COSEWIC
Assessment and Status Report

on the

Northern Red-legged Frog
Rana aurora

in Canada

SPECIAL CONCERN
2015

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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Northern Red-legged Frog — Northern Red-legged Frog (*Rana aurora*): adult (South Pender Island, British Columbia). Photo by Kristiina Ovaska.

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COSEWIC
Assessment Summary

Assessment Summary – May 2015

Common name
Northern Red-legged Frog

Scientific name
Rana aurora

Status
Special Concern

Reason for designation
The Canadian distribution of this species is restricted to southwestern British Columbia, where it overlaps areas of dense human population in the Lower Fraser Valley and southeastern Vancouver Island and actively managed forest lands within the remainder of its range. Over the past ten years, local declines and disappearances have been documented, but the species has persisted across its known historical range. The frog continues to face many threats from introduced species such as American Bullfrog and illegally stocked sport fish, road mortality, urban development, logging, dams and water management, and the pollution of breeding sites. If those threats are not effectively mitigated, the species is likely to decline further and become Threatened.

Occurrence
British Columbia

Status history
Designated Special Concern in April 1999. Status re-examined and confirmed in May 2002, November 2004, and May 2015.

COSEWIC
Executive Summary

Northern Red-legged Frog
Rana aurora

Wildlife Species Description and Significance

The Northern Red-legged Frog, *Rana aurora*, is a member of the family Ranidae, true frogs. The name *Rana aurora* was applied to *R. aurora* and *R. draytonii* (California Red-legged Frog) until 2004 when genetic evidence showed that they are distinct species. Only *R. aurora* occurs in Canada.

The Northern Red-legged Frog is a medium-sized frog with adult snout-vent length usually from 50 to 70 mm. The brown back is flecked with black spots and the legs have black bands. The common name refers to the red colour seen through translucent skin on the underside of the hind legs of adults.

The Northern Red-legged Frog plays important ecological roles both as a consumer of invertebrates, including insect pests, and as prey for fish, reptiles, birds, and mammals. Regular movements between aquatic and terrestrial habitats give it a role in transferring nutrients and energy between ecosystems. The species is sensitive to pollutants including pesticides and nitrogenous by-products.

Distribution

The range of the Northern Red-legged Frog extends from southwestern British Columbia, south along the Pacific coast, west of the Cascade Mountains, to northwestern California. An introduced population occurs in Chichagof Island, Alaska, and a population of unknown origin occurs on Graham Island, British Columbia. Recent distribution records for the Northern Red-legged Frog confirm that the species remains widespread on Vancouver Island and the adjacent mainland of British Columbia. New records extend the species' range throughout the Sunshine Coast (southern mainland coast northwest of Greater Vancouver) and the Sea-to-Sky Corridor (Highway 99 from Vancouver north to Whistler) and farther up valleys surrounding the Fraser Lowlands. Populations remain in some urbanized areas within the Lower Mainland and Fraser Valley, but failed searches over the past 5 years suggest they may be extirpated from parts of the cities of Vancouver, Richmond, and Delta, where they occurred historically. Intensive search effort and no detections at Stanley Park since the 1970s indicate that the species is extirpated there.

Habitat

The Northern Red-legged Frog requires both aquatic breeding and terrestrial foraging habitats at low elevations (usually below 500 m, although the species can occur as high as 1040 m). Eggs are laid on submerged parts of plants within permanent and temporary seasonal wetlands that have sun exposure, water at least 30 cm deep, and low flow. Tadpole survival is higher in temporary wetlands with complex structure and relatively few predators compared to permanent wetlands. Adults and juvenile frogs disperse up to 5 km away from wetlands into moist forest habitats, where they find refuge in moist burrows, under large pieces of downed wood, and within understory vegetation. Overwintering habitat includes below-ground refuges in forests and wetlands.

Habitat degradation and loss have been extensive on southern and eastern Vancouver Island and the Lower Fraser Valley because of agriculture, urbanization, roads, the introduction of American Bullfrogs, and logging.

Biology

Adults breed in the late winter or early spring, often returning to the same breeding sites year after year. Males produce an advertisement call under water. Females lay 200 to 1100 eggs in a single egg mass. Early mortality is relatively high but decreases when maturity is reached; annual adult survival is estimated at 69%. Males usually reach sexual maturity at 2 years of age, while females may take up to 4 years. The maximum reported lifespan of the Northern Red-legged Frog in captivity is 15 years. The generation time is estimated at 4 to 6 years.

Population Sizes and Trends

The population size of the Northern Red-legged Frog in British Columbia is probably over 100,000 adults. Breeding population sizes vary across sites with the largest occurring in relatively undeveloped areas of forest on the west coast of Vancouver Island. Counts of egg masses (an index of the number of breeding females) have been tallied at over 1400 per pond but such high numbers likely are extremely rare. Eighty percent of the ponds surveyed to date had less than 100 egg masses, and 35% had fewer than ten. Long-term population monitoring has been initiated but has not been carried out for sufficiently long to assess trends. Local declines and disappearances have been documented. The population in Delta seems to have declined slowly since the 1960s, but monitoring has been limited. At one wetland in the Sea-to-Sky Corridor, there was an estimated decline of 73 to 92% over 3 years as a result of highway construction and road mortality.

Threats and Limiting Factors

Threats known to impact the Northern Red-legged Frog are urban development, road mortality, logging, dams and water management, invasive species, introduced fish, disease, and pollution. Within the Lower Fraser Valley, human population growth is predicted to double every 20 – 30 years. Growth is also expected along the southeastern side of Vancouver Island, parts of the Sea-to-Sky Corridor, and the Sunshine Coast. Some of the existing habitat in urban and rural agricultural areas will be converted to housing and thereby undergo further fragmentation and exposure to pollution. American Bullfrog populations are predicted to grow and spread, increasing competition and predation pressure and augmenting damage to breeding habitats caused by dams and water management, introduced fish, and disease. Logging has the potential to alter habitat throughout the vast remote parts of the species' range. Temperature extremes, storms, and flooding events associated with climate change will likely exacerbate habitat loss and degradation caused by other factors.

Protection, Status, and Ranks

Globally, the Northern Red-legged Frog is ranked "apparently secure" (G4). In Canada the species is federally listed on Schedule 1 under the *Species at Risk Act* as "Special Concern", and it is on the Provincial Blue list of species at risk in British Columbia. Currently, about 3210 km^2 or 10% of the species' range below 500 m in elevation and 16% of occurrences are within protected areas. Much of the range and occurrences are on unprotected provincial or private forestry lands.

TECHNICAL SUMMARY

Rana aurora

Northern Red-legged Frog — Grenouille à pattes rouges du Nord

Range of occurrence in Canada (province/territory/ocean): British Columbia

Demographic Information

Generation time Estimated using available data on adult survival rate (See **Biology**).	4 – 6 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? Local declines observed, and declines across the range inferred from habitat trends. The number of mature individuals declined to zero in Stanley Park between the 1970s and the present; declines were noted in the Corporation of Delta since the 1960s; 73-92% decline over 3 years at Pinecrest site because of Highway 99 (see **Population Fluctuations and Trends**).	Yes, observed and inferred decline.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations] Insufficient data to estimate the magnitude of the decline.	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]. BC Conservation Data Centre (2014) states that the short-term trend over the past 10 yr or 3 generations was a decline of “10-50%”. However, there are insufficient data to reliably estimate the magnitude of the reduction.	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations]. No data are available.	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. No data are available. Historical sites have not been resampled in a consistent way to estimate numbers.	Unknown
Are the causes of the decline clearly reversible and understood and ceased? Negative effects of many threats, such as residential development, roads, and pollution, could potentially be mitigated. Effects of logging are reversible over time, if forests are allowed to mature and appropriate riparian reserves and upland patches of large trees are retained in each rotation.	Somewhat reversible; somewhat understood; not ceased
Are there extreme fluctuations in number of mature individuals? Egg mass counts (index of the number of reproductive females) do not show extreme fluctuations over relatively short monitoring periods (<10 years), but pond-breeding frogs in general are known to fluctuate widely in local abundance.	Unknown

Extent and Occupancy Information

Estimated extent of occurrence (EO).	75,625 km²

Calculated from all known observations.	
Index of area of occupancy (IAO). (Always report 2x2 grid value). Calculated from all known observations.	2,588 km² (discrete) but actual IAO is probably larger
Is the population severely fragmented? Ocean, lakes, rivers, mountains, roads, and land clearings fragment populations throughout the species' Canadian range and most severely in urban parts of the Lower Mainland and southeastern side of Vancouver Island. However, ≥50% of the entire Canadian population is not found in isolated habitat patches.	No
Number of locations*[*] One threat that would "rapidly affect all individuals of the taxon present within a single site" is housing and commercial development that involves draining an isolated wetland and clearing the surrounding forest. The total number of occurrences susceptible to residential development is 106. (There are at least 232 sites affected by other threats; see **Table 1**).	Unknown but much larger than 10*
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence? The EO known from historical records has not declined. Sampling effort and awareness of the species have increased over time and so has the known EO.	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy? Sampling effort and awareness of the species have increased over time and so has the known IAO. However, within the Lower Mainland, occupancy modelling predicts zero occupancy in areas where the species was documented in the past (See **Extent of Occurrence and Area of Occupancy**).	Yes (projected)
Is there an [observed, inferred, or projected] continuing decline in number of populations? Inferred and projected decline based on habitat trends and threats. One population has disappeared. Approximately 72% of localities with historical records have not been revisited in the past 30 years, and search effort has been limited at those that have been revisited.	Yes (inferred and projected)
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	Yes (projected)
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? Rapid human population growth in the Lower Mainland, Sea-to-Sky Corridor, Sunshine Coast, and southeastern Vancouver Island causes continual decline in area, extent and quality of habitat. Throughout the rest of the range, logging has reduced the quality of habitat, i.e., 13% of managed forests <500 m elevation in the species' range have been logged in the past 20 years, and logging continues (see **Habitat Trends** and **Threats – Biological Resource Use**).	Yes (observed, inferred and projected)
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No

[*] See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

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 Cumulative population size at wetlands that have been searched is over 32,000 (See **Population Sizes and Trends - Abundance**). Only a small portion of occupied habitat has been inventoried.	
Total	At least 100,000

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years]. No population viability analysis done at the B.C. scale. Analysis of the viability of a subpopulation near Whistler was done to assess the need for further mitigation to reduce road mortality. In that case, the subpopulation was predicted to go extinct in 20 to 40 years without mitigation (See **Threats – Roads**).	Insufficient data

Threats (actual or imminent, to populations or habitats)

Main threats: Residential and commercial development; Invasive Species (American Bullfrog; emerging diseases, such as chytridiomycosis); Pollution; Logging Climate change (summer droughts; premature drying of ephemeral breeding sites) Other threats with low or unknown impacts: agriculture; hydroelectric impoundments

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Status in United States is N4 – Apparently Secure; Washington S4 – Apparently Secure; Oregon S3S4 – Vulnerable to Apparently Secure; California S2? – Imperilled, rank is inexact.	
Is immigration known or possible? Individuals potentially could emigrate to Lower Mainland of BC from Washington State, although the status of the species in the border area is unknown. Much of the habitat is poor quality (intensive agriculture) along the accessible stretch of border in the lowlands between Blaine and Vedder Mountain.	Possible
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Possibly
Is rescue from outside populations likely?	Unlikely

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC: Designated Special Concern in April 1999. Status re-examined and confirmed in May 2002, November 2004, and May 2015.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric code:** Not applicable
Reasons for designation: The Canadian distribution of this species is restricted to southwestern British Columbia, where it overlaps areas of dense human population in the Lower Fraser Valley and southeastern Vancouver Island and actively managed forest lands within the remainder of its range. Over the past ten years, local declines and disappearances have been documented, but the species has persisted across its known historical range. The frog continues to face many threats from introduced species such as American Bullfrog and illegally stocked sport fish, road mortality, urban development, logging, dams and water management, and the pollution of breeding sites. If those threats are not effectively mitigated, the species is likely to decline further and become Threatened.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. The magnitude of declines is unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Both EOO and IAO are above threshold values.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. The population size exceeds thresholds.
Criterion D (Very Small or Restricted Population): Not applicable. The population is not large or restricted.
Criterion E (Quantitative Analysis): Not applicable. Insufficient data for analysis at the level of Canadian population.

PREFACE

Since the preparation of the previous COSEWIC status report in 2004, the Northern Red-legged Frog (*Rana aurora)* has been recognized as a distinct species from the California Red-legged Frog (*Rana draytonii*). It is now confirmed that one historical population has been extirpated from British Columbia's Lower Mainland (from Stanley Park; no records since the 1970s despite continuing survey efforts). Recent data collection and an occupancy model suggest that others in Delta and Richmond are on the brink of extirpation. During the same time period, intensified search efforts outside the Lower Mainland have revealed previously unknown populations along the Sea-to-Sky Corridor, Sunshine Coast, and Central Coast, and on Vancouver Island. Very little monitoring has been done to assess population trends; however, the population at one site has declined dramatically as a result of road construction and traffic mortality.

The Northern Red-legged Frog is considered as part of the provincial Environmental Assessment process in British Columbia that includes measures to avoid, lessen and monitor adverse effects of a project in a way that is consistent with the species' Management Plan. A draft Management Plan is currently under review. The Northern Red-legged Frog is listed as Identified Wildlife and managed under the *Forest and Range Practices Act* of British Columbia on provincial Crown lands. The Identified Wildlife Management Strategy provides policy, procedures, and guidelines for managing Identified Wildlife, including establishing Wildlife Habitat Areas and associated General Wildlife Measures. The species is now protected within 23 Wildlife Habitat Areas totalling 336 ha on Vancouver Island, and additional Wildlife Habitat Areas are being considered.

No Aboriginal traditional knowledge was available for the species.

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
(2015)

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

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

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

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

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

Canada

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

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

The Northern Red-legged Frog belongs to the large, nearly cosmopolitan family of Ranidae or “true frogs” (Amphibia: Anura: Ranidae: *Rana: Rana aurora* Baird and Girard, 1852). Eight species in the genus *Rana* are native to the west coast of North America: *Rana aurora*, *R. boylii* (Foothill Yellow-legged Frog), *R. cascadae* (Cascades Frog), *R. draytonii* (California Red-legged Frog), *R. muscosa* (Mountain Yellow-legged Frog), *R. pretiosa* (Oregon Spotted Frog), *R. luteiventris* (Columbia Spotted Frog), and *R. sierra* (Sierra Nevada Mountain Yellow-legged Frog). *Rana aurora* and *R. draytonii* were recently split into separate species based on differences in mitochondrial DNA (Shaffer *et al.* 2004) and the amino acid sequences of their skin peptides (Conlon *et al.* 2006) as well as differences in their morphology, behaviour, allele frequencies and chromosomal structure (Hayes and Miyamoto 1984; Green 1986).

The eight species that occur strictly in western North America form the *R. boylii* species group, which molecular evidence suggests is a well-defined, monophyletic group, about eight million years old (Macey *et al.* 2001; Hillis and Wilcox 2005). Relationships within the *R. boylii* group are incompletely understood, but recent mitochondrial DNA sequencing suggests that *R. aurora*, *R. cascadae*, and *R. muscosa* might be closely related (Macey *et al.* 2001; Hillis and Wilcox 2005).

