subspecies (Crother 2012). The French common name is salamandre tigrée de l'Ouest (Green 2012).

Morphological Description

Western Tiger Salamanders are large, robust mole salamanders that are among the largest terrestrial salamanders in North America. Males reach a total length of about 200 mm, while females are generally smaller (Sarell 1996; Petranka 1998; Hammerson 1999). Some salamanders reach over 300 mm in length, but these are generally neotenic, permanently aquatic forms that fail to transform and retain larval characters including gills and a tail fin in sexually mature adults (Figure 3; Cormie 1975). The largest reported body size is 385 mm for *A. m. diaboli* from Devils Lake, North Dakota (Larson 1968). The salamander has 11-14 costal grooves on each side of its body. Sexual dimorphism is subtle, with males having a longer tail, which is more laterally compressed than the tail of females, and a swollen vent during the breeding season (Schock 2001).

The colouration of terrestrial forms, though somewhat variable, has been used to discriminate subspecies of the Western Tiger Salamander from each other and from the Eastern Tiger Salamander. Metamorphosed adults have a blotched, barred or reticulate pattern of yellow (cream or white) on black (or grey, dark brown or olive green) background; the boundaries of blotches are not always sharp. The underside is sooty grey. In contrast to western forms, Eastern Tiger Salamanders have spots and lack blotches or bars. Distinguishing between the subspecies of Western Tiger Salamanders is more difficult. The distributions of the two subspecies found in Canada (*Ambystoma m. diaboli* and *Ambystoma m. melanostictum*) overlap extensively throughout Saskatchewan, and colour variations may exist even within subspecies or regions. *Ambystoma m. diaboli* typically have dark spotting on a light background (especially typical of large aquatic adults). Individual *Ambystoma m. melanostictum* transform into terrestrial stages with light markings on a dark background, and the background gradually reduces to spots with the former light spots and bars becoming a light background colour (Figure 2; Cook, unpubl. field observations in western provinces 1959-1970; Brunton 1998). Recently metamorphosed juveniles can be irregularly mottled or spotted without distinct blotches and often have a thin, dark line along the middle of the dorsum where the dorsal fin membrane was resorbed (Schock 2001).

Larvae hatch at about 15 mm in total length and have three long gill stalks and a broad dorsal fin membrane. Gill stalks are longer than the head and are swept back along the body. Tiger salamanders lack true balancers, but the lower pair of gills may act in their place. Larvae in June-July are translucent yellow-green. Toward the end of September the smallest larvae are 100-150 mm long and show some loss of the transparent quality of the tail fin and skin (Cormie 1975). Older individuals are grey and similar to younger larvae except for size and scarring. Permanently aquatic neotenes are large (often in excess of 300 mm long) and often heavily scarred, but otherwise similar to larvae. In spring, aquatic adults are easily distinguished from larvae based on their large size.

Cannibal morphs tend to occur in the southern subspecies *Ambystoma m. nebulosum* and *Ambystoma m. mavortium* (Lannoo and Bachmann 1984) but have not been reported for the subspecies found in Canada. Cannibal morphs of both larvae and neotenic adults are larger and have wider, flatter heads and an enlarged vomerine tooth ridge when compared to non-cannibal morphs (Collins *et al.* 1993). Large neotenic salamanders may occur in some Canadian localities and may cannibalize smaller larvae, without displaying morphological specializations.

Neoteny occurs throughout the range of the Western Tiger Salamander and has been reported from at least 5 sites in British Columbia (Sarell pers. comm. 2011), and occasionally from Alberta (e.g., Tyrrell Lake and Crooked Valley Reservoir near Calgary; Goater pers. comm. 2011) and Saskatchewan (e.g., near Saskatoon, Didiuk pers. comm. 2011). Neoteny is more common where terrestrial habitat is unsuitable or where water is permanent. Rarely, larvae may prolong metamorphosis until the following spring or summer provided they can overwinter in water. Prolonged metamorphosis may be more common in montane populations as a result of extended hydroperiods, lower temperatures, and associated slower growth and development rates, compared to prairie populations (Wissinger *et al.* 2010).

There is little chance for confusion between Western Tiger Salamanders and other salamanders as they are generally the only salamander present throughout their range. The exception is the Rocky Mountain ranges in Alberta and the Southern Mountain regions of British Columbia where their distribution overlaps with that of the Long-toed Salamander, *Ambystoma macrodactylum*. Terrestrial forms are easily distinguished by the greater size of the Western Tiger Salamander and their distinctive colouration.

Population Spatial Structure and Variability

Little is known about the spatial structure of Western Tiger Salamander populations in Canada. One study on landscape genetic structure of *A. m. melanostictum* examined 8 microsatellite loci from 10 sites across the northern range in Yellowstone National Park, Wyoming and Montana (Spear *et al.* 2005). The study revealed restricted gene flow among populations from different sites (F_{ST} = 0.24) and further isolation by distance and elevation (mean of 21.8 ± 15.2 km SD; range 0.5 to 53 km). River crossings and open shrub habitat were associated with greater gene exchange among populations, but movements appeared to be restricted due to topographical features. These results may apply to montane populations in British Columbia and Alberta but not to prairie populations. The only other study describing movements between populations is of marked individuals of *A. m. nebulosum* in Colorado (Denoel *et al.* 2007). The maximum distance between 8 study ponds was 100 m where up to 40% of individuals moved between ponds in a given year, and individuals visited up to 5 ponds within their life time (mean 1.6 ±0.1, *n* = 90 salamanders). Movement rates between ponds such as these may be more characteristic in the prairie pothole region of Manitoba, Saskatchewan and Alberta where terrestrial habitat is more suitable to dispersal. Movement among wetlands is less likely in British Columbia where populations are often separated by roads, xeric terrestrial habitat and wetlands occupied by introduced fish. However, movement patterns among wetlands have not been investigated in Canadian populations. Likewise, site philopatry, the propensity to return to a natal pond, has not been adequately explored, but could have strong effects on population spatial structure. Eastern Tiger Salamanders, *A. tigrinum*, have shown philopatric behaviour, whereby salamanders returned to their natal ponds despite other wetlands being available (Semlitsch 1983). Schock (unpubl. data) has observed similar philopatric behaviour for individually marked salamanders from a population of *A. m. diaboli* near Edenwold, Saskatchewan. Given the potential for philopatry in Western Tiger Salamanders, the destruction of a single breeding site could eliminate an entire population.

Structuring within populations may occur at sites where there is neoteny. Neotenic adults remain within the pond year-round and are thus capable of breeding in spring before metamorphic adults appear. Metamorphic adults are also the only individuals that might disperse and enter nearby populations across upland habitat. Furthermore, morphological differences between metamorphic and neotenic morphs may result in divergence of feeding habits (Denoel *et al.* 2006, 2007) during the breeding period, leading to spatial segregation within a pond.

Regionally, populations in the Southern Mountain region of British Columbia are geographically separated by the Rocky Mountains and are disjunct from the rest of the Canadian populations of Western Tiger Salamanders (Figure 1). The distribution of Western Tiger Salamanders in British Columbia is restricted to the South Okanagan, Lower Similkameen and Kettle River watersheds (Figure 4). There are no suitable habitats nearby, although there are apparently suitable wetlands and upland habitat further north (Ashpole pers. comm. 2011; Sarell pers. comm. 2011). Movement of salamanders between breeding ponds is unlikely as distance increases, and may be rare in general due to the arid sagebrush-bunchgrass plant community, which predominates in upland habitats in this area.

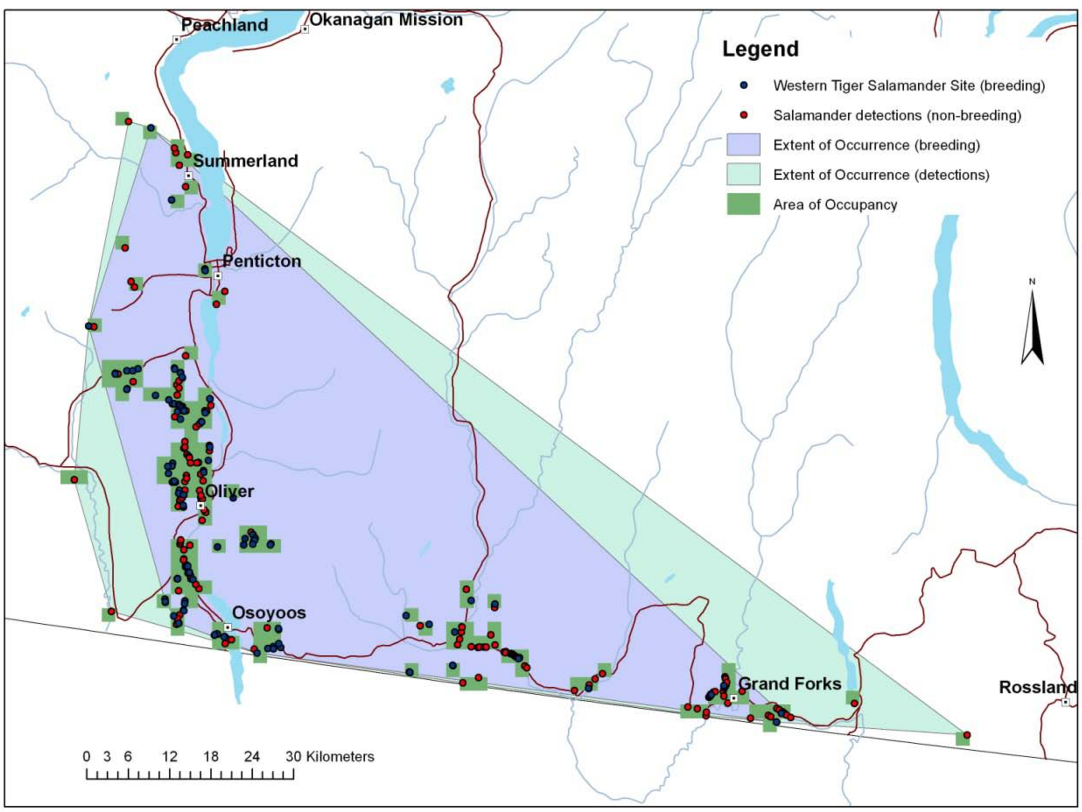

Figure 4. Distribution of Western Tiger Salamander occurrences in British Columbia. Shown are the extent of occurrence and index of area of occupancy (for breeding sites alone; 58 cells = 232 km^2). Map prepared by A. Whiting.

The remainder of the Canadian distribution consists of both the Blotched Tiger Salamander (*A. m. melanostictum*) in Alberta and Saskatchewan and the Gray Tiger Salamander (*A. m. diaboli*) in Saskatchewan and Manitoba. Though recognized as two separate subspecies, there has been no genetic work across the distribution to delineate clear genetic boundaries or barriers to dispersal. Subspecific designations are based only upon colour pattern variation between populations (Irschick and Shaffer 1997). Genetic differences in the genome of ranaviruses (FV3 and ATV) that commonly infect tiger salamanders could be used to identify host-pathogen differences that may be related to genetic barriers to the host populations. To date, there appears to be little genetic difference in ATV that might identify barriers to gene flow among salamander populations (Schock *et al.* 2009).

Designatable Units

The Western Tiger Salamander is considered to consist of two designatable units (DUs): Southern Mountain population in B.C. and Prairie / Boreal population in Alberta, Saskatchewan, and Manitoba. Western Tiger Salamanders in British Columbia and in the Prairie provinces occur in the Southern Mountain and Prairie ecological areas (or Intermountain and Prairie faunal provinces), respectively. They represent separate postglacial range expansions into Canada and are separated by the Rocky Mountains. It is unknown whether there are morphological or ecological adaptations to the different environments that the two populations occupy. However, there are differences in land uses and threats to which the salamanders are exposed. The Southern Mountain population was previously recognized as a DU, based on the disjunct distribution of these salamanders from the remainder of the species' distribution in Canada (Figure 1). The Prairie / Boreal population includes two subspecies, Gray and Blotched tiger salamanders. The two subspecies are not easily distinguishable, and further evidence to support their validity is required. Therefore, they are considered a single DU in this report. The Prairie / Boreal population, as had been described in the previous status report (Schock 2001), no longer includes tiger salamanders east of the Red River in Manitoba, as they are now recognized as Eastern Tiger Salamanders.

Special Significance

The Western Tiger Salamander is one of the largest terrestrial salamanders in North America and the only salamander species in Saskatchewan and one of two salamander species in Alberta. Tiger Salamanders have received little public attention in Canada; however, the interpretive centre in St. Leon, Manitoba, focuses on their life cycle. The Western Tiger Salamander was designated the state amphibian of Colorado in March 2012 (Colorado State 2012).

Tiger salamanders are generally the top predator in naturally fishless systems. In the Prairie Pothole regions, tiger salamanders may occupy the fish niche (Zaret 1980; Benoy 2008) and control macroinvertebrate abundance (Benoy *et al.* 2002; Benoy 2005, 2008), which in turn influences nutrient cycles and regulates phytoplankton biomass (Holomuzki *et al.* 1994). Salamander larvae transport energy from aquatic production to terrestrial uplands after metamorphosis; these exports may be significant in large populations (Gibbons *et al.* 2006; Regester *et al.* 2006a, b).

Tiger salamanders are frequently used as model species to develop and test evolutionary, ecological and physiological hypotheses, owing to their large size, phenotypic plasticity, wide geographic distribution, and ease with which they can be reared in laboratory settings. These same characteristics also make them common in the pet trade.

DISTRIBUTION

Global Range

The Western Tiger Salamander is widely distributed in the arid and semi-arid interior of western North America (Figure 1). Its range is bordered to the north by the mixed-wood and boreal forests in Alberta and Saskatchewan and the boreal plains in Manitoba. The eastern extent of the distribution appears to be Red River in Manitoba from where it extends south into Minnesota and Iowa, where subspecies of the Western Tiger Salamander (*A. m. diaboli* with *A. m. melanostictum,* and *A. m. mavortium*) overlap with the Eastern Tiger Salamander (Routman 1993). The exact distributions of the subspecies (Shaffer and McKnight 1996) remain unclear, and the distribution map created by Petranka (1998) is likely to change with continued research within contact zones in the east (Routman 1993; LeClere pers. comm. 2011). The eastern distribution extends through Nebraska, Kansas, Oklahoma and Texas, west along the border of Mexico and then north through Arizona along the eastern slopes of the Rocky Mountains north to Alberta. There is a disjunct distribution in Northern Oregon, Idaho and through Washington into the southern Okanagan region of British Columbia. The indistinct range boundary between subspecies complicates the mapping of distributions (Shaffer and McKnight 1996). Several subspecies of Western Tiger Salamander (usually *A. m. mavortium*) have been introduced into California and other western US states as a result of the practice of using salamander larvae as fish bait, thus complicating attempts to delineate subspecies boundaries (Fitzpatrick and Shaffer 2004, 2007; Johnson *et al.* 2010, 2011).

Canadian Range

In British Columbia, the Western Tiger Salamander occurs in the dry southern interior region of the province, south of Peachland. It is restricted to scattered, isolated populations in the South Okanagan, Lower Similkameen, and Kettle River watersheds (Figure 4) with the range extending south to the U.S. border.

The remainder of the species' distribution is relatively continuous and extends to the northern edge of the prairie ecozone up to the beginning of continuous coniferous forest (Cook 1960), covering a wide area in central and southern portions of Alberta, Saskatchewan and Manitoba within the aspen parkland and short grass prairie (Figure 5). Populations occur within the montane region of Alberta east of the Rocky Mountains up to elevations of 2,800 m in the Bow Valley area near Banff (Clevenger *et al.* 2001; Alberta FWMIS 2011) and at a number of sites within Waterton Lakes National Park (WLNP Wildlife Observations 2011). One population from the Wagner Natural Area, west of Edmonton, was previously incorrectly placed on maps near Slave Lake (Schock 2001). The distribution in Manitoba is south of the boreal plain ecozone from Riding Mountain National Park and the southern edge of Lake Manitoba east to Red River near Winnipeg and then south, west of Red River, to the US border. Red River appears to act as a dividing line between the Eastern Tiger Salamander and the Western Tiger Salamander, but the exact boundary is unclear and requires verification (Ngo *et al.* 2009). Recent efforts have identified populations of Eastern Tiger Salamanders from Tolstoi, Rosseau River, and Gardenton, all east of Red River (Collicutt pers. comm. 2011; Manitoba Herp Atlas 2011).

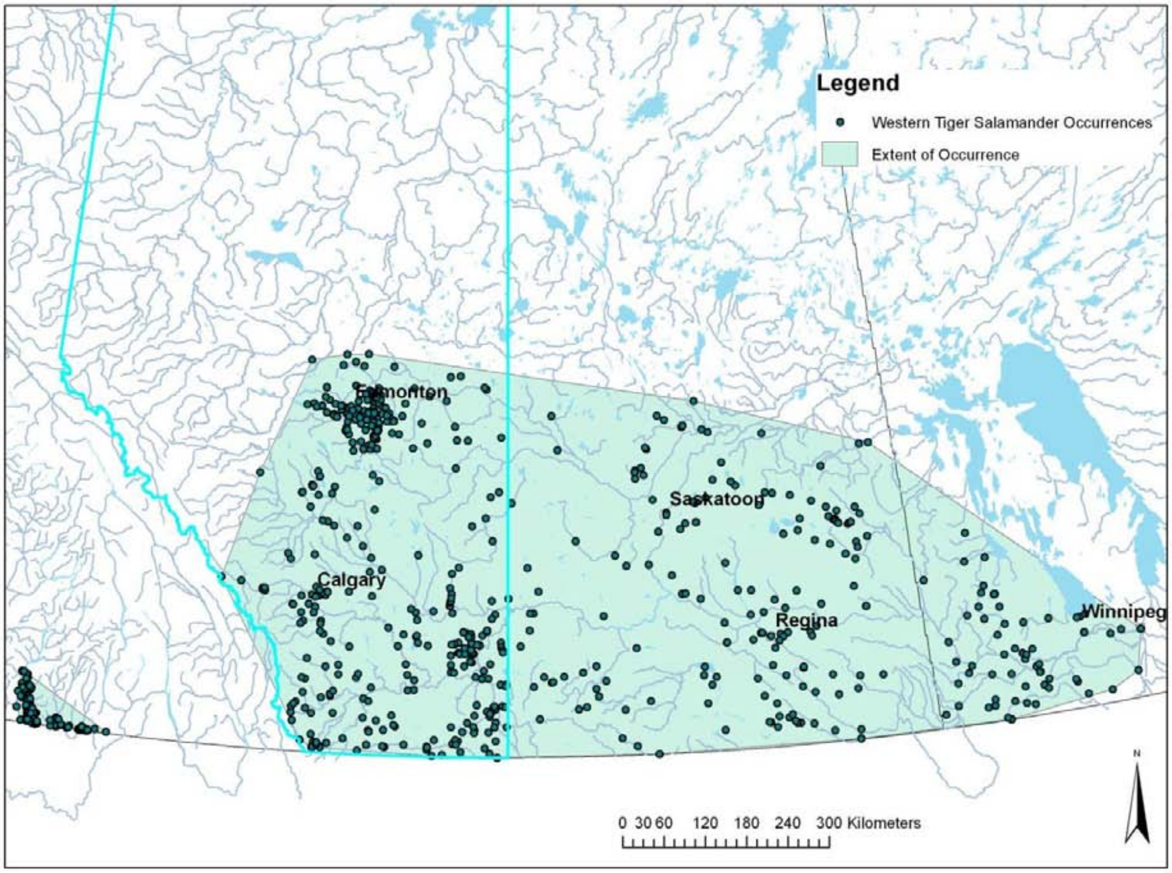

Figure 5. Canadian distribution of all occurrences of Western Tiger Salamander, showing the Southern Mountain DU in the west and Prairie DU in the east. Green shading indicates the total extent of occurrence (572,490 km^2). Map prepared by A. Whiting.

