COSEWIC
Assessment and Status Report

on the

Oregon Spotted Frog
Rana pretiosa

in Canada

ENDANGERED
2011

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

COSEWIC. 2011. COSEWIC assessment and status report on the Oregon Spotted Frog *Rana pretiosa* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 47 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Previous report(s):

COSEWIC. 2000. COSEWIC assessment and status report on the Oregon Spotted Frog *Rana pretiosa* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 22 pp.

Haycock, R.D. 2000. COSEWIC status report on the Oregon Spotted Frog *Rana pretiosa* in Canada, *in* COSEWIC assessment and status report on the Oregon Spotted Frog *Rana pretiosa* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-22 pp.

Production note:
COSEWIC would like to acknowledge Vanessa Craig for writing the status report on the Oregon Spotted Frog (*Rana pretiosa*) 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.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la grenouille maculée de l'Oregon (*Rana pretiosa*) au Canada.

Cover illustration/photo:
Oregon Spotted Frog — Denis Knopp photographs.

Catalogue No CW69-14/94-2011E-PDF
ISBN 978-1-100-18693-1

Recycled paper

COSEWIC
Assessment Summary

Assessment Summary – May 2011

Common name
Oregon Spotted Frog

Scientific name
Rana pretiosa

Status
Endangered

Reason for designation
This highly aquatic frog has a small Canadian distribution within the populated and highly modified Fraser River Basin in southwestern British Columbia. It currently occurs at four sites, isolated from one another, and has been extirpated from an additional three sites. One extant population is near extinction, and the remaining populations are small and vulnerable to disturbance and stochastic events. Habitat loss and fragmentation, hydrological alteration, disease, introduced predators, and poor water quality continue to threaten remnant populations.

Occurrence
British Columbia

Status history
Designated Endangered in an emergency assessment on 13 September 1999. Status re-examined and confirmed in May 2000 and in May 2011.

COSEWIC
Executive Summary

Oregon Spotted Frog
Rana pretiosa

Wildlife species description and significance

The Oregon Spotted Frog, *Rana pretiosa*, is a member of the family Ranidae, or true frogs. Prior to 1997, the name *Rana pretiosa* was applied to both *R. pretiosa* and *R. luteiventris* (Columbia Spotted Frog) as currently known. Therefore, when interpreting research conducted prior to 1997, a reader must note the geographic location of the study, which will indicate the species in question.

The Oregon Spotted Frog is a medium-sized frog with a body length in adults of 60 to 80 mm. The background colour is brown or reddish and becomes more reddish as the frogs age. The common name of the species is in reference to the dark spots with light centres that are present over the head, back, and legs. The underside of the legs and belly of juvenile frogs is white or cream-coloured, changing to orange or red in adults.

The distribution of the Oregon Spotted Frog overlaps with that of the Northern Red-legged Frog (*R. aurora*), with which it may be confused. The two species can be distinguished by subtle differences in appearance, including lack of green mottling in the groin, shorter legs, and more upturned eyes in the Oregon Spotted Frog. The Oregon and Columbia Spotted Frogs are very similar in appearance but are not found in the same areas.

This species is sensitive to contaminants in its environment including nitrates and nitrites, prevalent in run-off from agricultural areas. The Oregon Spotted Frog may serve as a bioindicator of the condition of shallow wetlands that it occupies.

Distribution

The historical range of the Oregon Spotted Frog extends from the Pit River drainage in California northward to southwestern British Columbia. The species has disappeared from many areas throughout its range, including three of seven known sites in British Columbia, all three known sites in California, 44 sites in Oregon, and 11 sites in Washington State. Its current range extends from extreme southwestern British Columbia southward to the Klamath Basin in Oregon. In Canada, the species is extant at four sites all within the Fraser River Basin of British Columbia: Aldergrove, Maria Slough, Mountain Slough, and Morris Valley.

Habitat

The Oregon Spotted Frog is usually associated with large (> 4 ha) wetlands with emergent or floating vegetation within forested landscapes. The frogs are highly aquatic and almost always found in or beside water. In spring, egg-laying occurs in shallow warm water in seasonally inundated areas. In summer, the frogs forage in shallow wetlands. In winter, they often over-winter in springs and seepages that do not freeze completely or in low-flow channels or ditches, or they may bury into silty soil or vegetation at such sites.

Biology

The frogs become active and begin breeding in spring after air temperatures reach approximately 5°C. Males produce a characteristic advertisement call consisting of a rapid series of short, low-pitched clucks, and usually call under water. Egg-laying is temperature-dependent and typically begins in March and continues for 2 to 4 weeks in British Columbia. Egg masses, each with up to 1500 eggs per mass, are laid in communal clusters with the tops of egg masses often exposed to the air. The placement of egg masses in shallows makes them vulnerable to freezing and desiccation caused by wind or receding water levels. In some years, embryonic survivorship can be zero. Survival of tadpoles can also be extremely low due to depredation. Most movements of individual frogs between breeding and wintering habitat are localized, but the frogs are capable of longer movements of up to about 3 km along water courses.

Population sizes and trends

Egg-mass counts at the four known extant Canadian sites suggest a total population size of fewer than 500 adult frogs in 2010. One population (Aldergrove) has declined precipitously since monitoring began in 1997 and is nearing extirpation. One population (Mountain Slough) appears stable, and one (Maria Slough) has fluctuated and may be declining. A new population (Morris Valley) was discovered in 2008 and has limited data.

Threats and limiting factors

The greatest threat to the species in Canada is continuing loss of suitable wetlands and associated terrestrial habitat and accompanying habitat fragmentation and population isolation. Additional threats include alteration of site hydrology, which can adversely affect egg-laying habitat and increase mortality of eggs; pollution affecting embryonic or tadpole survival; diseases such as chytridiomycosis and iridoviruses; and predators or competitors such as introduced American Bullfrogs, Green Frogs, and fish.

Protection, status, and ranks

The Oregon Spotted Frog was assessed in 2000 by COSEWIC as Endangered in Canada and is listed under Schedule 1 of the *Species at Risk Act*. The species is protected under the *British Columbia Wildlife Act* from being killed, wounded, transported, or collected without a permit. NatureServe (2010) lists the species as Imperiled (G2) globally; Critically Imperiled (N1) in Canada, and Imperiled (N2) in the U.S. In British Columbia, the species is Critically Imperiled (S1) and is on the provincial Red List of species at risk. The species is on the IUCN Red List as Vulnerable.

Two of four currently occupied sites (Mountain Slough and Morris Valley) are privately owned. The water body of one site (Maria Slough) is on Provincial Crown Land; however, the surrounding land is partially on First Nations Reserve land and partially on privately owned land. The remaining site (Aldergrove) is on federal land, managed by the Department of National Defence, which controls site access and limits activities in the surrounding area.

TECHNICAL SUMMARY

Rana pretiosa
Oregon Spotted Frog — Grenouille maculée de l'Oregon
Range of occurrence in Canada: British Columbia

Demographic Information

Generation time *Age of maturity + (1/annual mortality rate). See Biology: Life Cycle and Reproduction for details*	4.7 – 5.5 years
Is there a continuing decline in number of mature individuals? *Population at Aldergrove has had a 100% decline in the effective breeding population since monitoring began in 1997. Maria Slough population has fluctuated and might be declining.*	Yes
Estimated percent of continuing decline in total number of mature individuals within 5 years or 2 generations. *Extrapolation from annual egg mass counts suggest a decline of approximately 35% from 2000 to 2010 within continuously monitored areas at three sites (Aldergrove; Mountain Slough; Maria Slough); the decline is 19% if a new expanded search in 2010 at one of the sites (Mountain Slough) is included (see **Fluctuations and Trends**); there has been loss of one population (Aldergrove) within this period*.	Decrease of approximately 35%
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]. *Loss of one of four populations (Aldergrove) over the past 3-generation period, representing an inferred decline in mature individuals of approximately 25%.*	Decrease of uncertain magnitude
Projected or suspected percent reduction or increase in total number of mature individuals over the next 10 years or 3-generation period	Unknown
Observed, estimated, inferred, or suspected percent reduction or increase in total number of mature individuals over any 10 years or 3 generations period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased? *Potential causes of the decline are partially understood but have not ceased*.	No
Are there extreme fluctuations in number of mature individuals?	Unknown

Extent and Occupancy Information

Estimated extent of occurrence	303 km^2
Index of area of occupancy (IAO) – 2x2 km^2 grid cell	40 km^2
Is the total population severely fragmented? *Spatial separation between sites/populations is significant, and the viability of the populations is in doubt for at least two of the four populations (Aldergrove & Maria Slough); none may be viable over the long term.*	Yes
Number of locations *Threats that can rapidly affect the population at each of the four extant sites include run-off of pollutants from adjacent agricultural areas, grazing by livestock, and deterioration of breeding sites through vegetation succession. Each site is considered a separate location because the severity and type of threats is variable, depending on land ownership and activities in the surrounding area. However, if the invasion and spread by the non-native American Bullfrog is considered the most significant threat across the sites, then the number of locations is only one*.	1 - 4
Is there a projected continuing decline in extent of occurrence? *The Aldergrove population will likely be extirpated resulting in a reduction of 79% in EO to 63 km^2.*	Yes

Is there a projected continuing decline in index of area of occupancy? *The Aldergrove population will likely be extirpated, resulting in a reduction of 20% in IAO to 32 km²*.	Yes
Is there a projected continuing decline in number of populations? *The Aldergrove population will likely be extirpated*.	Yes
Is there a projected continuing decline in number of locations? *The Aldergrove population will likely be extirpate*.	Yes
Is there an observed and projected continuing decline in quality of habitat?	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population *(2010 estimate from egg-mass counts, assuming 1 adult female and 1 or 2 adult males to each female; see **Table 3**)*	**N Mature Individuals**
1. Aldergrove: No egg masses were discovered at the site from 2007 to 2011, but one adult male was seen there in 2009 and again in 2011.	~0 (nearing extirpation)
2. Mountain Slough: 29 egg masses were found in 2010 within the traditional search area, providing a population estimate of 58–87 adults. An additional 23 egg masses were discovered in an expanded search area, providing a population estimate of 104–156 adults.	104–156
3. Maria Slough (based on egg mass counts in 2010)	134–201
4. Morris Valley (based on egg mass counts in 2010)	78–117
Total	316–474

Quantitative Analysis

No PVA has been done.	Not available

Threats (actual or imminent, to populations or habitats)

Habitat loss, habitat fragmentation and genetic isolation, hydrological alteration, disease, introduced predators/competitors, water quality

Rescue Effect (immigration from outside Canada)

Status of outside population(s): United Stated: N2 (Imperiled); Washington: S1 (Critically Imperiled), listed as a State Endangered species; Oregon: S2 (Imperiled), listed as Critically Sensitive; California: S1 (Critically Imperiled), listed as a Species of Special Concern (potentially extirpated).	
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada? *Twelve sites have been identified as potential candidates for introduction of R. pretiosa; additional habitat assessments are required, but initial assessments are favourable (Pearson 2010b)*.	Possibly
Is rescue from outside populations likely?	No

Current Status

COSEWIC: Endangered (2011)
British Columbia: Provincial Red List; S1

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Endangered	B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v); C2a(i)
Reasons for designation: This highly aquatic frog has a small Canadian distribution within the populated and highly modified Fraser River Basin in southwestern British Columbia. It currently occurs at four sites, isolated from one another, and has been extirpated from an additional three sites. One extant population is near extinction, and the remaining populations are small and vulnerable to disturbance and stochastic events. Habitat loss and fragmentation, hydrological alteration, disease, introduced predators, and poor water quality continue to threaten remnant populations.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Although the total population is declining, the magnitude of the decline over three generations is uncertain.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered under B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v) as both the extent of occurrence (EO) and the index of area of occupancy (IAO) are below the thresholds for Endangered; there are fewer than 5 locations; the total population is severely fragmented; there is a continuing decline in the EO, IAO, area, extent and quality of habitat, number of locations and number of mature individuals.
Criterion C (Small and Declining Number of Mature Individuals): Meets Endangered under C2a(i) as there are fewer than 2,500 mature individuals, there is a continuing (observed and projected) decline in numbers of mature individuals, and no population exceeds 250 adults.
Criterion D (Very Small or Restricted Total Population): Meets Threatened under D1 as the total population has fewer than 1,000 mature individuals. Meets Threatened under D2 as there are fewer than 5 locations.
Criterion E (Quantitative Analysis): No population viability analysis done.

PREFACE

Since the preparation of the previous COSEWIC status report on *Rana pretiosa* in 2000 (Haycock 2000a), the species has been discovered at one additional site, bringing the total number of extant populations in Canada to four. This discovery resulted in an expansion of the extent of occurrence from 115 km^2 to 303 km^2, an increase of approximately 260%. During the same time period, one of the populations has declined > 98% and is nearing extirpation, even though a captive rearing program has released > 2,000 frogs and tadpoles, reared from eggs collected at the site; another population may be declining. The discovery of the additional population in 2008 resulted in a slight overall increase in the estimated number of mature adults in Canada since the previous estimate in 2000. However, egg mass counts at known sites suggest a continuing decline in the total population, and the number of mature adults in Canada remains small (less than 500 adults).

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
(2011)

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.

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

COSEWIC Status Report

on the

Oregon Spotted Frog

Rana pretiosa

in Canada

2011

TABLE OF CONTENTS

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE 4
Name and classification 4
Morphological description 4
Population spatial structure and variability 7
Designatable units 10
Special significance 10
DISTRIBUTION 10
Global range 10
Canadian range 12
Search effort 14
HABITAT 18
Habitat requirements 18
Habitat trends 20
BIOLOGY 21
Life cycle and reproduction 21
Physiology and adaptability 23
Dispersal and migration 25
Interspecific interactions 26
POPULATION SIZES AND TRENDS 27
Sampling effort and methods 27
Abundance 30
Fluctuations and trends 30
Rescue effect 32
THREATS AND LIMITING FACTORS 32
Habitat loss 32
Habitat fragmentation and genetic isolation 33
Hydrological alteration 34
Water quality 34
Disease 35
Introduced predators 36
Electromagnetic current 37
PROTECTION, STATUS, AND RANKS 37
Legal protection and status 37
Non-legal status and ranks 38
Habitat protection and ownership 38
ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED 39
INFORMATION SOURCES 39
BIOGRAPHICAL SUMMARY OF REPORT WRITER 47

List of Figures

Figure 1. *Rana pretiosa* adult (top; April 2003), feet showing webbing to end of toes (middle); juvenile (bottom left; Mountain Slough, 1997), and developing embryos in an egg mass (bottom right; Morris Valley, spring 2008). Denis Knopp photographs. 5

Figure 2. Bootstrapped neighbour-joining tree depicting genetic relationships among populations of *R. pretiosa* in Canada and the closest U.S. populations in Washington State. Genetic distances are based on data from 13 microsatellite loci and calculated using Nei's standard genetic distance. Illustration provided by I. Phillipsen and M. Blouin. 9

Figure 3. The historical global range of *Rana pretiosa* is restricted to the Fraser River Lowlands in British Columbia, disjunct areas in Washington and Oregon, and small areas of California. Adapted from IUCN *et al.* (2009)..... 11

Figure 4. Location of *Rana pretiosa* populations in Canada and their status. See Table 3 for additional details about the populations. 12

Figure 5. Sites searched for *Rana pretiosa* in Canada to 2009. See Table 2 for additional details. 15

List of Tables

Table 1. Mean body length and mass of adult male and female *R. pretiosa* in Canada. Data were obtained from Haycock (2001), which presents average body sizes for frogs at Aldergrove, Mountain Slough, and Maria Slough; and from Haycock (2005), which reports body sizes for frogs captured in 2001–2005 at MD Aldergrove. 6

Table 2. Areas searched during targeted surveys for *Rana pretiosa* from 1996 to 2010. 15

Table 3. Estimated number of breeding adults of *Rana pretiosa* at occupied sites in Canada, search effort, and information on egg collection for captive rearing and release of captive-reared frogs. Estimates are provided for historical populations where available. Adapted and updated from Haycock 2000a. 27

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and classification

Rana pretiosa, Baird and Girard, 1853, belongs to the family Ranidae, or true frogs. A single species was previously considered to encompass all populations of Spotted Frogs in western North America, including areas of Nevada, Utah, British Columbia, Washington, Oregon, Montana, Alberta, and Yukon. Thompson (1913) designated two subspecies, *R. p. pretiosa*, and *R. p. luteiventris*, based on colour and the presence or absence of tubercles. The inconsistency of these defining characteristics meant that the subspecific grouping by Thompson (1913) was generally not recognized (Nussbaum *et al.* 1983; Stebbins 1985). An analysis by Green *et al.* (1996) used variations in allozyme frequencies and morphometry to determine that the group included at least two distinct species. With further analysis, including additional samples, Green *et al.* (1997) reported that two groups (species) could be distinguished at the molecular level based on six diagnostic loci. Based on the samples examined, one species occurred in southwestern Washington and the Oregon Cascades, and Spotted Frogs in the remaining areas of North America belonged to the second species. Green *et al.* (1997) assigned Spotted Frogs in western British Columbia, Puget Sound, south-central Washington, and Oregon Cascades, to the Oregon Spotted Frog, *R. pretiosa*. Spotted Frogs in southwestern Yukon, southeastern British Columbia, Alberta, the Great Basin and Rocky Mountains, with isolated localities in Nevada and Utah, were assigned to the Columbia Spotted Frog, *R. luteiventris* Thompson, 1913 (Green *et al.* 1997). No subspecies are recognized for either *R. pretiosa* or *R. luteiventris*.