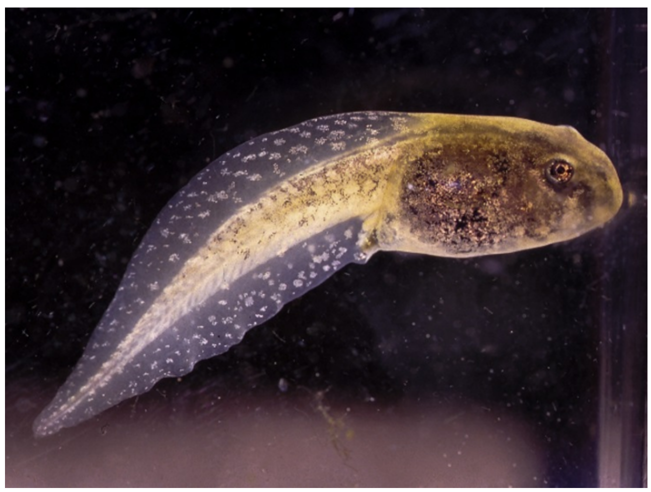
The accepted French name is Grenouille à pattes rouges du Nord (Green 2012).

Morphological Description

The Northern Red-legged Frog is a moderate-sized frog with snout-vent length of adults usually from about 50 to over 70 mm (Matsuda *et al.* 2006); females attain a somewhat larger body size than do males and may be up to about 100 mm long (Nussbaum *et al.* 1983). As is typical of most other North American ranids, these frogs have a smooth to somewhat rugose skin, a dorsolateral fold along each side of the body extending from near the eye to near the groin, relatively long legs when compared to other groups of frogs, and webbed feet. The back of the Northern Red-legged Frog is brownish, flecked with small black spots with indistinct edges; the dorsal surface of the limbs is often banded with black (Figure 1a). A dark mask typically extends from the eye to the jaw line and is bordered from below by a cream-coloured band. The throat and chest are grey or white with variable black, and sometimes red, flecking, and the undersides of the hind legs and the lower portion of the trunk are reddish, giving the species its common name. The brightness of the red varies both geographically and ontogenetically (Altig and Dumas 1972); small juveniles may lack the red colour altogether or show only a faint reddish or yellowish tint on the underside of the legs. Adult males are distinguished from females by nuptial pads visible on the thumb, year-round.

A)

B)



C)

Figure 1. A) Northern Red-legged Frog from British Columbia: adult (South Pender Island, B.C.), B) tadpole (Vedder Creek, B.C.), C) egg mass (Vedder Creek, B.C.). Photographs by Kristiina Ovaska.

Eggs are laid in large loose jelly masses that appear globular (10 to 20 cm in diameter). Each egg is 3 mm in diameter and surrounded by a wide jelly coat. Tadpoles are tan or greenish brown, and the trunk, tail, and fins are typically covered with gold- or brass-coloured flecking or blotches; the white underside often has a pinkish tinge. They can attain a relatively large size (up to about 70 – 80 mm) immediately before metamorphosis. The tail is relatively short (about 1.5 times or less the length of the body), and the dorsal fin is relatively tall (taller than the tail musculature at its widest point), resulting in a stubby appearance (Figure 1b; Corkran and Thoms 1996).

In British Columbia, the Northern Red-legged Frog may be confused with the Oregon and Columbia Spotted Frogs, which have a similar body form and reddish underside of the hind limbs and the lower portion of the trunk (Matsuda *et al.* 2006). The Northern Red-legged Frog is sympatric with the Oregon Spotted Frog in the Lower Fraser Valley, whereas it is largely allopatric with the Columbia Spotted Frog. Potential for overlap with the Columbia Spotted Frog exists at the southeastern and northern distributional limits of the Northern Red-legged Frog on the mainland (see **Canadian Distribution**), and specimens from these areas should be examined carefully.

Population Spatial Structure and Variability

There have been no studies on the spatial or genetic structure of populations of the Northern Red-legged Frog in British Columbia or elsewhere in its range. Some differentiation would be expected between populations on Vancouver Island, the Mainland, and islands within the Strait of Georgia and Johnstone Strait, because they are geographically isolated from each other by stretches of ocean. The extent of the open ocean between Vancouver Island and the mainland is smallest (< 1 km) through offshore islands in the Johnstone Strait. Given that the species is restricted to relatively low elevations, mountain ranges likely isolate populations in watershed valleys on the west coast of Vancouver Island, the Sunshine Coast (southern mainland coast northwest of Greater Vancouver), Sea-to-Sky Corridor (along Highway 99 from Vancouver north to Whistler), and north of the Fraser Valley. Research on other frog species has shown that mountain ridges have an isolating effect on gene flow (Funk *et al.* 2005).

Designatable Units

The Northern Red-legged Frog occurs within a restricted geographic area within one COSEWIC Terrestrial Amphibians and Reptiles Faunal Province (Pacific Coast). There is no evidence of significant genetic, ecological, or morphological variability within the Canadian population that would warrant more than a single designatable unit.

Special Significance

The Northern Red-legged Frog has relatively large spatial requirements, is dependent on both terrestrial and aquatic habitats, and is associated with moist forests, stream banks, and wetlands. Thus, the presence of the species indicates the persistence of landscape-wide habitat connections, ecosystem health, and wilderness values.

Northern Red-legged Frogs are consumers of invertebrates, including a variety of insects. As tadpoles or adults, they serve as prey for invertebrates, fish, amphibians, reptiles, birds, and mammals. Regular movements between aquatic and terrestrial habitats give the species a role in transferring nutrients and energy between ecosystems.

Frogs feature in the mythology and art of the Coastal Salish, Haida, and other First Nations groups of western Canada, but it is unknown whether the Northern Red-legged Frog in particular holds special significance to Aboriginal peoples.

DISTRIBUTION

Global Range

The global range of the Northern Red-legged Frog extends from southwestern British Columbia to northwestern California (Figure 2). This species occurs throughout western Washington and Oregon west of the Cascade Mountains to the Pacific coast. In northwestern California, the Northern Red-legged Frog occurs as far south as southern Mendocino County (Shaffer *et al.* 2004). There, it overlaps over several kilometres with the California Red-legged Frog (*R. draytonii*), the range of which extends south to Baja California, Mexico. An isolated population in southeastern Alaska is the result of a recent introduction (MacDonald 2010). A population in the Queen Charlotte Islands is probably also introduced. Approximately 35% of the global distribution of the Northern Red-legged Frog is in Canada.

Figure 2. Global range of the Northern Red-legged Frog. Source: IUCN (International Union for Conservation of Nature), Conservation International, and NatureServe. 2008. *Rana aurora*. The IUCN Red List of Threatened Species. Version 2014.3.

Canadian Range

In Canada, the Northern Red-legged Frog occurs in southwestern British Columbia, where it is found throughout Vancouver Island, on several of the islands in the Strait of Georgia and Johnstone Strait, and on the adjacent mainland, west of the Coast Mountains (Figure 3, Table 1). Vancouver Island comprises the bulk (over 50%) of the species' Canadian range. Most records are from elevations < 500 m, although the species has been reported from localities up to 1040 m.

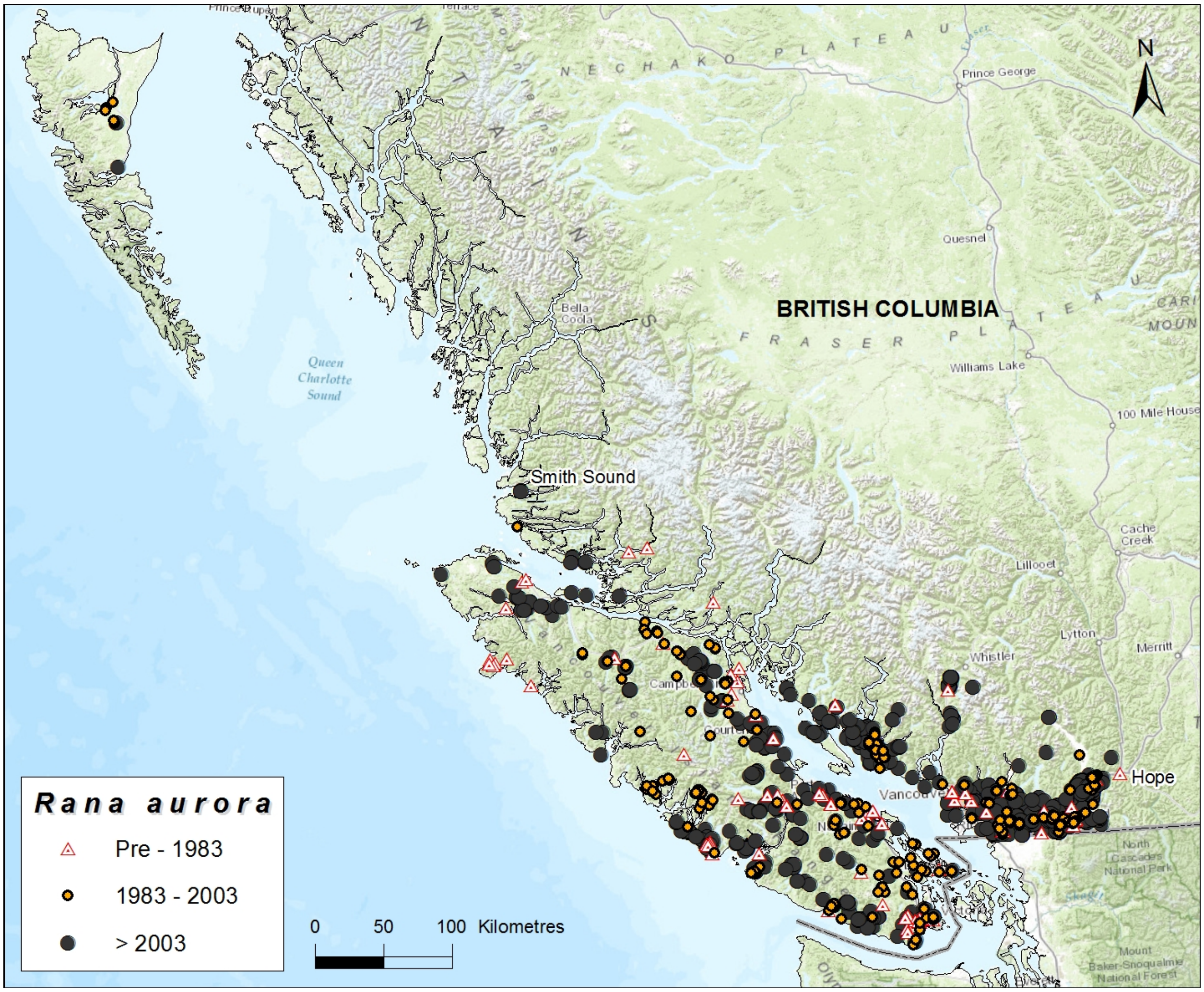


Figure 3. Canadian distribution of the Northern Red-legged Frog. Records are from data compiled for this status report. Map prepared by Jenny Wu, COSEWIC Secretariat.

Table 1. Number of occurrences of Northern Red-legged Frog within different parts of its range in British Columbia by period, and the number of historical occurrences documented only pre-1983.

Total number of occurrences for all years found in protected areas and an estimated number of those exposed to threats are shown on the right.

An occurrence is defined as any set of localities situated within a 1-km radius of each other when plotted on Google Earth. Occurrences were considered threatened by urban development, paved roads, and logging if these land uses were visible within 1 km (< 500 m for roads) of any localities within an occurrence on Google Earth. Occurrences were considered threatened by invasive species based on overlap with the mapped distribution of American Bullfrogs (Govindarajulu 2003; Govindarajulu pers. comm. 2014) and recent survey data (Murray *et. al*. in press; Mitchell *et al.* 2012). U - unknown, na - not applicable.

		Period					Site Protection/Threat					
General Area	**Range**	**Pre-1983**	**1983 - 2003**	**>2003 - 2014**	**Total for all years**	**Not re-documented since pre-1983**	**In Protected Areas**	**Urban Development**	**Roads**	**Logging**	**Invasive Species**	**Pollution**
Lower Mainland	Horseshoe Bay - Caulfield	0	1	1	2	na	0	1	1	0	U	0
	North Vancouver - Lynn Valley to Deep Cove	0	1	3	3	na	1	2	3	0	0	0
	Stanley Park	1	0	0	1	1	1	0	1	0	1	0
	Vancouver	1	0	1	2	1	1	1	2	0	2	0
	Burnaby	2	0	3	5	1	1	4	5	0	5	0
	Coquitlam	0	4	5	8	na	2	1	3	1	U	0
	Golden Ears Provincial Park	0	1	2	3	na	3	0	0	0	3	0
	Maple Ridge - Pitt Meadows	2	2	3	6	2	0	2	3	3	6	1
	Mission (Stave Falls to Lake Errock)	2	0	14	14	0	1	1	9	1	14	11
	Harrison Lake (west) - Harrison Mills to Port Douglas	0	2	6	7	na	0	1	1	7	1	0
	Sasquatch Provincial Park	1	3	2	3	0	3	0	0	0	U	0
	Agassiz-Harrison Hot Springs	0	3	21	21	na	0	2	14	0	U	18
	Laidlaw to Hope	1	0	2	4	1	1	0	3	0	U	0
	Chilliwack-Cultus Lk	4	12	31	37	2	4	4	26	4	12	16
	Abbotsford - Sumas Mountain area	0	3	15	17	na	0	10	7	1	U	1
	Abbotsford - Flats	1	2	7	7	0	2	6	7	0	7	7
	Aldergrove, Langley, Surrey	3	11	18	25	2	3	6	25	0	25	20
	Surrey	1	0	8	9	1	3	7	9	0	9	1
	Delta	0	11	0	11	na	0	0	0	0	11	1
	Richmond	0	0	3	3	na	0	3	3	0	3	1
Sea-to-Sky	Squamish to Calcheak	1	0	11	11	0	2	1	8	6	U	0
Sunshine Coast	Sechelt Peninsula (Gibson's to Doriston)	0	12	9	18	na	2	1	6	16	U	0

General Area	Range	Period: Pre-1983	Period: 1983 - 2003	Period: >2003 - 2014	Period: Total for all years	Period: Not re-documented since pre-1983	Site Protection/Threat: In Protected Areas	Site Protection/Threat: Urban Development	Site Protection/Threat: Roads	Site Protection/Threat: Logging	Site Protection/Threat: Invasive Species	Site Protection/Threat: Pollution
	Saltery Bay to Lund	1	0	6	7	1	0	1	3	7	2	0
	Tzoonie Watershed	0	0	2	2	na	0	0	0	2	0	0
Central Coast	Loughborough Inlet	1	0	0	1	1	0	0	0	1	0	0
	North Broughton Island	0	0	1	1	na	0	0	0	1	0	0
	Kingcome Inlet	2	0	0	2	2	0	0	0	1	0	0
	Lottie Lake, Well's Passage north of	0	0	2	2	na	0	0	0	2	0	0
	Bramham Island	0	1	0	1	na	0	0	0	0	0	0
	Greaves Island	0	0	2	2	na	0	0	0	2	0	0
Vancouver Island	Metchosin to Shirley (Sooke)	2	2	4	8	2	0	4	4	0	8	0
	Jordan River to Port Renfrew area	0	5	15	18	na	3	1	8	12	0	0
	Carmanah, Bamfield, China Creek	1	3	16	20	1	6	1	2	13	0	0
	Colwood to Cobble Hill area	8	10	8	20	5	3	6	9	6	20	1
	Duncan to Crofton area	2	11	10	20	1	1	2	4	16	10	2
	Nanaimo to Cameron Lake	9	8	10	23	6	6	9	11	6	23	7
	Port Alberni	5	2	9	16	5	0	2	7	11	16	3
	Barkley Sound (west of Trevor Channel) to Tofino	5	1	22	26	3	11	7	9	12	0	0
	Clayoquot Sound	0	16	0	16	na	0	0	0	15	0	0
	Bowser to Nootka	2	6	18	24	2	7	3	8	9	10	5
	Tsolum River to Black Ck	1	2	5	7	0	1	0	4	4	4	3
	Campbell River to Sayward	5	17	14	35	4	4	1	4	31	0	0
	Woss area	1	5	5	10	1	1	0	3	8	0	0
	Kyuquot to Brooks Peninsula	6	0	0	6	6	5	0	0	1	0	0
	Port McNeill to Shushartie & Cape Scott	3	0	15	18	3	3	2	5	15	0	0
Johnstone Strait	Malcolm Island	0	0	2	2	na	1	1	1	1	0	0
	Turnour Island	0	0	1	1	na	0	0	0	1	0	0
	Quadra Island	1	0	0	1	1	0	0	0	1	0	0
Strait of Georgia	Denman Island	0	0	1	1	na	1	0	0	1	U	0
	Texada Island	0	0	3	3	na	0	1	1	2	3	0
	Gambier Island	0	0	1	1	na	0	1	0	1	U	0
	Bowen Island	0	0	1	1	na	0	1	1	0	U	0
	Ruxton Island (near Valdes)	0	0	1	1	na	0	1	0	0	U	0
	Galiano Island	0	4	0	4	na	1	4	4	1	0	0
	Saltspring Island	0	5	1	6	na	0	3	6	U	6	2