Extent of Occurrence and Area of Occupancy

Calculations of the extent of occurrence and index of area of occupancy were completed using ArcGIS 10 by A. Whiting with the help of C. Nielsen at the University of Alberta.

Southern Mountain Population:

In British Columbia, declines in the area of occupancy and extent of occurrence reported in the previous status report (Schock 2001) were inferred from apparent extirpations at historical breeding sites, combined with extensive habitat loss (Southern Interior Reptile and Amphibian Recovery Team 2008). Since then, knowledge of the number of sites and number of populations has increased; there are now 86 known breeding sites of Western Tiger Salamanders (BC SPI 2011; BC CDC 2012), an increase from 41 sites (formerly listed as 41 locations; Schock 2001). Including the number of non-breeding detections, there are 331 occurrence records from the past 10 years (2001-2011). Using the most recent data available, and utilizing a buffer of 500 m around each occurrence point and joining points with overlapping buffers (referred to as sites) there are up to 68 sites that have had at least one life stage present in the past 10 years (since 2001). The increase in the number of sites represents greater survey effort (Noble and Spendlow 2006; Crosby unpubl. data) rather than an increase in occupied sites.

The extent of occurrence (EO) for British Columbia, using all detections, with the minimum convex polygon method is 5054 km^2 (Figure 4). B.C. Conservation Data Centre (Stipec pers. comm. 2012) calculated the EO as 2208 km^2 using an alpha convex polygon that excluded the northwestern mountainous area, which is unsuitable habitat. Both estimates are greater than the EO of 1,500 km^2 reported in the previous status report (Schock 2001); the increase is a result of increased surveys in neighbouring watersheds. Utilizing a point in the centre of each breeding site, the index of area of occupancy (IAO) using a 2x2 km grid and ignoring the total area of the water body is 232 km^2 (58 cells); IAO is 464 km^2 (116 cells) if all detections of individuals are included, even where breeding populations are unlikely. B.C. Conservation Data Centre (Stipec pers. comm. 2012) calculated an IAO of 248 km^2 given 62 occupied cells within the Southern Mountain area. AO was reported as 150 km^2 in the previous status report (Schock 2001); IAO was not calculated.

Prairie / Boreal Population:

Based on occurrence records with a buffer of 500 m placed around each point or group of points, there are over 597 known sites throughout the Prairie / Boreal population. However, some of these observations are over 40 years old and may not represent extant populations. Within the Prairie Provinces, there are no reports of changes in the distribution of the species through time, but systematic surveys are lacking. However, in the past 10 years since Schock's (2001) report, incidental reports of the presence of Tiger Salamanders leave the impression that the salamanders remain relatively widely distributed in Saskatchewan and Manitoba, although some populations are spatially isolated. A herpetological atlas currently under way in Manitoba has added 16 new sites in the past year (Manitoba Herp Atlas 2011). Efforts to conduct a herpetological atlas in Saskatchewan have been ongoing since 2001 (Schock 2001), but results are as yet unavailable. In Saskatchewan, Western Tiger Salamanders persist within the expected range (Didiuk pers. comm. 2011), but without systematic surveys it is unclear if there has been a change in EO or IAO. In Alberta, there are a number of new records, but data gaps remain, especially in the east (Alberta FWMIS 2011).

The EO for the Prairie Provinces is 567,437 km^2 based on data from recent surveys and historical records. This represents an increase of more than 67,000 km^2 since the last status report (Schock 2001). Based on available data, there are 597 cells with detections or occurrences resulting in an IAO of 2388 km^2. This estimate is much lower than the AO of 50,000 km^2 previously reported (Schock 2001), which may have been inferred based on habitat availability. The lack of reporting from Saskatchewan and Manitoba and lack of dedicated tiger salamander surveys in Alberta probably greatly underestimate the IAO.

Search Effort

Systematic surveys for Western Tiger Salamanders have been conducted only in British Columbia (Tarrangle and Yelland 2005; Noble and Spendlow 2006). These surveys included historical sites as well as new sites in potentially suitable habitats. Regional surveys for amphibians in the Okanagan are ongoing, and include those by Sara Ashpole and Christine Bishop and their students (e.g., Ashpole *et al*. 2011; de Jong 2008); currently Jonquil Crosby is documenting road mortality of Western Tiger Salamanders (Ashpole pers. comm. 2011). Ashpole *et al*. (2011) found the Western Tiger Salamander at 8 of 96 ponds surveyed from 2003 – 2006 in lowland valley and agricultural areas of the South Okanagan Valley. Tarrangle and Yelland (2005) found the species at 7 of 52 wetlands surveyed in South Okanagan. Tarrangle and Yelland (2005) found the species at 7 of 84 wetlands surveyed in the Okanagan, Similkameen, and Kettle Valley areas. Amphibian surveys by Mike Sarell (Ophiuchus Consulting) and by members of BCFrogwatch have resulted in additional tiger salamander records. Additional surveys in surrounding areas have supported the absence of tiger salamanders outside of their known B.C. range (Deguise and Richardson 2009; Dulisse and Hausleitner 2010; Voordouw *et al.* 2010). As of September 2011, there were 86 known tiger salamander breeding sites in British Columbia (BC CDC 2012). The number of occupied sites fluctuates annually but is likely unchanged from the last surveys in 2006 (Noble and Spendlow 2006). Given the restricted distribution of the species and persistent survey efforts, there are unlikely to be many undiscovered populations within the Southern Mountain population. There may still exist some unknown populations in oxbows on private land, but the presence of fish (native and introduced) and possibly Bullfrog (*Lithobates catesbeianus*) restricts this possibility (Ashpole pers. comm. 2011).

In the Prairie provinces, there have been no systematic surveys for Western Tiger Salamanders. In Alberta, the Fish and Wildlife Management Information System database provides records of the presence of tiger salamanders. The database consists of information by individuals that require a permit to conduct research on wildlife, but also receives reports from volunteer groups such as the Alberta Volunteer Amphibian Monitoring Program (AVAMP) and Researching Amphibian Numbers in Alberta (RANA). In addition to these volunteer networks, the national monitoring program Frogwatch, which focuses on calling anurans, provides occasional reports of salamander occurrence. An ongoing program to sample biodiversity throughout Alberta in 20 km^2 grid cells (Alberta Biodiversity Monitoring Institute 2008) will help fill knowledge gaps within the eastern prairie and parkland regions. Graduate student and academic research has included regional surveys for amphibians, some of which have focused on tiger salamanders in Manitoba (Alperyn 2005; Benoy *et al.* 2005, 2008). Other studies in Alberta and Saskatchewan have involved opportunistic observations of tiger salamanders (Puchniak 2002; Eaves 2004; Browne 2010; Pagnucco 2010; Scheffers 2010; Anderson pers. comm. 2011; Taylor pers. comm. 2011). Older records from museum collections dominate the occurrences for tiger salamanders in Saskatchewan and Manitoba, but there are anecdotal reports that salamanders still persist within the expected range (Didiuk pers. comm. 2011; Vanderschuit pers. comm. 2011).

HABITAT

Habitat Requirements

Western Tiger Salamanders are widely distributed in a variety of habitats including grasslands, parklands, subalpine meadows, and semi-deserts in arid regions. Key habitat features include sandy or friable soils surrounding semi-permanent to permanent fishless water bodies (Petranka 1998). The salamanders also appear to require burrows of small mammals for daily refuge use and overwintering sites (Whiteman *et al.* 1994; Koch and Peterson 1995; Richardson *et al.* 2000).

Aquatic breeding habitats must hold water for the 3 to 7 months required to complete development up to metamorphosis (McMenamin and Hadly 2010). Differences in hydroperiods can affect the number of metamorphs emerging from breeding sites, with more emerging from water bodies with a longer hydroperiod (Richardson *et al.* 2000; Wissinger *et al.* 2010). Longer hydroperiods may be required in cooler environs due to slower growth and prolonged time required to metamorphosis. Neotenic, aquatic populations require permanent water bodies lacking predatory fish and appear to be associated with cooler water bodies in mainly subalpine habitats. Western Tiger Salamanders are tolerant of alkaline or slightly saline environments, such as Tyrell Lake in Alberta, and of nutrient rich water bodies (Miller and Larsen 1986; Matsuda *et al.* 2006).

Terrestrial habitats of adults and metamorphosed juveniles include grassland, open woodlands such as found in the parkland of the Prairie provinces, and shrub-steppe in British Columbia. Western Tiger Salamanders occur in cultivated regions of the Prairie provinces. Individuals are often found inhabiting small mammal burrows or underneath debris or rocks. The extent of terrestrial habitat required is likely to vary depending on its configuration and quality. Movements are usually within 250 m from aquatic breeding habitats based on radio-telemetry studies (Richardson *et al.* 2000; Steen *et al.* 2006), but individuals are occasionally found over 1000 m from the nearest suitable water body (Sarell and Robertson 1994). During the fall migration, biologists are commonly inundated with calls that salamanders have fallen in window wells, sump pumps, or in-ground pools, or are found in basements (Ashpole pers. comm. 2011; Kendall pers. comm. 2011). These large urban pitfall traps highlight the degree to which salamander habitat has been modified and fragmented. The role of habitat fragmentation and use of corridor habitats for movements and dispersal by Western Tiger Salamanders have not received sufficient attention.

Habitat Trends

Habitat loss continues throughout the range of the Western Tiger Salamander. In British Columbia, much of the species' habitat occurs on private lands, which continue to be converted to agriculture (formerly orchards and now vineyards), leading to the additional threats of contamination of breeding sites from run-off. It was estimated that by the late 1980s, only 10% of natural ecosystems within the southern Okanagan remained relatively undisturbed (Redpath 1990). Of the riparian and upland habitat, about half has been lost to urban or agricultural development (Cannings *et al.* 1999), and only 15% of the original valley bottom riparian habitat remains (B.C. Ministry of Environment, Lands and Parks 1998). Habitat loss to urban and agricultural developments continues to threaten aquatic and terrestrial habitats of tiger salamanders and disrupt habitat connectivity (Southern Interior Reptile and Amphibian Recovery Team 2008). A number of small wetlands have been constructed for amphibians over the past 5 years (21 ponds, of which 4 are suitable for tiger salamanders; Ashpole pers. comm. 2011), but these do not nearly compensate for the loss of natural wetlands and habitat fragmentation occurring in the region. Habitat fragmentation is of growing concern due to increased traffic volumes, especially in South Okanagan, and high road mortality rate of tiger salamanders when migrating to and from breeding sites (see **THREATS AND LIMITING FACTORS**). Large-scale loss of wetlands has also occurred throughout the salamander's range in the Prairie provinces (Millar 1989; Watmough and Schmoll 2007). Drainage and infilling still occur, especially in association with urban developments and agriculture (Dahl and Watmough 2007; Bartzen *et al.* 2010).

Further reducing habitat quality and availability throughout the species' Canadian range is the purposeful (legal and illegal) introduction of trout (mainly Rainbow Trout, *Oncorhynchus mykiss*) and more recently in British Columbia Largemouth Bass (*Micropterus salmoides*) and Smallmouth Bass (*M. dolomieu*), into water bodies that formerly lacked large predatory fish (Carl and Guiguet 1958; Alberta FWMIS 2011; Sarell pers. comm. 2011; Saskatchewan Fish and Wildlife 2012). Figure 6 shows the prevalence of sport fish stocking in Alberta; a similar pattern is evident in the other provinces where the salamanders occur. Western Tiger Salamanders have reduced growth and survival in the presence of predatory fish (reviewed in Wind 2005). Neotenic salamander populations are at greatest risk after the introduction of predaceous fish, which consume both larvae and adult salamanders (Mitchell and Prepas 1990; Goater pers. comm. 2011; Haag pers. comm. 2011).

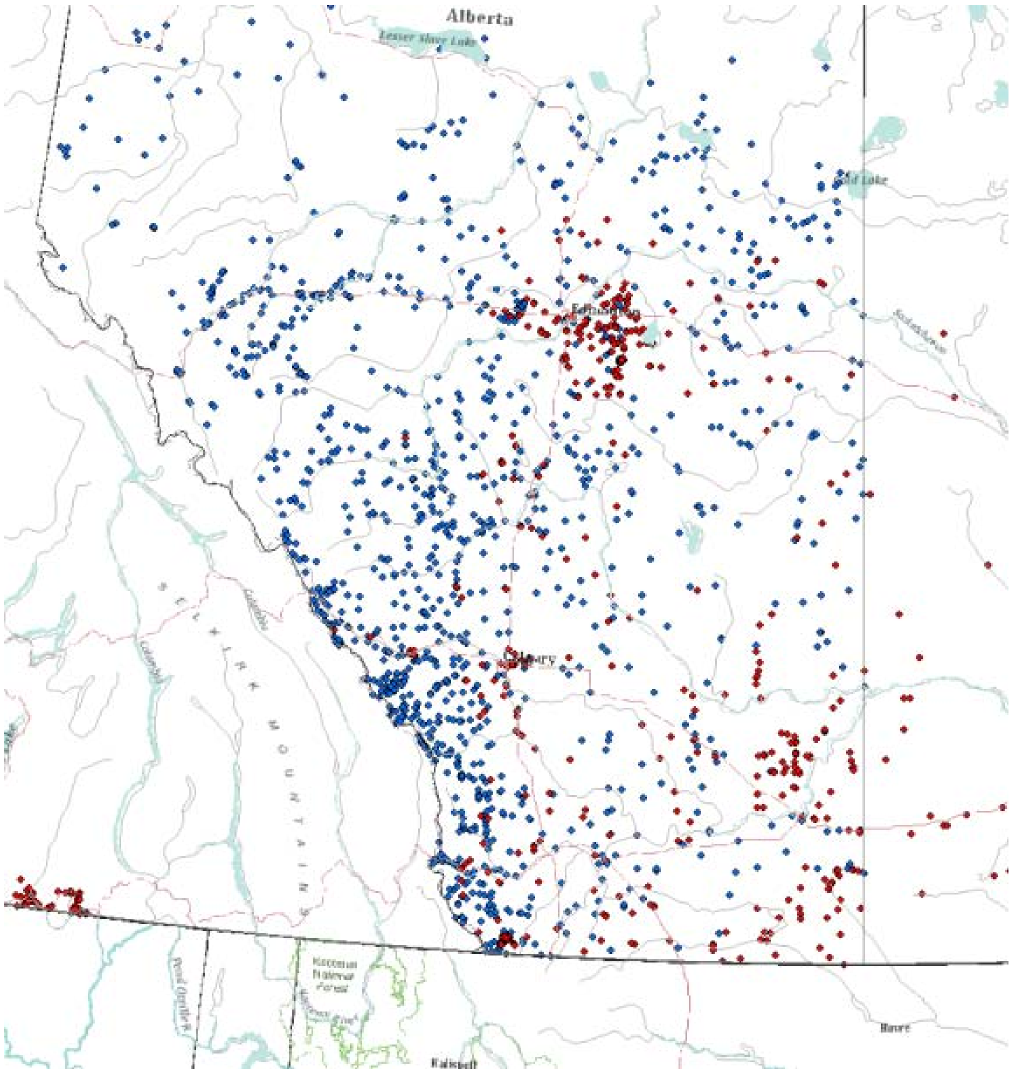

Figure 6. Distribution of water bodies that have been stocked with game fish in Alberta since 1920 (blue) and known Western Tiger Salamander records from central and southern Alberta (red). Fish stocking is similarly prevalent in British Columbia, Saskatchewan, and Manitoba, but data were not available for detailed mapping. Map prepared by A. Whiting.

Although adapted to arid and semi-arid regions, Western Tiger Salamander populations are vulnerable to prolonged and frequent droughts (Richardson *et al.* 2000), such as predicted under climate change, which can exacerbate effects of habitat loss and fragmentation. Since 2001, there have been two major droughts (in 2003 and 2009) (BC MOE 2010), the effects of which had subsided somewhat in 2010 and 2011 (Agriculture and Agri-Food Canada 2012). Hydroperiods and water levels were so low during the last decade that wetlands formerly known to be inhabited by salamanders were dry during the 2005 and 2006 breeding seasons (Tarangle and Yelland 2005; Noble and Spendlow 2006). The prairies have experienced a number of multi-year droughts, the most recent during 1999-2005 (Khandekar 2004; Bonsal *et al.* 2011; Hanesiak *et al.* 2011). Water deficits and short hydroperiods remain of concern.

BIOLOGY

Life Cycle and Reproduction

In British Columbia, breeding occurs in permanent or semi-permanent lakes and ponds from March to May, soon after spring rains and when overnight temperatures reach 12°C (Richardson *et al.* 2000; Sarell pers. comm. 2011). Throughout the rest of the species' Canadian range, breeding occurs soon after water is free of ice, in April to May after spring rains, in permanent or semi-permanent standing water, which may be less than 10°C (Russell and Bauer 2000).