Morphological description

The common name of *R. pretiosa* reflects the dark spots with light centres that are present over the head, back, and legs (Figure 1). These spots become larger and darker, and the edges more ragged, as the frogs age (McAllister and Leonard 1997). Small tubercles are also scattered over the back. Juveniles are typically brown, or occasionally olive-green (McAllister and Leonard 1997). Adults are brown or reddish, and become more reddish with age. Dorsolateral folds, which extend from behind the eye to the lower back, are typically light brown to orange. The underside is white or cream-coloured in juveniles, changing to orange or red in adults. A dark mottled pattern on the underside is prominent in adults but absent from newly metamorphosed frogs (Hayes 1997 *cited in* U.S. Fish and Wildlife Service 2010).

Figure 1. *Rana pretiosa* adult (top; April 2003), feet showing webbing to end of toes (middle); juvenile (bottom left; Mountain Slough, 1997), and developing embryos in an egg mass (bottom right; Morris Valley, spring 2008). Denis Knopp photographs.

Rana pretiosa is a medium-sized frog. The mean snout-urostyle length (SUL) of adult frogs captured in British Columbia from 1997 to 2001 was 58.1 mm (range: 38.5–80.2 mm; N = 727), and the mean mass of adult frogs was 21.0 g (range: 5.9–55.4 g; N = 733; Haycock 2001). Females are larger than males (Table 1; Haycock 2001, 2005). These values are similar to measurements from frogs in Thurston County, Washington, where males averaged 56 mm snout-vent length (SVL; approximately equivalent to SUL), and females averaged 66 mm SVL; and from two populations in the south Cascades of Washington, where males averaged 57 mm and females 75 mm SVL (McAllister and Leonard 1997). Egg masses are characteristically clumped, usually laid communally, although single egg masses are sometimes found. The number of eggs per mass has been reported to range from 643 to 940 at Canadian sites (Licht 1974; Haycock 2005; see **Biology: Life cycle and reproduction**), and up to 1,500 in Oregon and Washington (Cushman and Pearl 2007). Egg masses are never attached to vegetation (Licht 1971) and are laid in shallow water, with the result that much of the upper egg mass is exposed (McAllister and Leonard 1997). Average egg diameter is 2.31 mm ± 0.18 (1 SD); N = 292 (Licht 1971). Tadpoles are dark above with a light belly. Older tadpoles have metallic flecks on the head, body, and tail.

Table 1. Mean body length and mass of adult male and female *R. pretiosa* in Canada. Data were obtained from Haycock (2001), which presents average body sizes for frogs at Aldergrove, Mountain Slough, and Maria Slough; and from Haycock (2005), which reports body sizes for frogs captured in 2001–2005 at MD Aldergrove.

	Snout-urostyle length (mm)			Mass (g)			Source
	Mean	Range	n	Mean	Range	n	
Male	56.1	39.0–80.2	591	18.6	6.9–36.4	586	Haycock 2001
Female	66.1	38.5–80.2	142	30.8	5.9–55.4	141	Haycock 2001
Male	54.3	39–66	243	16.3	6.9–28.5	243	Haycock 2005
Female	64.6	48–72	25	24.5	12.7–38.8	25	Haycock 2005

Rana pretiosa is sympatric with the Northern Red-legged Frog (*R. aurora*), which is similar in body size and colouration. Adult *R. pretiosa* can be distinguished from *R. aurora* by the following features: eyes that are angled upwards instead of outwards; shorter legs; markings that resemble spots rather than freckles; the undersides of the legs and abdomen are less brightly coloured; mottling is present on the abdomen; groin mottling is absent or is black or grey on a light background, compared to brightly coloured groin mottling of black, green, yellow, or red on *R. aurora*; and toes that are fully webbed rather than semi-webbed (see Matsuda *et al.* 2006 for details). *Rana pretiosa* is not sympatric with *R. luteiventris* and therefore can be distinguished based solely on geographic distribution. Morphologically, these two spotted frogs are very similar (Green *et al.* 1997), but adult *R. pretiosa* can be distinguished from adult *R. luteiventris* by the presence of mottling on the abdomen (Hayes 1994 *cited in* U.S. Fish and Wildlife Service 2010; Hayes 1997 *cited in* McAllister and Leonard 1997).

Population spatial structure and variability

There are four extant populations of *R. pretiosa* in British Columbia, Maintenance Detachment (MD) Aldergove, Maria Slough, Mountain Slough, and Morris Valley, which are isolated from each other (Canadian Oregon Spotted Frog Recovery Team 2009a; see **Canadian Distribution**). In the U.S., known movements of individuals are almost entirely along aquatic corridors (Watson *et al.* 2003; Pearl and Hayes 2004; U.S. Fish and Wildlife Service 2010) and are less than 3 km (Cushman and Pearl 2007). Aldergrove is 50 to 60 km away from other occupied sites and is not linked to them by aquatic habitat. The Morris Valley population also does not have an aquatic connection to other populations; it is approximately 6.5 km in straight-line distance from the closest population at Mountain Slough and is separated from it by a mountain >800 m in elevation. Although Maria Slough and Mountain Slough have an aquatic connection along the Fraser River, the populations are >15 km apart, which is much greater than the yearly maximum known movement of the frogs. Movements of frogs between these populations would likely require the establishment of at least temporary populations to enable “stepping stone migration” between them (Blouin *et al.* 2010). The composition of habitat between the populations has not been formally described, but agricultural and urban development and roads have fragmented the terrestrial and remaining wetland habitats in the area (Canadian Oregon Spotted Frog Recovery Team 2009a). It is unlikely that sufficient suitable habitat remains to permit movements of individuals among populations (Knopp pers. comm. 2010).

Blouin (2002) conducted a genetic study of *R. pretiosa* based on samples from 20 populations in Washington and Oregon (toe snips), and from the Canadian Aldergrove population (adults and eggs). The U.S. populations were analyzed for variation at 13 microsatellite loci and 15 of the U.S. populations and the Aldergrove population for variation in mtDNA. The mtDNA results indicated that the Aldergrove population (N = 13 individuals tested) has a unique allele, but the sample size was inadequate for estimating allelic frequencies for the 13 microsatellite loci. Relatively high variation in allelic frequency for microsatellites among neighbouring U.S. populations (e.g., Fst = 0.23 for the Cascades Lakes population and 0.31 for the Klamath Basin population) suggested that there was little movement of frogs among sites and/or a high rate of genetic drift, even in relatively undisturbed habitat. This same degree of variation was not apparent in mtDNA. Overall, the results suggested that the populations have been isolated long enough for genetic drift to occur but not long enough for mutations to appear in mtDNA.

A subsequent study focused on examining 13 microsatellite loci from egg samples from the Aldergrove, Maria Slough, and Mountain Slough populations (N = 7 egg masses from each site; Blouin pers. comm. 2009). Data were compared to those from the same loci from 20 populations in Washington and Oregon. Canadian populations had relatively low within-population genetic diversity, as measured by expected heterozygosity (H_E), compared to populations in Washington and Oregon. H_E was 0.18 for Mountain Slough, 0.17 for Maria Slough, and 0.36 for Aldergrove populations, suggesting that at least the Mountain and Maria Slough populations have low effective sizes. A more recent analysis in 2009 that included a larger sample (N=30) of the Morris Valley, Mountain Slough, and Maria Slough populations found that H_E for the populations was 0.27, 0.36, and 0.22, respectively (Phillipsen and Blouin pers. comm. 2010). The genetic diversity of Maria Slough and Morris Valley populations was relatively low compared to populations in Washington (Dempsey Creek H_E = 0.46; Beaver Creek H_E = 0.47; Phillipsen and Blouin pers. comm. 2010). The analyses indicated that the populations at Morris Valley and Maria Slough are more similar to each other than either is to the population at Aldergrove (using data from the previous study) or Mountain Slough, and that all British Columbia populations are distinct from the remaining U.S. populations (Figure 2). Estimates of genetic diversity within the Canadian populations may be biased downwards, and estimates of genetic distances among them biased upwards, because of small sample sizes and because eggs were sampled (gametes from a single season's breeders), rather than the entire age distribution of adults (Blouin *et al.* 2010). The current Canadian populations appear to have small effective population sizes, and inbreeding is probably occurring, although its extent and effects on viability are unknown (Blouin pers. comm. 2009).

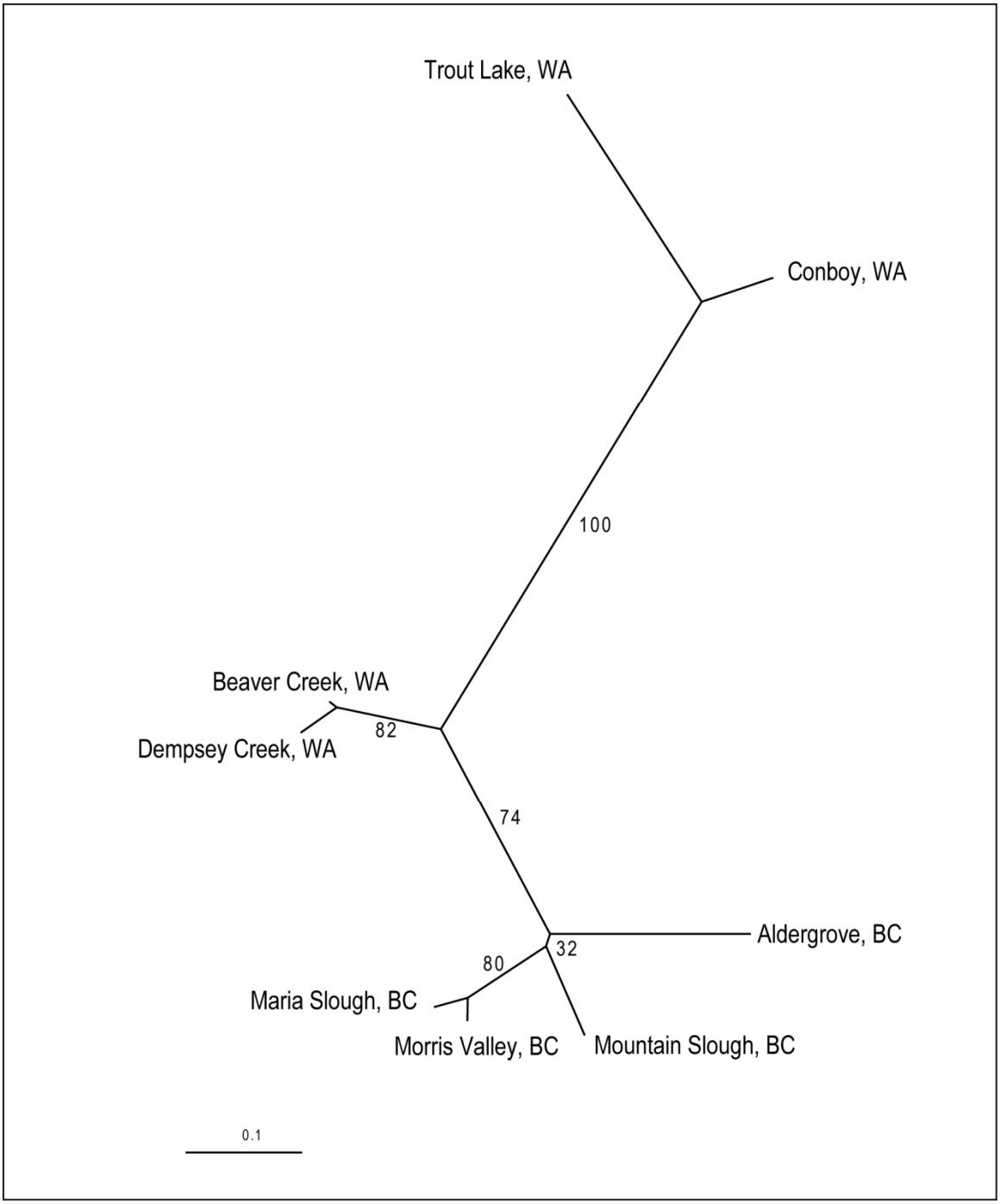

Figure 2. Bootstrapped neighbour-joining tree depicting genetic relationships among populations of *R. pretiosa* in Canada and the closest U.S. populations in Washington State. Genetic distances are based on data from 13 microsatellite loci and calculated using Nei's standard genetic distance. Illustration provided by I. Phillipsen and M. Blouin.

Designatable units

The entire range of the species in Canada is confined to the Fraser River Lowlands in British Columbia. Although the four extant populations are currently isolated, they are likely remnants of a larger population with a wider geographic distribution that has only relatively recently become fragmented (see **Population spatial structure and variability**). The four Canadian populations are closely related, compared to the genetic distances within the entire species (Blouin pers. comm. 2009; Phillipsen and Blouin pers. comm. 2010). These data suggest that the Canadian population is a single designatable unit.

Special significance

In Canada, *R. pretiosa* is found only in the Fraser Lowlands of British Columbia. Similar to many other amphibians, this species is sensitive to contaminants in the environment, which can cause sublethal effects at low doses (de Jong Westman *et al*. 2010). The highly aquatic lifestyle of this species increases its exposure to aquatic contaminants. It is particularly sensitive to nitrates and nitrites, prevalent in agricultural run-off (Hecnar 1995; Marco *et al.* 1999; Rouse *et al.* 1999). The species is a habitat specialist that requires wetlands with shallow areas and abundant emergent or floating vegetation. Presence of *R. pretiosa* might serve as a bioindicator of the condition of the shallow, warm water wetlands that it occupies (Canadian Oregon Spotted Frog Recovery Team 2009a).

DISTRIBUTION

Global range

The historical range of *R. pretiosa* is from the Pit River drainage in California, northward to southwestern British Columbia (Figure 3). The species has undergone severe declines and extirpations across its range. It has disappeared from three historical sites in British Columbia, all sites where it was known to occur in California, 44 sites in Oregon, and 11 sites in Washington (U.S. Fish and Wildlife Service 2010). The current geographic distribution of *R. pretiosa* extends from extreme southwestern British Columbia southwards through the Puget Sound / Willamette Valley Trough in Washington and Oregon and the Cascades range from south-central Washington to the Klamath Basin in Oregon (U.S. Fish and Wildlife Service 2010). There are four known extant sites in British Columbia and 38 in the U.S., including 8 in Washington, and 30 in Oregon. Although the species has disappeared from all known sites in California, surveys have been inadequate to determine whether it is extirpated throughout the state (U.S. Fish and Wildlife Service 2010). Range-wide, the species has disappeared from 70% of the known sites and from approximately 90% of its extrapolated historical range (Pearl and Hayes 2005; Pearl *et al.* 2005).

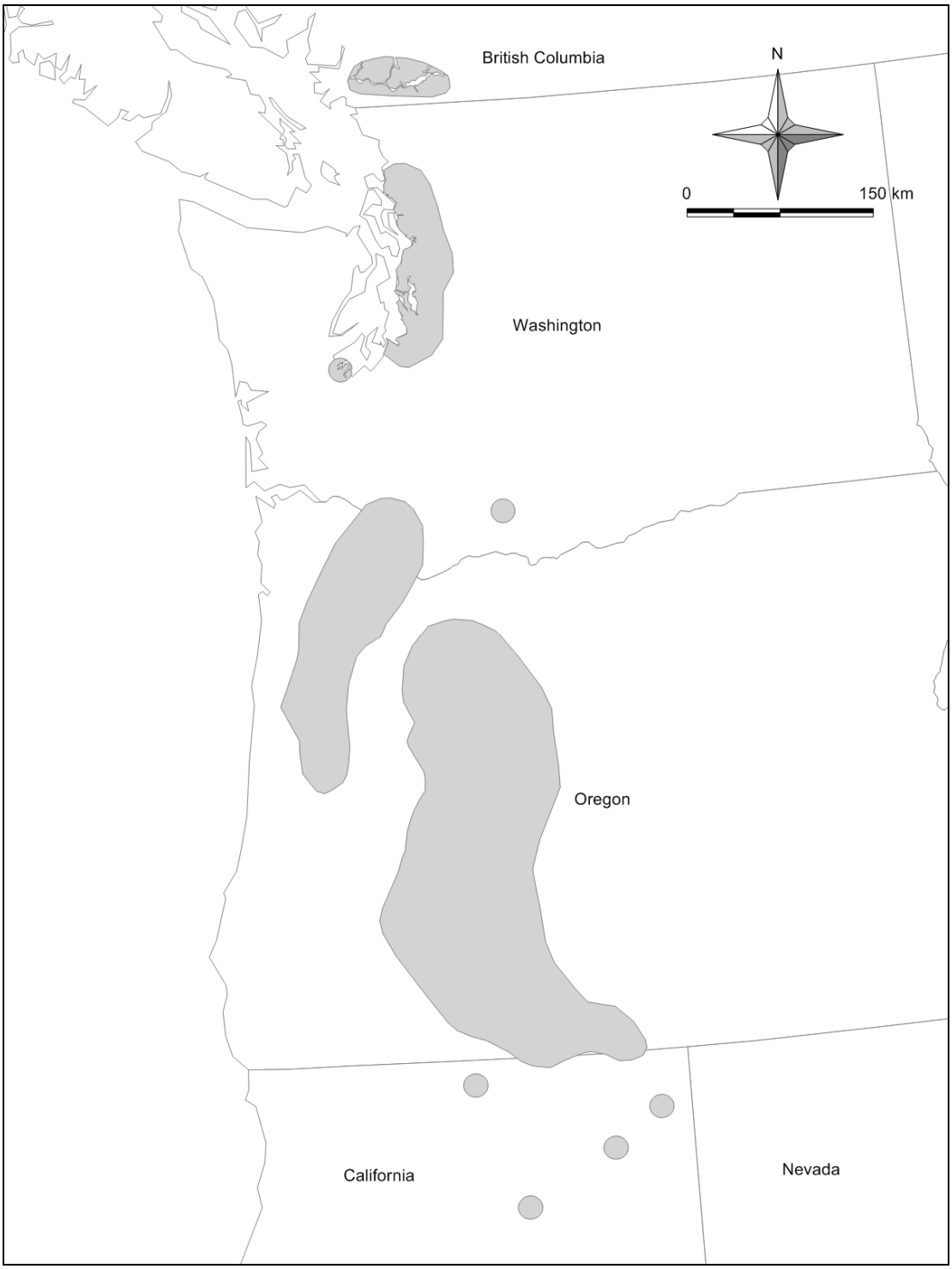

Figure 3. The historical global range of *Rana pretiosa* is restricted to the Fraser River Lowlands in British Columbia, disjunct areas in Washington and Oregon, and small areas of California. Adapted from IUCN *et al.* (2009).