General Area	Range	Period					Site Protection/Threat					
		Pre-1983	**1983 - 2003**	**>2003 - 2014**	**Total for all years**	**Not re-documented since pre-1983**	**In Protected Areas**	**Urban Development**	**Roads**	**Logging**	**Invasive Species**	**Pollution**
	Pender Island	1	1	0	1	1	1	1	1	0	1	0
	Saturna Island	0	1	1	1	na	1	1	1	0	U	0
TOTAL		76	168	341	525	55	86	106	232	222	202	100
% of total sampled all years		14	32	65			16	20	44	42	39	19
% of total sampled Pre-1983						72						

On the mainland, the species' distribution extends through the Lower Fraser Valley east to near Hope, through the Sea-to-Sky corridor north to Whistler, and along the Sunshine Coast and Central Coast to Smith Sound, just north of Cape Caution. Specimens from Manning Park in 1945 (RBCM #816, 817) were misidentified and are Columbia Spotted Frogs (inspection by K. Ovaska in August 2014). Farther north, an isolated record exists from near Kitimat on the central coast (RBCM #1199, 1200). Specimens associated with the Kitimat record could not be located but were probably misidentified and represent the Columbia Spotted Frog, which is known from the area. A sight record from the Cariboo region in 2004 (Packham pers. comm. 2013) may also represent the Columbia Spotted Frog.

The Northern Red-legged Frog was first documented on Haida Gwaii in 2001 but has probably been there much longer (Ovaska *et al.* 2002). The species was found at ten localities in the vicinity of Port Clements, Graham Island, including both settled and remote areas. In 2014, it was found to be abundant approximately 40 km away at the south end of Graham Island, near Skidegate (Ovaska pers. comm. 2014). The species has not been encountered in Gwaii Haanas National Park Reserve on South Moresby (Wojtaszek pers. comm. 2013). It is likely that the Graham Island population is a result of human introduction, similar to the deliberate release of individuals of the Pacific Treefrog (*Pseudacris regilla*), which is now widespread on the islands (Reimchen 1991). However, without further investigation the possibility that the Northern Red-legged Frog is an overlooked native species cannot be ruled out.

Records obtained since 2004 extend the known northern extent of the native range of the species (excluding the Kitimat and Haida Gwaii records) to Greaves Island (Powelson pers. comm. 2013), just north of a previous locality on Bramham Island (Meggill pers. comm. 2003). Three museum records exist from north of Powell River (from the Kingcome area and Loughborough Inlet near Powell River; CMC #1879, 1886A, B). The identification of these specimens was confirmed (in September 2003, by Dr. Francis Cook, Researcher Emeritus, Canadian Museum of Nature). Additional sightings have been reported from North Broughton Island, Caviar Cove, and north of Lund. Over the past ten years, there has been an increase in research and monitoring activity on wildlife in general, particularly on Calvert Island and the area around Bella Bella. There have been no reports of Northern Red-legged Frogs from this work, although Western Toads (*Anaxyrus boreas*) and Northwestern Salamanders (*Ambystoma gracile*) were found (Reynolds pers. comm. 2014).

Before 2003, only a few old (1940s) distribution records existed from the Sunshine Coast. Data collected over the past ten years show records along the Sechelt Peninsula from Gibsons to north of Lund (Mitchell *et al.* 2012). The species also occurs within the Tzoonie Watershed, a drainage that extends inland from Sechelt Inlet. There are many other coastal drainages that have not been surveyed for amphibians.

Within the Sea-to-Sky Corridor, inventories conducted since 2007 have added dozens of localities to the lone 1926 record at Daisy Lake. The species is scattered between Squamish and Whistler in wetlands and forests at relatively low elevations. There have been only a few surveys north of Whistler to Pemberton, and no records of the Northern Red-legged Frog (Malt 2011).

There were numerous historical localities in the Lower Fraser Valley from the coastline to Hope (west to east), and from the US border to the base of the Coast Mountains (south to north). Recent surveys indicate that the species remains widespread throughout this area, with the exception of Stanley Park (Stanley Park Ecology Society 2010) and urban areas, particularly in Vancouver, Richmond, and Delta (Malt 2013) (see **Search Effort**). A few new records are from the valleys of watersheds that drain the Coast Mountains into Pitt Lake, Slave Lake, and Henderson Lake on the north side of the Fraser River, and from watersheds that drain the North Cascades near Chilliwack. These records expand the historical range beyond the lowlands farther up into mountain valleys.

On Vancouver Island, recent records extend the species' range about 60 km northwest from Port Hardy to Cape Scott (B.C. Ministry of Environment 2012; McCurdy pers. comm. 2014). Brooks Peninsula has not been resurveyed for amphibians since 1981. There are many new localities from the species' historical range throughout the island, particularly in the north and on Nootka Island and on several islands within the Johnstone Strait and the Strait of Georgia.

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EO) in Canada is estimated to be 75,625 km^2, based on a minimum convex polygon containing all known occurrences (but excluding Haida Gwaii, where the species is probably introduced). This estimate is based on records derived from museum collections, published and unpublished research reports and datasets, and incidental observations. The EO includes areas at high elevation (>1100 m) and within the ocean that are unsuitable habitat for the species.

The index of area of occupancy (IAO) was calculated based on the number of occupied 2 km x 2 km grid cells. The IAO was estimated to be 2,588 km^2, likely an underestimate, as survey effort is incomplete.

Sampling effort and awareness of the species have increased over time and consequently so have the known EO and IAO. EO and IAO were not presented in the previous status report, but calculations from pre- 2003 records, as compiled for this report, resulted in an EO of 67,368 km^2 and IAO of 2,588 km^2. These values are 1.12 and 3.12 times higher, for EO and IAO respectively, than if all records including the above and those since 2003 are included. It is unknown whether the species continues to occur at all previous localities. In some parts of the species' range, i.e., Vancouver, Richmond and Delta, the IAO has declined.

Search Effort

Over 2500 records (grouped into 524 occurrences in Table 1) were used to determine the distribution, including EO and IAO, for the Northern Red-legged Frog. Most of these (60%) were obtained after 2004. Fewer than 200 records were obtained prior to 1983. As these numbers suggest, there has been a considerable search effort expended in recent years (see Table 2 for a description of search effort and where the species was found).

Table 2. Search effort since the 1990s to determine Canadian range, extent of occurrence, and area of occupancy for Northern Red-legged Frog.

Note that additional general surveys of wetlands as part of environmental assessments or other projects exist for some areas.

Vicinity	Period	Description of Search Effort and Occurrence
Lower Mainland		
Fraser Lowlands	Late 1990s	Egg mass surveys at over 94 ponds, targeting Oregon Spotted Frog (*Rana pretiosa*) habitat. *R. aurora* occupancy 50%. (Haycock and Knopp 1998)
	1997 - 2000	Egg masses collected at Towne Rd on periphery of Sumas Prairie for ecotoxicology studies. * (De Solla *et al.* 2002 a, b; Loveridge 2002)

Vicinity	Period	Description of Search Effort and Occurrence
	2005 - 2009	Egg mass surveys on at least 28 days over 5 years; >100 localities. Negative data not available. * Egg mass survey along ~1 km of ditch habitat at Towne Rd, Sumas Prairie in 2009 confirmed recent occupancy. (Knopp pers. comm. 2013)
	2010 - 2011	Egg mass surveys at 43 ponds / drainages, targeting *R. pretiosa* and Western Painted Turtle (*Chrysemys picta*) habitats. *R. aurora* occupancy 47%. (Pearson 2010, 2011)
	2012	Egg mass surveys at 119 ponds, sites selected on the basis of existing baseline data, geographic and ecological representation, and the known or potential occurrence of *R. pretiosa* and *C. picta*. *R. aurora* occupancy 48%. Data were used to summarize the probability of occupancy: zero for sites in Vancouver, Richmond and Delta; very low (< 0.2) for sites in Abbotsford and sites in the combined area of Pitt Meadows, Port Coquitlam and Coquitlam; average (~0.41) for Chilliwack, Burnaby, North Vancouver and Maple Ridge; high (≥ 0.5) for Surrey, Mission, Kent, Harrison, and the combined area of Anmore, Belcarra and Port Moody. (Map of occupancy in Appendix 1). (Malt 2013)
Chilliwack – Cultus Lake	2002 - 2011	Surveys on at least 31 days over 10 years; >40 localities. Negative data not available. (Knopp pers. comm. 2013) Pitfall trapping on ASU Chilliwack DND Lands. Details not available. *R. aurora* caught. (Hawkes pers. comm. 2013)
Chilliwack	2007	Salvage fish and amphibians from 16,000 m of ditch in 14 watercourses in summer. 2 *R. aurora* caught in 1 watercourse – 7%. (Blair 2007)
Abbotsford	2005	Salvaged fish and amphibians using a dip net from 8 creeks and ditches. *R. aurora* caught in 1 ditch – 12.5 %. (City of Abbotsford 2005)
Delta	1990 - 2002	Funnel trapping fish and amphibians at 145 water bodies (ditches and ponds) within 23 watersheds. *R. aurora* occupancy 43% at watershed level; not reported at pond level. Species was noted as being “Uncommon”. (Rithaler 2002a,b, 2003a,b; Danyluk pers. comm. 2014) Part of late summer and fall 1999 surveying farm near Annacis Hwy. 3 juvenile *R. aurora* caught. Knopp (pers. comm. 2013)
	2012	Malt (2013) surveys (described above) included 4 ponds within 4 watersheds in Delta. *R. aurora* occupancy 0%. Coordinates for the exact localities of 1990-2002 detections were not in databases and maps on file at the Corporation of Delta so comparison is limited. (Malt 2013)
Stanley Park, Vancouver	1998 - 1999	RISC standard surveys but no details given. *R. aurora* occupancy 0%. (Stanley Park Ecology Society 2010)

Vicinity	Period	Description of Search Effort and Occurrence
	2007 - 2013	Funnel trapping at 4 ponds (Beaver Lake, Biofiltration at Lost Lagoon, Beaver Pond and Moose Pond) 47 traps x 3 nights in 2007-09 and similar effort since then. Coverboards, 2 BioBlitzes, >100 h searching. *R. aurora* occupancy 0%. (Stanley Park Ecology Society 2010, Worcester pers. comm. 2014)
Burnaby	2011	Salvage using minnow traps and dip nets while draining containment pond. 86 *R. aurora* caught. (EBA 2011)
Coquitlam Reservoir	2011	Pitfall trapping for small mammals and amphibians, area-constrained surveys 111 person-hours and 17,757 trap-hours; 1 locality. 13 Adult *R. aurora* caught. (Golder and Associates 2011a)
Alouette Watershed	2011 - 2012	Surveys and funnel trapping at least 10 days. 26 localities. Negative data not available. (Knopp pers. comm. 2013) Egg mass surveys for species at risk at 6 ponds. *R. aurora* occupancy 50%. (Mitchell 2013)
Mission	2010	Pitfall trapping and minnow trapping, salvage. 4 *R. aurora* caught. (DWB Consulting Services Ltd. 2010)
Roche Creek, North Vancouver	2011	Pitfall trapping for shrews; 32 traps x 22 checks; 40 traps x 15 checks; 1 locality. 3 Adult & 1 unknown age *R. aurora* caught. (Dupuis 2011)
Sea-to-Sky Corridor		
Whistler Area	2004 - 2009	Egg mass surveys over at least 6 days at Pinecrest and area around Lava Lake. 27 localities. Negative data not available. (Knopp pers. comm. 2013)
Alice Lake Pinecrest Brandywine	2007 - 2010	Repeated egg mass surveys, minnow trapping and time-constrained surveys at 55 ponds. *R. aurora* occupancy 60% of ponds spread across all three areas. Pitfall trapping, mark-recapture, road surveys at Pinecrest. (Malt 2011)
Squamish to Pemberton WMA	2007 - 2010	One-day surveys at Brohm Lake, Cheakamus Lake, & proposed Pemberton Valley Wetlands Wildlife Management Area. Not detected at Pemberton Valley. Surveys targeting Western Toad (*Anaxyrus boreas*) at Mamquam River, Squamish River, Lucille Lake. *R. aurora* caught at Mamquam. (Malt 2011)
Pinecrest compensation ponds and Cheakamus storm water ponds	2012	Visual surveys from shore, minnow trapping 5 ponds x 8 checks; 4 ponds x 3 checks Occupancy 0 % of ponds. (Tayless 2012)
Sunshine Coast		
Sechelt Peninsula	2010 - 2011	Egg mass surveys at 4 ponds & summer surveys targeting *C. picta*. *R. aurora* occupancy 100%. (Mitchell *et al.* 2012)
Powell River	2010 - 2011	Egg mass surveys at 6 ponds & summer surveys targeting *C. picta*. *R. aurora* occupancy 66%. (Mitchell *et al.* 2012)

Vicinity	Period	Description of Search Effort and Occurrence
Texada Island	2010 - 2011	Egg mass surveys at 9 ponds & summer surveys targeting *C. picta*. *R. aurora* occupancy 44%. (Mitchell *et al.* 2012)
Central Coast		
Bella Bella Area	2009 - 2013	Stream/estuary surveys targeting salmon at 60 sites within area ~40 km north and south of Bella Bella (Hunter Island to Don Peninsula) over past 5 years. No records of *R. aurora*. (Reynolds pers. comm. 2014)
Vancouver Island		
Sayward	1997 - 2001	Radio-telemetry to observe habitat choice and movement patterns in clearcuts and forest stands (Chan-McLeod 2003), and variable retention blocks (Chan-McLeod and Wheeldon 2004; Chan-McLeod and Moy 2007).
Northeast Island	2002	Surveys at 113 small wetlands including 28 ephemeral ponds that were dry, 50% at elevations > 900 m. Occupancy ~13%. (Wind 2003)
North-Central Island Forest District	2006 - 2012	Egg mass surveys at 58 wetlands targeting *R. aurora*. Occupancy 45%. (B.C. Ministry of Environment 2012)
Campbell River Watershed	2001	Surveys and pitfall trapping at 15 sites (3 sites trapped with 3 pitfall arrays each). Occupancy 53%. None caught in pitfall traps. (Garcia 2001)
Salmon River	2003	Pitfall traps (4 open over 2.5 months, checked weekly) 2 *R. aurora* caught (Materi and Forrest 2004)
Campbell River Forest District	2006 - 2012	Egg mass surveys at 35 wetlands targeting *R. aurora*. Occupancy 40%. (B.C. Ministry of Environment 2012)
Quinsam Area	2011 - 2012	Surveyed 5 ponds, 15.2 person-h. *R. aurora* occupancy 40%. Salvage egg masses at 4 ponds; 0.48 ha, 5 hours x 2 people. 2 *R. aurora* caught at 1 pond. (Golder Associates 2011b, 2012)
Clayoquot Sound	1998 - 1999	Funnel trapping, shoreline surveys at 148 ponds in 6 watershed planning units. Occupancy 26% of ponds; 83% of watersheds. (Beasley *et al.* 2000)
Tofino - Ucluelet Pacific Rim	2008-2013	Egg mass surveys at 45 ponds. *R. aurora* occupancy 84% breeding; 89% all stages. (Beasley 2011; Beasley unpubl. data 2014)
SE Vancouver Island	2002	Surveys at 122 small wetlands including 44 ephemeral ponds that were dry, most at elevations < 600 m. Occupancy ~23%. (Wind 2003)
Englishman River Watershed	2008	Egg mass surveys and funnel trapping at Healy Lake (20 traps x 1 night) and Shelton Lake (25 traps x 1 night). *R. aurora* occupancy at both sites. (Wind 2008b)
South Island Forest District	2006 - 2012	Egg mass surveys at 104 wetlands targeting *R. aurora*. Occupancy 57%. (B.C. Ministry of Environment 2012)