Males may outnumber females at breeding sites, with sex ratios of 1.7:1 reported in Saskatchewan and Manitoba (Schock pers. comm. 2011). After courtship, the male deposits a spermatophore (sperm packet) on the bottom of the pond, which the female picks up with her cloaca. Shortly after mating, the female lays small eggs (< 10 mm in diameter) and attaches them either singly or in small clusters to twigs or stems of emergent plants or to stones or debris about 30 cm or more below the surface of the water (Russell and Bauer 2000; Sarell 2004; Matsuda *et al.* 2006). Clutch sizes have not been recorded for Canadian populations, but in the U.S. they range from a high of 5000 eggs (Bishop 1943; Rose and Armentout 1976) to a low of 100 eggs (Gopurenko *et al.* 2006), depending on geographic location and the female's body size. Hatching times vary based upon water temperature (Tanner *et al.* 1971; Sever and Dineen 1978), but eggs typically hatch in 2 – 3 weeks (Schock 2001; Sarell pers. comm. 2011).

Development of larvae to metamorphosis usually takes approximately 3-4 months and is dependent on water temperature, food availability, density of larvae, and pond hydroperiod (Wilbur and Collins 1973; Sexton and Bizer 1978; Collins and Cheek 1983). Metamorphosis has been observed as early as July 22 in the Okanagan (Sarell pers. comm. 2011), but generally metamorphs emerge in August throughout most of the Canadian distribution (Anderson pers. comm. 2011; Collicutt pers. comm. 2011; Didiuk pers. comm. 2011; Sarell pers. comm. 2011; Vanderschuit pers. comm. 2011). Metamorphosis occurs at larval total lengths of 80-150 mm, but varies depending on growing conditions, such as prey availability and larval density. In permanent water bodies without predatory fish in British Columbia and Alberta, larvae have been reported to overwinter occasionally and emerge the following summer at a much larger body size or remain as aquatic neotenic adults (B.C.: Ashpole pers. comm. 2011; Alberta: Anderson pers. comm. 2011; Goater pers. comm. 2011). In some montane populations of *A. m. nebulosum* in Colorado, metamorphosis may occur in the 2nd or 3rd summer, or individuals may simply remain as neotenic aquatic adults (Wissinger *et al.* 1999, 2010).

After metamorphosis, individuals migrate to the upland taking up residence in underground refuges and rarely emerge during the day. Migration from the water bodies seems to be triggered by rain in late summer, when the salamanders emerge by hundreds from breeding ponds (Patch and Stewart 1934). Overwintering likely occurs in small mammal burrows and forested areas near aquatic habitats (Whiteman *et al.* 1994; Koch and Peterson 1995; Richardson *et al.* 2000).

The prevalence of neoteny is not well studied in Canadian populations but has been reported from approximately 5 sites in British Columbia (Southern Interior Reptile and Amphibian Recovery Team 2008), at Tyrell Lake and several other sites in Alberta (Cormie 1975; Goater pers. comm. 2011; Paszkowski pers. comm. 2011), and in Saskatchewan (Didiuk pers. comm. 2011). There are no confirmed reports of neoteny from Manitoba, although it is suspected to occur in Ninette Lake (Preston 1982). Facultative pedomorphosis, the ability to metamorphose after sexual maturity, may occur during drought periods, but neotenic populations may be lost due to drying of the aquatic habitat.

Survivorship and Generation Time

Western Tiger Salamanders demonstrate an “r-selected” survival strategy: many eggs are produced, but larval mortality is high (Pfennig *et al.* 1991). High reproductive potential allows tiger salamanders to rapidly exploit recently filled water bodies (Sarell 1996). Survival to metamorphosis can be highly variable depending upon larval density, presence of cannibal morphs, food availability, and hydroperiod (Wissinger *et al.* 2010). The highly variable larval survival results in pulses of recruits that can vary enormously from year to year, resulting in high fluctuations in adult population size on a multi-year basis.

Inferred overwinter survival is low for young-of-the-year based on large numbers of metamorphs in fall and low numbers that return to the wetland the following spring in any given year (Richardson *et al.* 2000; Wissinger *et al.* 2010; Schock pers. comm. 2011). Time to sexual maturity is variable throughout the range, especially within montane regions, and may range from 1 to 4 years (Webb and Roueche 1971; Wissinger *et al.* 1999, 2010). Farther south in the US, individuals of *A. tigrinum* may return to breed the year after hatching, but are more likely to return in their second year of life (Semlitsch 1983). Females may take longer to mature than males (Schock, unpubl. data) and either breed every year or every second year, depending on climate and energy stores (Bailey *et al.* 2004; Church *et al.* 2007).

Adult survival estimated for three populations of *A. tigrinum* in the US over 4 years was 0.85, but varied with year and site (female annual survival range ~0.51 to 1.00; Church *et al.* 2007). Tiger salamanders are long-lived, with maximum life spans recorded at 16 (Russell and Bauer 2000) to 25 years (Tyning 1990). However, assuming constant survival each year, the probability of individuals reaching 16 years of age is 7% and may therefore occur only rarely. Schock (2001) reported individuals that were at least 5 years of age from a population from Saskatchewan, but a skeletal chronology study from neotenic and terrestrial populations found no individuals greater than 6 years of age (Allison, unpubl. data cited in Schock 2001).

The generation time using the harmonic average survival is 6.3 – 8.3 years, calculated as follows: age of maturity + (1/annual mortality rate), where age at maturity is 1 – 3 years, and annual mortality rate is 0.19, as per Church *et al.* 2007 for *A. tigrinum*). However, in exceptionally dry years mortality rate was 0.45 and would result in generation times of 3.2 to 5.2 years using the same equation. A generation time of 5 – 6 years is used in this report.

Physiology and Adaptability

Facilitated by their fossorial nature and use of underground refuges, Western Tiger Salamanders are capable of inhabiting dry upland habitats. The salamanders are active in burrows, where they feed and may be thermoregulating underneath the ground (Sarell pers. comm. 2011). However, in the absence of burrows or friable soils into which they can dig, the salamanders avoid habitats that increase desiccation rates (Cosentino *et al.* 2011). Tiger salamanders can occur in urban areas, where they have been found in gardens, earthen basements, and septic systems (Ashpole pers. comm. 2011; Kendall pers. comm. 2011); these novel habitats may either represent refuges or accidental entrapment while migrating across the landscape.

Larvae and adults are known to inhabit brackish and alkaline waters, and have been reported from waters with conductivity > 12000 µS cm^{-1} (Deutschmann and Peterka 1988) and total dissolved solids > 7000 mg/L (Mitchell and Prepas 1990). Tiger salamanders are also tolerant of acidic conditions, with egg mortality of 50% at pH of 4.2 (Whiteman *et al.* 1995). Western Tiger Salamanders can breed from cool subalpine waters to warmer prairie pothole wetlands. Although they are tolerant of a wide variety of aquatic conditions, large reductions in the length of hydroperiods due to droughts is detrimental and can limit recruitment of young or result in complete reproductive failure (Richardson *et al.* 2000; Wissinger *et al.* 2010).

Dispersal and Migration

Breeding migration occurs in spring and appears synchronized with adults of both sexes arriving within a few days of each other, and coincides with rain and relatively warm weather (Richardson *et al.* 2000; Wissinger *et al.* 2010; Sarell pers. comm. 2011). Fall migrations, similar to spring migrations, are associated with rain; however, temperature has less of an impact on the timing in fall than in spring (Patch and Stewart 1934; Richardson *et al.* 2000). Migrations of recently metamorphosed individuals are commonly reported in the Prairies during mid-late August (Didiuk pers. comm. 2011; Kendall pers. comm. 2011; Vanderschuit pers. comm. 2011).

In British Columbia, radio-tagged adults rarely moved more than 250 m from the wetland of capture, and their movements appeared unaffected by agricultural land use in the surrounding landscape (Richardson *et al.* 2000; Steen *et al.* 2006). Daily movements were generally constrained within a 5 m-radius and were often centred on abandoned animal burrows (Richardson *et al.* 2000). Anecdotal reports exist of salamanders found up to 3 km from the nearest wetland (Sarell and Robertson 1994). Mark-recapture studies in the US indicate that juveniles are more likely to disperse than are adults (up to 20% of juveniles versus 3-6% of adults moving between wetlands in any given year; Church and Wilbur, unpubl. data cited in Church *et al.* 2007). Denoel *et al.* (2007) reported inter-pond dispersal rates of 40% for adult *A. m. nebulosum* between years for a series of 8 ponds where the maximum distance between ponds was 100 m. In Yellowstone National Park, rivers and open habitats facilitated gene flow, whereas elevation and distance to nearest wetland (mean 21.8 km, range 0.5 to 53 km from n = 10 ponds) reduced gene exchange based on microsatellite analysis (Spear *et al.* 2005; McMenamin and Hadly 2010).

Interspecific Interactions

Tiger salamanders are opportunistic predators, and in some studies their stomach contents matched the diversity of pond invertebrates sampled with aquatic nets (Wissinger *et al.* 1999). However, in other studies larvae showed preferences for certain taxa (Leff and Bachman 1986; Zerba and Collins 1992). Diets of larval tiger salamanders vary by site but consist mainly of aquatic invertebrates such as dipterans, ostracods, gastropods, odonates and other zoobenthos like mayfly larvae (Holomuzki *et al.* 1994; Johnson *et al.* 2003; Benoy 2008). Diets may include larger prey, such as larval anurans (Loeb *et al.* 1994), larger macroinvertebrates (Alperyn 2005; Benoy 2005, 2008), and other salamander larvae including other tiger salamanders.

Tiger salamander larvae and adults are described as voracious predators of amphibians (Ferrari and Chivers 2008, 2009) and other prey in aquatic habitats (Benoy 2005, 2008). Neotenic individuals show divergence in diet from metamorphic adults during the breeding season (Denoel *et al.* 2007). In fishless ponds, larvae may function as top predators, assuming the role usually taken by large predatory fish (Zaret 1980): they reduce the invertebrate abundance, thereby increasing phytoplankton (Holomuzki *et al.* 1994). Larvae have been shown to decrease the density of several invertebrate taxa and may compete with dabbling ducks in fishless prairie pothole wetlands (Benoy *et al.* 2002; Benoy 2005). Whereas larval salamander density was positively correlated with diving duck occurrence, it was negatively correlated with dabbling duck distribution within and among wetlands (Benoy *et al.* 2002). In addition, there is a high degree of overlap among diets of the Western Tiger Salamander and introduced fish species such as Rainbow Trout (Olenick and Gee 1981). Tiger salamanders have been known to interfere with fish rearing operations in dugouts through competition for food, reducing fish growth (Schock 2001).

Larval tiger salamanders respond to predatory invertebrates with reduced activity and show reduced weight and increased tail fin depth (Storfer and White 2004). Increased tail fin depth provides for a rapid escape response to natural predators over short distances (Fitzpatrick *et al.* 2003). Natural predators include sit-and-wait invertebrate predators such as dragonfly larvae, dytiscid diving beetles, and giant water bugs (*Belostomatidae*) (Fitzpatrick *et al.* 2003). Transient predators that may have large impacts on larval populations include pelicans, herons, and cranes. The introduction of predatory fish represents a largely novel predator to the naturally fishless systems that Western Tiger Salamanders inhabit. Rapid escape responses by salamander larvae are not effective for avoiding active predators such as fish (i.e., trout and bass), which may make salamanders extremely vulnerable to fish introductions (Semlitsch 1987; Sepulveda and Lowe 2011).

Western Tiger Salamanders appear to be associated with the presence of burrowing small mammals. In British Columbia the distribution of salamanders has been suggested to reflect the presence of Northern Pocket Gophers (*Thomomys talpoides*) (Sarell pers. comm. 2011). Eradication of ground squirrels and pocket gophers on agricultural lands may ultimately limit the dispersal and overwintering sites available to salamanders in local areas (Kendall pers. comm. 2011; Sarell pers. comm. 2011).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Few studies have attempted to assess abundance of Western Tiger Salamanders in Canada. Two studies were conducted near Crow’s Nest Pass, Alberta by Cam Goater and in the vicinity of White Lake, British Columbia by John Richardson and colleagues. Most studies have noted only the presence of the species or have sampled tiger salamanders for disease agents without assessment of population density (Schock *et al.* 2009).

The most common methods of detecting the presence of Western Tiger Salamanders are the use of beach seining or terrestrial drift-fence arrays with pitfall traps. Other methods include minnow traps and other aquatic funnel traps, which commonly capture larvae and occasionally adult salamanders. Dip netting has proven to be inefficient at capturing or assessing the density of tiger salamanders (Donald pers. comm. 2011). Nightly road surveys are commonly employed in B.C. (Sarell pers. comm. 2011).

The only information on recent trends of the relative number of individuals comes from road mortality surveys in British Columbia (Crosby, unpubl. data; Sarell pers. comm. 2011). Few studies involving Western Tiger Salamanders in Canada have been long enough to identify trends in population size as most are rarely longer than 2 years (Richardson *et al.* 2000 and unpubl. data). Occasional short-term studies for other amphibians have recorded the relative abundance or occurrence of tiger salamanders (Puchniak 2002; Eaves 2004; Pagnucco 2010).

Abundance

The abundance of Western Tiger Salamanders in Alberta, Saskatchewan, and Manitoba is unknown. There is no formal database in either Saskatchewan or Manitoba that tracks occurrence records for the species, but changes to reporting and tracking are underway in both provinces (Keith pers. comm. 2011).

In British Columbia, adults at breeding ponds may number in the hundreds in good years, but the numbers can drop to well below 100 adults inter-annually, as estimated from pitfall trapping and partial drift fence arrays around ponds (Richardson *et al.* 2000 and unpublished data for 5 breeding sites in the White Lake area, trapped for 2 years in spring and 3 years in fall). The number of juveniles emerging from the ponds varied widely among sites and years, ranging from 7200 to 200 animals.

The BC CDC (2012) postulates that there are from 2,500 to 10,000 adults within the Southern Mountain population of British Columbia, but no accurate estimates are available. Assuming that there are 86 breeding sites and if each site supports 100 adults, the total population size could be roughly 8,600 adults. However, the numbers may be greater following wet years conducive to breeding; they could drop well below this value in years following prolonged multi-year droughts that can greatly reduce the breeding population size due to lack of recruits from sites that dry up before development is complete and produce no young.

Population Trends

In Saskatchewan and Manitoba, there are no studies or processes to document changes in abundance or trends in tiger salamander populations. In southern Alberta, unsuccessful searches for larvae in water bodies near Lethbridge suggest that formerly occupied sites no longer contain salamanders (Goater pers. comm. 2011). The species occurs at only one of 7 RANA monitoring sites in Alberta, at Cypress Hills, where amphibians have been monitored from 1998 – 2006. The population may be declining, but small and fluctuating numbers of adults complicate discerning trends. The long history (since early 1900s) and widespread practice of fish stocking throughout the prairies suggest that salamander populations may have similarly declined in Manitoba. Other factors contributing to possible declines may be the emergence of *Ambystoma tigrinum* virus, which can cause localized mass mortalities.

In British Columbia, populations are becoming increasingly limited to temporary wetlands as water bodies that retain water year-round are now inhabited by introduced fish (stocked trout and Large and Smallmouth Bass; BC CDC 2012). Sites where salamanders may have persisted after trout introduction are likely to be lost after the introduction of bass (Sarell pers. comm. 2011). Goldfish (*Crassius crassius*) have been introduced into some water bodies not suited to fish stocking, and anecdotal evidence suggest they have limited or eliminated salamander recruitment within those water bodies (Ashpole pers. comm. 2011). Ashpole *et al*. (2011) reported the disappearance of tiger salamanders from a breeding pond monitored from 2003 – 2005, after 2003 for unknown reasons, which may include pollutant run-off from surrounding agricultural area, introduction of Goldfish, or disease.

Occasional mass die-offs of larval Western Tiger Salamanders occur due to pond drying. The recent droughts in British Columbia and Washington have resulted in lack of normal seasonal filling of wetlands where salamanders were previously found (Dyer pers. comm. 2011; Hallock pers. comm. 2011; Sarell pers. comm. 2011). In some cases, there are more permanent water bodies nearby, but they either contain native or introduced predaceous fish (trout, bass), which limit populations and may prevent recovery. Current predictions of climate change indicate reduced precipitation in the prairie and parkland regions of Alberta and Saskatchewan (Hogg and Hurdle 1995; Frelich and Reich 2010), which could result in further breeding habitat loss for Western Tiger Salamanders and consequent population declines.

In British Columbia, only a few (1-3) occurrences are ranked as having good viability (BC CDC 2006). Although formal population viability analysis has not been conducted, there are virtually no populations that are not impacted by predatory fish, traffic mortality, or water levels that are so low that extended periods of drought prevent reproduction (BC CDC 2012). White Lake where tiger salamanders were studied in the late 1990s has been consistently dry since 2000 (Dyer per. comm. 2012).

Population Fluctuations

Pond-breeding amphibians often fluctuate greatly in abundance from year to year or on multi-year basis (Green 2003). Western Tiger Salamander populations are expected to fluctuate in size similar to tiger salamander populations in other areas (Pechmann *et al.* 1991; Semlitsch *et al.* 1996; Trenham *et al.* 2000), but there are no long-term studies of this species from Canada. Fluctuations in the number of larvae emerging from wetlands are notable but may be a poor indicator of adult population size (Semlitsch 1983). Richardson *et al.* (unpubl. data) found that the tiger salamander population from White Lake, British Columbia, decreased from 259 adult salamanders in one year to 98 the following year; there was a complete reproductive failure in the 3 subsequent years due to dry conditions. Such fluctuations in breeding population size may at least partially reflect reduced breeding activity in some years in response to unsuitable conditions, rather than true fluctuations in adult numbers. However, the resulting pulsed breeding pattern is expected to contribute to fluctuations in adult numbers, as the number of recruits to the adult population will vary on a multi-annual basis. Observed patterns of periodic low water tables may be the result of oscillating cycles in weather patterns such as the Pacific Decadal Oscillations or El Niño – Southern Oscillation, in which case tiger salamander populations that depend on wetlands may show corresponding long-term patterns in population size (Richardson 2002). Given that there can be a complete failure of reproduction in drought years and that multi-year droughts associated with pond-drying appear to be and are predicted to become more frequent in the arid environments inhabited by the salamanders, fluctuations in salamander population size are expected occur simultaneously over relatively large areas. The synchronicity of fluctuations may be particularly applicable for the Southern Mountain population, which occupies a relatively small geographic area that is subject to similar weather patterns.