Canadian range

In Canada, *R. pretiosa* is known from only seven sites, historical and recent, in the Fraser River Basin in the extreme southwest of British Columbia within the Pacific biogeographic zone (Figure 4). Three historical populations are now extirpated. A population was reported from the Sumas Prairie in 1932 (Logier 1932 *cited in* Carl and McTaggart-Cowan 1945), but the area has since been extensively modified, and no sign of the species was discovered during surveys in 1996–1997 (Haycock 1998) or in 2010 (Pearson 2010a). A population was reported from Nicomen Island (Carl and McTaggart-Cowan 1945), but the species was not found there during wetland surveys in 1997, 2000 (Haycock 2000a), or 2010 (Pearson 2010a). The third extirpated population was in the Campbell Valley Regional Park in Langley, where it was studied in the 1960s and 1970s (Licht 1969, 1971, 1974). The species was last seen at this site in 1981 (Green *et al.* 1997) and was not found during searches in 1996, 1997, 1999, or 2000 (Haycock 1999; Haycock unpubl. data in B.C. Ministry of Environment files examined by V. Craig in 2009).

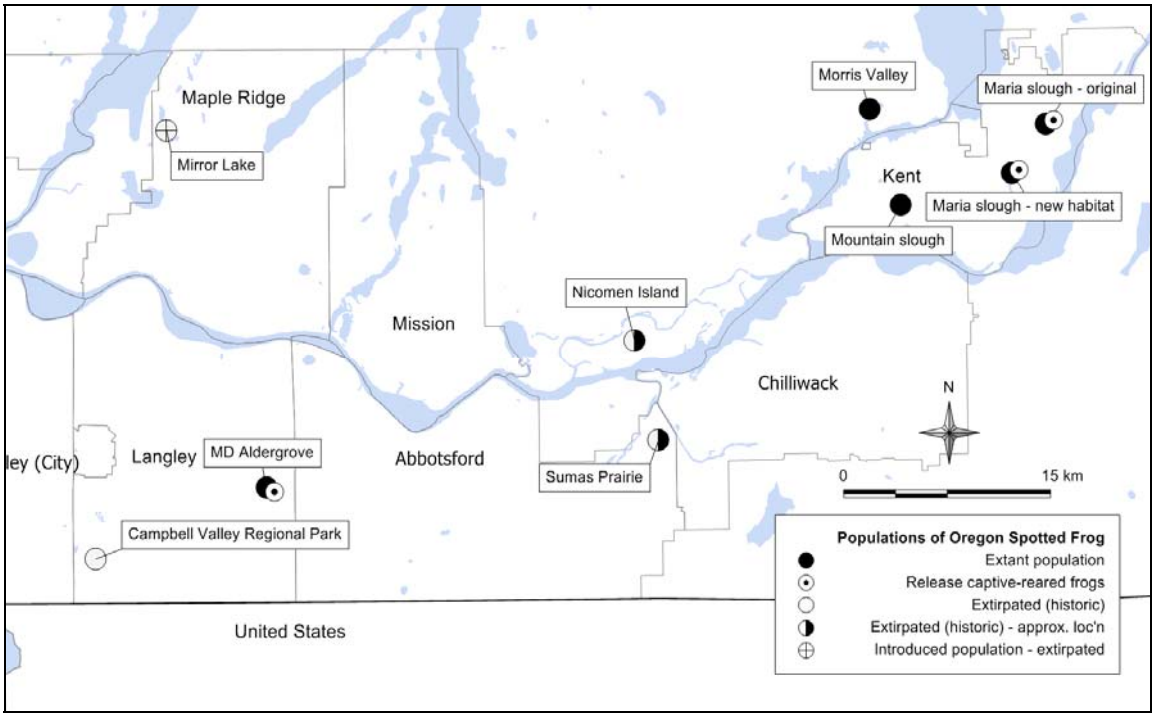

Figure 4. Location of *Rana pretiosa* populations in Canada and their status. See Table 3 for additional details about the populations.

Three previously unknown populations were discovered by Denis Knopp in 1996– 1997 during an extensive survey of wetlands in the Fraser River Lowlands (Knopp 1996, 1997; Haycock 1998). The locations are known as Maria Slough, Mountain Slough, and Maintenance Detachment (MD) Aldergrove (here referred to as Aldergrove). The fourth extant population, known as Morris Valley, in the Harrison Lake area was also discovered by Denis Knopp in 2008. The Maria Slough, Mountain Slough, and Morris Valley populations are all in the Harrison Lake area, where an adult *R. pretiosa* female was captured in the 1940s or 1950s; the specimen was recently discovered in a collection by G.D. Alcorn and J.R. Slater at the University of Puget Sound (B.C. Conservation Data Centre pers. comm. 2009). These four populations are probably currently isolated from each other.

Translocations have been conducted near the Maria Slough site in an attempt to establish a new subpopulation at restored habitat. Although a few egg masses have been found at the restored site indicating successful breeding (2–3 egg masses in 2008 and 2009; V. Craig pers. comm. 2011), this manipulated population is not regarded self-sustaining at this time (P. Govindarajulu pers. comm. 2011). Monitoring of the success of the translocation efforts is in progress (P. Govindarajulu pers. comm. 2011).

An experimental release in 2000 of approximately 700 metamorphs of *R. pretiosa* into Mirror Lake in the University of British Columbia Malcolm Knapp Research Forest, with the goal of establishing a new population, failed. The young-of-year frogs were raised in captivity from eggs collected from a population in Washington (Barnett and Richardson 2002). Although one frog was found at the site in 2003 (Hawkes 2009), no frogs or egg masses were found during a survey in 2009 (Knopp pers. comm. 2009).

Estimates of the species' range in Canada are based primarily on known oviposition sites at Maria Slough, Mountain Slough, and Aldergrove, with limited information from capture locations at Maria Slough in 2009 and 2010, and radiotelemetry data obtained in September to October 2009 from captive-reared frogs released at Maria Slough. The current extent of occurrence (EO) of *R. pretiosa* is 303 km^2. The discovery of the Morris Valley population in 2008 expanded the previously reported EO from 115 km^2 by approximately 260%. When historical populations are included in the estimate, the entire EO is 606 km^2; therefore, the current EO is approximately half of the known historical range of the species in Canada. The Canadian EO represents less than 5% of the species' global range, both current and historical. Based primarily on oviposition sites, with limited additional data from trapping and radiotelemetry of frogs, the known area of occupancy (AO) of the species is only approximately 1 km^2. The actual AO may be larger, because basing the estimate primarily on oviposition locations does not take into account use during other seasons, for which accurate data are not available. Radiotelemetry of one frog at Maria Slough in 2009 indicated that it over-wintered within the range identified by oviposition locations (Pearson 2010c). The Index of area of occupancy (IAO) is 40 km^2, based on a grid with 2 x 2 km^2 cells.

The number of locations, based on threats, ranges from one to four. Threats that can rapidly affect frogs at the four extant sites include run-off of pollutants from adjacent agricultural areas, grazing by livestock, and deterioration of breeding sites through vegetation succession. Each site is considered a separate location because the severity and type of threats is variable, depending on land ownership and activities in the surrounding area. However, if the invasion and spread by the non-native American Bullfrog is considered the most significant threat across the sites, then the number of locations is only one.

Search effort

Since 1996, there have been numerous surveys of potentially suitable habitat for the species in the Fraser River Lowlands (Figure 5, Table 2). Surveys include searching for egg masses during the breeding period (usually February through April), listening for calling frogs, or searching for tadpoles or frogs. Three historical sites (Sumas Prairie, Nicomen Island, Campbell Valley Regional Park) have been searched repeatedly without finding the species (see **Canadian Distribution**). Knopp and Haycock surveyed 45 sites with appropriate habitat in 1996 and 16 sites in 1997, six of which were resurveys of sites from 1996 (Haycock 1998; Knopp pers. comm. 2009). Note that 22 of the 45 sites surveyed in 1996 were surveyed in June or July, which is not the optimal time to detect the species (Bishop pers. comm. 2009; Knopp pers. comm. 2009). Eight additional sites were searched in 2009 (Pearson pers. comm. 2009) and 30 sites in 2010 (Pearson 2010a) without finding the species. Numerous general surveys for other wetland species have been conducted throughout the Fraser River Lowlands by researchers qualified to recognize *R. pretiosa*, without finding evidence of new populations (Albrecht pers. comm. 2009; Bishop pers. comm. 2009; Knopp pers. comm. 2009; Pearson pers. comm. 2009; Table 2). Surveyors conducting targeted searches for *R. pretiosa* spent more than 570 hours at the 80 survey sites for which search effort data are available (Table 2).

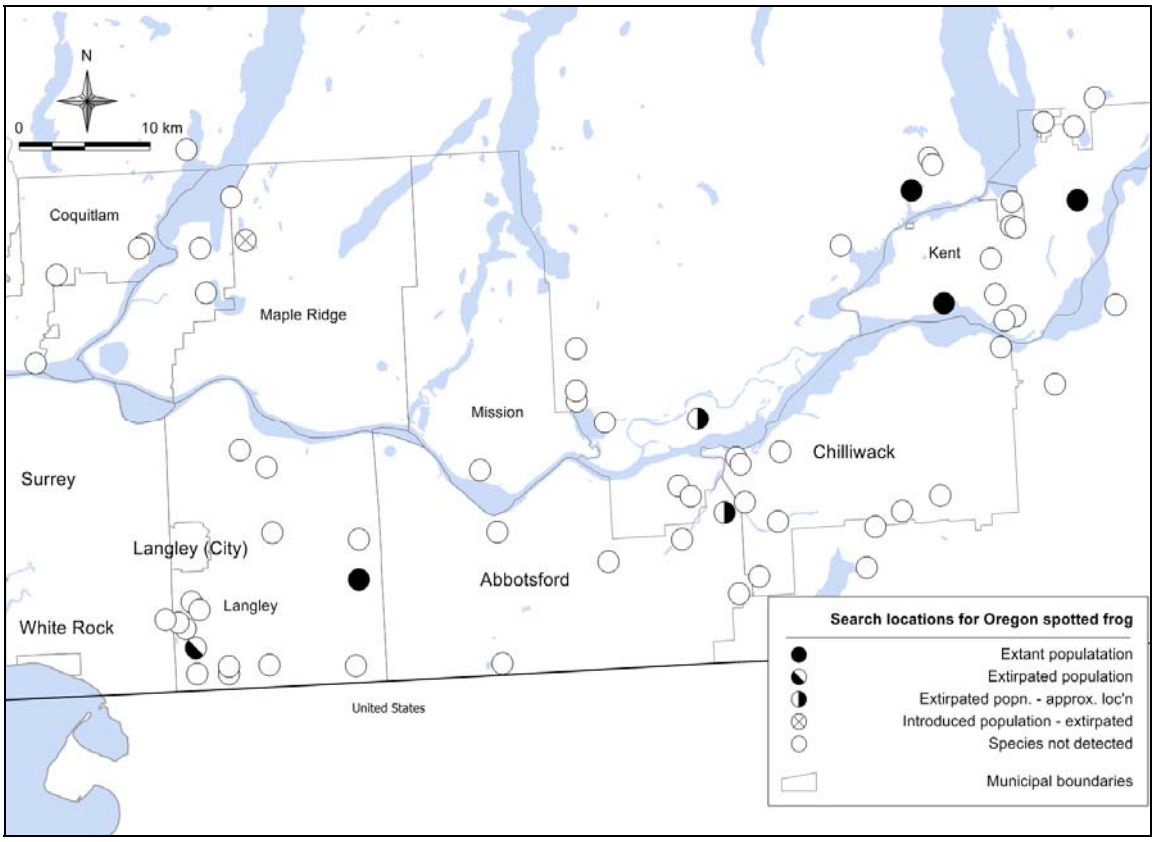

Figure 5. Sites searched for *Rana pretiosa* in Canada to 2009. See Table 2 for additional details.

Table 2. Areas searched during targeted surveys for *Rana pretiosa* from 1996 to 2010.

Year	Type[a]	Search hours[b]	Location	Month[c]	Surveyor	Sp. Det.[d]
1996	Visual	NA	24 Ave Subdivision	May	R. Haycock	N
1997	Visual	3.5	264 St & 8 Ave Marsh	March	D. Knopp	N
1996	Visual	NA	27 Ave and 196 St	April	R. Haycock	N
1996	Visual	NA	32nd Ave and 206th St	May	R. Haycock	N
1996	Visual	NA	6 Ave and 216 St	April	R. Haycock	N
1996	Visual	NA	7Ave. And 216 St	April	R. Haycock	N
1996	Visual	NA	88th Ave and 223rd St	May	R. Haycock	N
1996	Visual	NA	Addington Marsh	April	R. Haycock	N
1997	Visual	8	Agassiz Slough and Cheam Slough	April	D. Knopp	N
2010[e]	Visual	NA	Aldergrove mushroom farm	April	M.M. Pearson, A. Jonsson	N
1997	Visual	1.5	Belrose Road Ditch	March	D. Knopp	N
1996	Visual	NA	Blaney Creek	June	R. Haycock	N
2010[e]	Visual	2.2	Brae Slough	March	S. Scotton, S. Gabriel	N
1996	Visual	NA	Bridal Falls Golf and Country Club	May	D. Knopp	N
2010[e]	Visual	3.5	Brunette River	March	K. Scotton, G. Geisbrecht	N

Year	Type[a]	Search hours[b]	Location	Month[c]	Surveyor	Sp. Det.[d]
2009	Visual	12	Camp Slough	April	M. Pearson, M.P. Pearson	N
2010	Visual	9	Camp Slough	March	M. Pearson, V. Kilburn	N
1997	Trapping	17 day trapping period	Campbell Valley Regional Park	February, March	R. Haycock	N
1997	Visual	40	Campbell Valley Regional Park	NA	R. Haycock	N
1999	Visual	NA	Campbell Valley Regional Park	NA	R. Haycock	N
2000	Visual	60	Campbell Valley Regional Park	NA	R. Haycock	N
1996	Visual	2	Chadsey Lake (Pond)	July	D. Knopp	N
1997	Visual	1	Chapman Marsh	March	D. Knopp	N
1996	Visual	1	Cheam Lake Wetlands Regional Park	May	D. Knopp	N
2009	Visual	16	Cheam/Agassiz Slough	April	M. Pearson, M.P. Pearson	N
1996	Visual	0.5	Chilliwack River (pond)	July	D. Knopp	N
1996	Visual	3.5	Cook's Marsh	June	D. Knopp	N
1996	Visual	1.5	Deer Lake	July	D. Knopp	N
1996	Visual	3	Elbow Lake	June	D. Knopp	N
1996	Visual	NA	Essondale Lands	May	R. Haycock	N
1996	Visual	NA	Fern Ridge Lake	May	R. Haycock	N
1997	Visual	1	Gloucester Industrial	March	D. Knopp	N
2010[e]	Visual	1	Gordon's Brook	March	M.M. Pearson	N
2009	Visual	5.5	Grace Lake	NA	D. Knopp	N
2009	Visual	13	Great Blue Heron Reserve	April	M. Pearson, M.P. Pearson	N
2010[e]	Visual	6.5	Great Blue Heron Reserve	March	V. Kilburn	N
2008	Visual	2	Harrison area	March	D. Knopp, C. Albrecht	N
2009	Visual	69.09	Harrison area	March, April	M. Firman	N
2010[e]	Visual	3.5	Harrison River/Chehalis Delta	March, April	B. Johnson, A. Lentini, D. Knopp	N
2010[e]	Visual	NA	Harrison River (Harrison Bay marsh)	April	D. Knopp	N
1996	Visual	3	Hatzic Lake area	June	D. Knopp	N
2008	Visual	0.5	Hicks Creek	March	D. Knopp, Albrecht	N
1996	Visual	2.5	Hicks Lake (Beaver Pond)	July	D. Knopp	N
2010[e]	Visual	1	Hicks Lake (Beaver Pond)	July	D. Knopp	N
2009	Visual	1.25	Hogg Slough	March, April	M. Pearson, M.P. Pearson	N
2010[e]	Visual	1	Hogg Slough (upper)	March	M. Pearson	N
2010	Visual	>0.33	Hogg Slough (lower)	March	D. Knopp	N
2010	Visual	4.25	Hope Slough	March	V. Kilburn	N
1997	Visual	2	Hornby Lake	March	D. Knopp	N
1996	Visual	5.5	Hornby Lake (Ryder Lake Area)	July	D. Knopp	N
2010[e]	Visual	0.5	Johnson Slough	March	S. Knopp	N
1996	Visual	4	Judson Lake	July	D. Knopp	N