Vicinity	Period	Description of Search Effort and Occurrence
Nanaimo Lakes	2007	Egg mass surveys and summer surveys at 68 wetlands in 34 different sites. *R. aurora* occupancy 62 -74% (adults) and 4 - 19% (breeding). Range indicates the pre-harvest (first) and post-harvest (second) values for ponds. (Wind 2008a)
Nanaimo	2011	Salvage for amphibians in dewatered wetland complex. 6 *R. aurora* caught. (EcoDynamic Solutions 2011)
Saanich Peninsula	2002	Information collected on > 30 ponds to determine distribution of Bullfrogs (*Rana catesbeiana*), *R. aurora* noted at several but most were not checked thoroughly for *R. aurora*. During intensive mark-recapture of Bullfrogs at 4 ponds, *R. aurora* never caught in 1 pond, caught at low numbers in 2, and at high numbers in 1. (Govindarajulu 2003, Govindarajulu pers. comm. 2014)
Jordan River Watershed	2004 - 2005	Time-constrained surveys (5 dates, 2-3 people, total time 57 h) and road surveys (2 dates, 2 people, total distance 37 km). Caught 45 *R. aurora*. (Hawkes 2005)
	2012	Egg mass surveys at 2 constructed ponds. *R. aurora* occupancy 100%. (Tuttle 2013)
Strait of Georgia Islands		
Gulf Islands	1996	Time-constrained surveys (0.5 – 6.3 h/site) at 10 islands and ACOs at 4 islands, targeting Sharp-tailed Snakes (*Contia tenuis*). *R. aurora* occupancy 40% of islands. (Galiano, Pender, Saltspring, Saturna). (Engelstoft and Ovaska 1997, 1998)
Saltspring Island, Burgoyne Bay	2011	Time-constrained surveys during one BioBlitz day. 3 adult *R. aurora* caught. (Briony Penn Associates 2011)

Much of the recent effort has been directed at searching new areas beyond the species' previously known range, such as the Sunshine Coast (Mitchell *et al.* 2012) and Sea-to-Sky Corridor (Malt 2011). Although no targeted surveys have been done in the Central Coast, university and non-profit groups have conducted salmon-related research at many streams in the area around Bella Bella over the past decade (Reynolds pers. comm. 2014). The species has not been found.

The most extensive search effort has been expended on Vancouver Island by B.C. Ministry of Forest, Lands and Natural Resource Operations (B.C. Ministry of Environment 2012). They conducted a widespread inventory for breeding Northern Red-legged Frogs at almost 200 wetlands within managed forests in three Forest Districts. The species was found at half of those searched (at 99 of 197 ponds, some of which were clustered near each other; Table 2). The aim was to identify forested wetland habitats suitable for protection under the B.C. *Forest and Range Practices Act*.

Several non-profit groups and the B.C. Ministry of Transportation and Infrastructure have become increasingly aware of the numbers of amphibians killed on roads. Road surveys and wetland surveys adjacent to roads have uncovered numerous occurrences of the species (Blood and Henderson 2000; Beasley 2006; Materi 2008; Clegg 2011; Wind 2012). Environmental impact assessments and salvage operations carried out by a number of consultants have made similar observations.

Historical sites have received limited survey attention. Marion Lake (also known as Jacobs Lake) was one of two sites where almost all the demographic information was collected in the 1970s (Calef 1973 a,b). This population has not been resurveyed (Richardson pers. comm. 2014), even though it is located within the UBC Experimental Forest. The same water bodies of another historical research site at Little Campbell River (Licht 1969) have not been revisited, but nearby ponds were surveyed recently by volunteers from the non-profit group A Rocha (Baylis pers. comm. 2014). The species continues to breed within 600 m of the historical site.

A widespread survey was conducted to model wetland occupancy in Metro Vancouver and the Lower Fraser Valley in 2012 (Malt 2013; Appendix 1). One wetland site was randomly selected from each 10 km x 10 km cell of a grid overlaid across the region, and the resulting 64 wetlands were surveyed for Red-legged Frog breeding occupancy (presence of egg masses). An additional 55 wetlands were surveyed, as part of ongoing community-based monitoring in the Little Campbell River watershed, and ongoing work on two other species at risk, Oregon Spotted Frog and Western Painted Turtle (*Chrysemys picta*) (Pearson 2010, 2011, 2012; Mitchell *et al.* 2012). In these surveys, the species was found at 57 wetlands (see Threats and Limiting Factors: Residential and Commercial Development for results of the model).

There are notable historical occurrences where the species has not been detected in recent surveys despite considerable effort. At Stanley Park, the species has not been detected since the 1970s. Over the past 6 years the search effort has included repeated seasons of funnel trapping, visual surveys for egg masses, checking artificial cover boards, and requests to naturalists and other park users for observation data (Stanley Park Ecology Society 2010; Worcester pers. comm. 2014). Efforts at Stanley Park have been sufficient to indicate local extirpation. Vancouver, Delta and Richmond are three other historical areas, sampled in 2012, where experienced surveyors failed to detect the species using egg mass surveys (Malt 2013). However, as the search effort involved only two to four ponds per area in only one season, more effort is required before definite conclusions can be drawn.

HABITAT

Habitat Requirements

The Northern Red-legged Frog is an inhabitant of moist, lower elevation forests and requires both aquatic breeding habitats and terrestrial foraging habitats in a suitable spatial configuration to complete the different phases of its life cycle. Hibernation can occur either on land within the forest floor or in water (Licht 1969; Ritson and Hayes 2000 *in* Hayes *et al.* 2008). In Oregon, adults were known to overwinter in a small 0.03 ha pond that was 50 m from a larger 0.6 ha pond used for breeding (Hayes and Rombough 2004). Otherwise, little is known of specific requirements for overwintering sites.

Elevation

The species has been recorded from sea-level to elevations up to 860 m in Washington and to 1427 m in Oregon (Leonard *et al.* 1993). The highest locality record from British Columbia is from 1040 m (Wind 2003), but most records are from below 500 m. In the Clayoquot Sound area on the west coast of Vancouver Island, Beasley *et al.* (2000) found the Northern Red-legged Frog more frequently in wetlands below 500 m (30% were occupied) than in those above 500 m (14% were occupied). Wind (2003) surveyed 236 wetlands ranging in elevation from sea-level to 1200 m for amphibians on Vancouver Island. The mean elevation where this species was found was 515 m, but most sites were lower (mode = 180 m).

Aquatic Breeding Habitats

The Northern Red-legged Frog breeds in a variety of permanent and temporary water bodies, including potholes, ponds, ditches, springs, marshes, margins of large lakes, and slow-moving portions of rivers (Blaustein *et al.* 1995 and references therein). Salinity > 4.5% is lethal to embryos, as are waters that are too acidic (pH ≤ 3.5) or too basic (pH ≥ 9), and water temperatures > 21º C are unsuitable (Hayes *et al.* 2008 and references therein). Abundant emergent vegetation is typically present at breeding sites (Adams 1999; Ostergaard and Richter 2001; Pearl *et al.* 2005; Adams *et al.* 2011). Females deposit their eggs in quiet waters (water velocities < 5 cm/sec) in areas that receive sunlight for at least part of the day (Licht 1969; Richter and Azous 1995). Wind (2008a) found a high incidence of Northern Red-legged Frog adults using small, forested ponds in the Nanaimo Lakes area, but very few ponds were used for breeding. The incidence of breeding increased after logging reduced canopy coverage around some ponds.

In the Puget Lowlands, Washington State, the species was found most commonly in wetlands with shallow slopes and a southern exposure; pond slope and exposure explained 63% of the variation in wetland occupancy (Adams 1999). Breeding occurred in permanent water bodies that tended to be large wetlands with structural complexity. Also in Washington, Ostergaard and Richter (2001) found this species breeding in storm water storage ponds (i.e., small natural or modified catchment areas used for storage of storm water runoff). Its presence was positively correlated with wetland complexity, measured as the ratio of coverage by emergent vegetation to open water, and percentage of forest cover in the surrounding area. Egg masses were most numerous in ponds with over 30% forest cover within 200 m from the shore. Adams *et al.* (2011) found that wetlands having >35% of the shoreline covered with trees > 5 m tall, within 5 m of the bank, had the lowest probability of local extinction in the Willamette Valley in Oregon. In Clayoquot Sound, Vancouver Island, the Northern Red-legged Frog was more frequently found in bogs and fens than in other types of wetlands that included marshes, swamps, and shallow areas of larger water bodies (Beasley *et al.* 2000).

Adams (2000) found that the survival of tadpoles of the Northern Red-legged Frog in experimental enclosures was highly variable among sites but tended to be lower in permanent than temporary wetlands. The difference was possibly due to habitat gradients or effects of predators. These results suggest that permanent water bodies, which harbour more predators, may act as sink rather than source habitats for recruits to the population. However, caution should be exercised in inferring the suitability of breeding sites from presence/absence type of data, where survival patterns for larvae and metamorphs are unknown.

Terrestrial Foraging Habitats

Metamorphosed individuals spend a large proportion of their life in terrestrial habitats, and juveniles and adults are often encountered in upland areas and in the vicinity of small wetlands or along forested stream banks (Blaustein *et al.* 1995 and references therein). Chan-McLeod and Wheeldon (2004) observed frogs using residual patches > 0.7 ha of old forest (>140 years) within 1-year-old variable-retention cutblocks. Telemetry studies indicate that adults use forests with complex understory structure and are often associated with woody debris and Sword Fern (*Polystichum munitum*) (Haggard 2000; Ritson and Hayes 2000 *in* Hayes *et al.* 2008; Schuett-Hames 2004). Individual radio-tracked frogs were often relatively sedentary when they reached terrestrial environments, moving less than 10 m daily and up to 80 m seasonally (Hayes *et al.* 2008 and references therein). During a dry summer, radio-tracked frogs typically remained close to the edge of forest streams (Chan-McLeod 2003; see <u>Movements and Dispersal</u>). When conditions are suitable, these frogs can be encountered on the forest floor far from water bodies; distances of up to 400 m have been noted on rainy nights (Nussbaum *et al.* 1983; Beasley unpubl. data 2014).

The Northern Red-legged Frog occupies a variety of forest types and ages but appears to be most abundant in older, moist stands (reviewed in Waye 1999 and Blaustein *et al.* 1995; also see **THREATS AND LIMITING FACTORS** for interactions with forestry). In the Washington Cascade Range, this species was most abundant in mature stands (80-190 years) and least abundant in young stands (55-75 years) (Aubry and Hall 1991). Its abundance was negatively correlated with elevation and increasing slope. Captures were also associated with moderately moist conditions in older forest stands; very wet old-growth stands appeared to be somewhat less suitable. Within a younger set of chronoseries in second-growth Douglas-fir (*Pseudotsuga menzeisii*)-dominated forest, Aubry (2000) found that this species was more abundant in stands that were near harvesting age (50 – 70 years) than in younger stands, where few captures occurred. The near-rotation-age stands had a closed canopy and 30 – 45 m tall trees; the herb and shrub layer had re-established, but the abundance of coarse woody debris was depressed from old-growth conditions. In a study in Washington and Oregon, this species was most abundant at lower elevation habitats with relatively flat slopes, but there was no relationship to stand age (classed as old growth, mature, young) (Bury *et al.* 1991). It is likely that the association of the species with forest age varies geographically, with forest type, moisture and other conditions.

In British Columbia, distribution records and anecdotal observations suggest that the species is commonly found in second growth forests, and also occurs in suburban gardens and seasonal ponds in pasture and agricultural lands adjacent to forested areas. On Vancouver Island, Wind (2003) found the species in wetlands within both recently logged (< 5 years) and older (> 6 to 120+ years) forest. Relative abundance and survivorship characteristics were not studied (see **THREATS AND LIMITING FACTORS** for a review of effects of logging on this species).

Migration and Dispersal Habitats

Adult Northern Red-legged Frogs migrate up to 4.8 km from their breeding sites (Hayes *et al.* 2001, 2007), and juveniles can disperse over 500 m from wetlands where they developed (Beasley unpubl. data 2014). Pathways and temporary stopover locations include upland forests, streams, riparian areas, seeps, and emergent, shrub-scrub, and forested wetlands (Hayes *et al.* 2008 and references therein). Radio-tracked movements of experimentally displaced adults showed that clearcuts act as barriers on hot, dry days on northern Vancouver Island (Chan-McLeod 2003). Permeability increased on rainy days and at lower temperatures; individual frogs were capable of moving > 190 m (straight-line distance) through clearcuts during 2-3 rainy days (Chan-McLeod 2003). Frogs did not travel along creeks through clearcuts (Chan-McLeod 2003) or use residual tree-patches as stepping-stones through variable retention cutblocks (Chan-McLeod and Moy 2007). However, frogs were attracted to forested streams >1.8 m wide (Chan-McLeod 2003) and, when placed in residual tree patches, their residence time was highest in patches with streams (Chan-McLeod and Moy 2007). Frogs also made deliberate directional movements toward residual tree patches depending on the size of the patch and distance from patch. Selective movements toward the average-sized residual tree patch did not occur if the frog was > 20 m away, but frogs moved toward large patches (>0.8 ha) from 50 m away (Chan-McLeod and Moy 2007).

Habitat Trends

Over the past century, habitats of the Northern Red-legged Frog have been altered by human activity over most of the species' range in British Columbia. Habitat degradation and loss are extensive on southern and eastern Vancouver Island, the Lower Fraser Valley, the Sea-to-Sky Corridor, and parts of the Sunshine Coast. The rate and permanency of habitat loss are highest in these areas as a result of urbanization, intensive agriculture and road-building. Fragmented habitats that remain throughout much of the Lower Fraser Valley and southeastern Vancouver Island also have been degraded by the spread of the introduced American Bullfrog (*Lithobates catesbeianus*).

Habitat alteration on the more remote areas on northern and western Vancouver Island and the mainland coast north of Powell River result primarily from logging on crown lands. The impacts of logging practices subject to the *Forest and Range Practices Act* are potentially less severe and of shorter duration than impacts of other human activities, provided that wetlands are protected, road building is done carefully to minimize changes in hydrology, some forest structure such as downed wood is retained, and forests are allowed to regenerate.