Fluctuations from a low of 200 to 3,000 individuals (all life stages combined) over a 20-year period were observed for *A. m. nebulosum* at a site in Colorado (Wissinger *et al.* 2010). Adult neotenic individuals increased from 200 to nearly 1400 individuals in one year, but declines in the same population were rarely above 50%. A population of *A. tigrinum* in South Carolina has been observed to vary by as much as an order of magnitude over a 12-year period (Pechmann *et al.* 1991; Semlitsch *et al.* 1996). At one California Tiger Salamander (*A. californiense*) breeding site, adult female numbers varied by an order of magnitude (16-140; Trenham *et al.* 2000) and a similar pattern was observed at another site 200 km to the north (Loredo and Van Vuren 1996). Whether these results apply to Western Tiger Salamanders and Canadian populations is unknown.

Fragmentation of Populations

Severe fragmentation for the Southern Mountain population can be inferred from a) natural fragmentation of habitats and availability of suitable breeding sites; b) exacerbation of this fragmentation by human developments and activities, including roads, throughout the species' distribution in British Columbia, and particularly within the core area in South Okanagan; c) questionable viability of populations at most breeding sites due to threats from introduced fish, roads, and/or low water levels. In British Columbia, most of the known 86 breeding sites are within fragmented habitats, and most breeding sites are within the South Okanagan, where habitats continue to be lost and fragmented at a rapid pace. All breeding sites are within 700 m of a primary or secondary roadway, and successful migration between aquatic and terrestrial habitats may be hindered by the number of roads and developments in the upland habitat. Comparing the average nearest distance between any two breeding sites, there is 5.2 km between wetlands (range 131 m to 10.2 km). These distances exceed the typical between-site movements by Western Tiger Salamanders (see **Dispersal and Migration**). Not only are breeding sites far apart from each other, but they are also interspersed by water bodies that contain predacious fish and increasingly urbanized or agricultural areas. The viability of individual populations is unknown, but many populations are suspected to be small and declining. BC CDC assessed that only 1-3 of 48 breeding sites that had been mapped contained populations with good viability; this assessment was based on habitat condition following NatureServe Element of Occurrence Rank Assessment methodology (Gelling pers. comm. 2012). Although the assessment included only approximately one half of the known 86 sites, it is unlikely that there would now be more than 40 breeding sites (50%) with good viability considering continuing threats from roads, reduced water levels, fish and other sources. With predicted increase in droughts and drying up of breeding sites over periods of multiple years, a phenomenon that is already occurring, the persistence of local populations is expected to be perilous. For example, White Lake, a partially protected area where a population of tiger salamanders was studied in the late 1990s (Richardson *et al*. 2000), has been consistently dry for the past 10 years (Dyer pers. comm. 2012).

Populations within the Prairie / Boreal Tiger Salamander population may also be fragmented, but there is much uncertainty due to information gaps on the distribution and abundance of the species there. Because of the large area where the salamanders occur, multi-year fluctuations are unlikely to be synchronous across the entire distribution.

Rescue Effect

Dispersal of tiger salamanders from U.S. populations into southern British Columbia is possible, but the likelihood is low. The possibility of rescue from the US depends on salamanders dispersing longer than normal distances across dry mountainous terrain. The nearest known US population is 17 km SW of Oroville in Washington State, a distance greater than 20 km from the nearest Canadian population. The presence of the Oroville population was last confirmed in 1999 (Hallock pers. comm. 2011). There is no possibility of rescue of the Southern Mountain population from the Prairie / Boreal population. The two populations are separated by the Rocky Mountains and several hundred kilometres of inhospitable rocky terrain.

Connectivity is likely among populations in the Prairie provinces and those in adjacent areas in the U.S. However, poor knowledge of the status of tiger salamander populations on both sides of the border precludes an accurate evaluation of the potential for rescue.

THREATS AND LIMITING FACTORS

Western Tiger Salamanders face the same pressures and threats as other amphibians with biphasic life-histories and separate requirements for terrestrial adults and for aquatic developmental phases and include habitat loss and fragmentation. The IUCN Threats Calculator was applied to the Southern Mountain population and Prairie / Boreal population of the Western Tiger Salamander during separate conference calls that included species experts and the report writer, as well representatives from the B.C. government familiar with the species and with habitat trends within the range of the Southern Mountain population. The calculated overall threat impact was “very high – high” for both populations (Appendix 1 and 2). For the Southern Mountain population, “Transportation and Service Corridors”, mainly “Roads and Railroads”, were identified as the highest threat, whereas for the Prairie / Boreal population, “Natural System Modification”, mainly “Dams and Water Management”, was identified as the greatest threat. The main threats are discussed below.

Habitat Loss, Conversion and Fragmentation

Habitat change and wetland infilling continue to affect local populations throughout the Western Tiger Salamander’s range. Infilling of breeding ponds is particularly detrimental and can result in rapid loss of local populations. In developed landscapes, upland migration routes of salamanders can be disrupted and terrestrial refuge sites eliminated or degraded. In agricultural and range lands, soil compaction and the eradication of small burrowing mammals (*Thomomys* and *Spermophilus* species) can reduce terrestrial refuge and overwintering sites for salamanders (Ashpole pers. comm. 2011).

For the Southern Mountain population, conversion of land to housing, orchards, and vineyards is widespread and continues to degrade salamander habitats (Southern Interior Reptile and Amphibian Recovery Team 2008). Increase in urbanization is most notable in the Okanagan Valley, where populations occur in close proximity to human habitation and roadways. Salamanders may persist or continue to migrate through urban environments, but can become trapped within urban dwellings (sump pumps and basement) or fall into pools and hence be lost from the breeding pool (Ashpole pers. comm. 2011).

Within the range of the Prairie / Boreal population, mainly in Alberta and to a lesser extent in Saskatchewan and Manitoba, there has been a change from grazing and small farms to increased large-scale farming and conversion of habitat to accommodate growing urban populations and expansion of oil and gas developments (Rashford *et al.* 2011; Statistics Canada 2012). Continued infilling of wetlands throughout the species' range (Dahl and Watmough 2007; Bartzen *et al.* 2010) is expected to increase fragmentation of regional populations and increase isolation of small populations, thereby limiting their long-term persistence (Trenham and Shaffer 2005). Water management and use occurs throughout the species' range in the prairies, as every type of agriculture requires water management. Some impacts may be positive (digging of ponds) but most are probably negative, resulting from changes to hydro-periods at breeding sites and disturbance to the shoreline habitat. Tiger salamanders continue to persist in some urban environments (e.g., near Edmonton: Paszkowski pers. comm. 2011), but long-term viability of these populations is unknown.

Road Mortality

Western Tiger Salamanders are susceptible to road kill where roads intersect migration routes to and from breeding sites. Reductions in amphibian populations are correlated with increasing traffic volume (Fahrig *et al.* 1995; Clevenger *et al.* 2003 specifically for *A. m. melanostictum*). Installation of culverts or other underpasses can be effective in alleviating road mortality (Pagnucco *et al.* 2011), but salamander mortality on the vast majority of roads is unmitigated.

Within the Southern Mountain population, all known Western Tiger Salamander breeding sites are within 750 m of roads (based calculations from TRIM maps by Orville Dyer, B.C. Ministry of Natural Resource Operations). Recent expansion of Highway 97 to 4 lanes (Transport Canada 2012) to accommodate growing human populations and vineyard visitors has increased traffic volumes and roadkill threat to migrating salamanders. Traffic volumes in the South Okanagan along Highway 97 record a range of 6000-24,000 vehicles per day between April and September when tiger salamanders are active (4-16 vehicles per minute; B.C. Ministry of Transportation and Highways 2012). Mortality on B.C. roads has been documented by biologists (Richardson *et al.* 1998; Ashpole pers. comm. 2012; Sarell, unpubl. data). Richardson *et al.* (1998) reported 50 road mortalities in one day near a breeding site. Recent (2010-2011) surveys along a stretch of road near Oliver, B.C. also found high mortality rates (Crosby, unpubl. data). It is unclear how many salamanders attempted to cross the road.

Within the Prairie / Boreal population, road mortality may not be as great a threat as in British Columbia due to the widespread distribution of salamanders, combined with reduced traffic densities away from urban centres. However, there has been an increase in rural traffic in Saskatchewan, combined with an increase in industrial and rural development, as larger populations are now residing outside of urban areas. Road traffic in Saskatchewan has increased on average 16%, from 2006 to 2011 across the range of the salamanders (Saskatchewan Ministry of Highways and Infrastructure 2013a,b). A large number of citizens have reported mass migrations of tiger salamanders across roads and highways in fall in the Prairies (Didiuk pers. comm. 2011; Kendall pers. comm. 2011; Vanderschuit pers. comm. 2011), but no efforts have been made to quantify the losses and their significance to populations. The only well documented record of road mortalities is adjacent to Banff National Park, near Seebe on the TransCanada Hwy, where 183 Western Tiger Salamander were found dead within a 300 m section of the road, 163 of which occurred over a 4-day period in August (Clevenger *et al.* 2001).

Introduced Species: Fish

Ambystomatid salamanders do not coexist well with predatory fish such as trout and have poor anti-predator abilities towards fish predators (Kats *et al.* 1988; Tyler *et al.* 1998; Sih *et al.* 2003; Dunham *et al.* 2004). Introduced sport fish prey on both adult and larval tiger salamanders. Tiger salamander larvae are adapted for rapid acceleration rather than sustained swimming (Hoff *et al.* 1989), a behaviour effective against common sit-and-wait predators such as giant water bugs (Hemiptera: Belostomatidae), dragonfly nymphs (Odonata: Anisoptera), and predaceous diving beetle larvae (Choleoptera: Dytiscidae) (Fitzpatrick *et al.* 2003).

Many formerly fishless water bodies, including reservoirs, have been stocked with fish throughout the Western Tiger Salamander's range. Introductions of sport fish, mosquito fish (*Gambusia* sp.), and other small bodied, non-native fish into tiger salamanders habitats or nearby larger water bodies, from where they can spread, all pose risks. Introductions of Green Sunfish (*Lepomis cyanellus*) have directly caused local extinction of *A. m. stebbinsi* in the U.S. (Storfer *et al.* 2004). Mosquitofish consumed more *A. tigrinum* larvae compared to the consumption of anuran larvae present (except *Pseudacris triseriata*) in laboratory experiments (Zeiber *et al.* 2008). Genetic evidence of recent and historical declines of tiger salamanders due to fish stocking (mainly trout), combined with drought and potentially disease, was reported in Yellowstone National Park in Montana and Wyoming (Spear *et al.* 2006).

Within the range of the Southern Mountain population, sport fish stocking is widespread, and all water bodies that can support fish do or will eventually have fish (Southern Interior Reptile and Amphibian Recovery Team 2008; Herborg pers. comm. 2012). Introduction of trout and bass (*Micropterus dolomieu* and *M. salmoides*) are inferred to have reduced or extirpated several salamander populations in the Okanagan Valley (Sarell 1996 and pers. comm. 2011).

Introduction of Goldfish (*Crassius crassius*) in small water bodies has been practised in southern British Columbia to control mosquito populations as part of pro-active West Nile Virus mitigation. Other species of fish, including non-native Pumpkinseed (*Lepomis gibbosus*), Yellow Perch (*Perca flavescens*), and native shiners (*Richardsonius* spp.) and sculpins (*Cottus* spp.) have been introduced to formerly fishless small lakes and ponds in this province. Introductions into formerly fishless waters are likely to reduce the persistence of salamander populations (Sarell 1996; Monello and Wright 2001; Ashpole *et al.* 2011).

In the Prairies, there has also been widespread introduction of sport fish throughout the range of the Western Tiger Salamander (Figure 6). In Alberta, fish stocking is ongoing and continues to expand within the foothills region. Tyrell Lake in Alberta used to be known for its large population of tiger salamanders, including neotenic forms. After the introduction of Rainbow Trout in 1962, this population declined. In October 1962, 250 kg of salamanders were caught in one day, but only one salamander was caught in 1973 and a few in 1988 (Mitchell and Prepas 1990). Rainbow Trout continue to be stocked (last stocked with 450,000 fingerlings in April 2009; Alberta Fisheries Management Information System 2009). Salamanders remain at low densities in Tyrell Lake (Goater pers. comm. 2011).

Introduced Species: Bullfrogs

American Bullfrogs (*Lithobates catesbeianus*) have been introduced to the Southern Okanagan. Although tiger salamanders may consume Bullfrog tadpoles in laboratory experiments (McIntyre and McCollum 2000), adult Bullfrogs are a threat to Western Tiger Salamanders and other amphibians throughout their introduced range (Dumas 1966; Kiesecker and Blaustein 1997; Boone *et al.* 2004). Bullfrogs have a voracious appetite, are capable of laying up to 20,000 eggs in a clutch (Schwalbe and Rosen 1999), and unlike tiger salamanders are capable of coexisting with predatory fish (Hecnar 1997; Adams *et al.* 2003). Individual Bullfrogs are capable of dispersal distances up to 7-8 km (Schwalbe and Rosen 1999), and their breeding pond habitat preferences are similar to those of tiger salamanders in that both species require water bodies with relatively long hydro-periods required for larval development.

Bullfrog control is ongoing in the Okanagan, but eradication is extremely difficult, and Bullfrogs remain at low densities at some sites (Ashpole pers. comm. 2011). There is little direct evidence that Bullfrogs have contributed to the decline of tiger salamander populations in British Columbia (Southern Interior Reptile and Amphibian Recovery Team 2008). However, it is possible that Bullfrogs will become more widespread, adding to threats from introduced fish, road mortality, and habitat loss. Bullfrogs may also act as a reservoir host of amphibian chytrid fungus, which can cause disease and result in catastrophic declines (Daszak *et al.* 2004; Pearl *et al.* 2007).

Bullfrogs are not currently a threat for the Prairie / Boreal population.

Agriculture and Chemical Contaminants

Chemical contaminants (herbicides, pesticides and fertilizers) directly or indirectly affect all life stages of Western Tiger Salamanders (Bishop 1992; Larson *et al.* 1998; Bishop *et al.* 1999; Pauli *et al.* 2000; Griffis-Kyle and Ritchie 2007). The use of glyphosate-based herbicides in conjunction with different surfactants reduces the growth and survival of larval *A. tigrinum* (Brodman *et al.* 2010). Organophosphate insecticides (Malathion®) can reduce larval growth, although they may not result in direct mortality (Ramsey *et al.* 2008). Fertilizers do not directly reduce survival of salamander larvae (Griffis-Kyle 2005, 2007; Griffis-Kyle and Ritchie 2007), but indirect effects are of concern.

Mixtures of chemicals may combine synergistically and alter immune function. A study comparing the susceptibility of *A. tigrinum* to the *Ambystoma tigrinum* virus found that larvae exposed to a herbicide (Atrazine®) were more likely to contract and die of infections (Forson and Storfer 2006a,b) than were unexposed larvae. In contrast, an insecticide (Deltamethrin®), which on its own can cause acute toxicity in *A. tigrinum*, triggered no immunosuppression based on assays (Froese *et al.* 2009), but the study did not expose animals to live viral cultures.

Within the range of the Southern Mountain population, the use of chemicals in fruit farming continues to be of concern to salamander and other amphibian populations (Bishop 1992). Malathion® is the recommended pesticide for the control of mosquito populations to reduce the threat of West Nile Virus to humans. Malathion® has also been cleared for use to control the Spotted Wing Drosophila (*Drosophila suzukii*), an introduced pest that lays eggs in ripening fruit (United Agri Products 2010; B.C. Ministry of Agriculture 2011). Private landowners may apply Malathion® without a licence (Mullan pers. comm. 2012). Given the importance of agriculture within the species' range, the risk of chemical contaminants in salamander breeding sites is high.

The range of the Prairie / Boreal population overlaps with the main grain growing area of western Canada. The use of chemicals to augment crop production is of concern to salamander populations nearby crops. In urban wetlands, the use of pesticides, such as Malathion®, to control mosquitoes poses a risk to salamander populations.

Disease

Emerging infectious diseases have been implicated in the decline of amphibian populations worldwide (Daszak *et al*. 1999). Two diseases in particular pose threats to Western Tiger Salamanders: *Ambystoma tigrinum* virus (ATV) and amphibian chytrid fungus (*Batracochytridium dendrobatidis* or *Bd*). ATV, a ranavirus, is part of a group of closely related viruses belonging to the group Iridoviridae that infect many fishes and amphibians (Jancovitch *et al.* 2001). ATV has been identified as the causative agent in localized mass mortality events of Western Tiger Salamanders in Saskatchewan, Manitoba, and Alberta (Bollinger *et al.* 1999; Schock *et al.* 2009; Goater pers. comm. 2011) and in neighbouring U.S. states (Docherty *et al.* 2003). It was responsible for a mass die-off during the summer of 2011 in Waterton Lake National Park (Johnston pers. comm. 2011). The prevalence of ATV at any site in Alberta, Manitoba and Saskatchewan is high (up to 50%) in most populations examined in any given year (Goater pers. comm. 2011; Schock pers. comm. 2011).

Observations of mortality due to ATV are sporadic. Models of infection suggest that ATV spread increases with salamander density, but frequency-dependent mechanisms (including repeated exposure from surviving metamorphs) can maintain the virus within the environment even at low salamander densities (Brunner *et al.* 2004). Transmission of ATV in the water appears to involve close proximity of salamanders (Jancovitch *et al.* 2001; Brunner *et al.* 2007). Transmission may occur through consumption of dead infected salamanders, scavenging, or aggressive behaviours (cannibalism, nipping and biting) (Pearman *et al.* 2004; Brunner *et al.* 2005; Harp and Petranka 2006). The virus can be stored in substrates and may remain infectious in water for > 97 days (reviewed by Whittington *et al.* 2010). Host switching may be important for maintaining the virus in the system (in frogs: Schock *et al.* 2008; in fish: Jancovitch *et al.* 2005; Picco and Collins 2008; Picco *et al.* 2010). ATV may reside in persistent carriers such as metamorphosed amphibians that overwinter with the infection and then re-infect the population the following spring (Brunner *et al.* 2004). Individuals that do not die from infections within the first 2-3 weeks of exposure show reduced growth, which may prolong development and decrease the chance of surviving to metamorphosis as the pond dries (Parris *et al.* 2005). Western Tiger Salamanders may be particularly susceptible to the spread of ATV given low genetic diversity present at some sites (Spear *et al.* 2006; McMenamin and Hadly 2010) and the positive correlation between lack of genetic variability and increased susceptibility to disease (Pearman and Garner 2005).