Year	Type[a]	Search hours[b]	Location	Month[c]	Surveyor	Sp. Det.[d]
1996	Visual	NA	Knopp Ponds (Ryder Lake Area)	July	D. Knopp	N
1996	Visual	NA	Lafarge Lake - Coquitlam	May	R. Haycock	N
1996	Visual	6	Lakemount	June	D. Knopp	N
1996	Visual	NA	Latimer Pond - Surrey	May	R. Haycock	N
1996	Visual	NA	Majuba Hill (Jenson Creek)	May, June, July	D. Knopp	N
2010[e]	Visual	11	McGillavray/Bert Brink WMA	March, April	A. Gielens, D. Knopp, M. Pearson	N
2009	Visual	7	Mirror Lake	NA	D. Knopp	N
1996	Visual	6	Maria Slough area	June	D. Knopp	Y
1997	Visual	8	Maria Slough area	April	D. Knopp	N
2010	Visual	2	McLure wetland	March	M.M. Pearson, N. Cox	N
1996	Visual	5	McGillivray Creek (Beaver Pond)	June	D. Knopp	N
1997	Visual	3.5	McGillivray Creek Game Reserve	March	D. Knopp	N
1996	Visual	NA	McLean Pond - Langley	April	R. Haycock	N
1996	Visual	11.5	MD Aldergrove	May	D. Knopp	N
1997	Visual	55	MD Aldergrove	March, April	D. Knopp, R. Haycock	Y
1996	Visual	2.17	Miami Creek	July	D. Knopp	N
1997	Visual	8	Miami Creek and Hotsprings Slough	April	D. Knopp	N
1996	Visual	NA	Minnekhada Regional Park	June	R. Haycock	N
2010	Visual	4.5	Morris Rd/Chehalis estuary	March	M. Pearson, B. Johnson, A. Lentini	N
2008	Visual	22.5	Morris Valley	March	D. Knopp, C. Albrecht, K. McNeil	Y
1997	Visual	9	Mountain Slough	April	D. Knopp	Y
1996	Visual	NA	Murchie Pond - Langley	April	R. Haycock	N
1997	Visual	6	Nicomen Slough	NA	R. Haycock	N
2000	Visual	40	Nicomen Slough	NA	R. Haycock	N
2010[e]	Visual	2.25	Nicomen Slough	March, April	M. Pearson, M.P. Pearson, D. Knopp	N
1996	Visual	NA	Pitt Marsh	June	R. Haycock	N
2010[e]	Visual	5.5	Pitt Lake marsh	April	D. Knopp	N
1996	Visual	4	Ross Lake area	June	D. Knopp	N
1997	Visual	0.25	Ross Road & Railroad Crossing	March	D. Knopp	N
1996	Visual	NA	Rowlatt Pond - Langley	April, June	R. Haycock	N
1996	Visual	NA	Salmon River Marsh - Langley	May	R. Haycock	N
2010[e]	Visual	NA	Sechelt Inlet Rd (small beaver pond)	March	V. Kilburn, A. Mitchell	N
2010[e]	Visual	2.5	Shrew pond, Harrison West	March	D. Knopp	N
1997	Visual	2	Silverdale Creek	April	D. Knopp	N
1996	Visual	4	Smith Falls Creek (Beaver Pond)	July	D. Knopp	N
2010[e]	Visual	13	Smugglers Cove	April	V. Kilburn, A. Mitchell	N

Year	Type[a]	Search hours[b]	Location	Month[c]	Surveyor	Sp. Det.[d]
2010 [e]	Visual	3.5	Sterline Rd – N side of Fraser	April	D. Knopp	N
1996	Visual	NA	Straiton Bowl	May	D. Knopp	N
1996	Visual	NA	Sturgeon Slough	June	R. Haycock	N
1996	Visual	1	Sumas Mountain above Chadsey (Pond)	July	D. Knopp	N
1996	Visual	NA	Tall Timbers - Langley	May	R. Haycock	N
2010 [e]	Visual	2.5	Town Rd., N side of Vedder Mtn	April	D. Knopp	N
1996	Visual	2.5	Trout Lake	July	D. Knopp	N
1997	Visual	6	Trout Lake	April	D. Knopp	N
2010 [e]	Visual	9	UBC Farm 2	March	M. Pearson, D. Knopp	N
1996	Visual	4	Unnamed Cr. (East of Popkum)	July	D. Knopp	N
2010 [e]	Visual	12.5	West Creek wetland	March	A. Gielens, M. Pearson, M. Cruickshanks	N
1996	Visual	NA	Widgeon Creek	June	R. Haycock	N
2010 [e]	Visual	2	Wiliband	April	A. Gielens	N
2010 [e]	Visual	6.5	Wilson Farms	March	K. Scotton	N
2009	Visual	8	Wolf Lake	NA	D. Knopp	N

[a] Type of search: Visual – search for egg masses/frogs; Trapping – trapping program
[b] Search hours: Number of person hours in targeted search for the species. NA = data not available
[c] Month: The month the search took place
[d] Sp. Det.: Whether or not the species was detected. Y = Yes, N = No
[e] Search effort for 2010 are minimum estimates, based on Pearson 2010a.

HABITAT

Habitat requirements

Rana pretiosa is a habitat specialist associated with water bodies that have seasonally warm shallow areas with emergent or floating vegetation (Licht 1969, 1986a,b; McAllister and Leonard 1997). In Washington, the species prefers habitat with a large amount of open water and low to moderate amounts (25–50%) of cover by emergent vegetation (Watson *et al.* 2003). In Canada, populations are associated with low-elevation water bodies. Maria Slough, Mountain Slough, and Morris Valley sites are all <25 m in elevation; Aldergrove is at approximately 100 m, and the extirpated population in Campbell Valley Regional Park was at 70 m in elevation (Licht 1986b). In Washington State, sites up to 850 m in elevation provide suitable habitat for the species (Germaine and Cosentino 2004), but based on a relationship between elevation and latitude for 73 known populations in the U.S. and Canada, Pearl and Hayes (2004) suggested that the species is unlikely to be found above 200 m in Canada. A screening model developed to identify potential habitat for the species in Washington specified that soils characteristic of occupied sites are loams, mucks, loamy sands, or other poorly drained fibrisols, mesisols, organic cryosols, gleysols, and humisols (Germaine and Cosentino 2004).

The species is usually associated with large (>4 ha) marshes within forested landscapes (Hayes 1994 *cited in* U.S. Fish and Wildlife Service 2010). Smaller wetlands may not have extensive shallows with seasonally warm water and may not provide sufficient space for the population to persist under high larval predation rates (Hayes 1994 *cited in* U.S. Fish and Wildlife Service 2010). Although *R. pretiosa* has been reported from sites as small as 1 ha in the United States, Pearl and Hayes (2004) suggested that these are remnant populations at sites that were previously connected to larger wetlands. All known populations in Canada are associated with marshes >4 ha in size.

Rana pretiosa has three distinct activity seasons: breeding, summer foraging, and over-wintering periods. Oviposition occurs in shallow warm water in seasonally inundated areas (Licht 1969; McAllister and Leonard 1997; Watson *et al.* 2003). These areas of slow-moving or still water are near to or seasonally connected with larger bodies of water. Oviposition sites usually have abundant aquatic vegetation. Eggs are rarely laid over open soil or rock substrates (Pearl and Hayes 2004), although at Mountain Slough, egg masses are often laid on top of soft mud (Knopp pers. comm. 2009). Across the species' range, oviposition sites have been found in water 5 – 30 cm deep (Licht 1969; Pearl and Hayes 2004; Haycock 2000a). The shallow margins of wetlands, ponds and rivers used for oviposition become seasonally warm (Licht 1971). Water temperatures recorded at Canadian oviposition locations range from 4 °C to 14 °C, with an average daytime temperature of 9 °C (Canadian Oregon Spotted Frog Recovery Team 2009a).

In summer, the frogs stay close to shallow wetlands and are usually found in water or along the shoreline, close to water (Licht 1986a). The preferred habitat has abundant floating emergent vegetation within warm, shallow wetlands (Licht 1971; Hayes 1997 *cited in* U.S. Fish and Wildlife Service 2010). In British Columbia, frogs remained within densely vegetated portions of the wetland, dominated by floating *Potamogeton* spp., with some submerged *Potamogeton* species present as well (Canadian Oregon Spotted Frog Recovery Team 2009a). At a site in Washington, frogs selected Hardhack (*Spiraea douglasii*)-dominated areas in summer (Watson *et al.* 2003). Watson *et al.* (2003) reported that summer locations in Washington were in deeper water (average 23.6 cm ± 1.0) than water depths at random locations (average 16.5 cm ± 1.0). In Canada, summer locations were in water 42–112 cm deep (Canadian Oregon Spotted Frog Recovery Team 2009a).

Areas used in winter are in deeper water. Watson *et al.* (2003) reported that water depth at winter locations of frogs in Washington was on average 17.4 ± 0.8 cm. Pearl and Hayes (2004) provided data from other studies in Washington that reported mean water depth at winter locations as follows: 0–120 cm (average 22 cm) (Risenhoover *et al.* 2001 *cited in* Pearl and Hayes 2004); 1–88 cm (26.2 cm average) (Hallock and Pearson 2001 *cited in* Cushman and Pearl 2007); 6–111 cm (averages of 62, 49, 34, and 29 cm) (Hayes *et al.* 2001 *cited in* Pearl and Hayes 2004). Frogs will often use springs and seeps that do not freeze or low-flow channels (Hayes *et al.* 2001 *cited in* Pearl and Hayes 2004). Data from Oregon indicated that in winter *R. pretiosa* used a

small natural spring that was rarely used during the rest of the year (Chelgren *et al.* 2007). At a low elevation site in Washington, over-wintering frogs selected open water with submerged vegetation and some emergent vegetation (Risenhoover *et al.* 2001 *cited in* Pearl and Hayes 2004). Over-wintering frogs may also bury themselves in silty bottom substrate or in aquatic vegetation (McAllister and Leonard 1997). Frogs in Washington have also been reported using ditches in late autumn or winter (Watson *et al.* 2003; Hayes *et al.* 2001 *cited in* Pearl and Hayes 2004). Watson *et al.* (2003) reported that frogs at a site in Washington buried themselves at the base of clumps of Soft Rush (*Juncus effusus*), and remained immobile from mid-December through January under ice <5 cm thick.

Data on winter habitat use by *R. pretiosa* in Canada are limited. For one frog, which was captive-reared in 2008, allowed to over-winter in captivity, and subsequently released at Maria Slough, telemetry data were collected from September 2009 to February 2010. This frog spent most of December and January in a Cattail (*Typhus* sp.) marsh at the perimeter of the wetland, before moving back to the main wetland in late January (Pearson 2010c). The researchers recorded the frog moving underneath 2 to 10 cm of ice. Four captive-reared and over-wintered frogs at Aldergrove were also tracked to their over-wintering sites in 2009 – 2010: one frog used an active beaver dam, one used a submerged island of Hardhack vegetation, one used a small island of Hardhack vegetation connected to an inactive beaver dam, and one was in an area of thick Hardhack roots and debris (Govindarajulu 2009). An earlier radiotelemetry study by R. Haycock of Canadian frogs suggested a possible association between winter habitat and areas impacted by Beaver (*Castor canadensis*) activity, which resulted in deeper water (Canadian Oregon Spotted Frog Recovery Team 2009a). This relationship between Beaver activity and winter habitat has also been noted in the United States (Hayes pers comm. 2008).

Habitat trends

Wetland habitats required by *R. pretiosa* are declining in the Fraser River Lowlands (Boyle *et al.* 1997; Moore pers. comm. 2009). Historically, extensive dyking of river ways, starting in the 1860s and completed in the 1930s, reduced flooding and eliminated suitable habitat. In particular, the draining of the large, shallow Sumas Lake in the 1920s significantly modified drainage patterns and resulted in loss of associated wetlands. This lake and associated wetlands were comprised of 8000 ha of marshlands and slough and 3600 ha of open water, and tripled in area during freshet flooding (Chilliwack Museum 2009). Boyle *et al.* (1997) estimated that the activities of draining and conversion of land to agriculture reduced fen and swamp/bog/marsh habitat, which had formed 10% of the area of the Lower Fraser Basin prior to 1820, by 21% by 1930, and by 85% by 1990. A more recent study by Moore *et al*. (2003) assessed the changes to 320 freshwater wetlands in the Fraser Basin between 1989 and 1999 by comparing orthophotos taken during the 2 years. They found that 71 of the 320 wetlands, approximately 20%, had lost habitat due to encroachment from development. Approximately 41% of habitat loss was due to agricultural development, the rest to urban development including golf courses, or habitat removal while the

land was in transition to some future land use. Of the affected wetlands, two wetlands lost >50% of their area, 36 lost <5% of the area, and 33 lost 5–50% of the area. These changes resulted in a total loss of 965 ha of wetlands during the decade. The extensive creation of dykes, ditches, and channels fragmented the remaining wetlands.

Habitat rehabilitation and creation have occurred at three of the extant locations of *R. pretiosa* in Canada. At Aldergrove, 1,300 m^2 of wetland habitat was constructed in 2001, an additional area of 18,000 m^2 was constructed in 2004, and large areas of invasive Reed Canarygrass (*Phalaris arundinacea*) were removed. Beaver dams continue to increase habitat through flooding (Knopp pers. comm. 2009). At Maria Slough, 1,500 m^2 of habitat was created approximately 4 km from the known oviposition location, an additional 1,000 m^2 was rehabilitated in 2000, and Reed Canary Grass was removed in 2003. In 2009 the created habitat was expanded by 5,000 m^2, and it was expanded by another 3,000 m^2 in 2010. At Mountain Slough, 1,800 m^2 of habitat was constructed in 2005, and remaining habitat has also been rehabilitated.

Potentially suitable habitat for *R. pretiosa* is declining in Washington and Oregon. Throughout Washington, at least 33% of wetlands were drained, dyked, or filled in by the 1980s (Canning and Stevens 1990 *cited in* U.S. Fish and Wildlife Service 2010), and the rate of loss is even higher within the historical range of *R. pretiosa* (McAllister and Leonard 1997). From 1780s to 1980s, 38% of wetland habitat was lost In Oregon and 91% in California (Dahl 1990).

BIOLOGY

Prior to 1997, the name *Rana pretiosa* was applied to both *R. pretiosa* and *R. luteiventris*, as it is now known. Therefore, when interpreting results of research prior to 1997 the reader must note the geographic location of the research, which will indicate which species was studied. The majority of research on *R. pretiosa* in Canada was conducted by L. Licht, whose series of papers focused on a now-extirpated population in Campbell Valley Regional Park (Licht 1969, 1971, 1974, 1975, 1986a,b). D. Knopp, R. Haycock, and C. Bishop have studied the extant populations in Canada since the 1990s, and their data are available primarily in unpublished reports to the B.C. Ministry of Environment, the Canadian Wildlife Service, the Canadian Oregon Spotted Frog Recovery Team, and the Department of National Defence (Bishop 2007; Haycock 1999, 2000b, 2001, 2005; Knopp 1996, 1997; McKibbin *et al.* 2008). *Rana pretiosa* has been well-studied in the United States (Chelgren *et al.* 2008; McAllister and Leonard 1997; Pearl and Hayes 2004; U.S. Fish and Wildlife Service 2010; Watson *et al.* 2003).

Life cycle and reproduction

The frogs become active and begin breeding early in the spring, after the air temperature reaches approximately 5°C (Licht 1969). In southwestern B.C., breeding activity begins in February or March when males arrive at traditional breeding sites and begin calling (Licht 1969). The advertisement call is species-specific and consists

of rapid series of low-pitched clucks; it has little carrying power in the air as males usually call under water (Matsuda *et al*. 2006). Males are not territorial and will form groups in small areas (Licht 1969). Egg-laying is temperature-dependent; females begin to lay eggs when water temperatures reach approximately 6°C (Licht 1971). Egg-laying usually begins in March, and continues for 2 to 4 weeks (Licht 1969; Bishop pers. comm. 2009; Pearson pers. comm. 2009). Egg-laying occurs at traditional sites that are used in successive years, which suggests that these sites offer specific, required features (Licht 1969; Knopp pers. comm. 2009).