Recent land cover values were obtained from Baseline Thematic Mapping layers available from Hectares B.C. (2014). Values were calculated for elevations ≤ 500 m in each of the two British Columbia Ministry of Environment regions where Red-legged Frogs occur. Vancouver Island Region includes Vancouver Island and the Gulf Islands as well as an adjacent area on the mainland north of the Sunshine Coast. Lower Mainland Region extends from Vancouver to Hope and Pemberton, and includes the Sunshine Coast.

Vancouver Island Region: Urban areas covered about 3.3% (about 845 km^2) of the region in 2006 (Hectares BC 2014). Urban areas on the southeast island are expected to expand as human populations continue to grow. For example, Nanaimo Regional District expected a 60% increase in residents by 2036 with a demand for over 30,000 single detached units, 9600 row home units and 7600 apartment units (Urban Futures 2007). Despite strategies to increase housing densities and contain urban development, the Capital Regional District had an increase in urbanized land area of 3% (421 ha) within its urban containment area and 12% (1200 ha) outside from 2001 to 2007 (Capital Regional District 2008). The four-lane highway constructed between Campbell River and Nanaimo in 2001 has facilitated development northward.

Logging has affected a large proportion of the low-elevation (< 500 m) forest in this region. Approximately 16% (4130 km^2) was recently logged (<20 years ago) and 36% (9380 km^2) is young forest (<140 years) (Hectares B.C. 2014). Recent cutblocks are visible in the large tracts of old-growth forest northwest of Knight Inlet (Google Earth 2013). Habitats are expected to improve as second-growth forests mature and wetlands recover; however, on much of the island, logging of low elevation second-growth forests is in progress, and the regenerated habitats are again being degraded. Wildlife Habitat Areas established as a result of Identified Wildlife Habitat Guidelines have protected approximately 336 ha of important Northern Red-legged Frog breeding and terrestrial habitat in mature second-growth and old-growth forests, and these areas are expected to increase marginally over time (see **Habitat Protection and Ownership**).

Lower Mainland Region: Metro Vancouver and the Lower Fraser Valley were likely an important component of the species' range in British Columbia in the past, because these areas once provided productive and extensive low-elevation forested and wetland habitats. Since European settlement, much of the forest cover has permanently disappeared, and wetlands have decreased from about 10% of the area to only 1% in 1990 (Boyle *et al.* 1997). In 2006, urban areas covered approximately 13% (1260 km^2) of the region and agriculture covered an additional 8% (7760 km^2) (Hectares B.C. 2014). Urban development and agriculture continue to expand as this is one of Canada's fastest growing areas. The human population on the Lower Mainland grew by 102% from 1971 to 2006 (Statistics Canada 2009), and this growth is shifting from Vancouver to outlying communities in the Fraser Valley between Surrey and Chilliwack, as well as along the Sea-to-Sky Corridor. Human populations are expected to continue to double in the next 20-30 years in the Fraser Valley Regional District (Fraser Valley Regional District 2004) and Squamish-Lillooet Regional District (Squamish-Lillooet Regional District 2008). Consequently, there is intense pressure to develop lands, including remnant mature forest stands and wetlands. Although growth strategies include goals to create higher densities within urban containment areas, sprawling development is expected to continue. For example, Metro Vancouver is expected to grow by over 35,000 residents per year and growth in the number of dwelling units by 2040 is predicted to be 31% within the urban centres and 1% within rural/agricultural/conservation/recreation areas (Metro Vancouver 2014).

On the Sunshine Coast, residential development along coastal regions between Gibsons and Powell River has increased over the past decade with consequent alteration and loss of wetlands and adjacent forest cover. A further 12.8% increase is predicted for the next 10-year period (2015 – 2025; BC Stats 2014). Areas subject to forestry are also extensive, especially in low-elevation habitats along the coast (Sunshine Coast Regional District 2003; forest cover map).

BIOLOGY

The Northern Red-legged Frog has a biphasic life-cycle typical of aquatic-breeding amphibians in the northern hemisphere: Eggs are laid in water and develop into aquatic larvae, which then metamorphose into juveniles that leave the water. Juvenile frogs forage in terrestrial and riparian habitats for 1 to 2 years (males) and 2 to 4 years (females) before sexually mature individuals return to reproduce in aquatic habitats. Outside the breeding season, adults of the Northern Red-legged Frog are highly terrestrial and can be found far from water.

Licht (1969, 1971, 1974) and Calef (1973a,b) studied the reproductive biology and survivorship of the Northern Red-legged Frog in southern British Columbia. These studies remain the most detailed treatments of the species' biology and natural history in Canada to date. A mark-recapture study conducted in Umpqua, Oregon, provides the only known demographic data for the species in the United States (Hayes pers. comm. 2012).

Life Cycle and Reproduction

The Northern Red-legged Frog is an explosive breeder (*sensu* Wells 1977), and adults congregate at breeding sites for a short period (2 – 4 weeks) in late winter or early spring (depending on elevation), often immediately after the breakup of ice. Males are vocal and have a distinct advertisement call; however, they typically call from under water and, as a result, breeding choruses are inaudible or only barely detectable to the human ear from above the water's surface (Licht 1969). The timing of the breeding migration and egg laying varies both geographically and from year to year depending on air and water temperatures; water temperatures of at least 6 – 7°C appear to be required for egg laying, but temperatures frequently drop below this value during embryonic development (Licht 1974; Brown 1975). In southern British Columbia, breeding has been reported from January to April but is typically completed by the end of March (Licht 1969; Calef 1973b; Beasley unpubl. data 2014). While males are capable of breeding multiple times during each breeding season, mating success appears to be highly variable (Calef 1973a). Adult females reproduce each year (Licht 1974; Hayes pers. comm. 2012). In the populations studied in British Columbia, sexual maturity by both sexes was attained at three or more years of age (Licht 1974). In Oregon populations, some males were shown to become sexually mature within 1 year (Hayes and Hayes 2003); the probability of maturation for females was 74% at two years and 26% at three years of age (Hayes pers. comm. 2012).

As in most aquatic-breeding anurans, fertilization is external. Females lay their eggs in a large (20 – 30 cm diameter) gelatinous cluster, which they often attach to submerged vegetation (Leonard *et al.* 1993; Figure 1c). The average clutch size in marshes near Vancouver was 680 eggs (range: 243 – 935 eggs; Licht 1974); at another site on the lower mainland (Marion Lake) it was 531±19 eggs (mean±SE; Calef 1973b).

The duration of the incubation and larval period is temperature-dependent and highly variable under natural conditions. Hatching can take place as soon as nine days from oviposition (under constant temperature of 18.3°C; Storm 1960) but usually takes much longer. In southern British Columbia, hatching may occur as early as mid-March or during the first half of May (Calef 1973b). The duration of the larval period is about 11 – 14 weeks (Calef 1973b). Most tadpoles transform from early July to early August, but the timing of metamorphosis varies both annually and with location (Licht 1969, Calef 1973b). Overwintering by tadpoles has been noted in Oregon and British Columbia (Corkran pers. comm. 2007; Beasley unpubl. data 2014).

The Northern Red-legged Frog exhibits a Type III survivorship curve with high juvenile mortality. Annual survivorship of individuals surviving the critical early period then increases greatly. For this species the greatest mortality occurs during the tadpole stage, whereas embryonic mortality and that of metamorphosed individuals is relatively low (Calef 1973b; Licht 1974). Licht (1974) reported survival rates of over 90% for embryos from oviposition to hatching, less than 1% for tadpoles from hatching to metamorphosis in a pond that dried up, and 5.3% for tadpoles to metamorphosis in a permanent water body (the flooded portion of the Little Campbell River). Calef (1973b) reported 5% survival through the tadpole stage at another Lower Mainland site (Marion Lake); small tadpoles were particularly vulnerable to predation, and most mortality occurred within the first 3 – 4 weeks from hatching. Survival of recruits to the Little Campbell River population over their first year as frogs was estimated to be 52%, and the annual survival of adults (sexes combined) was 69% (Licht 1974). Hayes (pers. comm. 2012) reported similar low values for larval survival in Oregon (3.2 – 5.5%) and high values for adult survival (adult females 79 - 89%; adult males 67 – 80%). Based on the range of these findings, the generation time for Northern Red-legged Frog is estimated to be 4 – 6 years.

While fungal infections and desiccation due to fluctuating water levels contribute to embryonic mortality, predation is thought to be the main source of mortality (Calef 1973b; Licht 1974). Experiments in field enclosures where numbers of predators (Rough-skinned Newt *Taricha granulosa*) were manipulated documented the importance of predation as a mortality factor for tadpoles (Calef 1973b).

Adult males greatly outnumber females at breeding sites, but outside the breeding season the sex ratio of Northern Red-legged Frogs appeared to be at parity (Calef 1973a). Adult longevity under field conditions is estimated to be 8 to 12 years (Hayes *et al.* 2008); a lifespan up to 15 years has been reported in captivity (McTaggart Cowan 1941). Populations of many aquatic-breeding anurans fluctuate widely from year to year (Pechmann and Wilbur 1994), and in a portion of the Willamette Valley in Oregon, local extinction and colonization of ponds by the Northern Red-legged Frog was frequent (Adams *et al.* 2011). Data on population fluctuations of this species in Canada are limited to very few wetlands for less than ten years and do not show wide fluctuations (Beasley unpubl. data 2014). Waye (1999) and Hayes *et al.* (2008) pointed out that populations of the Northern Red-legged Frog are likely to withstand 1 – 2 years of low recruitment through the survival of adults for multiple years.

Physiology and Adaptability

The Northern Red-legged Frog is adapted to breeding in cold conditions (Licht 1971). Adults are active early in the spring when air and water temperatures are low, and males may call at water temperatures as low as 4 – 5° C (Licht 1971; Calef 1973a; Brown 1975). The eggs can withstand exposure to similarly low temperatures, although egg laying typically occurs in somewhat warmer water. The thermal tolerance of young embryos (up to Gosner developmental stage 11) ranges from 4 to 21°C (Licht 1971). Both the lethal maximum and minimum are the lowest reported for North American *Rana*, and the pattern most closely resembles that of the cold-adapted Wood Frog (*Lithobates sylvaticus*) from Alaska. The thermal tolerance of embryos increases as development proceeds. In nature, the eggs are protected within a gelatinous mass and are typically submerged in water; both factors buffer them from thermal fluctuations (Licht 1971), but a portion of the eggs in a clutch closest to the water surface will die under freezing conditions (Beasley unpubl. data 2014).

Red-legged Frogs are not known to be freeze-tolerant, as are the Wood Frog and a few other northern anurans. Instead, they overwinter in the bottom of pools or on the forest floor, presumably in microhabitats that are buffered from below-freezing conditions.

Dispersal and Migration

Metamorphs remain on the shores of breeding habitats for days or weeks after metamorphosis (Licht 1969). In Oregon, metamorphs left a breeding site 1 – 86 days after metamorphosis (Chelgren *et al.* 2008). Juveniles have been captured up to 500 m from natal sites during the fall dispersal period (Beasley unpubl. data 2014). Movements of older juveniles are unknown. Mark-recapture and radio-tracking studies indicate that the distance travelled by adults between breeding sites and summer foraging areas is highly variable. In Oregon, four adult frogs were found in May to July 2002 at a straight-line distance of 3.5 to 4.8 km from their capture points the previous January to February (Hayes *et al.* 2007). In Washington, five adult females equipped with radio-transmitters moved relatively long distances (up to 80 m day) during the spring migration period to settle approximately 312 m away in straight-line distance from breeding sites (Serra Shean 2002). Once adults arrive in terrestrial habitats, movement distances are typically short, although occasionally longer movements have been recorded during this time (Chan-McLeod 2003; Chan-McLeod and Wheeldon 2004; Chan-McLeod and Moy 2007).

Individual males showed site-fidelity to particular breeding sites from year to year, and about 20% of the males marked in one year were recaptured the following year at the same site (Calef 1973a). Furthermore, about 58% of the recaptured males returned to the same weed-bed, and many others occupied adjacent weed-beds within 100 m of their original capture locations. Females spend less time at wetlands, and consequently their site-fidelity has been poorly documented (Calef 1973a).

Interspecific Interactions

Predators and parasites

Predators of tadpoles of the Northern Red-legged Frog include carnivorous fish such as the introduced Rainbow Trout (*Onchorynchus mykiss*), salamanders (Rough-skinned Newt and Northwestern Salamander), and various invertebrates such as dragonfly larvae (Odonata) and the Giant Water Bug (*Lethocerus americanus*) (Calef 1973b). Leeches prey on anuran tadpoles and eggs (Licht 1974). The introduced American Bullfrog is a predator of both larvae and adults (Janicowski and Orchard 2013). Various other vertebrate and invertebrate predators that include metamorphosed frogs and tadpoles in their diets are often present at aquatic habitats occupied by this species, including Raccoon (*Procyon lotor*), Great Blue Heron (*Ardea herodias*), Belted Kingfisher (*Megaceryle alcyon*), and Common Garter Snake (*Thamnophis sirtalis*) (Licht 1974).

The Northern Red-legged Frog is a host for various parasites and disease-causing organisms. The most important are probably the chytrid fungus *Batrachochytrium dendrobatidis* (Bd), which has been detected in the species in California (Nieto *et al.* 2007), Oregon and Washington (Pearl *et al.* 2007), and British Columbia (Govindarajulu *et al.* 2013; Richardson *et al.* 2014), and iridoviruses that have been isolated from Northern Red-legged Frog tadpoles in California (Mao *et al.* 1999). The iridovirus found in Northern Red-legged Frogs was identical to that in a sympatric fish species, suggesting that fish (native and introduced) may act as reservoirs of the virus (Mao *et al.* 1999).

Prey and interspecific interactions

The diet of adults and metamorphosed juvenile Northern Red-legged Frog consists of a wide variety of small invertebrates, including spiders (Araneae), beetles (e.g., families Carabidae, Staphylinidae, Chrysomelidae, and Curculionidae, and Limnebiidae), leaf hoppers (Cicadellidae), damsel bugs (Nabidae), and slugs (Arionidae) (Licht 1986; Beasley unpubl. data 2014). Tadpoles feed largely on filamentous green algae. Experiments in enclosures indicated that feeding by tadpoles of this species altered both the composition and abundance of periphyton (Dickman 1968). Dickman (1968) suggested that feeding by tadpoles might initiate seasonal succession of periphyton in water bodies, which in turn could result in widespread effects within food webs.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Surveys to assess breeding populations of the Northern Red-legged Frog have been conducted at sites across Vancouver Island since 2006, and at a number of wetlands that contain other species at risk (Oregon Spotted Frog, Western Painted Turtle) in the Lower Fraser Valley since 2010 (Table 2). Counts of egg masses are an efficient way to obtain an index of the population size because each individual female lays a single egg mass per year, and egg masses are much easier to census than any other life stage.

On the Lower Mainland, counts of Northern Red-legged Frog egg masses have been conducted in conjunction with counts for the endangered Oregon Spotted Frog. Sampling has been relatively thorough because sites are visited repeatedly throughout the breeding season (Pearson 2010, 2011, 2012). Multi-day counts have also been done to cover the extensive areas of oviposition habitat dispersed throughout Swan Lake (4 ha) and Wood Lake (2 ha) near Ucluelet on Vancouver Island. Counts at other sites on Vancouver Island, the Lower Mainland, Sunshine Coast, and Texada Island involved a single day, or part thereof. Only accessible areas were surveyed at many of these sites (McConkey unpubl. data 2008; Beasley unpubl. data 2014; Mitchell pers. comm. 2014).