The prevalence of ATV within the Western Tiger Salamander's range in British Columbia has not been assessed (Ashpole pers. comm. 2011), but its presence is probable given its widespread distribution in the prairies and in montane regions of the U.S. (Spear *et al.* 2006). Reports of mass mortalities due to ATV are numerous in Alberta and in parts of Saskatchewan and Manitoba where it has been investigated. Populations generally contain ~50% of individuals that test positive for the virus but show no mortality or morbidity except in apparently random years (Schock *et al.* 2010; Goater pers. comm. 2011). Other stress factors may be involved in disease outbreaks.

A second disease agent which may cause population declines is the amphibian chytrid fungus, *Bd*, which is linked to amphibian declines worldwide (Daszak *et al*. 1999; Schloegel *et al.* 2006). *Bd* is capable of infecting tiger salamanders (Davidson *et al.* 2003) and has been implicated in mortality events in Saskatchewan and Manitoba (Bollinger *et al.* 1999). However, the putative role of *Bd* in these declines is unclear in light of the prevalence of ATV in the region (Schock *et al.* 2010).

Bd is widespread in various species of amphibians in British Columbia (Deguise and Richardson 2009; Voordouw *et al.* 2010), but data for tiger salamanders are lacking. A recent survey of the occurrence and prevalence of *Bd* in Alberta found that it occurred at 44% of sites (*n* = 92 sites) across the province with a prevalence of 22% of individual amphibians at each site; however, no tiger salamanders (n = 3) were positive for *Bd* (Stevens *et al.* 2012). There is currently no evidence of chytrid-associated population declines in Alberta. *Bd* has also been reported from Saskatchewan, but no province-wide study has been completed (Canadian Cooperative Wildlife Health Centre 2011). The main disease threat is more likely to be ATV as there are few reports of *Bd* in Western Tiger Salamanders (Bollinger pers. comm. 2011).

The practice of using tiger salamander larvae as bait for fishing in some areas may facilitate the spread of ATV (Jancovitch *et al*. 2010) and *Bd* among watersheds. In B.C., live bait is not allowed. In some areas, including Manitoba and Alberta, collection of salamanders for personal use is legal. In Alberta live bait can be collected for personal use in fishing but has to be used within that site and not moved to another lake.

Number of Locations

Southern Mountain population:

The greatest new threat to the salamanders in the Okanagan is introduced Bullfrogs, which could invade lakes and wetlands where salamanders occur. Based on the potential rate of spread of Bullfrogs and considering the likelihood of their establishment with respect to the topography of the area, it is estimated that Bullfrogs account for 1 location in the Okanagan and other threats account for 13 locations within the remaining part of the range of the Southern Mountain population; therefore there are 14 threat-based locations for this population.

Bullfrogs are already established in the South Okanagan and could spread into the Osoyoos area, even if unassisted by humans. This area is counted as 1 location, based on Bullfrog threat. Given the topography and a greater distance requiring dispersal, Bullfrogs are unlikely to reach the lower Similkameen or Kettle rivers within the next 15 - 20 years without human aid. Disease or habitat destruction/alteration are considered most important threats at 4 locations near Grand Forks and at 9 locations along the Kettle River west of Midway. Introduced predatory fish will impact individual subpopulations where fish have been or will be introduced, but introductions may also spread into entire watersheds and into separated but adjacent ponds during flooding events.

Prairie / Boreal population:

There are 597 known sites. This is a conservative estimate due to limited surveys and occurrence information. The greatest threats are disease, fish stocking, and habitat loss due to urban, agricultural and industrial development. These threats are likely to have their greatest impact at the local population or site level, and therefore the estimated number of IUCN threat-based locations is large, probably over 500.

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

The Southern Mountain population of the Western Tiger Salamander is listed federally as Endangered in Canada and is in Schedule 1 of the *Species at Risk Act*. The British Columbia *Wildlife Act* affords protection such that the tiger salamander cannot be killed, collected, or held in captivity without special permits.

The Prairie / Boreal population has no legal federal status, based on the previous assessment of tiger salamanders and their designation as Not at Risk by COSEWIC in 2004. This assessment included the taxon now known as Eastern Tiger Salamander, *A. tigrinum*, from Manitoba. The Prairie / Boreal population as defined in this report has not been previously assessed by COSEWIC as a separate entity.

Non-Legal Status and Ranks

The Canadian Endangered Species Conservation Council lists the Western Tiger Salamander as Secure in Alberta, Saskatchewan, and Manitoba and At Risk in British Columbia (CESCC 2011). NatureServe (2011) lists *A. mavortium* (Barred Tiger Salamander) as G5 (secure) globally, N5 (secure) nationally in Canada and in the U.S., S4S5 (apparently secure to secure) in Manitoba, and S2 (imperiled) in British Columbia, where the species is also on the provincial Red List of species at risk. NatureServe (2011) lists the species as *A. tigrinum* (Tiger Salamander) with a rank of S4 (apparently secure) in Alberta and with a rank of S5 (secure) in Saskatchewan.

In the U.S. adjacent to Canada, NatureServe (2011) lists this species as *A. tigrinum* (Tiger Salamander) with a rank of S5 in Idaho, S4 in Montana, and S3 in Washington State, where the species is also a “State Monitor” species (Washington Herp Atlas 2011).

Habitat Protection and Ownership

In British Columbia, 14 breeding sites (16.2% of 86 known sites) are within protected areas in parks (9 sites) or in Wildlife Habitat Areas on Crown land (5 sites). An additional 23 sites (26.7%) receive or are expected to receive some form of protection through voluntary stewardship agreements. There are no known breeding sites in the large South Okanagan Wildlife Management Area, probably due primarily to the invasion/introduction of predatory fish. Important protected sites include South Okanagan Grasslands Provincial Park, White Lake Grasslands Provincial Park, and the Kilpoola property acquired by The Nature Trust of B.C. A few wetlands occupied by Western Tiger Salamanders occur on Ducks Unlimited property, with additional small wetlands being constructed (Ashpole pers. comm. 2011). There are only two protected sites in the Kettle Watershed and none in the Similkameen or at the northern edge of the species’ range around Summerland (BC CDC 2012). The remaining 57% of known breeding sites occur on unprotected private lands (BC CDC 2012). The Southern Interior Amphibian and Reptiles Recovery Team is attempting to build support for habitat protection by stakeholders and the public to secure both aquatic and terrestrial habitat within the core of the species’ distribution.

In Alberta, Saskatchewan and Manitoba, there are no areas set aside for Western Tiger Salamanders, but they are found within nature preserves, natural areas including Nature Conservancy of Canada properties, provincial and national parks, and other types of Crown land in all three provinces. There are 188 sites (22%) within protected lands in Alberta, 21 sites (6.4%) in Saskatchewan, and 13 sites (8%) in Manitoba. Within those areas, the salamanders are afforded some form of protection through relevant provincial or federal wildlife or protected areas legislation (e.g. Alberta *Parks Act* 45.1 and the *Canada National Parks Act*). Outside these areas, they are not afforded any special protection.

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INFORMATION SOURCES

Adams, M.J., C.A. Pearl, and R.B. Bury. 2003. Indirect facilitation of an anuran invasion by non-native fishes. Ecology Letters 6:343-351.

Agriculture and Agri-Food Canada. 2012. Drought watch. Web site: http://www.agr.gc.ca/pfra/drought/mapscc_e.htm [accessed March 15, 2012].

Alberta Biodiversity Monitoring Institute. 2008. Program Overview. Alberta Biodiversity Monitoring Institute, Alberta. Web site: www.abmi.ca [accessed Sept 12, 2011].

[Alberta FWMIS] Alberta Fish and Wildlife Management Information Service. 2011. Database of Tiger salamander occurrence records. [accessed Sept 2011].

Alberta Fisheries Management Information System. 2009. Stocking report 2009. Website: http://www.mywildalberta.com/Fishing/documents/Fish-Stocking-Report-2009.pdf [accessed March 2012].

Alperyn, M. 2005. Factors affecting the community ecology of predaceous diving beetles (Coleoptera: Dytiscidae) in boreal and prairie ponds across southern Manitoba. MSc. dissertation, University of Manitoba, Winnipeg, Manitoba, 144 pp.

Anderson, N., pers. comm. 2011. *Personal conversations with A. Whiting*. August 2011. Graduate Student, University of Alberta, Edmonton, Alberta.

Ashpole, S. pers. comm. and unpublished data. 2011 *Email and phone correspondence to A. Whiting*. August-September 2011. Ecologist, University of Waterloo, Ontario.

Ashpole, S.L., C.A. Bishop, and J.E. Elliott. 2011. Unexplained die-off of larval Barred Tiger Salamanders (*Ambystoma mavortium*) in an agricultural pond in the South Okanagan Valley, British Columbia, Canada. Northwestern Naturalist 92:221-224.

Bailey, L., W. Kendall, D. Church, and H. Wilbur. 2004. Estimating survival and breeding probability for pond-breeding amphibians: A modified robust design. Ecology 85(9):2456-2466.

Bartzen, B.A., K.W. Dufour, , R.G. Clark, , and F.D. Caswell. 2010. Trends in agricultural impact and recovery of wetlands in prairie Canada. Ecological Applications 20:525-538.

[BC CDC] B.C. Conservation Data Centre. 2006. BC Species and Ecosystems Explorer. B.C. Ministry of Environ. Victoria, B.C. Web site: http://a100.gov.bc.ca/pub/eswp/ [accessed Mar 11, 2012].

[BC CDC] B.C. Conservation Data Centre. 2012. BC Species and Ecosystems Explorer. B.C. Ministry of Environment, Victoria, British Columbia. Web site: http://a100.gov.bc.ca/pub/eswp/ [accessed Mar 11, 2012].

B.C. Ministry of Agriculture. 2011. Spotted Wing Drosophila (*Drosophila suzukii*), a new vinegar fly pest in British Columbia. Web site: http://www.agf.gov.bc.ca/cropprot/swd_brochure.pdf [accessed March 19, 2012].

[BC MOE] B.C. Ministry of Environment. 2010. British Columbia drought response plan. B.C. Ministry of Environment 36 pp.

B.C. Ministry of Environment, Lands and Parks. 1998. Habitat atlas for wildlife at risk: South Okanagan and Lower Similkameen. British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia.

B.C. Ministry of Transportation and Highways. 2012. Traffic data program. Web site: http://www.th.gov.bc.ca/trafficdata/tradas/ [accessed March 21, 2012].

[BC SPI] B.C. Species Inventory Database. 2011. BC Species Inventory Web Explorer. B. C. Ministry of Environment. Victoria, British Columbia. Web site: http://a100.gov.bc.ca/pub/siwe/search_reset.do [accessed Sept 19, 2011].

Benoy, G.A. 2005. Variation in tiger salamander density within prairie potholes affects aquatic bird foraging behaviour. Canadian Journal of Zoology 83(7):926-934.

Benoy, G.A. 2008. Tiger salamanders in prairie potholes: a 'fish in amphibian's garments?'. Wetlands 28(2):464-472.

Benoy, G., T. Nudds, and E. Dunlop. 2002. Patterns of habitat and invertebrate diet overlap between tiger salamanders and ducks in prairie potholes. Hydrobiologia 481(1-3):47-59.

Bishop, C.A. 1992. The effects of pesticides on amphibians and the implications for determining causes of declines in amphibian populations. Canadian Wildlife Service Occasional Paper 76:67−70.

Bishop, C., N. Mahony, J. Struger, P. Ng, and K. Pettit. 1999. Anuran development, density and diversity in relation to agricultural activity in the Holland River watershed, Ontario, Canada (1990-1992). Environmental Monitoring and Assessment 57(1):21-43.

Bishop, S.C. 1943. Handbook of salamanders. Comstock Publishing Company Inc., Ithaca, N.Y., pp. 159–174.

Bollinger, T., pers. comm. 2011. *Email correspondence with A. Whiting.* September 2011. Regional Director, Canadian Cooperative Wildlife Health Centre, Saskatoon, Saskatchewan.

Bollinger, T., J. Mao, D. Schock, R. Brigham, and V. Chinchar. 1999. Pathology, isolation, and preliminary molecular characterization of a novel iridovirus from tiger salamanders in Saskatchewan. Journal of Wildlife Diseases 35(3):413-429.

Boone, M.D., E.E. Little and R.D. Semlitsch. 2004. Overwintered bullfrog tadpoles negatively affect salamanders and anurans in native amphibian communities. Copeia 2004(3):683-690.

Bonsal, B.R., E.E. Wheaton, A.C. Chipanshi, C. Lin, D.J. Sauchyn, and L. Wen. 2011. Drought research in Canada: a review. Atmosphere-Ocean 49(4): 303-319.

Brodman, R., W. Newman, K. Laurie, S. Osterfeld, and N. Lenzo. 2010. Interaction of an aquatic herbicide and predatory salamander density on wetland communities. Journal of Herpetology 44(1):69-82.

Browne, C. 2010. Habitat use of the western toad in north-central Alberta and the influence of scale. Ph.D. dissertation, University of Alberta, Edmonton, AB, Canada. 264 pp.

Brunner, J.L., K. Richards, and J.P. Collins. 2005. Dose and host characteristics influence virulence of ranavirus infections. Oecologia 144(3):399-406.

Brunner, J., D. Schock, and J. Collins. 2007. Transmission dynamics of the amphibian ranavirus *Ambystoma tigrinum* virus. Diseases of Aquatic Organisms 77(2):87-95.

Brunner, J., D. Schock, E. Davidson, and J. Collins. 2004. Intraspecific reservoirs: Complex life history and the persistence of a lethal ranavirus. Ecology 85(2):560-566.

Brunton, D.F. 1998. Skin pigmentation change in tiger salamanders, *Ambystoma tigrinum*, from Alberta. Blue Jay 56(1):63-67.

Canadian Cooperative Wildlife Health Centre. 2011. Canada's national wildlife disease database. Web site: http://www.ccwhc.ca/ccwhc_database.php [accessed October 2011].

Cannings, S.G., L.R. Ramsay, D.F. Fraser, and M.A. Fraker. 1999. Rare amphibians, reptiles, and mammals of British Columbia. B.C. Ministry of Environment, Lands and Parks, Wildlife Branch and Resources Inventory Branch, Victoria, BC. 198 pp.

Carl, C.G., and C.G. Guiguet. 1958. Alien Animals in British Columbia. *In*: Klinkenberg, Brian. (Editor) 2011. E-Fauna BC: Electronic Atlas of the Fauna of British Columbia [www.efauna.bc.ca]. Lab for Advanced Spatial Analysis, Department of Geography, University of British Columbia, Vancouver. [accessed March 17, 2012].

[CESCC] Canadian Endangered Species Conservation Council. 2011. Wild Species 2010: The General Status of Species in Canada. National General Status Working Group. Web site: http://www.wildspecies.ca/reports.cfm [accessed September 23, 2011].

Church, D., L. Bailey, H. Wilbur, W. Kendall, and J. Hines. 2007. Iteroparity in the variable environment of the salamander *Ambystoma tigrinum*. Ecology 88(4):891-903.

Clevenger, A.P., B. Chruszcz, and K.E. Gunson. 2003. Spatial patterns and factors influencing small vertebrate fauna road-kill aggregations. Biological Conservation 109:15-26.

Clevenger, A., M. Mcivor, D. Mcivor, B. Chruszcz, and K. Gunson. 2001. Tiger Salamander, *Ambystoma tigrinum*, movements and mortality on the trans-Canada highway in southwestern Alberta. Canadian Field-Naturalist 115(2):199-204.

Collicutt, D., pers. comm. 2011. *Email correspondence to A. Whiting.* July and Sept 2011. Manitoba Herp Atlas, NatureNorth, Winnipeg, MB.

Collins, J., and J. Cheek. 1983. Effect of food and density on development of typical and cannibalistic salamander larvae in *Ambystoma tigrinum nebulosum*. American Zoologist 23(1):77-84.

Collins, J., K. Zerba, and M. Sredl. 1993. Shaping intraspecific variation - development, ecology and the evolution of morphology and life-history variation in tiger salamanders. Genetica 89(1-3):167-183.

Colorado State. 2012. A bill for an act: Concerning the designation of the Western Tiger Salamander as the state amphibian. House Bill 12-1147.

Cook, F.R. 1960. New localities for the Plains Spadefoot Toad, Tiger Salamander, and the Great Plains Toad in the Canadian prairies. Copeia 1960(4):363-364.

Cook F.R. Unpublished field observations in western provinces 1959-1970. Information provided as part of review of a draft of this report.

Cormie, G.W. 1975. An examination of neoteny in *Ambystoma tigrinum* of Tyrrell's Lake, Alberta. M.Sc. dissertation, University of Alberta, Edmonton, AB, Canada.

Cosentino, B.J., R.L. Schooley, and C.A. Phillips. 2011. Connectivity of agroecosystems: dispersal costs can vary among crops. Landscape Ecology 26(3):371-379.

Crosby, J. unpublished data. 2011. *Email correspondence with A. Whiting*. August 2011. Graduate Student, University of Waterloo, Waterloo, ON.

Crother, B.I. (ed.). 2012. Scientific and standard English names of amphibians and reptiles of North America north of Mexico, with comments regarding confidence in our understanding. SSAR Herpetological Circular 39:1–92.

Dahl, T.E., and Watmough, M.D. 2007. Current approaches to wetland status and trends monitoring in prairie Canada and the continental United States of America. Canadian Journal of Remote Sensing 33:S17-S27.

Daszak, P., L. Berger, A.A. Cunningham, A.D. Hyatt, D.E. Green, and R. Speare. 1999. Emerging infectious diseases and amphibian population declines. Emerging Infectious Diseases 5:735–748.