In Canada, *R. pretiosa* probably become sexually mature by the age of 3 years (Licht 1974). Based on measurements of male and female frogs in amplexus at Aldergrove, Haycock (2005) estimated that males begin to breed in their third year, and females in their third or fourth year. In Washington, males begin to breed at 2 years and females at 3 years of age (McAllister and Leonard 1997). In the Klamath Basin, Oregon, both males and females begin breeding when 2 years old (Haycock 2000a). Females breed every year (Licht 1974), lay one egg mass per year, and mate with one male (Phillipsen *et al.* 2009).

Licht (1974) reported that the average number of eggs per egg mass was 643 in Campbell Valley Regional Park (N = 9); Haycock (2005) reported an average (± 1SE) of 861 ± 247, 940 ± 296, and 649 ± 67 eggs/mass in 2003, 2004, and 2005, respectively at Aldergrove. At one site in Washington, there was an average of 598 eggs/cluster (McAllister and Leonard 1997). Cushman and Pearl (2007) reported that clusters in Washington and Oregon could contain up to 1,500 eggs. Development of *R. pretiosa* from hatching through to metamorphosis takes approximately 3 to 4 months (Licht 1974).

Survival rates of *R. pretiosa* vary with life stage and can vary substantially between areas and years. For the population at Campbell Valley Regional Park, Licht (1974) estimated that embryonic survivorship varied from 68% to 74% (N = 22) in 1968 but probably would have been 0% in 1969 had he not moved egg masses four times to compensate for receding water levels. The potential stranding of egg masses has also been reported for Aldergrove (Haycock 2000a) and for two locations in Washington (McAllister and Leonard 1997). Monitoring of embryonic survivorship in partial egg masses placed in floating cages to protect them from predators at Maria Slough and Aldergrove between 2002 and 2009 indicated that survivorship at Maria Slough ranged from an average of 76.6% ± 34.5% in 2004 to 96.0% ± 8.9% in 2007 (Potvin 2009). Embryonic survivorship was much lower at Aldergrove, where it ranged from 40.4% ± 43.2% in 2004 to 60.6% ± 34.5% in 2002 (Potvin 2009). In 2005, survivorship at one subsite of Aldergrove was only 9% (McKibbin *et al.* 2008). At both Maria Slough and Aldergrove, egg masses were monitored and moved if necessary to avoid desiccation. The higher survival rates reported by Potvin (2009) compared to those by Licht (1974) probably reflect the fact that the eggs in Potvin's study were protected from predation and were not threatened by changes in water levels. Shortly after hatching there is a high rate of tadpole mortality, probably from predation. Licht (1974) estimated that only 1% of tadpoles survived to metamorphosis at one site in one year of his study;

at another site survival was 7.3%. First-winter minimum survival rate for juveniles was 67.1%, and yearly minimum survival rates for adult frogs were estimated to be 44.9% for males and 66.7% for females (Licht 1974). A mark-recapture study in Oregon found that annual survival was 23% and 68% for small (<53 mm SUL) and large (>53 mm SUL) female frogs respectively, and annual survival was 12% and 57% for small and large male frogs respectively (Chelgren *et al.* 2008). A separate mark-recapture study focused on over-winter survival instead of annual survival reported a minimum 27% winter survival estimate (U.S. Fish and Wildlife Service 2010).

Little information exists on longevity of *R. pretiosa*. At Maria Slough, a marked frog captured in 2009 was probably released in 2002, and a marked frog captured at Aldergrove in 2009 was probably released in 2003 (Potvin 2009). In Washington, an adult male was at least 11 years old, and several other frogs from Oregon populations were thought to have been adults for at least 7 or 8 years (U.S. Fish and Wildlife 2010). U.S. studies of lines of arrested bone growth suggested that younger frogs make up the majority of the population (U.S. Fish and Wildlife 2010).

Little information is available on the sex ratio of *R. pretiosa*. Although males are predominant in trapping samples, the samples are probably biased towards males because they remain at the breeding area for much longer than do females (Haycock 2005). A mark-recapture study of the now-extirpated Campbell Valley Regional Park population showed a male to female sex ratio of 0.6:1 in 1968 (N = 183 frogs) and 0.4:1 in 1969 (n = 117 frogs) (Licht 1974). Trapping and hand-capture at Aldergrove from 2001 to 2005 showed a male to female sex ratio of 3.5:1 (N = 350 frogs) (Haycock 2005). A project in Oregon, which involved intensively trapping and relocating an entire resident population of *R. pretiosa*, resulted in the capture of 9 females, 11 males, and 21 juveniles, which would give a male to female sex ratio estimate of 1.2:1 (Chelgren *et al.* 2008); however, this small population may not be representative of larger populations. C. Pearl suggested that, for estimating population size, calculations should assume that one egg mass is equivalent to one mature female and one to two mature males (U.S. Fish and Wildlife 2010). The generation time is 4.7 – 5.5 years, calculated as follows: age of maturity + (1/annual mortality rate), where age at maturity is 3 years (Licht 1974) and annual mortality rate is the average of values from Licht (1974) (mortality rate = 0.4) and from Chegren *et al*. 2008 (mortality rate = 0.6). Hammerson and Pearl (2004) also reported generation length of about 5 years for this species.

Physiology and adaptability

Rana pretiosa shows strong site-fidelity, probably related to its specific habitat requirements, especially for oviposition sites (see **Life cycle and reproduction**). Embryos of this species have a fairly wide temperature tolerance; at least 50% of embryos will develop normally between 6 ˚C and 28 ˚C, and they can survive temperatures as low as 1˚C for several hours (Licht 1971).

Females lay eggs communally at the edge of shallow, often temporarily inundated areas of water, with the result that the pile of egg masses is partially exposed to air. Communal oviposition and the placement of egg masses in the shallows increases the rate of embryonic development by maximizing the temperature around eggs, but it also makes eggs extremely vulnerable to freezing and to drying by wind or receding water levels (Licht 1969, 1974; McAllister and Leonard 1997; Haycock 2000a; Watson *et al.* 2000). In some years, the entire reproductive output at a site can be lost due to water fluctuations (Licht 1974). Females will deposit their egg masses in almost the exact same place year after year (Licht 1969). This reliance on traditional oviposition sites increases the vulnerability of the species to habitat alteration.

Egg masses collected from *R. pretiosa* populations in Canada have been successfully reared in captivity. Early attempts resulted in high mortality from disease, including iridovirus, *Aeromonas hydrophilia*, *Pseudomonas* species, and associated bacterial infections (Hawkes 2009). Recent efforts at captive rearing at Mountain View Conservation Society and at the Greater Vancouver Zoo have been more successful, achieving embryonic survivorship similar to that seen for egg masses *in situ* that were kept in protected net cages (Bishop pers. comm. 2009). Survivorship of captive-reared tadpoles through metamorphosis averaged approximately 23% in 2007 and ranged from 28 to 41% in 2008, which is much higher than the estimated 1% to 7.3% tadpole survivorship reported by Licht (1974). The resulting captive-reared metamorphs have been either released in autumn, or over-wintered in captivity for release the following summer. Until recently, frogs were released only at the site where the eggs were collected; however, in 2009, some captive-reared Maria Slough frogs were released at Aldergrove as part of a radio-telemetry project (Govindarajulu pers. comm. 2010). There is some evidence that captive-reared frogs survive in the wild. In 2009, three frogs captured at Maria Slough had been captive-reared and released in 2006, and another frog had been released in 2007 (Potvin 2009). In addition, egg masses have been discovered at Maria Slough in habitat created 4 km from the original population, where captive-reared frogs were released. Because the longest recorded movement of *R. pretiosa* is 2.8 km (Cushman and Pearl 2007), the presence of egg masses could indicate that the released frogs were breeding. An attempt to establish a population of *R. pretiosa* at Mirror Lake in the University of British Columbia's Malcolm Knapp Research Forest failed, with no signs of oviposition detected at the site (Knopp pers. comm. 2009). However, this site was at a higher elevation (260 m) and was smaller (2 ha) than would be considered optimal (Hayes 1994; Pearl and Hayes 2004). In Oregon, a population of *R. pretiosa* was relocated in 2001 to a newly created habitat (Chelgren *et al.* 2008). The population increased in size and continued to persist in 2009 (U.S. Fish and Wildlife Service 2010). Chelgren *et al.* (2008) reported that the initial survival rate for relocated frogs was lower than for frogs reared from eggs at the site. The Canadian Oregon Spotted Frog Recovery Team has identified 12 candidate areas for release of *R. pretiosa* to establish new populations. Additional habitat surveys and disease testing are required to determine the suitability of these areas (Pearson 2010b).

Frogs are being held for a captive breeding program at the Vancouver Aquarium and the Toronto Zoo. Captive females held at the Aquarium since 2002 were gravid in 2009, but no males were available for breeding (Thoney pers. comm. 2009). In 2010, for the first time, two pairs of captive *R. pretiosa* bred, producing 600–900 eggs.

Dispersal and migration

Rana pretiosa is highly aquatic. Aquatic connections between over-wintering and breeding habitat may be essential (Watson *et al.* 2003; Pearl and Hayes 2004; Canadian Oregon Spotted Frog Recovery Team 2009a). A radio-telemetry study of 18 captive-reared frogs in 2009 at Maria Slough revealed that the frogs were almost always at the water's edge on or in islands of vegetation (Pearson 2010c). Only one frog frequently used terrestrial habitat, where it was found in tunnels created by tree roots and vegetation (Pearson 2010c). A similar telemetry study on habitat selection of 11 captive-reared frogs released at Aldergrove in 2009 revealed that the frogs preferred habitats with complex emergent vegetation. These sites were near open water with submergent vegetation and deep sediment; some frogs also temporarily resided in beaver dams (Govindarajulu 2009). In Washington, 99% of locations of radio-tagged frogs (N = 654) were in at least 1 cm of water (Watson *et al.* 2003). A road blocked the access to a major breeding pond in this study, but the authors found no road-killed *R. pretiosa*, although there were mortalities of *R. aurora* and *Pseudacris regilla*. They suggested that *R. pretiosa* accessed the pond via a culvert. Watson *et al.* (2003) reported an overland movement through marshy habitat.

Movement distances of *R. pretiosa* vary by season. Radio-telemetry projects in Washington and Oregon revealed that individual frogs moved substantially more during the spring breeding and autumn periods than during the dry summer season (Watson *et al.* 2003; Chelgren *et al.* 2008). Home ranges during the breeding and autumn seasons averaged 1.8–1.9 ha, whereas the dry-season home range averaged only 0.9 ha (Watson *et al.* 2003). Individual frogs can move 100s of metres between breeding and winter habitats. In Washington, Watson *et al.* (2003) reported movements of 32 – 111 m/day for 2 to 18 days, which suggests that the frogs are capable of longer-distance dispersal. One telemetry project indicated that the frogs did not usually move more than 400 m from the original capture location (Hallock and Pearson 2001 *cited in* Cushman and Pearl 2007); another study found that the frogs usually moved less than 100 m between years (U.S. Fish and Wildlife Service 2010). However, movements of >1 km have been recorded within wetland complexes and along linear riparian systems (Watson *et al.* 2003; Pearl and Hayes 2004). The longest reported movement is of an adult female frog along Jack Creek in Oregon, which moved 2,799 m (stream distance) from her original capture location (Cushman and Pearl 2007). In the same study, two juvenile frogs were recorded moving 1,245 m and 1,375 m downstream from their initial capture location. In Washington, three frogs moved 2.4 km along a creek (McAllister and Walker 2003 cited in U.S. Fish and Wildlife Service 2010).

The four extant populations of *R. pretiosa* in Canada are most likely isolated from each other. Suitable connecting habitat that would allow movement of individuals between populations is not available (see **Population spatial structure and variability**).

Interspecific interactions

This species is preyed upon by a large number of aquatic and terrestrial vertebrates including mammals, birds, reptiles, and other amphibians (Licht 1974; Watson *et al.* 2000, Watson *et al.* 2003; Hayes *et al.* 2005; Pearl *et al.* 2005; Pearl and Hayes 2005; U.S. Fish and Wildlife Service 2010). Both introduced American Bullfrogs (*Lithobates catesbeianus*) and introduced fish, such as Brook Trout (*Salvelinus fontinalis*) and centrarchids, have been suggested as contributors to the decline of the species across its range (U.S. Fish and Wildlife Service 2010), including the Aldergrove and Campbell Valley populations in Canada (Govindarajulu pers. comm. 2010; see **Threats and Limiting Factors: Introduced predators**). The American Bullfrog is a predator of both tadpoles and adults of *R. pretiosa* (McAllister and Leonard 1997) and was documented to prey on tadpoles at Aldergrove (recorded on video by R. Haycock and reported to the Recovery Team). It is also a carrier of the fungus *Batrachochytrium dendrobatidis*, which causes chytridiomycosis; testing of Bullfrogs at Aldergrove and Maria Slough indicated that they carry the pathogen (Potvin 2009; Govindarajulu pers. comm. 2010). Introduced predaceous fish probably consume tadpoles and over-wintering frogs (U.S. Fish and Wildlife Service 2010; see **Threats and Limiting Factors: Introduced Predators**).

The River Otter (*Lontra canadensis*) is confirmed as a predator of adult *R. pretiosa* at Aldergrove and Maria Slough (Govindarajulu 2009; Pearson 2010c); Great Blue Heron (*Ardea herodias*) preys on adults (Licht 1974); Gartersnakes (*Thamnophis* spp.) prey on larvae and adults (Licht 1974; Watson *et al.* 2000, 2003; Pearl and Hayes 2005). Other potential major predators include the Belted Kingfisher (*Megaceryle alcyon*) (Licht 1974; U.S. Fish and Wildlife Service 2010) and Raccoon (*Procyon lotor*) (U.S. Fish and Wildlife Service 2010). Licht (1974) lists the following important predators of tadpoles and/or eggs: larval Northwestern Salamander (*Ambystoma gracile*), Rough-skinned Newt (*Taricha granulosa*), Giant Water Bug (*Lethocerus americanus*), larval backswimmers (*Notonecta* spp.), leeches (*Batrachobdella picta*), and dragonfly nymphs.

Rana pretiosa has a broad diet. Tadpoles are grazers, feeding on plant tissue, algae, detritus, and rotting organic matter (Licht 1974; McAllister and Leonard 1997). Newly transformed frogs eat spiders (Arachnida), long-legged flies (Dolichopdidae), hover flies (adult Syrphidae), spittlebugs (Cercopidae), ants (Formicidae), and aphids (Aphididae; Licht 1986b). Adults consume a variety of insects such as ground beetles (Carabidae), rove beetles (Staphylinidae) and long-legged flies, spiders, and small vertebrates such as newly metamorphosed *R. aurora*, juvenile *Anaxyrus (Bufo) boreas*, juveniles of their own species, and adult *Pseudocris regilla* (Licht 1986b; Pearl and Hayes 2002; Pearl *et al.* 2005).

POPULATION SIZES AND TRENDS

Sampling effort and methods

Extensive surveys have been carried out, usually annually, at each of the known extant locations of *R. pretiosa* in Canada since their discovery (Table 3). Additional surveys have been conducted at historical and other potential sites (Table 2, Table 3). The most efficient method of sampling to estimate the size of the breeding population is by searching for egg masses in spring (Knopp pers. comm. 2009). The surveys involve repeated visits to a site and visually searching for egg masses in shallow water. The amount of survey effort has been highly variable across sites and years (Table 2), but recent survey effort has been more systematic and has hence resulted in more accurate counts of egg masses. In 2009, surveyors spent more than 400 hours looking for egg masses at the four known extant locations of *R. pretiosa* in Canada.

Table 3. Estimated number of breeding adults of *Rana pretiosa* at occupied sites in Canada, search effort, and information on egg collection for captive rearing and release of captive-reared frogs. Estimates are provided for historical populations where available. Adapted and updated from Haycock 2000a.