Two mark-recapture studies at breeding sites in British Columbia (Licht 1969, 1971, 1974; Calef 1973a, b) provided information about population sizes: Marion Lake (also known as Jacobs Lake) near Maple Ridge (Calef 1973a, b); Little Campbell River marshes in Surrey (Licht 1969, 1974).

Abundance

Early studies on Northern Red-legged Frogs at two sites on the mainland documented over 600 egg masses at Marion Lake (Calef 1973 a, b) and fewer than 40 egg masses at ponds near the Little Campbell River (Licht 1969, 1971, 1974). Recent inventories at 197 wetlands from widespread localities across the species' range but mostly from Vancouver Island indicate that most sites have relatively few egg masses (Figure 4). Surveyors found ten or fewer egg masses at 35% of the wetlands and >100 egg masses at only 20% of the sites surveyed. The highest counts were at sites on the west side of Vancouver Island (Pixie Lake near Port Renfrew: 1400; Swan Lake and "Lost Shoe 4" near Ucluelet: 1374, 618, respectively; Julia Passage in Barkley Sound: 445) (B.C. Ministry of Environment 2012; Beasley 2011, pers. comm. 2013). There were very high counts in the Lower Mainland as well, particularly at the Oregon Spotted Frog breeding sites (Maria Slough Chaplin Rd: 678; Maria Slough: 404; Mountain Slough: 236; Morris Valley: 203) and at other sites in the Fraser Valley (base of Vedder Mountain on Town Road in Chilliwack: 392; AAFC Farm 2: 285) (Pearson 2010, 2011, 2012).

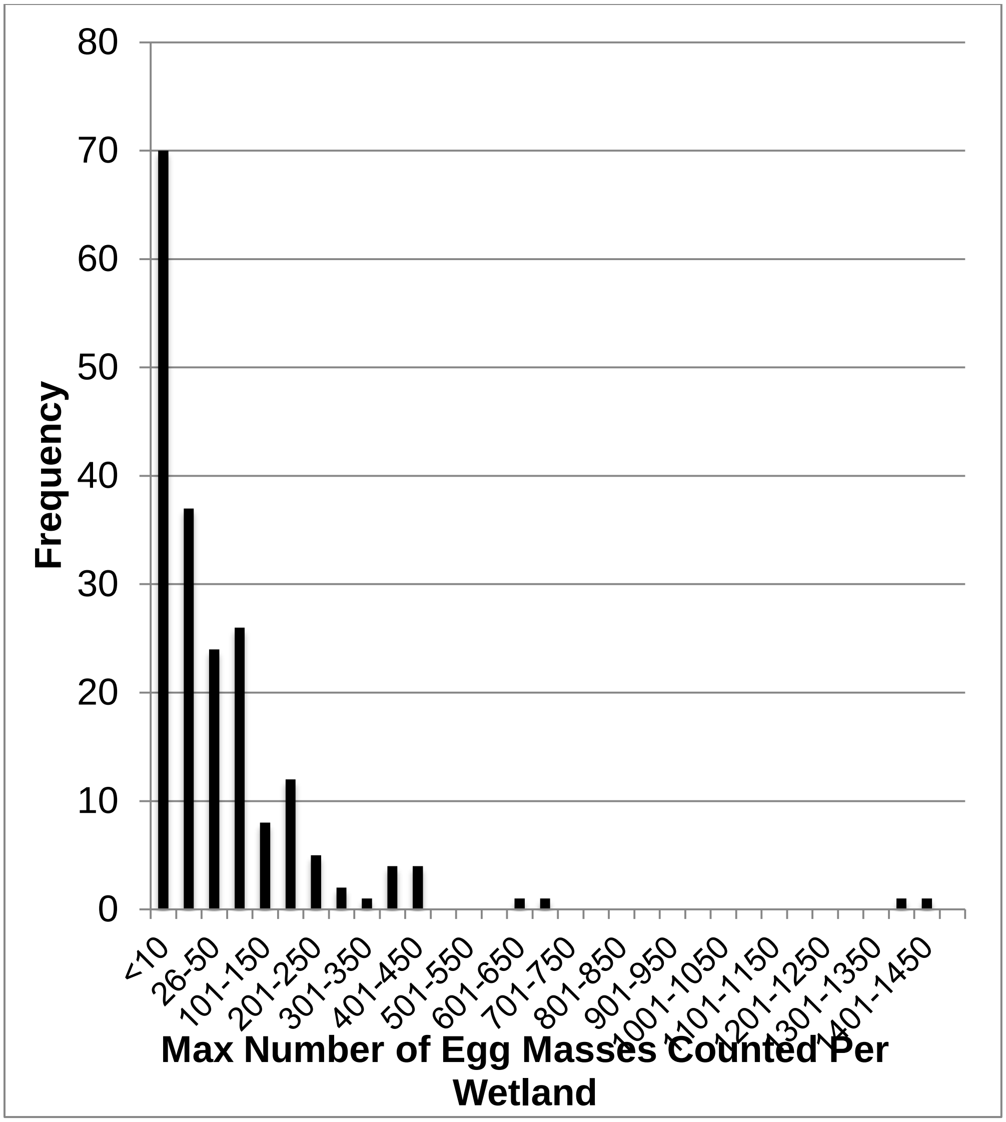


Figure 4. Frequency distribution of the number of egg masses of Northern Red-legged Frog counted at occupied wetlands (N=197) in British Columbia 2006 – 2013. Maximum counts per wetland per year were used for those that were surveyed over multiple years. Note that the interval on the x-axis changes between the first three bars and then becomes consistent. Data sources: Beasley 2011; Beasley unpubl. data 2014; B.C. Ministry of Environment 2012; Malt 2011; Mitchell *et al.* 2012; Mitchell pers. comm. 2014; Pearson 2010, 2011, 2012). Notes: (i) not all surveys were conducted at the ideal time or under ideal conditions to detect egg masses; (ii) in some cases several water bodies within the same wetland complex are presented as individual data points but do not represent independent populations.

It is possible that sites with small counts comprise portions of a larger population, or metapopulation, spread among multiple breeding ponds, as may often be the case for amphibians (Marsh and Trenham 2001). Alternatively, they may represent isolated small but persistent populations.

The total Canadian population of the Northern Red-legged Frog can be roughly estimated to be well over 100,000 adults based on the known abundance of 12,603 egg masses counted at 197 wetlands in the past ten years (Table 3), which comprise less than half of the known occurrences. If each breeding female requires one male, then the number of breeding adults at inventoried sites is at least 32,446. If only a portion of the adult male population breeds each year, as estimated by Calef (1973a) and Licht (1969), then the population of Northern Red-legged Frogs at the inventoried sites could be 3 – 6 times larger than the number of egg masses.

Table 3. Estimated number of breeding adults of Northern Red-legged Frog at occupied wetlands that have been surveyed in spring for egg masses.

Area / Time Period	Number of occupied wetlands that were surveyed	Average number of egg masses per year for the area *	Range in number of egg masses per year for the area	Estimated number of breeding adults at surveyed sites **
Vancouver Island				
Campbell River Forest District 2005 - 2012	14	537	388 - 719	1,438
North & North-Central Island Forest District 2006 - 2012	29	360	233 - 493	986
South Island Forest District 2006 - 2012	61	4,105	3,257 – 5,114	10,228
Ucluelet – Tofino 2008 - 2013	38	4,837	3,216 – 6,242	12,484
Mainland				
Lower Mainland and Fraser Valley 2010 - 2012	36	2,382	1,621 – 3,211	6,422
Sea-to-Sky 2007 - 2010	8	48	32 - 66	132
Sunshine Coast 2010 - 2012	6	285	242 - 328	656
Strait of Georgia				
Texada Island 2010 - 2012	5	49	48 – 50	100
B.C. TOTAL	197	12,603		32,446

* Most wetlands were not surveyed repeatedly each year so the "average number of egg masses per year for the area" was calculated by taking the average number of egg masses counted at each wetland per year and then adding those averages together. The range was calculated in a similar way, summing the minimums and maximums counted at each wetland per year, respectively. ** Estimated number of breeding adults was calculated by doubling the maximum value in the range, assuming that there is at least one male for every female that laid eggs, and that not every adult breeds each year. This is still a very conservative estimate given the findings of Licht (1969) and Calef (1973b).

Table 4. Summary of main threats to the Northern Red-legged Frog as per threats assessment using IUCN threat categories.

Threat number	Threat description	Scope[a]	Severity[b]	Timing[c]	Impact[d]	Populations or areas affected
1	Residential and commercial development	Small	Extreme	High	Low	Lower Mainland & southeast Van Isle
1.1	Housing and urban areas	Small	Extreme	High	Low	
4	Transportation and service corridors	Large	Moderate	High	Medium	Rangewide except remote parts of west Van Isle & Central Coast
4.1	Roads and railroads	Large	Moderate	High	Medium	
5	Biological resource use	Restricted - Small	Moderate	High	Low	Rangewide except urban/ agricultural areas
5.3	Logging and wood harvesting	Restricted - Small	Moderate	High	Low	
7	Natural system modifications	Small	Moderate	High	Low	Southeast Van Isle, Campbell River, Fraser Valley
7.2	Dams and water management / use	Small	Moderate	High	Low	
8	Invasive and other problematic species and genes	Pervasive - Large	Serious - Moderate	High	High - Medium	Rangewide for *Bd*; Lower Mainland & southeast Van Isle for bullfrogs
8.1	Invasive non-native / alien species	Pervasive - Large	Serious - Moderate	High	High - Medium	
8.2	Problematic native species	Restricted - Small	Serious - Moderate	High	Medium - Low	
9	Pollution	Small	Moderate - Slight	High	Low	Lower Mainland Lower Fraser Valley
9.3	Agricultural and forestry effluents	Small	Moderate - Slight	High	Low	
9.5	Air-borne pollutants	Unknown	Moderate - Slight	High	Low	
11	Climate change and severe weather	Pervasive	Unknown	High	Unknown	Range-wide, especially Coastal Douglas-fir on southeast Van Isle
11.1	Habitat shifting and alteration	Negligible	Unknown	High	Negligible	
11.2	Droughts	Pervasive	Unknown	High	Unknown	
11.3	Temperature extremes	Pervasive	Unknown	High	Unknown	
11.4	Storms and flooding	Small	Unknown	High	Unknown	

[a] **Scope** – Usually measured as a proportion of the species' population in the area experiencing the threat. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%; Negligible < 1%). [b] **Severity** – Within the scope, usually measured as the degree of reduction of the species' population. (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%; Negligible < 1%; Neutral or Potential Benefit > 0%). [c] **Timing** – High = continuing; Moderate = only in the short-term future or now suspended; Low = only in the long term future or now suspended; Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

[d] **Impact** – Reflects a reduction of a species' population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: Very High (75% declines), High (40%), Medium (15%), and Low (3%). Definitions from Salafsky *et al.* 2008.

Fluctuations and Trends

There have been two documented population declines, and anecdotal evidence of a third, in addition to the disappearance of the population in Stanley Park (Stanley Park Ecology Society 2010). First, Rithaler (2002a, 2003a) kept spawning records from 1962 to 2002, and qualitatively described a decline in the abundance of Northern Red-legged Frogs within the area encompassed by the Corporation of Delta (Delta, Ladner, Tsawwassen). Recent surveyors did not detect egg masses at four sites (Malt 2013) and after days of searching located only a single Northern Red-legged Frog in the least developed portion of the area at Burns Bog (Robertson Environmental 2013). Second, Malt (2012) used population data collected from salvage operations before construction and compared them to data collected afterwards using mark-recapture to assess the effects of the realignment of Highway 99 to Whistler in 2008. He estimated that at one of the wetlands fragmented by the highway construction, the local population declined from 357 in 2007 to 30 – 96 frogs in 2010, a 73 – 92% population reduction. Third, there appear to be few or no Northern Red-legged Frogs in Victoria wetlands where American Bullfrogs have invaded, while the species persists in large numbers in suburban sites in the absence of Bullfrogs (Ovaska pers. comm. 2014; Fraser pers. comm. 2014).

A few long-term monitoring projects have been initiated in the past 2 – 6 years in different parts of the range: the west coast of Vancouver Island (Beasley 2011), the Sunshine Coast, Texada Island, and Lower Mainland at sites important for Western Painted Turtles (Mitchell *et al.* 2012), and the Fraser Valley sites important for Oregon Spotted Frogs (Pearson 2012). Egg mass counts fluctuate slightly from year to year, but it is too early to detect trends.

Herpetologists have reported declines in the southern portion of the species' range in California (Jennings and Hayes 1994), and in the Willamette Valley, Oregon (Blaustein *et al.* 1994) since the mid-1970s. Reproductive populations remain on the valley floor of the Willamette Valley despite extensive habitat alteration (Pearl 2005) and a 5-year monitoring program (from 2004-2008) found stable occupancy probabilities (range 0.38 to 0.43) within the Willamette Valley Refuge Complex where, unlike the rest of the area, wetland loss had been minimal (Adams *et al.* 2011). However, there was considerable local extinction and colonization of wetlands in the Refuge Complex: in 17 instances the Northern Red-legged Frog was not detected at a site where it was found the year before, and in 13 instances the species was detected at a site where it was not seen the year before (Adams *et al.* 2011).

The Northern Red-legged Frog appears to remain relatively common in at least some areas of Washington State (Adams *et al.* 1998, 1999), including human-modified landscapes (Richter and Azous 1995; Ostergaard *et al.* 2008).

Rescue Effect

The potential of a rescue effect for Canadian populations due to dispersal from nearby U.S. populations is limited. There are several records from near the international border on the Lower Mainland, but most of these date from before 1960, and it is unknown whether these populations still exist. Dispersal across the border from the United States could potentially occur through the lowlands west from the Columbia Valley near Cultus Lake, but this area is highly fragmented and heavily modified by agriculture, residential developments, and roads. Some forested areas remain in the immediate vicinity of the border. Immediately east of the Columbia Valley, the high peaks of the Cascade Mountain Range pose barriers to dispersal.

THREATS AND LIMITING FACTORS

Limiting Factors

The present northern distributional limits of the Northern Red-legged Frog are probably a result of the glacial history of the area and not a reflection of its physiological or ecological tolerance limits, as attested by two isolated introduced northern populations, in Haida Gwaii and southeast Alaska. The species may still be expanding its range northwards along the Pacific coast, but altitudinal barriers (and possibly interactions with the Columbia Spotted Frog or other species) may pose limits to its range expansion inland.

Threats

A threats assessment was carried out using the IUCN threats calculator (Master *et al.* 2009). Each threat was ranked according to the proportion of the Canadian population or range under threat ("scope") over the next ten years, the magnitude of the threat in terms of projected population decline over the next three generation period ("severity"), and the immediacy of the threat ("timing"). Assessment of scope relied on land-use information for Vancouver Island provided by Baseline Thematic Mapping available from Hectares BC (2014) and predicted land use changes summarized in the regional growth strategies of several regional districts within the species' range. The combination of ranks for these three measures was used to calculate the overall "impact" of the threat. The overall threat impact for the species was calculated as "high", based on six "low" to "high" impact threats, summarized in Table 4 and described below.

Threats for the Northern Red-legged Frog were assessed for the entire Canadian range of the species, but there are clear differences in the scope and level of impact of threats in different parts of the range, particularly the Lower Mainland and southeastern Vancouver Island compared to the rest of Vancouver Island, and the mainland north of the Sunshine Coast (Table 1).