Daszak, P., A. Stierby, C.C. Brown, A.A. Cunningham, J.S. Longcore, and D. Porter. 2004. Experimental evidence that the bullfrog (*Rana catesbeiana*) is a potential carrier of chytridiomycosis, an emerging fungal disease of amphibians. Herpetological Journal 14:201-207.

Davidson, E., M. Parris, J. Collins, J. Longcore, A. Pessier, and J. Brunner. 2003. Pathogenicity and transmission of chytridiomycosis in tiger salamanders (*Ambystoma tigrinum*). Copeia 2003(3):601-607.

Deguise, I. and J.S. Richardson. 2009. Prevalence of the chytrid fungus (*Batrachochytrium dendrobatidis*) in Western Toads in southwestern British Columbia, Canada. Northwestern Naturalist 90:35-38.

de Jong, A. 2008. Examining the impacts of pesticide exposure on the survivorship and development of Great Basin Spadefoot (*Spea intermontana*) and Pacific Treefrog (*Pseudacris regilla*) in a laboratory environment. MSc. dissertation, University of British Columbia, Vancouver, British Columbia, Canada. 115 pp.

Denoel, M., H.H. Whiteman, and S.A. Wissinger. 2006. Temporal shift of diet in alternative cannibalistic morphs of the tiger salamander. Biological Journal of the Linnean Society 89(2):373-382.

Denoel, M., H.H. Whiteman, and S.A. Wissinger. 2007. Foraging tactics in alternative heterochronic salamander morphs: trophic quality of ponds matters more than water permanency. Freshwater Biology 52(9):1667-1676.

Deutschman, M.R., and J.J. Peterka. 1988. Secondary production of tiger salamanders (*Ambystoma tigrinum*) in three North Dakota lakes. Canadian Journal of Fisheries and Aquatic Sciences 45:691–97.

Didiuk, A., pers. comm. 2011. *Email and phone correspondence to A. Whiting*. June and September 2011. Biologist, Canadian Wildlife Service, Saskatoon, Saskatchewan.

Docherty, D.E., C.U. Meteyer, J. Wang, J. Mao, S.T. Case, and V. Chinchar. 2003. Diagnostic and molecular evaluation of three iridovirus-associated salamander mortality events. Journal of Wildlife Diseases 39(3):556-566.

Donald, D., pers. comm. 2011. *Email correspondence to A. Whiting*. September 2011. Environment Canada, Saskatoon, Saskatchewan.

Dulise, J., and D. Hausleitner. 2010. 2009 amphibian survey Columbia Forest District. Report prepared for Fish & Wildlife Compensation Program, Nelson, B.C. 35 pp.

Dumas, P.C. 1966. Studies of the *Rana* species complex in the Pacific Northwest. Copeia 1966:60-74.

Dunham, J., D. Pilliod, and M. Young. 2004. Assessing the consequences of nonnative trout in headwater ecosystems in western North America. Fisheries 29(6):18-26.

Dyer, O., pers. comm. 2011. *Email correspondence to A. Whiting*. Co-Chair of Tiger salamander recovery team. BC Ministry of Environment, Penticton, BC.

Eaves, S.E. 2004. The distribution and abundance of amphibians across land-use types in Alberta's Aspen Parkland. M.Sc. dissertation, University of Alberta, Edmonton, AB, Canada. 124 pp.

Fahrig, L., J. H. Pedlar, S. E. Pope, P. D. Taylor and J. F. Wegner. 1995. Effect of road traffic on amphibian density. Biological Conservation 73:177-182.

Ferrari, M.C,, and D.P. Chivers. 2008. Cultural learning of predator recognition in mixed-species assemblages of frogs: the effect of tutor-to-observer ratio. Animal Behaviour 75(6):1921-1925.

Ferrari, M.C., and D.P. Chivers. 2009. Latent inhibition of predator recognition by embryonic amphibians. Biology Letters 5(2):160-162.

Fitzpatrick, B., M. Benard, and J. Fordyce. 2003. Morphology and escape performance of tiger salamander larvae (*Ambystoma tigrinum mavortium*). Journal of Experimental Zoology Part A-Comparative Experimental Biology 297A(2):147-159.

Fitzpatrick, B., and H. Shaffer. 2004. Environment-dependent admixture dynamics in a tiger salamander hybrid zone. Evolution 58(6):1282-1293.

Fitzpatrick, B.M., and H. Shaffer. 2007. Hybrid vigor between native and introduced salamanders raises new challenges for conservation. Proceedings of the National Academy of Sciences, USA 104(40):15793-15798.

Forson, D., and A. Storfer. 2006a. Atrazine increases ranavirus susceptibility in the tiger salamander, *Ambystoma tigrinum*. Ecological Applications 16(6):2325-2332.

Forson, D., and A. Storfer. 2006b. Effects of atrazine and iridovirus infection on survival and life-history traits of the long-toed salamander (*Ambystoma macrodactylum*). Environmental Toxicology and Chemistry 25(1):168-173.

Frelich L.E., and P.B. Reich. 2010. Will environmental changes reinforce the impact of global warming on the prairie-forest border of central North America? Frontiers in Ecology and the Environment 8:371-378.

Froese, J., J. Smits, D. Forsyth, and M. Wickstrom. 2009. Toxicity and immune system effects of dietary deltamethrin exposure in tiger salamanders (*Ambystoma tigrinum*). Journal of Toxicology and Environmental Health, Part A: Current Issues 72(7-8):518-526.

Gehlbach, F.R. 1967. *Ambystoma tigrinum* (Green) Tiger salamander. Catalogue of American Amphibians and Reptiles: 52.1-52.4.

Gelling, L., pers. comm. 2012. *Email correspondence with K. Ovaska*. November 2012. Zoologist, Conservation Centre, Victoria, British Columbia.

Gibbons, J., C.T. Winne, D.E. Scott, J.D. Willson, X. Glaudas, K.M. Andrews, B.D. Todd, L.A. Fedewa, L. Wilkinson, R.N. Tsaliagos, S.J. Harper, J.L. Greene, T.D. Tuberville, B.S. Metts, M.E. Dorcas, J.P. Nestor, C.A. Young, T. Akre, R.N. Reed, K.A. Buhlmann, J. Norman, D.A. Croshaw, C. Hagen, and B.B. Rothermel. 2006. Remarkable amphibian biomass and abundance in an isolated wetland: Implications for wetland conservation. Conservation Biology 20(5):1457-1465.

Goater, C., pers. comm. 2011. *Phone and email correspondence with A. Whiting*. September 2011. Professor, University of Lethbridge, Lethbridge, Alberta.

Gopurenko, D., R.N. Williams, C.R. McCormick, and J. Dewoody. 2006. Insights into the mating habits of the tiger salamander (*Ambystoma tigrinum tigrinum*) as revealed by genetic parentage analyses. Molecular Ecology 15(7):1917-1928.

Griffis-Kyle, K. 2005. Ontogenic delays in effects of nitrite exposure on tiger salamanders (*Ambystoma tigrinum tigrinum*) and wood frogs (*Rana sylvatica*). Environmental Toxicology and Chemistry 24(6):1523-1527.

Griffis-Kyle, K.L. 2007. Sublethal effects of nitrite on eastern tiger salamander (*Ambystoma tigrinum tigrinum*) and wood frog (*Rana sylvatica*) embryos and larvae: implications for field populations. Aquatic Ecology 41:119-127.

Griffis-Kyle, K.L., and M.E. Ritchie. 2007. Amphibian survival, growth and development in response to mineral nitrogen exposure and predator cues in the field: an experimental approach. Oecologia 152:633-642.

Green, D.M. 2003. The ecology of extinction: population fluctuation and decline in amphibians. Biological Conservation. 111:331-343.

Green, D.M. (éd.) 2012. Noms français standardisés des amphibiens et des reptiles d’Amérique du Nord au nord du Mexique. SSAR Herpetological Circular 40:1-62.

Haag, M., pers. comm. 2011. *Conversation with A. Whiting.* September 2011. Faculty Service Officer, University of Alberta, Edmonton, Alberta.

Hallock, L., pers. comm. 2011. *Email and phone correspondence with A. Whiting*. September 2011. Biologist, Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Hammerson, G.A. 1999. Amphibians and reptiles in Colorado. Second edition. Colorado Division of Wildlife Publication, University Press of Colorado, Niwot, Colorado, USA.

Hanesiaka, J.M, R.E. Stewarta, B.R. Bonsalb, P. Hardera, R. Lawforda, R. Aiderc, B.D. Amirod, E. Atallahe, A.G. Barrb, T.A. Blackf, P. Bullockd, J.C. Brimelowa, R. Browncg, H. Carmichaele, C. Derksenh, L.B. Flanagani, P. Gachonc, H. Greenej, J. Gyakume, W. Hensone, E.H. Hoggk, B. Kochtubajdaj, H. Leightone, C. Linc, Y. Luol, J.H. McCaugheym, A. Meinertn, A. Shabbarh, K. Snelgroveo, K. Szetoh, A. Trishchenkol, G. van der Kampb, S. Wangl, L. Wene, E. Wheatonp, C. Wielkij, Y. Yangl, S. Yirdawo, and T. Zhaq. 2011. Characterization and summary of the 1999-2005 Canadian Prairie drought. Atmosphere-Ocean 49(4):421-452.

Harp, E.M., and J.W. Petranka. 2006. Ranavirus in wood frogs (*Rana sylvatica*): Potential sources of transmission within and between ponds. Journal of Wildlife Diseases 42(2):307-318.

Hecnar, S.J. 1997. Amphibian pond communities in southwestern Ontario. Pp. 1-15. *In* D.M. Green (ed.) Amphibians in Decline: Canadian Studies of a Global Problem. Herpetological Conservation, Number 1, Society for the Study of Amphibians and Reptiles, St. Louis, Missouri.

Herborg, M., pers.comm. 2012. *Email correspondence to A. Whiting*. Aquatic invasive species coordinator, Conservation Science Section, B.C. Ministry of Environment, Victoria, British Columbia.

Hoff Kv.S., N. Huq, V.A. King, and R.J. Wassersug. 1989. The kinematics of larval salamander swimming (Ambystomatidae: Caudata). Canadian Journal of Zoology 67:2756–2761.

Hogg E.H., and P.A. Hurdle. 1995. The aspen parkland in western Canada: a dry-climate analogue for the future boreal forest? Water, Air and Soil Pollution 82:391-400.

Holomuzki, J., J. Collins, and P. Brunkow. 1994. Trophic control of fishless ponds by tiger salamander larvae. Oikos 71(1):55-64.

Irschick, D., and H. Shaffer. 1997. The polytypic species revisited: Morphological differentiation among tiger salamanders (*Ambystoma tigrinum*) (Amphibia: Caudata). Herpetologica 53(1):30-49.

Jancovich, J.K., M. Bremont, J.W. Touchman, and B.L. Jacobs. 2010. Evidence for multiple recent host species shifts among ranaviurses (Family *Iridoviridae*). Journal of Virology 84(6):2636-2647.

Jancovich, J., E. Davidson, A. Seiler, B. Jacobs, and J. Collins. 2001. Transmission of the *Ambystoma tigrinum* virus to alternative hosts. Diseases of Aquatic Organisms 46(3):159-163.

Jancovich, J., E. Davidson, N. Parameswaran, J. Mao, V. Chinchar, J. Collins, B. Jacobs, and A. Storfer. 2005. Evidence for emergence of an amphibian iridoviral disease because of human-enhanced spread. Molecular Ecology 14(1):213-224.

Johnson, E.B., P. Bierzychudek, and H.H. Whiteman. 2003. Potential of prey size and type to affect foraging asymmetries in tiger salamander (*Ambystoma tigrinum* nebulosum) larvae. Canadian Journal of Zoology 81(10):1726-1735.

Johnson, J.R., B.M. Fitzpatrick, and H.B. Shaffer. 2010. Retention of low-fitness genotypes over six decades of admixture between native and introduced tiger salamanders. BMC Evolutionary Biology 10:147.

Johnson, J.R., R.C. Thomson, S.J. Micheletti, and H.B. Shaffer. 2011. The origin of tiger salamander (*Ambystoma tigrinum*) populations in California, Oregon, and Nevada: introductions or relicts? Conservation Genetics 12:355-370.

Johnston, B., pers. comm. 2011. *Email and phone correspondence to A. Whiting*. September 2011. Biologist, wildlife and aquatics specialist, Parks Canada, Waterton Lakes National Park, AB.

Jones, T., and J. Collins. 1992. Analysis of a hybrid zone between subspecies of the tiger salamander (*Ambystoma tigrinum*) in central New Mexico, USA. Journal of Evolutionary Biology 5(3):375-402.

Kats, L., J. Petranka, and A. Sih. 1988. Antipredator defenses and the persistence of amphibian larvae with fishes. Ecology 69(6):1865-1870.

Keith, J., pers. comm. 2011. *Email correspondence with A. Whiting*. July 2011. Saskatchewan Conservation Data Centre, Ministry of Environment, Regina, Saskatchewan.

Kendall, K., pers. comm. 2011. *Phone correspondence with A. Whiting*. September 2011. Biologist, Alberta Conservation Association, Sherwood Park, Alberta.

Khandekar, M.L. 2004. Canadian prairie drought: a climatological assessment. Alberta Environment, Publication No. T/787. 37 pp.

Kiesecker, J.M., and A.R. Blaustein. 1997. Population differences in responses of red-legged frog (*Rana aurora*) to introduced bullfrogs. Ecology 78:1752-1760.

Koch, E.D., and C.R. Peterson. 1995. The amphibians and reptiles of Yellowstone and Grant Teton National Parks. University of Utah Press, Salt Lake City, UT. 188 pp.

Lannoo, M.J., and M.D. Bachmann. 1984. Aspects of cannibalistic morphs in a population of *Ambystoma t. tigrinum* larvae. American Midland Naturalist 112:103-109.

Larson, D.L., S. McDonald, A.J. Fivizzani, W.E. Newton, and S.J. Hamilton. 1998. Effects of the herbicide Atrazine on *Ambystoma tigrinum* metamorphosis: Duration, larval growth, and hormonal response. Physiological Zoology 71:671-679.

Larson, D.W. 1968. The occurrence of neotenic salamanders, *Ambystoma tigrinum diaboli* Dunn, in Devils Lake, North Dakota. Copeia 1968:620-621.

LeClere, J., pers. comm. 2011. *Email correspondence with A. Whiting*. September 2011. Biologist, Minnesota Herpnet.net, St. Paul, Minnesota, USA.

Leff, L.G., and M.D. Bachmann. 1986. Ontogenetic changes in predatory behavior of larval tiger salamanders (*Ambystoma tigrinum*). Canadian Journal of Zoology 64:1337–44.

Loeb, M., J. Collins, and T. Maret. 1994. The role of prey in controlling expression of a trophic polymorphism in *Ambystoma tigrinum nebulosum*. Functional Ecology 8(2):151-158.

Loredo, I., and D. Van Vuren. 1996. Reproductive ecology of a population of the California tiger salamander. Copeia 1996:895–901.

Manitoba Herp Atlas. 2011. Barred Tiger Salamander. Web site: http://www.naturenorth.com/Herps/MHA_Salamanders.html [accessed September 2011].

Matsuda, B.M., D.M. Green, and P.M. Gregory. 2006. Amphibians and reptiles of British Columbia. Royal British Columbia Museum, Victoria, British Columbia. 288 pp.

McIntyre, P., and S. McCollum. 2000. Responses of bullfrog tadpoles to hypoxia and predators. Oecologia 125(2):301-308.

McMenamin, S.K., and E.A. Hadly. 2010. Developmental dynamics of *Ambystoma tigrinum* in a changing landscape. BMC Ecology 10:10.

Millar, J.B. 1989. Perspectives on the status of Canadian prairie wetlands. Freshwater Wetlands and Wildlife 61:829-852.

Miller, B.T., and J.H. Larsen, Jr. 1986. Feeding habits of metamorphosed *Ambystoma tigrinum melanostictum* in ponds of high pH (>9). Great Basin Naturalist 46:299-301.

Mitchell, P., and E.E. Prepas (eds). 1990. The atlas of Alberta lakes. University of Alberta Press, Edmonton, Alberta. 675 pp.

Monello, R.J., and R.G. Wright. 2001. Predation by Goldfish (*Carassius auratus*) on eggs and larvae of the Eastern Long-toed Salamander (*Ambystoma macrodactylum columbianum*). Journal of Herpetology 35:350-353.

Mullan, J., pers. comm. 2012. *Email correspondence with A. Whiting regarding the use of Malathion in British Columbia*. March 2012. Pesticides Officer, Integrated Pest Management Unit, B.C. Ministry of Environment, Victoria, British Columbia.

NatureServe. 2011. NatureServe explorer: An online encyclopedia of life [web application]. NatureServe, Arlington, Virginia. www.natureserve.org/explorer.

Ngo, A., V.L. McKay, and R.W. Murphy. 2009. Recovery strategy for Tiger Salamander (*Ambystoma tigrinum*) (Great Lakes Population) in Canada [Proposed]. Species at Risk Act Recovery Strategy Series. Parks Canada Agency. Ottawa. v + 28 pp. + 1 Appendix.

Noble, R., and I. Spendlow. 2006. South Okanagan, Similkameen and Kettle Valley tiger salamander (*Ambystoma tigrinum*) inventory – 2006. BC Conservation Corps, Kelowna, British Columbia. 15 pp.

Olenick, R. J., and J.H. Gee. 1981. Tiger salamanders (*Ambystoma tigrinum*) and stocked rainbow trout (*Salmo gairdneri*): potential competitors for food in Manitoba prairie pothole lakes. Canadian Field Naturalist 95:129–32.

Pagnucco, K. 2010. Using under-road tunnels to protect a declining population of long-toed salamanders (*Ambystoma macrodactylum*) in Waterton Lakes National Park. M.Sc. dissertation, University of Alberta, Edmonton, Alberta. 127 pp.

Pagnucco, K.S., C.A. Paszkowski, and G.J. Scrimgeour. 2011. Using cameras to monitor tunnel use by long-toed salamanders (*Ambystoma macrodactylum*): an informative, cost-efficient technique. Herpetological Conservation and Biology 6(2):277-286.