Site & year	Total number of egg masses	Number of communal oviposition sites	Estimated number of breeding adults[a]	Comments	Activity type[b]	Survey effort[c]	No. of surveyors[d]
Extant populations							
MD Aldergrove:							
1996	0	0	NA[e]	2 metamorphs	V	11.5	1
1997	105	6	210–315		V	55	1
1999[f]	14	1	28–42		V	18	1
2000	29	6	58–87		V	128	1
	Collected 300 eggs				EC		
2001	31	6	62–93		V	NA[e]	1
2002	34	7	68–102		V	NA[e]	1
2003[g]	12	5	24–36		V	NA[e]	1
	Collected 1,860 eggs				EC		
2004	10	4	20–30		V	NA[e]	NA[e]
	Collected 1,800 eggs				EC		
2005	7	4	14–21		V	NA[e]	NA[e]
	Collected 900 eggs				EC		
	Released 317 young-of-year frogs				R		
2006	5	5	10–15		V	~144	2
	Collected a total of 750 eggs at Maria Slough and MD Aldergrove				EC		
	Released 115 young-of-year frogs				R		
2007	0	0	0		V	156h	1
2008	0	0	0		V	~144	3
2009[h]	0	0	1[i]	1 adult male seen	V	~144	1
2010	0	0	0		V	NA[e]	1
Mountain Slough							
1997	16	2	32–48	1 adult seen	V	9h	1

Site & year	Total number of egg masses	Number of communal oviposition sites	Estimated number of breeding adults[a]	Comments	Activity type[b]	Survey effort[c]	No. of surveyors[d]
	Collected ~ 160 eggs						
	~140 metamorphs released				R		1
2000	43	4	86–129		V	32h	1
2001[f]	70	12	140–210		V	NA[e]	NA[e]
	Collected 2,500 eggs				EC		
2002[f]	96	7	192–288		V	NA[e]	NA[e]
2003	54	5	108–162		V	NA[e]	NA[e]
2004	62	6	124–186		V	NA[e]	NA[e]
2005	49	8	98–147		V	NA[e]	NA[e]
2006	NA[e]	NA[e]	NA[e]		V	NA[e]	NA[e]
2007	37	NA[e]	74–111		V	NA[e]	NA[e]
2008	50	5	100–150	1 juvenile seen	V	27.5	1
2009[h,j]	45	8	90–135		V	60	3
2010[i,k]	52	13	104–156	4 oviposition sites had 1 egg mass	V	NA[e]	3
Maria Slough							
1996	0	0	NA[e]	~350 larvae found	V	6	1
1997	38	3	76–114		V	16	1
2000	75	3	150–225		V	40	1
	Released 400 juveniles				R		
2001	71	10	142–213		V	NA[e]	NA[e]
	~7,000 embryos translocated to new habitat created in 2000				EC		
2002	144	7	288–432		V	NA[e]	NA[e]
	20 egg masses (about 7,500 embryos) translocated to new habitat created in 2000				EC		
	Collected 2,000 eggs				EC		
	Collected 159–265 eggs for genetic analysis				EC		
	Released 461 young-of-year frogs				R		
	Released 100 metamorphs + 25 tadpoles				R		
2003[f]	127	6	254–381		V	NA[e]	NA[e]
	Released 34 over-wintered frogs				R		
	Released 381 young-of-year frogs						
	~10,500 embryos translocated to new habitat created in 2000				EC		
2004	117	5	234–351		V	NA[e]	NA[e]
	Collected >1,300 embryos				EC		
	Released 836 young-of-year frogs/larvae				R		
	~10,000 embryos translocated to new habitat created in 2000				EC		
2005	125	4	250–375		V	~144	3
	Collected 480 eggs				EC		
2006	99	NA[e]	198–297		V	~144	3
	Collected a total of 750 eggs at Maria and MD Aldergrove				EC		
	Released 308 young-of-year frogs				R		
2007	21	NA[e]	42–63		V	~144	3
	Collected 4,250 eggs						
	Released 846 young-of-year frogs				R		
2008	67	10	134–201		V	~144	3
	Collected 3,800 eggs				EC		
	Released 1,012 young-of-year frogs				R		
2009[g,h]	43	10	86–129		V	~148	3

Site & year	Total number of egg masses	Number of communal oviposition sites	Estimated number of breeding adults[a]	Comments	Activity type[b]	Survey effort[c]	No. of surveyors[d]
	Collected 2,500 eggs				EC		
	Released 357 over-wintered frogs in April				R		
	Released 1257 young-of-year-frogs				R		
2010	67	NA[e]	134–201		V	NA[e]	2
Morris Valley							
2008	77	15	154–231		V	33	3
2009[h]	63	5	126–189		V	50	2
2010[j]	39	7	78–117	2 oviposition locations had 1 egg mass	V	NA[e]	6
Extirpated populations							
Campbell Valley Regional Park							
1968	30	NA[e]	60–90		V	NA[e]	1
1969	54	NA[e]	108–162		V	NA[e]	1
1981			+	Frogs present	V	NA[e]	1
1996	0	0	0		V	21	1
1997	0	0	0		V	200	1
1999	0	0	0		V	17	1
2000	0	0	0		V	82	1
Mirror Lake - introduced population							
2000	~700 young-of-the-year frogs released				R		
2002	0	0	0	1 adult/juvenile trapped	V	NA[e]	1
2009	0	0	0		V	7h	1

[a] Assume female frogs lay one annual clutch of eggs. Assume egg mass = 1 adult female + 1 to 2 adult males (range)

[b] Activity type: V = visual search; EC = egg collection; R = release

[c] Survey effort: total number of person-hours

[d] No. surveyors: number of people who completed survey. Number hours per surveyor not known

[e] Data not available

[f] Incomplete survey

[g] Includes a count of one pair observed in amplexus. Egg mass not located

[h] minimum # egg masses; visits by multiple researchers confused count

[i] no egg masses discovered; estimate of breeding population from the 1 frog trapped

[j] one site had multiple single egg masses, which were moved due to water fluctuations

[k] Only 29 egg masses were found in the traditional search area. After expansion of the search area by up to 2 km, 23 additional egg masses at 5 sites were discovered.

Licht (1974) conducted a mark-recapture study of the now-extirpated Campbell Valley Regional Park population in 1968 and 1969 and estimated population sizes for those years (Table 3). He captured frogs by hand two to three times per week from February to November and marked them for individual recognition. Trapping and marking has occurred at Aldergrove from 2001 to 2009, and at Maria Slough in 2008-2009 (Bishop pers. comm. 2009; Haycock unpubl. data). Trapping effort has been variable and, until recently, poorly documented. The trapping program provided information on body size of frogs, and more recently on survival of wild, marked and/or captive-released frogs (Bishop pers. comm. 2009). However, the limited amount of mark-recapture trapping that has occurred is insufficient to generate estimates of population size, or to determine population age structure.

Abundance

The total population size of *R. pretiosa* in Canada cannot be estimated accurately based on available data. However, based on the number of egg masses, it is possible to estimate the number of breeding individuals per site given the following assumptions: (1) mature females breed every year (Licht 1974); (2) females lay one egg mass per year and mate with one mature male (Phillipsen *et al.* 2009); and (3) all egg masses are discovered. It can be assumed that one egg mass equals one adult female and one to two adult males (U.S. Fish and Wildlife Service 2010). Using this range in the number of mature males, in 2010 the total adult population of *R. pretiosa* in Canada was estimated to be 316 to 474 frogs (Table 3). It should be noted that considerable error might be associated with estimates from egg-mass counts. However, the total number of individuals is likely to be <500 and is almost certainly <1,000.

Fluctuations and trends

The four populations of *R. pretiosa* show different patterns of abundance. The Aldergrove population is nearing extirpation, even though >2,000 captive-reared frogs and tadpoles were released into the population from 2000 to 2006 (Table 3). The abundance of mature individuals has declined from an estimated breeding population of 210–315 in 1997, to 0 in 2007 through 2010 (Table 3). Since 1997, search effort has increased more than two-fold. Although there is no evidence of breeding, some frogs still exist at the site; one adult captive-reared male, originally released in 2006, was captured in 2009. Enhancing the population through the release of captive-reared frogs ended in 2006. Previously, only frogs that were reared from eggs collected at the site were eligible for release back to the site; therefore, the lack of egg masses in the past four years prevented captive rearing. Most of the frogs released at the site were expected to have reached breeding age by 2009. In 2009, 11 frogs captive-reared from eggs collected from Maria Slough were released into the wetland as part of an ongoing telemetry study (Govindarajulu 2009). A population trend analysis for *R. pretiosa* in Canada from 1997 to 2007 was completed by B. Smith, Environment Canada (Bishop 2007; Smith pers. comm. 2009). The analyses by Smith were part of a science assessment for Environment Canada and were presented to the Recovery Team in 2008 (no report was produced). The model estimates the most likely population

outcome over time, assuming a simple exponential trend in population size (Bishop 2007). The inter-annual variation in population estimate was assumed to follow a negative binomial distribution. Based on data up to 2007, Smith reported that there was an 80% probability that the Aldergrove population would become extirpated before 2011. The probability of long-term (>2050) persistence of the population at Aldergrove was calculated as <1% (Bishop 2007). Data collected since 2007 do not suggest recovery of the population. The recent increase in the American Bullfrog population size at the site has been suggested as contributing to the dramatic population decline through predation and spread of disease (Govindarajulu 2009).

The overall breeding population at Mountain Slough has been fairly stable since the population was discovered in 1997 (Table 3). However, water levels were very low in 2010, and only 29 egg masses were discovered within the traditional search area, a large decline from previous years. Expanding the search area by up to 2 km along connected waterways resulted in the discovery of 23 egg masses at five previously unknown oviposition sites (Pearson 2010a). A population trend analysis for 1997 and 2009, conducted by B. Smith as described above for Aldergrove, indicated that there was a 17.2% probability of population extinction by 2015, a 32.5% probability of extinction by 2020, and that the population has an approximate 50% probability of continuing past 2050 (Smith pers. comm. 2009).

The breeding population at Maria Slough has fluctuated broadly since monitoring began in 1996. The estimated number of mature adults has declined from highs of over 200–432 frogs in 2002–2006, to an estimated 134–201 frogs in 2010. The estimates of number of breeding adults since 2006 is the lowest recorded since search effort increased starting in 2000. From 2000 to 2009, over 6,000 captive-reared frogs were released into the population (Table 3). Over 2,600 frogs were released in 2008 and 2009; these are expected to be of breeding age in 2010 or 2011. A population trend analysis for data collected from 1997 to 2009 indicated a 46.5% probability that the population will be extirpated by 2015, a 61.7% probability of extinction by 2020, and an approximately 70% chance of extirpation by 2035. There is an approximately 28% probability the species will still inhabit the site past 2050 (Smith pers. comm. 2009).

Only three years of data are available for the Morris Valley population, discovered in 2008. The estimate of number of breeding individuals declined by half from 2008 to 2010, but the time series is too short for meaningful conclusions about trends. Of concern is an apparent reduction in the number of oviposition sites, which could indicate that the habitat has become less suitable (Welstead pers. comm. 2009).

Three populations have been extirpated from Canada. The population in Campbell Valley Regional Park in Langley was estimated to have 6 –90 and 108–162 breeding adults in 1968 and 1969, respectively (Licht 1974). Estimated total population size for those years, based on a mark-recapture study, was 183 (69 males and 123 females) in 1968, and 117 (31 males and 82 females) in 1969 (Licht 1974). The species continued to persist at the site in 1981 (Green *et al.* 1997), but was extirpated by 1996 (Haycock 2000a). The movement of Bullfrogs into the breeding site in 1970 (Licht 1974), together with significant successional habitat changes that resulted in loss of suitable breeding habitat and habitat connectivity (Haycock 1999), might have contributed to the decline of *R. pretiosa* at the site. There are no estimates of historical breeding population size from the Nicomen Slough and the Sumas Prairie areas.

Simple extrapolation from egg-mass counts suggests that the size of the total adult population in the three most well-studied populations combined (Aldergrove, Maria Slough, and Mountain Slough) has declined by 34.7% from 2000 to 2010 (only traditional search area for Mountain Slough included). Including the expanded search area at Mountain Slough in 2010 resulted in a corresponding estimated decline of 19% for the three populations combined. The discovery of the Morris Valley population in 2008 increased the overall total known adult population in Canada by 6.9% from 2000 to 2010. This apparent increase is an artifact of incomplete previous knowledge and does not reflect a true population increase. The magnitude of population decline over the past 3 generations (14-17 years) is uncertain.

Rescue effect

Populations of *R. pretiosa* in Canada are >200 km from the closest populations in Washington and embedded within a highly modified environment on the Lower Mainland of British Columbia; therefore populations are isolated both from each other, and from U.S. populations. Given the species' specific habitat requirements and limited range of dispersal, a rescue effect between Canadian populations or from U.S. populations is highly unlikely. Suitable habitat is available if populations were introduced (Pearson 2010b).

THREATS AND LIMITING FACTORS

The Canadian Oregon Spotted Frog Recovery Team (2009a) has identified the following main threats to the species: habitat loss, habitat fragmentation and genetic isolation, hydrological alteration, water quality, disease, and exotic predators.

Habitat loss

Habitat loss is the largest historical and imminent threat to *R. pretiosa* in Canada (see **Habitat trends**). Habitat loss is still occurring at occupied sites. Activities that have been documented at occupied sites include: municipal stream and ditch maintenance that can include clearing and brushing, which reduces available habitat (Mountain

Slough); agricultural land use changes including the establishment of new crops, which can involve the placement of drain tiles and removal of riparian vegetation (Mountain Slough); grazing by livestock, which could lead to trampling of egg masses, bank erosion and input of nutrients to the system through input of manure (Morris Valley); and burning for vegetation management, which can cause direct mortality of frogs and removes important habitat for juveniles (Morris Valley) (Canadian Oregon Spotted Frog Recovery Team 2009a).

Natural succession modifies the structure of wetlands and reduces the amount of suitable oviposition habitat for *R. pretiosa* (Chelgren *et al.* 2007). Growth of vegetation reduces the available areas of shallow water and also shades the surrounding area, reducing habitat suitability for oviposition. Chelgren *et al.* (2007) reported reduced larval survival *R. pretiosa* in Oregon, caused by pond succession. Natural succession is of concern at Maria Slough and Aldergrove.

Habitat loss is also caused by growth of the exotic invasive Reed Canarygrass. Reed Canarygrass changes the structure of the wetland community, creating a dense vegetated area around the perimeter of wetlands that eliminates or reduces the amount of suitable oviposition habitat for *R. pretiosa* (McAllister and Leonard 1997; U.S. Fish and Wildlife Service 2010). Results of telemetry studies in British Columbia show varying use of Reed Canarygrass by frogs, ranging from avoidance of dense beds at Aldergrove in 2001–2002 (Haycock, unpublished data) to use of floating mats in autumn but not in winter, also at Aldergrove (Govindarajulu 2009), to extensive use in both autumn and winter at Maria Slough (Pearson 2010c). Reed Canarygrass is present at Aldergrove, Maria Slough and Mountain Slough. Attempts to remove it have taken place at all three locations.

Habitat fragmentation and genetic isolation

Widespread loss of habitat in the Fraser River Basin since the 1860s (Boyle *et al.* 1997; Moore 1990) has led to fragmentation of the remaining wetlands and population isolation. Research on movements of *R. pretiosa* indicates that frogs move almost exclusively along connected watercourses, and that movements are usually short (Hallock and Pearson 2001 *cited in* Cushman and Pearl 2007; U.S. Fish and Wildlife Service 2010). Because of lack of connecting habitat, the four extant populations are now probably isolated from each other (see **Population spatial structure and variability**). It is unknown how the frogs dispersed across the landscape historically, but it is possible that occasional floods of the Fraser River might have provided dispersal habitat (Weldstead pers. comm. 2009). In addition, yearly flooding of areas around the Fraser River during the spring freshet (Boyle *et al.* 1997), now prevented from occurring by dykes, would have provided suitable dispersal habitat.

Hydrological alteration

Rana pretiosa oviposits at the edge of shallow wetlands, and its egg masses are very susceptible to mortality caused by changes in water levels (Licht 1974; McAllister and Leonard 1997; U.S. Fish and Wildlife Service 2010). Changes to the hydrology of occupied sites are an imminent threat to oviposition sites. Specific issues include a planned upgrade to the pump station at Mountain Slough, which could potentially require a drawdown of the site (Canadian Oregon Spotted Frog Recovery Team 2009a). Depending on the timing, the event could adversely affect *R. pretiosa* egg masses. Removal of culvert blockages in spring can cause sudden fluctuations in water level, which can strand egg masses; this has occurred at Maria Slough in the past. Diversion of water, for irrigation or other purposes, can also lower water levels.

Normally, flooding caused by beaver dams helps create suitable habitat by flooding areas or creating stable water levels (Haycock 2000a; Canadian Oregon Spotted Frog Recovery Team 2009a; U.S. Fish and Wildlife Service 2010). Habitat creation by Beavers has been documented at Aldergrove, Mountain Slough, and Morris Valley. Beaver activity can limit habitat in some cases, as documented at Aldergrove (Haycock 2000a,b); flooding behind beaver dams in 1995–1999 removed approximately 300 m of suitable oviposition habitat, and the remaining habitat was either too steep or too vegetated to be useful (Haycock 2000a,b).

Mining or quarrying can require explosives, which can change the groundwater flow and may eliminate the water source to an area (Canadian Oregon Spotted Frog Recovery Team 2009a). This is a potential threat at Mountain Slough, where blasting in 2009 at the adjacent quarry removed a hillside along which flowed a stream that fed into an oviposition site in the slough (pers. obs. by V. Craig 2009; Knopp pers. comm. 2009).

Water quality

Aquatic habits of the frogs make them vulnerable to contaminants accumulating in water bodies. This species is sensitive to the presence of nitrates, nitrites, and ammonium (Marco *et al.* 1999; Rouse *et al.* 1999). Nitrates and nitrites are toxic even at low levels. Marco *et al.* (1999) found that the median lethal concentration at 15 days of exposure was 0.57 mg/L of nitrite and 16.45 mg/L of nitrate for embryos collected in Oregon. The recommended maximum level of nitrate for drinking water in the U.S. and Canada (10 mg/L) was moderately toxic to *R. pretiosa* embryos (Marco *et al.* 1999). Hecnar (1995) suggested that nitrate fertilizers might be an important contributor to amphibian declines, and that ammonium nitrate concentrations in agricultural areas commonly exceeded levels that were toxic to tadpoles of the American Toad (*Anaxyrus americanus*), Western Chorus Frog (*Pseudacris triseriata*), Northern Leopard Frog (*Lithobates pipiens*), and Green Frog (*Lithobates clamitans*). de Jong Westman *et al*. (2010) reported that exposure of Northern Pacific Treefrog (*Pseudacris regilla*) and Great Basin Spadefoot (*Spea intermontana*) embryos and tadpoles to field-measured concentrations of the pesticide endosulfan resulted in changes in behaviour, and increased mortalities and deformities. The Morris Valley,

Maria Slough, and Mountain Slough locations are within largely agricultural areas, and water quality in these areas could be affected by fertilizers or pesticides. At Maria Slough and Aldergrove, water testing in March and April indicated that levels of nitrate and total nitrogen were below levels that would affect *R. pretiosa* (McKibbin *et al.* 2008); however, levels would likely be much higher later in the season after fertilizer was applied to the adjacent agricultural fields (Bishop pers. comm. 2009).