Description of the Threats

Landscape fragmentation and cumulative effects

The occurrence and persistence of Northern Red-legged Frog populations are known to be affected by habitat conditions within and surrounding breeding sites (Richter and Azous 1995; Adams 1999; Ostergaard *et al.* 2008; Adams *et al.* 2011; Malt 2013). The distribution of the species in Canada overlaps the most human-populated and fastest growing parts of the province in the Lower Fraser Valley and on southern and eastern Vancouver Island (Figure 3). Frogs currently persist in these regions within numerous small remnant patches of habitat surrounded by agricultural lands and urban developments. Continued human population growth will lead to the expansion of residential use and intensified agricultural practices, which are expected to cause further habitat loss and degradation over the next ten years (see **Habitat Trends**). Within less human-populated parts of the species' range (on northern and western Vancouver Island, the Sunshine Coast, and areas northward along the coast), forestry activities are extensive and continue to modify habitats and fragment habitats. Forest succession means there is a progression of effects after logging.

Although the provincial *Water Act* and Riparian Area Regulation will protect wetlands and some riparian areas (e.g., 5 m buffers around streams with fish habitat), much of the forest habitat will be altered, and what is left will be further fragmented. Fragmentation affects metapopulation processes by restricting movements between local populations at the landscape level. In other areas, habitat fragmentation has been shown to contribute to local declines and disappearances of forest-dwelling, pond-breeding amphibians that rely on dispersal among subpopulations across the landscape (e.g., *Ambystoma maculatum*; Gibbs 1998). Green (2003) compared population trend data and demographic parameters of a large number of amphibian species and populations and concluded that "curtailment of recolonizations in an obligately dispersing species with highly fluctuating populations and high frequencies of local extinctions, such as pond-breeding amphibians, is likely to be affected rapidly and catastrophically by habitat fragmentation" (p. 341). These considerations are expected to apply to the Northern Red-legged Frog, although details of its population fluctuations and dynamics in space and time are unknown.

A compounding threat in the urban-agricultural areas of the Lower Mainland and southern and eastern Vancouver Island is the continued population growth and range expansion of the invasive American Bullfrog. Introduced American Bullfrogs are predators and competitors of native frog species and can spread disease. Their presence usually overlaps with degraded habitats as well as introduced fish predators. Several efforts have tried to tease apart the influence of each of these factors in contributing to declining populations of the Northern Red-legged Frog (Adams 1999; Govindarajulu 2004; Pearl *et al.* 2005; Adams *et al.* 2011), and there appear to be several indirect effects and synergistic interactions.

Other ongoing anthropogenic threats throughout the species' range include roads, dams and water management, invasive plant species, stocking of sports fish in breeding habitats, and pollution from agricultural and forestry effluents. The threat of disease, especially an epidemic of chytridiomycosis, is a major concern because it has caused anuran population declines and extinctions around the world. Global climate change has the potential to exacerbate many of these effects. Synergistic interactions among various factors, human-induced and natural, are probably common and can affect amphibians in unpredictable ways.

<u>Invasive and other problematic native species – High to Medium Impact</u>

Epidemic disease is considered to be a potential threat to all amphibian species. Chytridiomycosis, caused by the amphibian chytrid fungus *Batrachochytrium dendrobatidis* (*Bd*), has been implicated in rapid amphibian declines and extirpations around the world (Lips *et al.* 2008), including western United States. Nieto *et al*. (2007) detected *Bd* in Northern Red-legged Frog tadpoles in northern California. Pearl *et al.* (2007) detected *Bd* on 28% of sampled amphibians at 43% of field sites surveyed in Oregon and Washington. Northern Red-legged Frogs and American Bullfrogs were among four of seven species that tested positive for *Bd* in the study. *Bd* occurs on Northern Red-legged Frogs sampled throughout B.C. as well, but no outbreaks of disease have been reported (Govindarajulu *et al.* 2013; Richardson *et al.* 2014). It is possible that Northern Red-legged Frogs are resistant to chronic levels of *Bd* and that the probability of a disease outbreak is low, unless their resistance is lowered or new strains of the fungus emerge or become prevalent. Future conditions that result from climate change could affect resistance and the emergence of new strains. Temperature variability (extreme diurnal range) has been shown to affect amphibian immune function (Raffel *et al.* 2006) and has been linked to disease outbreaks in other species (Rohr and Raffel 2010). A mesocosm experiment showed that greater temperature variability had a negative effect on body condition of Northern Red-legged Frog tadpoles exposed to *Bd* (Hamilton *et al.* 2012).

In addition to *Bd*, iridioviruses cause illnesses that are lethal to amphibians (Daszak *et al.* 2003; Blaustein *et al.* 2012). Iridioviruses have been associated with numerous amphibian mass mortality events around the world and were prevalent in most of the investigated amphibian die-offs in the late 1990s throughout the United States (Green *et al.* 2002) and parts of Canada, i.e., Saskatchewan and Ontario (Bollinger *et al.* 1999; Greer *et al.* 2005). Diagnostic samples for iridioviruses have not been collected in British Columbia, so its prevalence is unknown (Govindarajulu pers. comm. 2015). An iridiovirus was isolated in two Northern Red-legged Frog tadpoles collected from Redwood National Park in California in 1994 and 1996 (Mao *et al.* 1999), but otherwise its incidence in the species has been unreported. Environmental changes resulting from habitat loss and degradation are known to alter the prevalence of iridioviruses, transmission rates, and host susceptibility (Gray *et al.* 2009; Blaustein *et al.* 2012), so the potential threat cannot be ignored.

Within the range of the Northern Red-legged Frog, the American Bullfrog is known from most of the Lower Mainland, Sunshine Coast, southeastern Vancouver Island from Victoria to Campbell River, and from some of the Gulf Islands (Govindarajulu 2003; Mitchell *et al.* 2012). American Bullfrogs were introduced to Maple Ridge and Aldergrove in the 1940s, and their known current distribution in the Lower Fraser Valley extends from Stanley Park, Vancouver (Stanley Park Ecology Society 2010), eastward to Morris Lake near Harrison Mills (Murray *et al.* in press). Occupancy modelling predicts that Bullfrogs will overlap most of the range of the Northern Red-legged Frog in the Lower Fraser Valley in another 70 years (Murray pers. comm. 2014). Bullfrogs have also rapidly expanded their range on Vancouver Island and the Gulf Islands since the 1990s (Govindarajulu 2004) and are also spreading on the Sunshine Coast (Mitchell *et al.* 2012). On Vancouver Island, American Bullfrogs now reach from Sooke northward to Campbell River in the east and as far west as Port Alberni, approximately 20% of the Northern Red-legged Frog's range on the island. They are known to occur on Saltspring, Pender, Lasqueti, and Texada Islands, and parts of the Sechelt Peninsula (Mitchell *et al.* 2012; Govindarajulu pers. comm. 2014).

The introduction and spread of American Bullfrogs are thought to have contributed to declines of the Northern Red-legged Frog throughout its range; however, there is uncertainty about how strong their effect has been (Pearl *et al.* 2005; Adams *et al.* 2011). Bullfrogs are known predators of Red-legged Frogs in British Columbia (Janicowski and Orchard 2013). In some situations in British Columbia, such as Stanley Park and Delta, Bullfrogs seem to have completely displaced Northern Red-legged Frogs (Rithaler 2002b, 2003a; Stanley Park Ecology Society 2010), likely as a result of many contributing factors. For example, in the Corporation of Delta on the Lower Mainland, habitat modification, particularly the removal of riparian vegetation and channel deepening, appear to have contributed to the expansion of populations of Bullfrogs and Green Frogs (*Lithobates clamitans*) and the disappearance of the Northern Red-legged Frog from particular wetlands (Rithaler pers. comm. 2014). In other areas, Northern Red-legged Frogs seem to persist in wetlands with Bullfrogs at least over the short term but at reduced numbers (Govindarajulu pers. comm. 2014). Northern Red-legged Frogs do have breeding refuges in ephemeral or temporary pools, while Bullfrogs and introduced fish are restricted to permanent water bodies.

Stocking of non-native and native sport fish has been a common practice throughout the range of the Northern Red-legged Frog in B.C. (Wind 2005; Freshwater Fisheries Society of BC 2014). Non-native fishes, such as bass (*Micropterus* species), sunfish (*Lepomis* species), and perch (*Perca* species) are illegally released, and Brook Trout (*Salvelinus fontinalis)* and Brown Trout *(Salmo trutta)* were legally stocked on Vancouver Island and the Lower Mainland up until ~20 years ago (Silvestri pers. comm. 2014). Now, all legal stocking in these areas is done with native Rainbow Trout and Cutthroat Trout (*Oncorhynchus clarkii*), most of which are sterilized through a pressure shocking technique that causes them to become triploid (Silvestri pers. comm. 2014). Illegal fish-stocking is of greatest concern because populations are not controlled. Fish prey on Northern Red-legged Frog larvae and can reduce populations, unless wetland habitats are complex enough to provide sufficient refuge (Adams *et al*. 2011). Stocked fish can also introduce diseases, such as protozoan parasites (Neite *et al.* 2007) or *Saprolegnia* (Kiesecker *et al.*

2001), which may reduce the hatching success of Northern Red-legged Frogs. Several studies have shown negative associations of Northern Red-legged Frogs with the presence of non-native fish (Adams 1999; Adams 2000; Pearl *et al*. 2005).

Transportation and Service Corridors – Medium Impact

Roads occur in such high density that 44% of the known occurrences of the Northern Red-legged Frog are within 500 m of roads (Table 1). At elevations < 500 m across the species' Canadian range, 94% is within 5 km, 77% within 1 km, 65% within 500 m, and 36% within 100 m of a road (Hectares BC 2014).

Roads pose a threat to amphibians in a variety of ways. Road construction causes habitat loss. Roads are often constructed in lowland areas where the frogs are most abundant. For example, in the case of the expansion and improvement of Highway 99 within the Sea-to-Sky Corridor, near the community of Pinecrest, a 1.9 km alignment was created through a large wetland complex occupied by the Northern Red-legged Frog and several other amphibian species (Golder Associates Ltd. 2008). A total of 695 individual Northern Red-legged Frogs were salvaged from the area before the new alignment was constructed (Golder Associates Ltd. 2006, 2007, 2008). At one of the wetland sites fragmented by the new highway alignment, there has been an estimated 73 – 92% reduction in the population from pre-highway construction in 2007 to post-construction in 2010 (Malt 2012). Two other major highway expansion projects occurred recently within the area occupied by Northern Red-legged Frogs on the Lower Mainland, e.g., Port Mann Highway 1 Expansion and South Fraser Perimeter Road, and more are expected in the next ten years.

Traffic poses an ongoing threat to populations that cross roads during their seasonal migrations. Local populations of amphibians around the world have been known to decline (Fahrig *et al.* 1995), become genetically isolated (Reh 1989; Vos *et al.* 2001), and even become extinct (Cooke 1995 *in* Puky 2003) as a result of road mortality. The threat of road mortality on a population depends upon traffic volume (Hels and Buchwald 2001), the width of the road, and the speed and number of individuals trying to cross. Service roads, such as those used for logging have low levels of traffic at dusk and in the evenings when frogs are moving. However, even relatively low levels of traffic, e.g., 21 to 542 vehicles per hour can have isolating effects on populations through road mortality (Fahrig *et al.* 1995). Road mortality of Northern Red-legged Frogs has been documented on Highway 4 near Coombs (Blood and Henderson 2000), Nanaimo Lakes Road in Nanaimo (Wind 2012), Highway 4 within Pacific Rim National Park Reserve (Beasley 2006), Ryder Lake Road in the Fraser Valley (Clegg 2011), Laburnum Road in Qualicum (Materi 2008), Lazo Road in Comox (Wind 2012), Wake Lake near Duncan (Wind 2012), and the new Sea-to-Sky Highway at Pinecrest (Malt 2012). It is unknown how much unreported road mortality occurs, but it is likely to be high given the extensive road network across the species' range. Heavy traffic at the Pinecrest site on the Sea-to-Sky Highway is predicted to cause extirpation of the local population of Northern Red-legged Frogs in 20 – 40 years, if the current set of underpasses and barriers are not improved (Malt 2012). It is important to note that the Sea-to-Sky Highway site and Laburnum Road in Qualicum had high rates of roadkill despite having installed specially designed amphibian tunnels meant to provide safe passage, until barrier fences were installed.

In addition to habitat loss and direct mortality, roads act as barriers to movement in dry conditions because Northern Red-legged Frogs rarely cross roads unless it is raining (Beasley unpubl. data 2014). Road deicing salts and other pollutants from roads drain into ditches and wetlands (included under Pollution). The species spends time, and sometimes breeds, in roadside storm-water ponds where they are vulnerable to the entire suite of negative impacts associated with roads.

Residential and Commercial Development – Low Impact

Urban land cover currently comprises ~ 211,000 ha or 6% of the species' Canadian range at elevations <500 m (Hectares BC 2014). Approximately 20% of the species' known occurrences are within 1 km of existing residential or commercial development (Table 1). Housing development is expected to expand at a rapid rate, particularly in the Lower Fraser Valley and Squamish (see **Habitat Trends**). Permanent land conversion for housing is currently underway around urban and suburban centres. Examples include, but are not limited to, Maple Ridge, South Surrey, Delta, Mission, Sumas Mountain, Chilliwack, Squamish, and the Sunshine Coast. Large tracts of forests surrounding wetlands are becoming rare, and highly fragmented landscapes are becoming more common.

Expanding residential and commercial development results in irreversible loss of habitat and contributes to habitat fragmentation. The results of an occupancy model for the Lower Mainland supports purported declines of the Northern Red-legged Frog as a result of urbanization. Malt (2013) conducted systematic surveys to assess the breeding occupancy (presence / not detected) at 64 wetlands within municipalities throughout Metro Vancouver and the Fraser Valley in spring 2012. An additional 55 sites were surveyed as part of ongoing work for other species at risk. Egg masses of Northern Red-legged Frogs were present at 48% of the sites (Appendix 1). The data were used to examine the probability of occupancy with respect to surrounding land use. There was a decreased probability of occupancy as the percentage of urban land increased within a 2 km zone around each site using 2007 – 2008 land cover data. The probability of occupancy was zero for sites in Vancouver, Richmond, and Delta (Malt 2013). These results fit with regional trends in species decline and habitat losses in the Pacific Northwest of U.S.A. (Hayes *et al.* 2008 and citations within). Amphibian species richness in wetlands was shown to be negatively associated with the amount of surrounding urbanization in several studies in which Northern Red-legged Frogs were part of the species assemblage (Ostergaard *et al.* 2008).

Biological Resource Use – Logging – Low Impact

Approximately 80% of the total area ≤ 500 m in elevation within the range of the Northern Red-legged Frog is within managed forests. These forests include areas that were logged within the past 20 years (13%) and 20 – 140 years ago (38%), as well as mature forests over 140 years of age (29%) (Hectares BC 2014). If logging continues at the same rate, then 5% of the species' range will be cut in the next 10 years. Recent development plans on the coast set a sustainable rate of cut at ~1% of the Timber Harvesting Land Base (THLB) per year. If 50% of the managed forest >140 years old is within the THLB and will be logged in the next ten years, then 1.5% (i.e., 0.01/yr x 10 yrs x 0.5 x 0.29) of the area occupied by Red-legged Frogs will be harvested over the next ten years. This is an underestimate because maturing forests of 80 years in age, not just those over 140, are currently being logged.