Parris, M.J., A. Storfer, J.P. Collins, and E.W. Davidson. 2005. Life-history responses to pathogens in tiger salamander (*Ambystoma tigrinum*) larvae. Journal of Herpetology 39(3):366-372.

Paszkowski, C., pers. comm. 2011. *Personal correspondence with A. Whiting*. January-September 2011. Professor University of Alberta, Edmonton, Alberta.

Patch, C.L. and D.A. Stewart. 1934. The tiger salamander at Ninette, Manitoba. Canadian Field-Naturalist 38(3):124-126.

Pauli, B.D., J.A. Perrault, and S.L. Money. 2000. RATL: a database of reptile and amphibian toxicology literature. Technical Report Series No. 357. Canadian Wildlife Service, Hull, Québec. 494 pp.

Pearl, C.A., E.L. Bull, D.E. Green, J. Bowerman, M.J. Adams, A. Hyatt, and W.H. Wente. 2007. Occurrence of the amphibian pathogen *Batrachochytrium dendrobatidis* in the Pacific Northwest. Journal of Herpetology 41(1):145-149.

Pearman, P., and T. Garner. 2005. Susceptibility of Italian agile frog populations to an emerging strain of Ranavirus parallels population genetic diversity. Ecology Letters 8(4):401-408.

Pearman, P., T. Garner, M. Straub, and U. Greber. 2004. Response of the Italian agile frog (*Rana latastei*) to a Ranavirus, frog virus 3: A model for viral emergence in naive populations. Journal of wildlife diseases 40(4):660-669.

Pechmann, J.H.K., D.E. Scott, R.D. Semlitsch, J.P. Caldwell, L.J. Vitt, and J.W. Gibbons. 1991. Declining amphibian populations: the problem of separating human impacts from natural fluctuations. Science 253:892–895.

Petranka J.W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington DC, USA. 587 pp.

Pfennig, D., M. Loeb, and J. Collins. 1991. Pathogens as a factor limiting the spread of cannibalism in tiger salamanders. Oecologia 88(2):161-166.

Picco, A.M., and J.P. Collins. 2008. Amphibian commerce as a likely source of pathogen pollution. Conservation Biology 22(Suppl. 6):1582-1589.

Picco, A.M., A.P. Karam, and J.P. Collins. 2010. Pathogen host switching in commercial trade with management recommendations. EcoHealth 7(2):252-256.

Preston, W.B. 1982. The amphibians and reptiles of Manitoba . Manitoba Museum of Man and Nature, Winnipeg, Manitoba. 128pp.

Puchniak, A.J. 2002. Recovery of bird and amphibian assemblages in restored wetlands in Prairie Canada. M.Sc. dissertation, University of Alberta, Edmonton, AB, Canada. 220 pp.

Ramsey, H., S. Kennedy-Stoskopf, J. Levine, S. Taylor, D. Shea, and M. Stoskopf. 2008. Acute toxicity and tissue distributions of malathion in *Ambystoma tigrinum*. Archives of Environmental Contamination and Toxicology 55(3):481-487.

Rashford, B.S., C.T. Bastian, and J.G. Cole. 2011. Agricultural land-use change in Prairie Canada: Implications for wetland and waterfowl habitat conservation. Canadian Journal of Agriculture 59(2):185-205.

Redpath, K. 1990. Identification of relatively undisturbed areas in the South Okanagan and Similkameen valleys, British Columbia. Canadian Wildlife Service, Pacific and Yukon Regular Technical Report Service No. 108. 9 pp.

Regester, K.J., K.R. Lips, and M.R. Whiles. 2006a. Energy flow and subsidies associated with the complex life cycle of ambystomatid salamanders in ponds and adjacent forest in southern Illinois. Oecologia 147(2):303-314.

Regester, K., M. Whiles, and C. Taylor. 2006b. Decomposition rates of salamander (*Ambystoma maculatum*) life stages and associated energy and nutrient fluxes in ponds and adjacent forest in southern Illinois. Copeia 2006(4):640-649.

Richardson, J.S., W. Klenner, and J. Shatford. 1998. Tiger salamanders (*Ambystoma tigrinum*) in the south Okanagan: effects of cattle grazing, range condition and breeding pond characteristics on habitat use and population ecology. Habitat Conservation Trust Fund, Victoria, British Columbia. Annual Program Report.

Richardson, J.S., W. Klenner, and J. Shatford. 2000. The tiger salamander in British Columbia: an amphibian in an endangered desert environment. Pp. 407-412, *in* L.M. Darling (ed.) Proceedings of the Biology and Management of Species and Habitats at Risk, Kamloops, British Columbia, Feb. 15-19. 1999.

Richardson, J.S., W. Klenner, and J. Shatford. Unpublished data. Manuscript provided to A. Whiting in 2011.

Rose, F.L., and D. Armentrout. 1976. Adaptive strategies of *Ambystoma tigrinum* (Green) inhabiting the Llano Estacado of west Texas. Journal of Animal Ecology 45:713-729.

Routman, E.J. 1993. Population structure and genetic diversity of metamorphic and paedomorphic populations of the tiger salamander, *Ambystoma tigrinum*. Journal of Evolutionary Biology 6:329-357.

Russell, A.P., and A.M. Bauer. 2000. The amphibians and reptiles of Alberta. University of Alberta Press, Edmonton. 279 pp.

Sarell, M.J. 1996. Status of the tiger salamander (*Ambystoma tigrinum*) in British Columbia. B.C. Ministry of Environment, Lands and Parks, Wildlife Branch, Oliver, British Columbia.

Sarell, M.J. 2004. Tiger Salamander, *Ambystoma tigrinum*. *In* Accounts and Measures for Mapping Identified Wildlife – Accounts V. B.C. Ministry of Water, Land and Air Protection, Victoria, British Columbia. 9 pp.

Sarell, M.J., pers. comm. and unpublished data. 2011. *Email and phone correspondence with A. Whiting*. August 2011. Biologist/Consultant, Ophiuchus Consulting, Oliver, British Columbia.

Sarell, M.J., and S. Robertson. 1994. Survey of tiger salamanders (*Ambystoma tigrinum*) in the Okanagan Sub-region (1994). B.C. Environment, Victoria, British Columbia. 5 p.

Saskatchewan Fish and Wildlife. 2012. Database of fish stocking records. [accessed March 2012].

Saskatchewan Ministry of Highways and Intrastructure. 2013a. 2011 Traffic Volume map. Web site: http://www.highways.gov.sk.ca/ [accessed September 15, 2013].

Saskatchewan Ministry of Highways and Intrastructure. 2013b. 2006 Traffic Volume map. Web site: http://www.highways.gov.sk.ca/ [accessed September 15, 2013].

Scheffers, B. 2010. The value of stormwater wetlands for supporting multiple life-history stages of the wood frog (*Lithobates sylvaticus*) in the City of Edmonton, Alberta, Canada. M.S. dissertation, University of Alberta Edmonton, Alberta. 144 pp.

Schloegel, L.M., J.M. Hero, L. Berger, R. Speare, K. McDonald, and P. Daszak. 2006. The decline of the sharpsnouted day frog (*Taudactylus acutirostris*): the first documented case of extinction by infection in a free-ranging wildlife species? EcoHealth 3:35–40.

Schock, D.M. 2001. COSEWIC status report on the Tiger Salamander, *Ambystoma tigrinum*, in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario. 44 pp.

Schock, D.M., pers. comm. and unpublished data. 2011. *Email and phone correspondence with A. Whiting.* August and September 2011. Biologist/Instructor, Keyano College, Fort McMurray, Alberta.

Schock, D.M., T.K. Bollinger, V.G. Chinchar, J.K. Jancovich, and J.P. Collins. 2008. Experimental evidence that amphibian ranaviruses are multi-host pathogens. Copeia (1):133-143.

Schock, D.M., T.K. Bollinger, and J.P. Collins. 2009. Mortality rates differ among amphibian populations exposed to three strains of a lethal Ranavirus. Ecohealth 6(3):438-448.

Schock, D.M., G.R. Ruthig, J.P. Collins, S.J. Kutz, S. Carriere, R.J. Gau, A.M. Veitch, N.C. Larter, D.P. Tate, G. Guthrie, D.G. Allaire, and R.A. Popko. 2010. Amphibian chytrid fungus and ranaviruses in the Northwest Territories, Canada. Diseases of aquatic organisms 92(2-3):231-240.

Schwalbe, C.R. and P.C. Rosen. 1999. Bullfrogs – the dinner guests we're sorry we invited. Sonorensis 19:8-10.

Semlitsch, R.D. 1983. Structure and dynamics of two breeding populations of the eastern tiger salamander, *Ambystoma tigrinum*. Copeia 1983(3):608-616.

Semlitsch, R.D. 1987. Interactions between fish and salamander larvae. Costs of predator avoidance or competition? Oecologia 72(4):481-486.

Semlitsch, R.D., D.E. Scott, J.H.K. Pechmann, and J.W. Gibbons. 1996. Structure and dynamics of an amphibian community: evidence from a 16-year study of a natural pond. In Cody, M.L. and J. Smallwood (eds). Long-term studies of vertebrate communities. Academic Press, San Diego.

Sepulveda, A.J., and W.H. Lowe. 2011. Coexistence in stream: do source-sink dynamics allow salamanders to persist with fish predators? Oecologia 166: 1043-1054.

Sever, D.M. and C.F. Dineen. 1978. Reproductive ecology of the tiger salamander, *Ambystoma tigrinum*, in northern Indiana. Proceedings of the Indiana Academy of Science 87:189–203.

Sexton, O.J., and J.R. Bizer. 1978. Life history patterns of *Ambystoma tigrinum* in montane Colorado. American Midland Naturalist 99:101-118.

Shaffer, H., and M. McKnight. 1996. The polytypic species revisited: Genetic differentiation and molecular phylogenetics of the tiger salamander *Ambystoma tigrinum* (Amphibia: Caudata) complex. Evolution 50(1):417-433.

Sih, A., L. Kats, and E. Maurer. 2003. Behavioural correlations across situations and the evolution of antipredator behaviour in a sunfish-salamander system. Animal Behaviour 65:29-44.

Southern Interior Reptile and Amphibian Recovery Team. 2008. Recovery strategy for the Tiger Salamander (*Ambystoma tigrinum*), Southern Mountain Population in British Columbia. Prepared for the B.C. Ministry of Environment, Victoria, British Columbia. 22 pp.

Spear, S.F., C.R. Peterson, M.D. Matocq, and A. Storfer. 2005. Landscape genetics of the blotched tiger salamander (*Ambystoma tigrinum melanostictum*). Molecular Ecology 14(8):2553-2564.

Spear, S.F., C.R. Peterson, M.D. Matocq, and A. Storfer. 2006. Molecular evidence for historical and recent population size reductions of tiger salamanders (*Ambystoma tigrinum*) in Yellowstone National Park. Conservation Genetics 7(4):605-611.

Statistics Canada. 2012. Farm and farm operator data: 2011 Census of Agriculture. Web site: http://www.statcan.gc.ca/pub/95-640-x/2012002-eng.htm [accessed September 13, 2013].

Stebbins, R.C. 1985. A Field Guide to Western Reptiles and Amphibians. Houghton Mifflin Co., Boston, Massachusetts. 336 pp.

Steen, D., L. Smith, G. Miller, and S. Sterrett. 2006. Post-breeding terrestrial movements of *Ambystoma tigrinum* (Eastern Tiger Salamanders). Southeastern Naturalist 5(2):285-288.

Stevens, S.D., D.R.C. Prescott, and D.P. Whiteside. 2012. Occurrence and prevalence of chytrid fungus (*Batrachochytrium dendrobatidis*) in amphibian species of Alberta. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Report No. 143, Edmonton, Alberta. 24 pp.

Stipec, K., pers. comm. 2012. *Email sent to Lea Gelling forwarded to A. Whiting,* February 2012. Species at Risk Information Specialist, B.C. Conservation Data Centre, Ministry of Environment, Victoria, British Columbia.

Storfer, A., S. Mech, M. Reudink, R. Ziemba, J. Warren, and J. Collins. 2004. Evidence for introgression in the endangered Sonora Tiger Salamander, *Ambystoma tigrinum stebbinsi* (Lowe). Copeia 2004(4):783-796.

Storfer, A., and C. White. 2004. Phenotypically plastic responses of larval tiger salamanders, *Ambystoma tigrinum*, to different predators. Journal of Herpetology 38(4):612-615.

Tanner, W.W., D.L. Fisher and T.J. Willis. 1971. Notes on the life history of *Ambystoma tigrinum nebulosum* Hallowell in Utah. Great Basin Naturalist 31:213-222.

Tarangle, D. and M. Yelland. 2005. 2005 South Okanagan tiger salamander (*Ambystoma tigrinum*) larvae inventory. Report prepared for B.C. Ministry of Environment, Penticton, British Columbia.

Taylor, M., pers. comm. 2011. *Personal conversation with A. Whiting*. August 2011. Graduate Student, University of Alberta, Edmonton, Alberta.

Transport Canada. 2012. Current Projects: British Columbia. Web site: http://www.tc.gc.ca/eng/programs/surface-highways-bc-874.htm [accessed March 19, 2012].

Trenham, P., and H. Shaffer. 2005. Amphibian upland habitat use and its consequences for population viability. Ecological Applications 15(4):1158-1168.

Trenham, P.C., H.B. Shaffer, W.D. Koenig, and M.R. Stromberg. 2000. Life history and demographic variation in the California tiger salamander (*Ambystoma californiense*). Copeia 2000:365–377.

Tyler, T., W. Liss, L. Ganio, G. Larson, R. Hoffman, E. Deimling, and G. Lomnicky. 1998. Interaction between introduced trout and larval salamanders (*Ambystoma macrodactylum*) in high-elevation lakes. Conservation Biology 12(1):94-105.

Tyning, T.F. 1990. A guide to amphibians and reptiles. Little, Brown and Company, Boston, Massachusetts. 400 pp.

United Agri Products. 2010. Malathion 85E commercial insecticide usage instructions. United Agri Products Canada Inc. Web site: http://www.al.gov.bc.ca/pesticides/malathion_emergency_%20label.pdf [accessed March 16, 2012].

Vanderschuit, W., pers. comm. 2011. *Email correspondence to A. Whiting*. August and September 2011. Ecosystem Scientist, Riding Mountain National Park, Parks Canada, Wasagaming, Manitoba.

Voorduow, M.J., D. Adama, B. Houston, P. Govindarajulu, and J. Robinson. 2010. Prevalence of the pathogenic chytrid fungus, *Batrochochytrium dendrobatidis*, in an endangered population of northern leopard frogs, *Rana pipiens*. BMC Ecology 10:1-6.

Washington Herp Atlas. 2011. Tiger Salamander. Web site: http://www1.dnr.wa.gov/nhp/refdesk/herp/speciesmain.html [accessed September 2011].

[WLNP Wildlife Observations] Waterton Lakes National Park Wildlife Observations. 2011. Database of wildlife observations, query for tiger salamanders, Accessed September 2011. Parks Canada.

Watmough, M.D., and M.J. Schmoll. 2007. Environment Canada's Prairie and Northern Region habitat monitoring program phase II: recent habitat trends in the Prairie Habitat Joint Venture. Technical Report Series No. 493. Environment Canada, Canadian Wildlife Service. Edmonton, Alberta. 135 pp.

Webb, R. G., and W. L. Roueche. 1971. Life history aspects of the tiger salamander (*Ambystoma tigrinum mavortium*) in the Chihuahuan Desert. The Great Basin Naturalist 31:193-212.

Whiteman, H., R. Howard, and K. Whitten. 1995. Effects of pH on embryo tolerance and adult behavior in the tiger salamander, *Ambyostoma tigrinum tigrinum*. Canadian Journal of Zoology 73(8):1529-1537.

Whiteman, H., S. Wissinger, and A. Bohonak. 1994. Seasonal movement patterns in a subalpine population of the tiger salamander, *Ambystoma tigrinum* nebulosum. Canadian Journal of Zoology 72(10):1780-1787.

Whittington, R.J., J.A. Becker, and M.M. Dennis. 2010. Iridovirus infections in finfish - critical review with emphasis on ranaviruses. Journal of Fish Disease 33:95-122.

Wilbur, H.M., and J.P. Collins. 1973. Ecological aspects of amphibian metamorphosis. Science 182(4119):1305-1314.

Wind, E. 2005. Effects of nonnative predators on aquatic ecosystems. Report prepared for the B.C. Ministry of Water, Land and Air Protection, Victoria, British Columbia.

Wissinger, S., H. Whiteman, M. Denoel, M. Mumford, and C. Aubee. 2010. Consumptive and nonconsumptive effects of cannibalism in fluctuating age-structured populations. Ecology 91(2):549-559.

Wissinger, S., H. Whiteman, G. Sparks, G. Rouse, and W. Brown. 1999. Foraging trade-offs along a predator-permanence gradient in subalpine wetlands. Ecology 80(6):2102-2116.

Zaret, T. M. 1980. Predation and freshwater communities. Yale University Press, New Haven, CConnecticut. 187 pp.

Zeiber, R., T. Sutton, and B. Fisher. 2008. Western mosquitofish predation on native amphibian eggs and larvae. Journal of Freshwater Ecology 23(4):663-671.

Zerba, K., and J. Collins. 1992. Spatial heterogeneity and individual variation in diet of an aquatic top predator. Ecology 73(1):268-279.

BIOGRAPHICAL SUMMARY OF REPORT WRITER

Arthur Whiting received his B.Sc. in Zoology at the University of Guelph in 1999, where he completed a project on isozyme inheritance in *Ambystoma maculatum* with Jim Bogart. He completed his M.Sc. ("Population ecology of the western chorus frog *Pseudacris triseriata*") at McGill University in 2004. Arthur completed his Ph.D. on the "Factors affecting larval growth and development of the boreal chorus frog *Pseudacris maculata*" in 2010. Arthur is currently engaged in postdoctoral research on the phenology of amphibians and birds in response to climactic conditions and global change as part of a continental network of researchers TWGCRN.

Arthur's research has focused on the determining factors that affect the recruitment, growth and diet of larval anurans, and determining habitat use of terrestrial anurans; much of his effort centres on chorus frogs (*Pseudacris*), but he maintains a healthy interest in all amphibians. He has recently instructed courses on Population Ecology at the University of Alberta and is currently a sessional instructor at NAIT for Limnology.