Eutrophic conditions can cause algal blooms, high pH, and low dissolved oxygen and have been implicated in the decline of a population of *R. pretiosa* in Oregon (U.S. Fish and Wildlife Service 2010). Eutrophic conditions may exist in areas of historical *R. pretiosa* populations. de Solla *et al.* (2002) suggested that poor water quality associated with low dissolved oxygen levels, high levels of nitrogenous compounds such as ammonia, and organophosphate pesticides, contributed to low hatching success of *R. aurora* and *Ambystoma gracile* at sites in the Sumas Prairie.

Acidification of water (low pH) has been linked to decreased embryonic survival in numerous species of amphibians (Boyer and Grue 1995). Leachate from the nearby quarry at Mountain Slough could reduce pH and increase iron content in the slough (Canadian Oregon Spotted Frog Recovery Team 2009a). Comparison of water quality at Aldergrove and Maria Slough indicated that pH and dissolved oxygen levels were not likely to cause problems in embryonic survivorship at these locations; however, low chloride and conductivity levels at the Aldergrove site might have contributed to low embryonic survivorship during the study period (McKibbin *et al*. 2008). Water quality at Mountain Slough and Morris Valley has not been examined.

Disease

Disease, in particular chytridiomycosis and iridoviruses, has been identified as a contributor to amphibian declines around the globe (Daszak *et al.* 1999). Chytridiomycosis, caused by the chytrid fungus *Batrachochytrium dendrobatidis*, has been linked to amphibian mass mortalities (Daszak *et al.* 1999; Lips *et al.* 2006; Rachowicz *et al.* 2006; Voyles *et al.* 2009). The risk to *R. pretiosa* populations in Canada is unknown (Pearl *et al.* 2009). Chytrid infection has been reported as common in wild *R. pretiosa* populations in Washington and Oregon (Pearl *et al.* 2007, 2009). Twelve *R. pretiosa* from Maria Slough were tested for the presence of chytrid, and at least 1 frog tested positive; American Bullfrogs at both the Aldergrove and Maria Slough sites also tested positive (Potvin 2009; Govindarajulu pers. comm. 2010). Some *R. pretiosa* in the captive rearing program tested positive for chytrid and were not released. The potential impact of iridovirus to *R. pretiosa* is also unclear, but iridovirus has been documented to cause high mortality in some amphibian species (Daszak *et al.* 1999). Iridovirus outbreaks have been identified as a major cause of mortality during captive rearing of *R. pretiosa* in Canada (Welstead pers. comm. 2009).

Introduced predators

The introduced American Bullfrog has been proposed as a cause for the disappearance of *R. pretiosa* from areas in Washington (Nussbaum *et al.* 1983) and may negatively affect *R. pretiosa* populations across its range (U.S. Fish and Wildlife Service 2010). Bullfrogs may have contributed to the decline of the population at Aldergrove (Govindarajulu 2009) and Campbell Valley Regional Park, where Bullfrogs first appeared at the breeding area in 1970 (Licht 1974). The American Bullfrog uses similar habitats as *R. pretiosa* and has been shown to outcompete or displace *R. aurora* (Kiesecker and Blaustein 1998; Kiesecker *et al.* 2001). Pearl *et al.* (2004) determined that *R. pretiosa* was more vulnerable than *R. aurora* to predation by American Bullfrog. Bullfrogs have been documented as predators of hatchling *R. pretiosa* at Aldergrove (R. Haycock unpubl. data), and of tadpoles and adults at a population in Washington (McAllister and Leonard 1997). However, a small study of Bullfrog stomach contents at Aldergrove (N = 21) in 2006 did not find evidence of recent consumption of *R. pretiosa* (Govindarajulu 2006). Another potentially negative effect of Bullfrogs on *R. pretiosa* is that this species commonly carries the chytrid fungus, and can serve as an asymptomatic vector of disease (Daszak *et al.* 2004). Testing of Bullfrogs at Aldergrove in 2006 (Govindarajulu 2006) and 2008 (Potvin 2009), and Maria Slough in 2009 (Govindarajulu pers. comm. 2010) confirmed that they are infected with chytrid at these sites.

The Green Frog is another invasive introduced species that occurs at the Maria Slough and Mountain Slough sites. This species has been noted to degrade habitat quality for *R. aurora* by displacing them from preferred habitat (COSEWIC 2004). Adult Green Frogs may prey on young *R. pretiosa* (Canadian Oregon Spotted Frog Recovery Team 2009a), but predation has not been documented.

Introduced fish could also have a negative impact on *R. pretiosa* by consuming tadpoles and by preying on frogs at over-wintering sites (Pearl *et al.* 2009; U.S. Fish and Wildlife Service 2010). The concentration of *R. pretiosa* in warm water oviposition sites and cold water springs in winter may increase its exposure to these nonnative species, particularly during drought years (U.S. Fish and Wildlife Service 2010). In Washington, sites with significant populations of Brook Trout (*Salvelinus fontinalis*) or Fathead Minnow (*Pimephales promelas*) showed evidence of poor recruitment of *R. pretiosa* and had a disproportionate ratio of older to younger frogs (Hayes 1997 *cited in* U.S. Fish and Wildlife Service 2010).

Electromagnetic current

There is a proposal to install a second 500 KV transmission line at the Morris Valley site, which would be placed directly over known oviposition sites of *R. pretiosa*. The level of magnetic field that a frog at the Morris Valley population is expected to experience is 200–250 mG (Canadian Oregon Spotted Frog Recovery Team 2009a). Severini *et al.* (2003, 2010) reported that amphibian larvae exposed to 25 microteslas (250 milliGauss; mG) of magnetic radiation for 12 h/day during their development experienced significant maturation delays. The Morris Valley frogs will experience this level continuously from at least egg-laying through metamorphosis (Canadian Oregon Spotted Frog Recovery Team 2009a). It is possible that *R. pretiosa* at Morris Valley may experience maturation delays if the transmission line is installed, which may have detrimental effects on their survival (see Balmori 2006). The currently available evidence of effects of electromagnetic current on amphibians is limited.

PROTECTION, STATUS, AND RANKS

Legal protection and status

In Canada COSEWIC ranked *R. pretiosa* as Endangered in an emergency listing in 1999 and re-examined and confirmed it as Endangered in 2000. The species is listed under Schedule 1 of the *Species at Risk Act* (SARA). General prohibitions under SARA currently apply on federal lands and protect individuals of *R. pretiosa* and their residences. The species is protected under the *British Columbia Wildlife Act* from being killed, wounded, transported, or collected without a permit.

In the U.S., the Pacific Coast populations of the Spotted Frog complex (now *R. pretiosa*) have been federal candidates for listing under the *U.S. Endangered Species Act* since 1993 (McAllister and Leonard 1997). In Washington, *R. pretiosa* was listed by the state as an endangered species in 1997 (U.S. Fish and Wildlife Service 2010). Listed species are protected from being removed, but their habitat is not protected. Although the Washington State Forest Practices Board is able to designate critical habitat for listed species, critical wildlife habitat has not been proposed to date (U.S. Fish and Wildlife Service 2010). In Oregon, *R. pretiosa* is on the sensitive species list and is considered critically sensitive; however, this designation provides little protection (U.S. Fish and Wildlife Service 2010). Although Oregon has an *Endangered Species Act*, *R. pretiosa* is not listed in the state. In California, the species is listed as a Species of Special Concern (DFG 2011).

Non-legal status and ranks

According to NatureServe (2009), *R. pretiosa* is considered Imperiled (G2) globally, Critically Imperiled (N1) in Canada, and Imperiled (N2) in the U.S. It is Critically Imperiled (S1) in California and Washington State, and Imperiled (S2) in Oregon. In British Columbia, the species is considered Critically Imperiled (S1) and is on the provincial Red List of species at risk. This species is on the IUCN Red List as Vulnerable (Hammerson and Pearl 2004).

Habitat protection and ownership

Habitat protection of the four known locations of *R. pretiosa* in Canada is limited. There is some protection afforded to the habitat through federal and provincial fisheries legislation. Habitat for *R. pretiosa* has some protection under the federal *Fisheries Act*. The *Act* controls activities that can cause harmful alteration, disruption or destruction of fish habitat; its goal is to ensure no net loss of fish habitat. Additional protection is provided by the British Columbia *Water Act* and the provincial Riparian Areas Regulation. Both protect the in-stream environment and surrounding habitat, and apply to projects associated with specific activities that can alter fish or wildlife habitat. The Recovery Team has drafted a recovery strategy and a definition of critical habitat for the species (Canadian Oregon Spotted Frog Recovery Team 2009a,b). Five recovery implementation groups have been formed: (1) habitat protection, management and restoration; (2) husbandry, invasive species and disease; (3) recovery planning; (4) science acquisition, information management and inventory/monitoring; and (5) outreach/stewardship (Canadian Oregon Spotted Frog Recovery Team 2009a).

The development potential of the occupied wetlands appears to be limited (Canadian Oregon Spotted Frog Recovery Team 2009a). The Mountain Slough and Morris Valley sites are privately owned. Maria Slough itself is recorded as Provincial Crown Land; however, the land on the southeast side of the Slough is located on First Nations Reserve land, and the north side is private land. The Aldergrove site is federally owned by the Department of National Defence. Access to the site is restricted, which affords some protection to the species. In addition, spraying of pesticides is prohibited at the site (Haycock 2000b). A management plan was developed in 2000 for this population (Haycock 2000b).

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

Thanks to the Canadian Oregon Spotted Frog Recovery Team for access to unpublished information and participation in team meetings. Monique Goit and Alain Filion from the COSEWIC Secretariat answered questions. Denis Knopp, Kym Welstead, Christine Bishop, Purnima Govindarajulu, Tracy Cornforth, Bob Woods, Barry Smith, Monica Pearson, Marc Hayes, Deanna Lynch, Kathleen Moore, Annette Potvin, Michael Blouin, and Ivan Phillipsen answered questions about the species and/or provided unpublished information for inclusion in the report. This document benefited from comments by Kristiina Ovaska, Jacqueline Litzgus and Cynthia Paszkowski (members of the Amphibians and Reptiles Subcommittee, COSEWIC); David Anthony Kirk; and Christine Bishop. The B.C. Conservation Data Centre provided access to data. Funding for this project was provided by Environment Canada.

Authorities consulted included: Stephen Hureau, David Toews, and Kevin Fort (Canadian Wildlife Service); Patrick Nantel and Gilles Seutin (Parks Canada); Dave Fraser (BC Ministry of Environment); Kristina Stipec (BC Conservation Data Centre), Lynn Gillespie and Michèle Steigerwald (Federal Biodiversity Information Partnership - Canadian Museum of Nature); Sonia Schnobb, Gloria Goulet, Alain Filion, and Monique Goit (COSEWIC Secretariat); Kym Welstead, Bob Woods, Purnima Govindarajulu (Canadian Oregon Spotted Frog recovery team chairs); Christine Bishop, Tracy Cornforth, Andrea Gielens, Sylvia Letay, and Monica Pearson (Recovery Team members); Denis Knopp (Canadian researcher), and Marc Hayes, Deanna Lynch, and Christopher Pearl (U.S. researchers).

INFORMATION SOURCES

Albrecht, C., pers. comm. 2009. Email conversation with V.J. Craig. November 2009. Biologist, Keystone Wildlife Research Ltd., Surrey, B.C.

Baird, S.F., and C. Girard. 1853. Communication regarding *Rana pretiosa* and *Bufo columbiensis*. Proceedings of the Academy of Natural Sciences Philadelphia 6:378–379.

Balmori, A. 2006. The incidence of electromagnetic pollution on the amphibian decline: Is this an important piece of the puzzle? Toxicological and Environmental Chemistry 88:287–299.

Barnett, H.K., and J.S. Richardson. 2002. Predation risk and competition effects on the life-history characteristics of larval Oregon spotted frog and larval red-legged frog. Oecologia 132:436–444.

B.C. Conservation Data Centre, pers. comm. 2009. *Records provided to V.J. Craig*. June 2009. Victoria, B.C. http://www.env.gov.bc.ca/cdc/.

Bishop, C. 2007. Scientific assessment of the status of Oregon spotted frog in British Columbia. Unpublished report prepared for Environment Canada. 33 pp.

Bishop, C., pers. comm. 2009. *Email correspondence to V.J. Craig*. November 2009. Research Scientist, Environment Canada, Delta, B.C.

Blouin, M. 2002. Final report for USGS FY 2000 Species at Risk Program project: "Genetic data for recovery of the Oregon Spotted Frog, *Rana pretiosa*, in the Western United States". 14 pp.

Blouin, M., pers. comm. 2009. *Email correspondence to V.J. Craig*. June, November 2009. Professor, Department of Zoology, Oregon State University, Corvallis, OR 97331–2914.

Blouin, M.S., I.C. Phillipsen, and K.J. Monsen. 2010. Population structure and conservation genetics of the Oregon spotted frog, *Rana pretiosa*. Conservation Genetics. Online First, DOI: 10.1007/s10592-010-0104-x

Boyer, R., and C.E. Grue. 1995. The need for water quality criteria for frogs. Environmental Health Perspectives 103:352–357.

Boyle, C.A., L. Lavkulich, H. Schreier, and E. Kiss. 1997. Changes in land cover and subsequent effects on Lower Fraser Basin ecosystems from 1827 to 1990. Environmental Management 21:185–196.

Calef, G.W. 1973. Natural mortality of tadpoles in a population of *Rana aurora*. Ecology 54:741–758.

Canadian Oregon Spotted Frog Recovery Team. 2009a. Recovery Strategy for the Oregon Spotted Frog (*Rana pretiosa*) in British Columbia. Prepared for the B.C. Ministry of Environment, Victoria, BC. 62pp.

Canadian Oregon Spotted Frog Recovery Team. 2009b. Preliminary partial critical habitat identification for Oregon Spotted Frog. Draft. 30 pp.

Canning, D.J., and M. Stevens. 1990. Wetlands of Washington: a resource characterization. Shorelands and Coastal Zone Management Program, Wash. Department of Ecology, Olympia. 54 pp.

Carl, G.C., and I. McTaggart-Cowan. 1945. Notes on some frogs and toads of British Columbia. Copeia 1945:52–53.

Chelgren, N.D., C.A. Pearl, J. Bowerman, and M.J. Adams. 2007. Oregon Spotted Frog (*Rana pretiosa*) movement and demography at Dilman Meadow: implications for future monitoring. U.S. Geological Survey, Reston, Virginia. 27 pp.

Chelgren, N.D., C.A. Pearl, M.J. Adams, and J. Bowerman. 2008. Demography and movement in a relocated population of Oregon Spotted Frogs (*Rana pretiosa*); influence of season and gender. Copeia 2008:742–751.

Chilliwack Museum. 2009. Chilliwack museum and archives: history. Accessed online at http://www.chilliwack.museum.bc.ca/HistoryLandPage.html.

COSEWIC. 2004. COSEWIC assessment and update status report on the Red-legged Frog *Rana aurora* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 46 pp.

Cushman, K.A., and C. Pearl. 2007. A conservation assessment for the Oregon spotted frog (*Rana pretiosa*). USDA Forest Service Region 6. USDI Bureau of Land Management, Oregon and Washington. 47 pp.

Craig, V., pers. comm. 2011. Email communication to K. Ovaska. April 2011. Biologist, EcoLogic Research, Gabriola Island, B.C.

Dahl, T.E. 1990. Wetlands losses in the United States 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/wetlands/wetloss/index.htm (Version 16JUL97).

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. Strieby, A.A. Cunningham, J.E. Longcore, C.C. Brown, 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.

DFG (State of California Department of Fish and Game). 2011. http://www.dfg.ca.gov/biogeodata/cnddb/pdfs/SPAnimals.pdf (accessed April 2011).

de Jong Westman, A., J. Elliott, K. Cheng, G. van Aggelen, and C.A. Bishop. 2010. Effects of environmentally relevant concentrations of endosulfan, azinphosmethyl, and diazinon on Great Basin spadefoot (*Spea intermontana*) and Pacific treefrog (*Pseudacris regilla*). Environmental Toxicology and Chemistry 29:1604-1612.

de Solla, S.R., K.E. Petit, C.A. Bishop, K.M. Cheng, and J.E. Elliott. 2002. Effects of agricultural runoff on native amphibians in the Lower Fraser River Valley, British Columbia, Canada. Environmental Toxicology and Chemistry 21:353–360.

Germaine, S.S., and B.L. Cosentino. 2004. Screening model for determining likelihood of site occupancy by Oregon Spotted Frogs (*Rana pretiosa*) in Washington State. Final Report. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Govindarajulu, P.P. 2006. Assessing the impact of introduced bullfrogs (*Rana catesbeiana*) as predators and disease reservoirs at the Aldergrove breeding site of the endangered Oregon Spotted Frog (*Rana pretiosa*). Unpublished report. Prepared for Public Works and Government Services Canada, Office of Greening Government Operations, Pacific Region. 6 pp.

Govindarajulu, P. 2009. DND environmental science advisory committee, 2009 research report. Draft. Unpublished report prepared for DND ESAC. 8 pp.

Govindarajulu, P., pers. comm. 2010. *Email conversations with V.J. Craig*. May 2010. Amphibian, reptile, small mammal specialist, and Chair of the Canadian Oregon Spotted Frog Recovery Team; B.C. Ministry of Environment, Victoria, B.C.

Govindarajulu, P., pers. comm. 2011. *Conversations with K. Ovaska*. April 2011. Amphibian, reptile, small mammal specialist, and Chair of the Canadian Oregon Spotted Frog Recovery Team; B.C. Ministry of Environment, Victoria, B.C.

Green, D.M. 1985. Natural hybrids between the frogs *Rana cascadae* and *Rana pretiosa* (Anura: Ranidae). Herpetologica 41:262–267.

Green, D.M., T.F. Sharbel, J. Kearsley, and H. Kaiser. 1996. Postglacial range fluctuation, genetic subdivision and speciation in the western North American spotted frog complex, *Rana pretiosa*. Evolution 50:374–390.

Green, D.M., H. Kaiser, T.F. Sharbel, J. Kearsley, and K.R. McAllister. 1997. Cryptic species of spotted frogs, *Rana pretiosa* complex in western North America. Copeia 1997:1–8.

Hallock, L. and S. Pearson. 2001. Telemetry study of fall and winter Oregon spotted frog (*Rana pretiosa*) movement and habitat use at Trout Lake, Klickitat County, Washington. 36 pp.

Hammerson, G. and C. Pearl 2004. *Rana pretiosa*. In: IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2. <www.iucnredlist.org>. Downloaded on 4 September 2009.

Hawkes, V.C. 2009. A strategic and operational framework for reintroducing the Oregon spotted frog (*Rana pretiosa*) to British Columbia Phase 1: information review and reintroduction strategy outline. Unpublished report by LGL Limited, LGL Project EA3121 for Public Works and Government Services Canada, Victoria, BC. 98 pp + Appendices.

Haycock, R.D. 1998. Amphibian survey with special emphasis on the Oregon spotted frog *Rana pretiosa*. Selected wetland sites: Fraser River Lowlands and corridors to the interior plateau. Unpublished report prepared for B.C. Ministry of Environment, Victoria, B.C. xxiv + 230 pp.

Haycock, R.D. 1999. Oregon spotted frog (*Rana pretiosa*): Evaluation of potential reintroduction sites at Campbell Valley Regional Park, Langley. B.C. Greater Vancouver Regional District, Parks Department. 19 pp.

Haycock, R. D. 2000a. COSEWIC status report on the Oregon Spotted Frog *Rana pretiosa* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ontario. 22 pp.

Haycock, R.D. 2000b. Status update and management plan for the Oregon spotted frog (*Rana pretiosa*) at Naval Radio Section Aldergrove. Director General of the Environment, National Defence Headquarters, Ottawa, Canada. 30pp + Appendices.

Haycock, R.D. 2001. Status update for the Oregon spotted frog (*Rana pretiosa*) at Seabird Island, Agassiz. Seabird Island First Nations, Agassiz, BC. Unpublished report.

Haycock, R. 2005. Components of a demographic sensitivity analysis for the Oregon spotted frog (*Rana pretiosa*). Draft. Prepared for National Defence Headquarters, Ottawa, ON. 27 pp.

Hayes, M.P. 1994. The spotted frog (*Rana pretiosa*) in western Oregon. Part I. Background. Part II. Current status. Oregon Department of Fish and Wildlife Technical Report 94–1–01. Unpublished Report.

Hayes, M.P. 1997. Status of the Oregon spotted frog (*Rana pretiosa* sensu stricto) in the Deschutes basin and selected other systems in Oregon and northeastern California with a rangewide synopsis of the species' status. Final report prepared for The Nature Conservancy under contract to the U.S. Fish and Wildlife Service, Portland, Oregon. Unpublished Report. 57 pp.

Hayes, M.P., pers. comm. 2008. *Email correspondence to V.J. Craig*. May 2008. Senior Research Scientist. Washington Department of Fish and Wildlife, Olympia, Washington.

Hayes, M.P., J.D. Engler, S. Van Leuven, D.C. Friesz, T. Quinn, and D.J. Pierce. 2001. Overwintering of the Oregon spotted frog (*Rana pretiosa*) at Conboy National Wildlife Refuge, Klickitat County, Washington, 2000–2001. Final Report to the Washington Department of Transportation. Washington Department of Fish and Wildlife. Olympia. 86 pp.

Hayes, M.P., C.J. Rombough, C.B. Hayes, and J.D. Engler. 2005. *Rana pretiosa* (Oregon spotted frog) predation. Herpetological Review 36:307.

Hecnar, S.J. 1995. Acute and chronic toxicity of ammonium nitrate fertilizer to amphibians from southern Ontario. Environmental Toxicology and Chemistry 14:2131–2137.

IUCN, Conservation International, and NatureServe. 2009. Global Amphibian Assessment. IUCN, Conservation International, and NatureServe, Washington, DC and Arlington, Virginia, USA.

Kiesecker, J.M., and A.R. Blaustein. 1998. Effects of introduced bullfrogs and smallmouth bass on microhabitat use, growth, and survival of native red-legged frogs (*Rana aurora*). Conservation Biology 12:777–787.

Kiesecker, J.M., A.R. Blaustein, and C.L. Miller. 2001. Potential mechanisms underlying the displacement of native red-legged frogs by introduced bullfrogs. Ecology 82:1964–1970.

Knopp, D.H. 1996. Wetlands of the Fraser Valley – amphibian survey. Unpublished report prepared for the Ministry of Environment, Lands and Parks, Victoria, B.C. 6 pp. + Appendix.

Knopp, D.H. 1997. Oregon spotted frog in the Fraser River Lowlands. Unpublished report prepared for the Ministry of Environment, Lands and Parks, Victoria, B.C. 5 pp. + Appendix.

Knopp, D.H., pers. comm. 2009. *Numerous email and telephone conversations, and site visits to Morris Valley, Mountain Slough, and Maria Slough with V.J. Craig*. May to November 2009. BC's Wild Heritage, Chilliwack, British Columbia.

Knopp, D.H., pers. comm. 2010. *Email and telephone conversations with V.J. Craig*. May 2010. BC's Wild Heritage, Chilliwack, British Columbia.

Licht, L.E. 1969. Comparative breeding behavior of the red-legged frog (*Rana aurora aurora*) and the western spotted frog (*Rana pretiosa pretiosa*) in southwestern British Columbia. Canadian Journal of Zoology 47: 1287–1299.

Licht, L.E. 1971. Breeding habitat and embryonic thermal requirements of the frogs, *Rana aurora aurora* and *Rana pretiosa pretiosa,* in the Pacific Northwest. Ecology 52:116–124.

Licht, L.E. 1974. Survival of embryos, tadpoles, and adults of the frogs *Rana aurora aurora and Rana pretiosa pretiosa* sympatric in southwestern British Columbia. Canadian Journal of Zoology 52:613–627.

Licht, L.E. 1975. Comparative life history features of the western spotted frog, *Rana pretiosa,* from low- and high-elevation populations. Canadian Journal of Zoology 53:1254–1257.

Licht, L.E. 1986a. Comparative escape behavior of sympatric *Rana aurora* and *Rana pretiosa.* The American Midland Naturalist 115:239–247.

Licht, L.E. 1986b. Food and feeding behavior of sympatric red-legged frogs, *Rana aurora*, and spotted frogs, *Rana pretiosa*, in southwestern British Columbia. The Canadian Field-Naturalist 100:22–31.

Lips, K.R., F. Brem, R. Brenes, J.D. Reeve, R.A. Alford, J. Voyles, C. Carey, L. Livo, A.P. Pessier, and J.P. Collins. 2006. Emerging infectious disease and the loss of biodiversity in a Neotropical amphibian community. Proceedings of the National Academy of Sciences 103:3165–3170.

Logier, E.B.S. 1932. Some account of the amphibians and reptiles of British Columbia. Transactions of the Royal Canadian Institute 18:311–336.

Marco, A., C. Quilchano, and A.R. Blaustein. 1999. Sensitivity to nitrate and nitrite in pond-breeding amphibians from the Pacific Northwest, USA. Environmental Toxicology and Chemistry 18:2836–2839.

Matsuda, B.M, D.M. Green, and P.T. Gregory. 2006. Amphibians and Reptiles of British Columbia. Royal British Columbia Museum Handbook, Victoria, BC. 266 pp.

McAllister, K.R., and W.P. Leonard. 1997. Washington State status report for the Oregon spotted frog. Washington Department of Fish and Wildlife, Seattle, WA.

McAllister,K.R. and M. Walker. 2003. An inventory of Oregon spotted frogs (*Rana pretiosa*) in the upper Black River drainage, Thurston County, Washington. Unpublished report. Washington Department of Fish and Wildlife, Olympia. 12 pp.

McKibbin, R., W.T. Dushenko, G. van Aggelen, and C.A. Bishop. 2008. The influence of water quality on the embryonic survivorship of the Oregon spotted frog (*Rana pretiosa*) in British Columbia, Canada. Science of the Total Environment 395:28–40.

Moore, K.E. 1990. Urbanization in the Lower Fraser Valley, 1980–1987. Technical Report Series No. 120. Canadian Wildlife Service, Environment Canada. 12 pp.

Moore, K.E., P. Ward, and K. Roger. 2003. Urban and agricultural encroachment onto Fraser lowland wetlands-1989 to 1999. Proceedings of the 2003 Georgia Basin/ Puget Sound Research Conference.Abstract and Powerpoint presentation. Unpublished data.

Moore, K.E., pers. comm. 2009. *Email correspondence to V.J. Craig*. October 2009. Environment Canada, Delta, B.C.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: October 8, 2009).

Nussbaum, R.A., E.D. Brodie, Jr., and R.M. Storm. 1983. Amphibians and reptiles of the Pacific Northwest. University of Idaho Press, Moscow.

Pearl, C.A., M.J. Adams, R.B. Bury, and B. McCreary. 2004. Asymmetrical effects of introduced bullfrogs (*Rana catesbeiana*) on native ranid frogs in Oregon. Copeia 2004:11–20.

Pearl, C.A., M.J. Adams, and N. Leuthold. 2009. Breeding habitat and local population size of the Oregon spotted frog (*Rana pretiosa*) in Oregon, USA. Northwestern Naturalist 91:136–147.

Pearl, C.A., J. Bowerman, and D. Knight. 2005. Feeding behavior and aquatic habitat use by Oregon spotted frogs (*Rana pretiosa*) in central Oregon. Northwestern Naturalist 86:36–38.

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 41:145–149.

Pearl, C.A. and M.P. Hayes. 2002. Predation by Oregon spotted frogs (*Rana pretiosa*) on western toads (*Bufo boreas*) in Oregon. American Midland Naturalist 147:145–152.

Pearl, C.A., and M.P. Hayes. 2004. Habitat associations of the Oregon Spotted Frog (*Rana pretiosa*): a literature review. Final report. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Pearl, C.A. and M.P. Hayes. 2005. Family Ranidae: *Rana pretiosa* Baird and Girard 1853c, Oregon spotted frog. Pp 577–588, *in* M. Lannoo (editor). Amphibian Declines: The Conservation Status of United States Species. University of California Press. Berkeley, California.

Pearson, M. 2010a. Inventory and long-term monitoring of Oregon spotted frog and red-legged frog egg masses in the Fraser Valley Lowlands. Unpublished report prepared for: B.C. Ministry of Environment, Oregon spotted frog recovery team, South Coast Conservation Program, and B.C. Conservation Foundation. 35 pp.

Pearson, M. 2010b. Oregon spotted frog habitat prioritization in preparation for OSF introduction to new habitats. Unpublished report prepared for: Oregon spotted frog recovery team, Fraser Valley Conservancy, B.C. Conservation Foundation, and South Coast Conservation Program. 31 pp.

Pearson, M. 2010c. Oregon spotted frog radio telemetry pilot project, Maria Slough/Seabird Island: September 2009–February 2010. Unpublished report prepared for: Canadian Wildlife Service, Environment Canada, and Oregon Spotted Frog recovery team. 29 pp.

Pearson, M., pers. comm. 2009. *Email correspondence to V.J. Craig*. October, November 2009. Balance Ecological, Vancouver, B.C.

Phillipsen, I.C., and M. Blouin, pers. comm. 2010. *Email correspondence to V.J. Craig*. May 2010. Oregon State University, Department of Zoology, Corvallis OR.

Phillipsen, I.C., J. Bowerman, and M. Blouin. 2009. Effective number of breeding adults in Oregon spotted frogs (*Rana pretiosa*): genetic estimates at two life stages. Conservation Genetics 11:737-745.

Potvin, A. 2009. Final report: recovery of the Oregon spotted frog population in the Fraser Valley. Project #1355. Unpublished report prepared for: Interdepartmental Recovery Fund, Canadian Wildlife Service, Environment Canada. 39 pp.

Rachowicz, L.J., R.A. Knapp, J.A.T. Morgan, M.J. Stice, V.T. Vredenburg, J.M. Parker, and C.J. Briggs. 2006. Emerging infectious disease as a proximate cause of amphibian mass mortality. Ecology 87:1671–1683.

Risenhoover, K.L, T.C. McBride, K.R. McAllister, and M. Goliet. 2001. Oviposition behavior of the Oregon spotted frog (*Rana pretiosa*) along Dempsey Creek, Thurston County, Washington, Port Blakely Tree Farms Technical Report RD-01-02.

Rouse, J.D., C.A. Bishop, and J. Struger. 1999. Nitrogen pollution: an assessment of its threat to amphibian survival. Environmental Health Perspectives 107:799–803.

Severini, M., A.M. Dattilo, and A. De Gaetano. 2003. Sublethal effect of a weak intermittent magnetic field on the development of *Xenopus laevis* (Daudin) tadpoles. International Journal of Biometeorology 48:91–97.

Severini M, L. Bosco, R. Alilla, M. Loy, M. Bonori, L. Giuliani, A. Bedini, C. Giliberti, R. Palomba, S. Pesolillo, E. Giacomozzi, and A.C. Castellano. 2010. Metamorphosis delay in *Xenopus laevis* (Daudin) tadpoles exposed to a 50 Hz weak magnetic field. International Journal of Radiation Biology 86: 37-46.

Smith, B., pers. comm. 2009. *Email correspondence to V.J. Craig*. November 2009. Regional Director, Canadian Wildlife Service, Environment Canada, Delta, B.C.

Stebbins, R.C. 1985. A field guide to western reptiles and amphibians. Second revised edition, Houghton Mifflin Company, Boston, MA.

Thompson, H. B. 1913. Description of a new subspecies of *Rana pretiosa* from Nevada. Proceedings of the Biological Society of Washington 26:53–56.

Thoney, C., pers. comm. 2009. *Telephone conversation with V.J. Craig and the Oregon Spotted Frog recovery team*. October 2009. Director of Facility Operations and Animal Management, Vancouver Aquarium, Vancouver, B.C.

U.S. Fish and Wildlife Service, Department of Interior. 2010. Species assessment and listing priority form for the Oregon spotted frog (*Rana pretiosa*). Washington Fish and Wildlife Office, Lacey, Washington. 82 pp. http://ecos.fws.gov/docs/candidate/assessments/2010/r1/D02A_V01.pdf (accessed January 2010)

Voyles, J., S. Young, L. Berger, C. Campbell, W.F. Voyles, A. Dinudom, D. Cook, R. Webb, R.A. Alford, L.F. Skerratt, and R. Speare. 2009. Pathogenesis of chytridiomycosis, a cause of catastrophic amphibian declines. Science 326:582–585.

Watson, J.W., K.R. McAllister, D.J. Pierce, and A. Alvarez. 2000. Ecology of a remnant population of Oregon spotted frogs in Thurston County, Washington. Final Report. Washington Dept. of Fish and Wildlife.

Watson, J.W., K.R. McAllister, and D.J. Pierce. 2003. Home ranges, movements, and habitat selection of Oregon spotted frogs (*Rana pretiosa*). Journal of Herpetology 37:292–300.

Welstead, K., pers. comm. 2009. *Numerous email and telephone correspondence to V.J. Craig*. May to September, 2009. Senior Ecosystems Biologist, B.C. Ministry of Environment, Surrey, B.C.

BIOGRAPHICAL SUMMARY OF REPORT WRITER

Vanessa Craig is a Director of EcoLogic Research, based on Gabriola Island. She holds a Ph.D. from the Faculty of Forestry at the University of British Columbia (UBC), an M.Sc. from the Centre for Applied Conservation Biology at UBC, and a B.Sc. (Honours) in Biology from Simon Fraser University. Her >20-year career as a biologist in British Columbia has included work on amphibians, small mammals, and bats. Vanessa's recent work has focused on the Oregon Spotted Frog and Pacific Water Shrew; both are species at risk with ranges constrained to the lower mainland of British Columbia. Vanessa recently co-authored the recovery strategies for Oregon Spotted Frog and Pacific Water Shrew, and authored draft definitions of critical habitat for both species. She is a member of the Pacific Water Shrew recovery team.