COLLECTIONS EXAMINED

University of Alberta Zoological Museum, specimen 2999, to verify locality (tag locality differed from Museum database – tag locality was chosen based on distribution map).

Photos of Manitoba Museum specimens MM365, MM367, MM368, MM373, MM375, MM377, MM379, MM380, MM384 to confirm identity of Barred Tiger Salamanders versus Eastern Tiger Salamanders (MM375).

Appendix 1: Threats Calculator results for the Southern Mountain population of the Western Tiger Salamander in British Columbia (February 2012).

Species or Ecosystem Scientific Name	*Ambystoma mavortium* - Southern Mountain population
Date (Ctrl + ";" for today's date):	23/02/2012
Assessor(s):	Original assessment by P Chytyk 2008; L Gelling transferred reviewed scores in 2008. Reviewed and updated in Feb 2012 by K. Ovaska, P. Govindarajulu, D. Fraser, L. Gelling, M. Herborg , S. Ashpole, A. Whiting, J. Hobbs, L. Ramsay
References:	2012 draft COSEWIC status report; 2008 Recovery Strategy

Overall Threat Impact Calculation Help:

Threat Impact		Level 1 Threat Impact Counts high range	low range
A	Very High	1	0
B	High	1	0
C	Medium	2	3
D	Low	3	4
	Calculated Overall Threat Impact:	Very High	High

Assigned Overall Threat Impact:	
Impact Adjustment Reasons:	
Overall Threat Comments	***Generation time 6.5 years, 3 generations = approximately 20 years. Old notes are in black and the new comments recorded during the expert committee review are in purple bold italic; ** separates old from new comments.***

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 - Moderate (11-70%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Small (1-10%)	Serious - Moderate (11-70%)	High (Continuing)	Land development has eliminated and continues to eliminate suitable habitat adjacent to water bodies (ESR - Sarell 1996). Housing and agricultural developments are the most serious threats to Tiger Salamanders and continue to be widespread and severe throughout their range (citations within Recovery Strategy); Developments have fragmented habitats that create potential disruption for dispersal and migration (citations within Recovery Strategy + SA). ***** Tiger Salamanders can be extirpated in urban areas (2 examples from Okanagan), but there is not a high probability of current wetlands getting filled in the next 10 years. However, scope includes both wetlands and uplands (the salamanders spend 99% of their time in uplands); if only wetlands are considered then scope might be less than 11%, but if we include uplands then "restricted" scope should be used.***
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	***Packing houses, car wrecking areas, currently in area. New prison in antelope brush habitat.***
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	***Potential for recreation along the shoreline, golf courses***
2	Agriculture & aquaculture	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	***The two threats act in different areas and so are additive and hence roll up to a higher scoring than individually***
2.1	Annual & perennial non-timber crops	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	. ...housing and agricultural developments (orchards/vineyards) are the most serious threats to Tiger Salamanders and continue to be widespread and severe throughout their range (citations within Recovery Strategy) *****Irrigation system control pits (ca. 10 to 12 per 10 acre of farm) can act as deadly pitfall traps in vineyards and orchards. A new vineyard with leveling and grading might kill most of the salamanders in the area, but at a population level tiger salamanders might be able to migrate back into the area.***
2.2	Wood & pulp plantations						***Not an issue within the BC range of the species.***

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.3	Livestock farming & ranching	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	Trampling by cattle in shallow ponds has a negative effect (Sarell 1996). *****Most of the higher elevation tiger salamander occurrences have cows. Trampling by cows would be limited, but in drought years tiger salamanders will compete for water and may get trapped in deep pock marks of hoof prints (few examples of this from the Okanagan); trampling might also increase in drought years.***
3	Energy production & mining						***Not considered an issue within the species' range in BC***
4	Transportation & service corridors	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	
4.1	Roads & railroads	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	***Almost all occurrences are within 1 km of a road (90% are within ~650 m of a road; 100% of breeding sites are within 750 m of road); juveniles are the most vulnerable. High mortality of tiger salamanders on highway 97 near Oliver (ongoing study of HWY twinning)***
4.2	Utility & service lines		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	***Hydro lines exist within the species' range, but impacts on salamanders are unclear.***
5	Biological resource use		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	***Collection of salamanders for pets and other purposes might be happening at a low level. Collection for bait is prohibited in BC.***
5.3	Logging & wood harvesting		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	22/75 known occurrences are within Parks /WHA's (30%) (Sarell 1996). ***Scope – Tiger Salamanders' range is not in areas with extensive logging; Pine beetle salvage harvesting is in higher elevations than where the salamanders occur.***
6	Human intrusions & disturbance						
6.1	Recreational activities						***We did not consider mud bogging as an issue when we did the assessment but may need to double check this.***
7	Natural system modifications	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	
7.1	Fire & fire suppression		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	***It is thought that when there is a fire, most salamanders are underground and survive, unless the fire is very hot and raises soil temperatures significantly; fire suppression is not considered an issue.***

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%)	Extreme (71-100%)	High (Continuing)	Breeding sites have been lost to infilling of wetlands, drought or water diversion; irrigation intakes also kill salamanders (Sarell 1996) - ***** Comment: What has been lost in the past is irrelevant for current assessment but can be noted as historical. Similkameen drainage (US plans to flood the Similkameen as part of a dam for drought abatement), but only a few tiger salamander occurrences are from this area. There are irrigation issues (as noted by Sarell above) at a few sites. If wetlands are being drained, then impacts are great - so severity is scored as extreme***
8	Invasive & other problematic species & genes	AC	Very High - Medium	Pervasive (71-100%)	Extreme - Moderate (11-100%)	High (Continuing)	
8.1	Invasive non-native/alien species	AC	Very High - Medium	Pervasive (71-100%)	Extreme - Moderate (11-100%)	High (Continuing)	Tiger Salamanders have disappeared from several lakes (at least two populations) due to the introduction of fish and numbers have dramatically declined in others (Sarell 1996). Bullfrogs may contribute to site extirpations in the Osoyoos area (Ashpole, pers. comm. 2006 within the recovery strategy). *Batrachochytrium dendrobatidis* mortality has not been noted from this species yet, however, it should be monitored. ***** Spread of non-native fish in the last 10 to 20 years is extensive in the South Okanagan. Small wetland used by salamanders for breeding are usually fishless. In some larger water bodies there may be co-existence between salamanders and non-native fish, but we don't know if there were declines post non-native fish introduction. Most ponds that can support fish will get fish. There is one example from the Okanagan of a small pond being converted to "fishery" by stocking with sport fish. Fish introduction also occurs for mosquito control - bulletin put out by the Health Ministry suggested introducing fish into ponds in response to West Nile virus control. There is an example of 2 ponds with goldfish where tiger salamanders disappeared; once fish eradication was achieved, salamanders moved back in.***
8.2	Problematic native species		Unknown	Unknown	Unknown	Unknown	***Trout stocking is captured in the above row 8.1. Ambystoma tigrinum virus causes high mortality east of the Rockies, but there is uncertainty of its prevalence and impacts in BC.***

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.3	Introduced genetic material		Unknown	Unknown	Unknown	Unknown	*Other Ambystoma salamanders are found in pet stores - there is no regulation or enforcement of regulation in pet stores. Other tiger salamanders can hybridize (e.g., in California), but there is no information for this species.*
9	Pollution	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	
9.1	Household sewage & urban waste water		Unknown	Small (1-10%)	Unknown	High (Continuing)	*At least a few breeding populations occur in sewage lagoons (Oliver, Osoyoos), but we don't know effects of pollutants there.*
9.3	Agricultural & forestry effluents	CD	Medium - Low	Large (31-70%)	Moderate – Slight (1-30%)	High (Continuing)	*Ashpole correlated amphibian egg mortality and reduced survival with high levels of orchard pesticides in the South Okanagan (references in Recovery Strategy). Scope – air-borne pollution appears to be increasing (confirmed by MOE), possibly also in higher elevation lakes.*
9.4	Garbage & solid waste						*In-filling of shallow wetlands with garbage is not a threat currently*
9.5	Air-borne pollutants						*We have included agricultural air-borne pollution in 9.3.*
9.6	Excess energy		Unknown	Unknown	Unknown	Unknown	*Light pollution may be a problem at some sites impacts unknown (effects shown on anurans)*
11	Climate change & severe weather	D	Low	Small (1-10%)	Serious - Moderate (11-70%)	High (Continuing)	
11.2	Droughts	CD	Medium - Low	Restricted (11-30%)	Serious - Moderate (11-70%)	High (Continuing)	*Climate change models show warmer summers with less precipitation and warmer winters with more precipitation. A significant number of small wetland have gone dry or almost dry - tiger salamanders have been forced into small wetlands due to fish stocking in the larger wetlands and these small wetlands are more vulnerable to climate change effects; multiple years of drying can be problematic, e.g., White Lake has been consistently dry over 10 years.*
11.3	Temperature extremes		Unknown	Unknown	Unknown	Unknown	*Water temperature increases could be a threat, but the animal is fairly tolerant; adults can go underground Prevalence or virulence of some diseases (ATV?) could potentially increase at higher temperatures.*

Appendix 2: Threats Calculator results for the Prairie / Boreal population of the Western Tiger Salamander (September 2012).

Species or Ecosystem Scientific Name	*Ambystoma mavortium* – Prairie / Boreal population			
Date (Ctrl + ";" for today's date):	11/09/2012			
Assessor(s):	C. Paszkowski, K. Ovaska, D. Schock, A. Whiting			
References:	2012 COSEWIC status report (draft)			
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	1	0
	C	Medium	5	3
	D	Low	3	6
		Calculated Overall Threat Impact:	Very High	High
		Assigned Overall Threat Impact:		
		Impact Adjustment Reasons:		
		Overall Threat Comments	***Generation time 5-6 years, 3 generations = approximately 15-18 years.***	

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 - Moderate (11-70%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Small (1-10%)	Serious - Moderate (11-70%)	High (Continuing)	Expanding residential development is occurring around major centres. Some populations NW of Saskatoon, studied by D. Schock, don't exist anymore due to development. In and around Edmonton, some breeding sites have been destroyed, but salamanders exist in natural and constructed wetlands within the city (long term viability of these populations is unknown).
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)	
2	Agriculture & aquaculture	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	
2.1	Annual & perennial non-timber crops	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	Alberta: New ground is broken occasionally (e.g., conversion to irrigated farmland for potatoes); amount of row crops is declining, especially in northern Alberta; intensification has happened and continues to happen. Same is true for SK & MB. Crop agriculture is more intensive in SK than in AB.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.2	Wood & pulp plantations		Negligible	Negligible (<1%)	Extreme – Serious (31-100%)	High (Continuing)	Aspen plantations are present in Alberta and SK and continue to be developed; this usually involves conversion of land that is already disturbed or in small woodlots; plantations are intensively managed & have short rotations.
2.3	Livestock farming & ranching	CD	Medium - Low	Restricted (11-30%)	Moderate - Slight (1-30%)	High (Continuing)	Restricted footprint; 27% of Alberta Parkland is in pasture; 46% in crop; Prairie area of Alberta: 42% in crop, 12% in pasture. Northern Alberta: Clearing of forest for cattle is ongoing but may increase open habitat available for salamanders. Manitoba: Lots of mixed farming (livestock & crops). Throughout the species' range, crops are more widespread than cattle ranching. Intensity of stocking affects severity. Trampling of shallow ponds by cattle has a negative effect (Sarell 1996); rodent eradication is also a potential problem in upland habitat. Comment for BC population: In drought years tiger salamanders compete for water and may get trapped in deep pock marks of hoof prints (Sara Ashpole has seen a few examples of this); trampling might also increase in drought years.
2.4	Marine & freshwater aquaculture		Unknown	Unknown	Extreme (71-100%)	High (Continuing)	Stock ponds & wetlands on private land (under aquaculture licences in AB); common practice in SK. Some landowners purposeful poison ponds first & put in fish for harvesting the same year (copper sulphite to remove algae & other poisons for existing fish). In 2003, AB aquaculture produced 2109 tonnes of fish. http://www.foecanada.org/WSP%20Lexicon/Freshwater%20Aquaculture%20in%20Canada.pdf
3	Energy production & mining	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	
3.1	Oil & gas drilling		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Widespread in southern AB, SK, MB. We consider here the footprint of actual drilling, compression stations & other infrastructure (not pipelines); AB (Prairies): <2% developed for industry (space impacted by infrastructure; mostly oil & gas); also widespread in SK. Source of AB numbers: http://www.abmi.ca/abmi/humanfootprint/hfsummary.jsp
3.2	Mining & quarrying	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	Infrastructure only considered; potash, coal mining, gravel pits; widespread in SE SK
3.3	Renewable energy		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Wind farms in southern AB (not close to where salamanders occur); usually not put in salamander habitat
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)	Severity varies with road type; some farm roads and service roads have little traffic, reducing overall severity. Lowered from "Serious - Slight" to "Moderate - Slight" (based on post-conference review by K. Ovaska and C. Paszkowski)
4.2	Utility & service lines	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Prairie Alberta: 2-3% of land area affected; negative effects on salamanders through barriers to movement and habitat loss (through draining of wetlands) but might also result in pond creation.
5	Biological resource use		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.1	Hunting & collecting terrestrial animals		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Collection of salamanders for pets etc. might be happening at a low level. Collection for bait allowed in MB for personal use, but scale is small; in AB live bait can be collected for personal use in fishing but has to be used that site and not moved to another lake.
5.3	Logging & wood harvesting		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Potential concern by altering habitat but not all effects are necessarily deleterious, as logging opens up habitat & might make it more suitable for salamanders (might even facilitate range expansion northwards in AB as ground squirrels and other grassland species follow clearing of closed forest stands).
6	Human intrusions & disturbance	D	Low	Small (1-10%)	Serious - Slight (1-70%)	High (Continuing)	
6.1	Recreational activities	D	Low	Small (1-10%)	Serious - Slight (1-70%)	High (Continuing)	Off-road vehicles, mostly ATVs, and mud-bogging in particular are an issue throughout the prairies. Some people target wetlands and can destroy habitat and all eggs in the entire pond.
6.2	War, civil unrest & military exercises		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	DND training occurs in areas with salamanders (Suffield, Wainright & others have tiger salamanders); some military exercises create pond habitat.
7	Natural system modifications	BD	High - Low	Large (31-70%)	Serious – Slight (1-70%)	High (Continuing)	
7.1	Fire & fire suppression		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Fire suppression: Parkland is encroaching on Prairies in Alberta, and closed forest stands are encroaching on Parkland; treed habitat is still usable by salamanders, provided the canopy is not too closed. From BC assessment: It is thought that when there is a fire, most salamanders are underground and survive, unless the fire is very hot and raises soil temperatures substantially.
7.2	Dams & water management/use	BD	High - Low	Large (31-70%)	Serious - Slight (1-70%)	High (Continuing)	Management of water occurs throughout the species' range; every type of agriculture requires water management. Some impacts may be positive (digging of ponds) but most are probably negative.
7.3	Other ecosystem modifications		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Reclamation of land, e.g., from mining.
8	Invasive & other problematic species & genes	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	
8.1	Invasive non-native/alien species	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	Rainbow Trout, other introduced fish, and *Batrachochytrium dendrobatidis* (Bd; might be native) considered. Tiger salamanders do poorly with fish. Fish stocking is widespread in AB, SK and MB and overlaps with salamander distribution. Bd associated mortality has not been noted from this species yet, however, should be monitored. Lowered from "Serious - Moderate" to "Moderate" (based on post-conference review by K. Ovaska and C. Paszkowski).

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.2	Problematic native species	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Trout stocking (introduced and native species are captured in the above row 8.1. *Ambystoma tigrinum* virus (ATV) is prevalent throughout the species' range, but doesn't always result in disease. Epidemics are poorly documented except for some areas in SK. Habitat connectivity is an issue and affects spread of disease. Invasive non-native strains of ATV may be present due to moving around larvae and fish. Impacts tied to other land uses. There are places around Regina with no recovery after an epidemic. Severity lowered from "Serious - Slight" to "Moderate - Slight" (based on post-conference review by K. Ovaska and C. Paszkowski).
8.3	Introduced genetic material		Unknown	Unknown	Unknown	Unknown	From BC assessment: *Ambystoma* salamanders can be found in pet stores - there is no regulation or enforcement of regulations about amphibians in pet stores. COSEWIC status report suggests that other tiger salamanders (e.g., in California) are hybridizing, but there is no information for this species.
9	Pollution	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	
9.1	Household sewage & urban waste water	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Eutrophication, occasional heavy metals; many drainages in AB are naturally eutrophic to hypereutrophic.
9.2	Industrial & military effluents	D	Low	Small (1-10%)	Serious - Moderate (11-70%)	High (Continuing)	Oil spills; coal mines; potash & other mining effluents.
9.3	Agricultural & forestry effluents	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	Round-up, run-off, sedimentation, fertilizers. Lowered from "Serious to Moderate" to "Moderate" (based on post-conference review by K. Ovaska and C. Paszkowski)
9.4	Garbage & solid waste		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
9.5	Air-borne pollutants		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Pollutant release from oil & gas development, including heavy metals, and from cities; acid rain in some areas, as shown for mountain of AB; these pollutants can travel great distances.
9.6	Excess energy		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Heated water from power plants. Light pollution may be a problem at some sites but impacts are unclear (impacts have been shown for anurans)
11	Climate change & severe weather	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	
11.2	Droughts	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	Most important predicted impacts are from droughts, which are already happening; 2002 drought affected entire southern portion of SK. Impacts on salamanders are context-dependent: some populations may be wiped out, whereas those in other areas would be less affected. Severity score lowered from "Serious - Moderate" to "Moderate - Slight" (based on post-conference review by K. Ovaska and C. Paszkowski).
11.3	Temperature extremes		Unknown	Unknown	Unknown	Unknown	Colder winters could be a problem, if variability in winter temperatures increases. Increased water temperatures are probably not a threat because the salamanders are relatively tolerant and occur far south; adult animals can retreat underground.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.4	Storms & flooding		Unknown	Unknown	Unknown	Unknown	In general, more severe and frequent storms are predicted. Flooding caused by storms could increase pollutant and fish transport into breeding ponds.