Vegetation removal and road building associated with logging can lead to changes in watershed hydrology that may affect the suitability of wetland habitats in ways that are potentially beneficial and/or detrimental. Some wetlands have increased hydroperiods post-logging (Wind 2008a), whereas others dry up before larval development is complete (Beasley *et al.* 2000; Wind and Dunsworth 2006). The removal of trees from riparian areas around small ponds in the Nanaimo Lakes area eliminated shade and increased water temperatures, and more Northern Red-legged Frogs began laying egg masses at some sites (Wind 2008a). The resulting concern was whether metamorphs, emerging from ponds into clearcuts, would survive without moisture and cover in riparian areas. Currently, there are no data to answer this question. Modelling studies suggest that the stressors that impact metamorphs and juvenile frogs have the greatest potential to influence population fluctuations (Biek *et al.* 2002; Govindarajulu *et al.* 2005). Small wetlands (< 0.5 ha) are important for hydration and foraging habitat during the dry summer (Golder Associates Inc. 2007), as well as for breeding. However, small wetlands do not receive protection under the *Forest and Range Practices Act* in B.C. In fact, small wetlands are usually not identified on maps (Beasley *et al.* 2000; Wind 2008a).

Forestry activities modify terrestrial habitats in a variety of ways. Tree canopy removal causes lower humidity, greater fluctuations in temperature, and increasing wind on the forest floor (Chen *et al.* 1990, 1992). Soil compaction and mechanical disturbance reduces downed wood, leaf litter, and underground burrows. These physical changes alter food resources (i.e., invertebrate abundance, see Addison *et al.* 2003), daytime refuges, cover from predators, and hibernacula for amphibians (Hayes *et al.* 2008). Chan-McLeod (2003) showed that clearcuts less than 12 years old were barriers to Northern Red-legged Frog movement in dry weather (see Migration and Dispersal Habitats). Existing clearcuts will become more hospitable as canopy cover returns (Chan-McLeod 2003) and forests age (Aubry and Hall 1991; Aubry 2000); however, the recurrent threat of logging will happen on an 80-year (or less) rotational basis.

The negative effects of logging can be mitigated to some degree by adjusting the spatial configuration of cut areas and the size and location of residual tree patches (Chan-McLeod and Moy 2007). Thus, the impacts of future logging will depend on whether the amount and configuration of canopy retention, at stand and landscape scales, provides sufficient habitat protection and connectivity.

Natural Systems Modifications – Low Impact

Hydroelectric projects create impoundments that may flood river valleys, wetlands and upland forests. For example, the Jordan River watershed on Vancouver Island was impounded in the late 1900s, creating large reservoirs that altered over 90 ha of suitable Northern Red-legged Frog breeding habitat (Hawkes 2005). Other impoundments include Kettle Lake, Buttle Lake, Elsie Lake (72 ha lost) and Campbell River. Fluctuating water levels prevent development of shallow shoreline habitat with emergent vegetation needed for oviposition, e.g., water levels at Division Reservoir in Jordan River Watershed fluctuates as much a 9.6 m during the critical breeding period for Northern Red-legged Frogs (Hawkes 2005). Water management structures are also used to control flooding and to improve habitat for waterfowl. Many dykes in the Lower Mainland are old and need to be replaced, e.g., the dykes at Minnekhada Regional Park and Codd Wetland. Failure to replace these structures could lead to inundation of salt water that would destroy the freshwater habitat of Northern Red-legged Frogs. Managing for waterfowl can be at odds with managing for amphibians. For example, at Lake Mount Marsh, water levels were lowered to improve forage and nesting habitat for waterfowl but led to the loss of breeding habitat for Red-legged Frogs.

There has been a rapid spread of invasive plants, such as Reed Canary Grass (*Phalaris arundinacea*) and Purple Loosestrife (*Lythrum salicaria*) in coastal B.C. Reed Canary Grass occurs in wetlands throughout the Lower Mainland, which makes up >10% of the Red-legged Frog's range.

Pollution – Low Impact

The Northern Red-legged Frog is exposed to pollution from a variety of sources, including urban waste water, industrial effluents, agricultural effluents, forestry effluents, and air-borne pollutants. Pools, ponds, and other wetland habitats act as sinks for various pollutants, resulting in the exposure of aquatic-breeding amphibians to contaminants during critical periods in their early development (Vitt *et al.* 1990). Chemicals are readily absorbed through amphibian skin and jelly coatings of eggs. Storm water conditions (sediment metals and chloride from road salts) are known to be toxic to ranid frog embryos and larvae (Snodgrass *et al.* 2008).

Organochlorine pesticides were applied widely to the Fraser Valley in the 1970s (Finizio *et al.* 1998) and then replaced by organophosphate pesticides (De Solla *et al.* 2002a). Atrazine is used on field corn throughout most of the Fraser Valley (Belzer *et al.* 1998; Pearson pers. comm. 2011), and residues may remain in soils and water bodies (Top 1996; Environment Canada 2011a). Glyphosate is used on non-organic farms for blackberry control along fences, field preparation in the spring, on "Round-up Ready" corn, and sometimes directly along waterways (Pearson pers. comm. 2011; Environment Canada 2011a). Beyond the commercial application of herbicides and pesticides, nitrate / nitrite / phosphate runoff and groundwater leachate is well documented and increasing in the Fraser Valley as livestock densities have increased dramatically (Schindler *et al.* 2006; Environment Canada 2011b).

Many agricultural pesticides and fertilizers are known to be toxic to amphibians, causing mutagenic effects and developmental abnormalities (Bonin *et al.* 1997) and reduced food availability. The hatching success of Northern Red-legged Frog eggs experimentally set in agricultural ditches around Sumas Prairie, B.C., was strongly depressed (up to 9% and 34% in two years, respectively) compared to those (85% or higher) set in reference sites with lower exposure to agricultural runoff (De Solla *et al.* 2002a). The agricultural ditches had higher levels of ammonia, biochemical oxygen demand (BOD), and total phosphate (De Solla *et al.* 2002a) but similar and non-toxic levels of organochlorine pesticides and polychlorinated byphenyls (PCBs) (De Solla *et al.* 2002b; Loveridge *et al.* 2007). Laboratory investigations of nitrogenous by-products from agricultural fertilizers in the Williamette Valley indicated that Northern Red-legged Frog larvae were sensitive to ammonium sulfate and ammonium ions derived from related compounds (Schuytema and Nebeker 1999; Nebeker and Schuytema 2000). Ammonium nitrate and ammonium sulfate are known to reduce growth rates and kill frog larvae at concentrations lower than typical application levels, which are lower than U.S. Environmental Protection Agency water quality criteria for either human drinking water or warm water fishes (Marco *et al.* 1999). Atrazine is known to act as an endocrine disruptor that causes feminization of male Leopard Frogs (*Lithobates pipiens*) at concentrations far below standard application levels in the laboratory and the wild (Hayes *et al.* 2003). In northwestern California, adult male and subadult Northern Red-legged Frogs produced a biomarker implying exposure to feminizing compounds (Bettaso *et al.* 2002 *in* Hayes *et al.* 2008). It is likely that numerous substances exist with some endocrine disrupting action in urban and agricultural effluents and as yet are untested for their effects on amphibians (Hayes *et al.* 2008).

A portion (<30%) of the Northern Red-legged Frog's habitat is expected to be under intensive silvicultural management, where herbicides may be used. Amphibians, in general, are sensitive to the effects of glyphosate herbicides that are used in forestry for site preparation and conifer release (Govindarajulu 2008). Although application guidelines protect most water bodies and riparian areas, these herbicides may be sprayed over dry creeks and temporary ponds. For example, a forestry company applied glyphosate from helicopters over a forest stand near two salmon-bearing creeks and a wetland at Port Neville Inlet on Vancouver Island in 2009 (Sowden pers. comm. 2011). Laboratory studies indicate that a commonly used herbicide, Diuron™, can slow the development of limbs and reduce survival of Northern Red-legged Frogs in the laboratory at concentrations higher than those found in normal field spray situations, but possibly encountered in small ponded areas where the herbicide collects after application (Schuytema and Nebeker 1998).

There is little information about the extent of airborne pollutants in B.C., but several organophosphorus insecticides, including diazinon and malathion, have been found in atmospheric samples taken in Abbotsford, as recently as 2005 (Raina *et al.* 2010). In California, wind-borne agricultural pesticides have been implicated in population declines of California Red-legged Frogs (Davidson *et al.* 2002).

Climate Change – Unknown Impact

The majority of the Northern Red-legged Frog's range is within the Coastal Western Hemlock biogeoclimatic zone, which is expected to expand due to climate change over the next 35 years, mainly to higher elevations (Wang *et al*. 2012). The Coastal Douglas-fir biogeoclimatic zone (currently 0.25 million hectares, ~6% of the species' range ≤ 500 m elevation on Vancouver Island) will shrink 19% from its current extent and expand 16% into other areas by 2050 (Wang *et al.* 2012), resulting in a low net loss (-3%). It is possible that Northern Red-legged Frogs will shift habitats, given their capacity to move long distances (see Migration and Dispersal Habitats). They could, for example, move to higher elevations as temperatures increase, but this is uncertain, given that the species is usually found lower than 500 m on relatively flat terrain (see Elevation and Terrestrial Foraging Habitats).

As temperatures rise and weather events become more extreme with climate change, models predict wetter winters and drier summers within the species' Canadian range. Hydrological changes have the potential to have mixed effects on amphibian populations (Walls *et al.* 2013). For Northern Red-legged Frogs, wetter winters could be beneficial in terms of providing more breeding habitat during the egg laying period from February to April. Drier summers could also be beneficial if permanent water bodies become ephemeral ponds that have fewer predators. There are potential negative consequences as well. Coastal wetlands could be waterlogged repeatedly due to sea level rise and increased winter storm surge (Beckmann *et al.* 1997). Summer droughts may cause ephemeral wetlands to have shorter hydroperiods than the time required for Red-legged Frog larva to develop and increase mortality of dispersing post-metamorphic frogs because the distance between moist habitats would be greater.

A model addressing predicted changes in maximum summer temperatures throughout the current Canadian range indicates that 45% of the species' distribution will occur in thermally limiting environments by 2080 (Gerick *et al.* 2014). Extreme fluctuations in temperature, freezing in spring, or too much warmth too early in the season could be detrimental to embryos or larvae. Rates of larval development, size at metamorphosis and probability of survival to metamorphosis will be altered by combined changes in temperature and hydroperiod, but outcomes will depend on how well increased temperature can compensate for more rapid drying and plasticity in developmental rate (O'Regan *et al.* 2014). Cattle tank experiments showed that Northern Red-legged Frog larvae responded to higher temperatures and increased drying by developing more quickly and undergoing earlier metamorphosis. There was little size tradeoff at metamorphosis because warming increased periphyton availability to a level that kept up with the higher metabolic demands of tadpoles. There was low mortality because the experimental hydroperiod was long enough for the species to develop. If exposed to more variable and faster drying than the conditions simulated in the experiment, O'Regan *et al.* (2014) predict that Northern Red-legged Frogs would suffer greater lethal effects.

Additional possible consequences of climate change depend on interactions with other threats. The probability of chytrid disease outbreak could increase with more extreme temperature variability (i.e., more extreme temperatures between daytime and nighttime) (Hamilton *et al.* 2012). Rising temperatures could lead to enhanced eutrophication in warmer water receiving agricultural runoff (particularly in the Fraser lowlands) and increased rate of invasion and productivity of American Bullfrogs (Compass Resource Management 2007). Warmer waters will also lead to the range expansion of native and exotic warm-water fishes (Chu *et al.* 2005; Rahel and Olden 2008). Exposure to UV-B radiation could increase if water levels drop, and although hatching rates of Northern Red-legged Frogs were not reduced by ambient UV-B radiation (Blaustein *et al.* 1996; Ovaska *et al.* 1997), slower larval growth and development were associated with experimental embryonic exposure (Belden and Blaustein 2002a).

Number of Locations

There is an unknown but large number of locations for the Northern Red-legged Frog that could be affected by a single threat, given the distribution of known occurrences and types of threats (Table 1). Logging threatens 222 occurrences throughout the remote parts of the species' range. Roads and land development for housing and commercial activity threaten 232 and 106 occurrences, respectively, in human-dominated areas. These latter threats would be much faster acting, as indicated by the population decline that occurred when Highway 99 was realigned through a Northern Red-legged Frog breeding wetland. It is unlikely that climate change effects and severe weather, such as prolonged droughts, will rapidly affect a large portion of the species' range, at least over the short term.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

In Canada, COSEWIC assessed the Northern Red-legged Frog as Special Concern in 1999, and the status was re-examined and confirmed in 2002, 2004, and May 2015. It is listed as Special Concern on Schedule 1 of the *Species at Risk Act* (SARA). Under SARA, there are no immediate habitat protection requirements for species with this status. However, the species is considered part of the Environmental Assessment process that requires potential adverse effects of a project be identified, and, if a project is carried out, that measures be taken to avoid or lessen and monitor those adverse effects. Such measures must be consistent with any applicable management plans for a species of Special Concern (Species at Risk Public Registry 2013). A draft management plan for this species is currently under review (Govindarajulu pers. comm. 2015).

The British Columbia *Wildlife Act* prohibits the collection, possession, and trade of all native vertebrates, including amphibians. This law has limited effectiveness in protecting frogs, because it is difficult to enforce and does not cover damage to habitats.

Non-Legal Status and Ranks

The Northern Red-legged Frog has the global status of G4 (“apparently secure”; designated in June 2008) (Hammerson 2008). In the United States, its national status is N4 (“apparently secure”; designated in November 1996). Its status in the different states is as follows: California S2? (“imperilled?”); Oregon S3S4 (“vulnerable to extirpation or extinction” to “apparently secure); Washington S4 (“apparently secure”) (NatureServe 2013). The S3S4 rank indicates the species is at a moderate risk of extirpation within the U.S. federal and state jurisdictions due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors.

In British Columbia, the Northern Red-legged Frog has the conservation status S3S4 (designated in December 2010) (B.C. Conservation Data Centre 2014). It is on the provincial blue list of species at risk. Blue-listed species are “taxa of Special Concern” that “have characteristics that make them particularly sensitive or vulnerable to human activities or natural events” (BC Species and Ecosystems Explorer 2013). It was added to the list of Identified Wildlife included in the Identified Wildlife Management Strategy (IWMS) Version 2004. IWMS Version 2004 contains specific guidelines for management of the Northern Red-legged Frog habitat, and guidelines for Wildlife Habitat Areas on forestry lands.

Habitat Protection and Ownership

Parks and other protected areas

Approximately 16% of the species’ documented occurrences are within protected areas (Table 1). The amount of area within these parks and ecological reserves comprise 1900 to 3013 km^2 of land at elevations below 500 m and 1000 m, respectively (Table 5). On Vancouver Island, about 13% of the land base is protected. A total of 24% of the island is privately owned, 75% of which is private forestry lands (van Kooten 1995; Sierra Club 2003). Most of the private forestry lands and urban/agricultural developments are found in the southeastern quarter of Vancouver Island. This region appears to be an important area for the Northern Red-legged Frog due to the abundance of low-elevation forests and wetlands. Yet this region contains relatively little protected land. In 2003, the Gulf Islands National Park Reserve was established off the southeastern coast of Vancouver Island. The new park is composed mainly of lands that were already protected as provincial or regional parks, but some new acquisitions were also included. Several areas within this park contain habitat for the Northern Red-legged Frog. The western and northern parts of Vancouver Island are primarily crown land and used mainly by forestry companies for logging, although two large areas are protected within Brooks Peninsula and Cape Scott Provincial Parks and a narrow strip is protected in Pacific Rim National Park Reserve, which expands at Nitnat and connects to Carmanah-Walbran Provincial Park. The Long Beach Unit of Pacific Rim National Park Reserve is divided by a highway, which is a site with chronic levels of road mortality for the species (Beasley 2006).

Table 5. Protected Areas occupied by the Northern Red-legged Frog in British Columbia, Canada from historic records (indicated with superscript [h]) and records collected since 1983.

*Type of Protection codes: CA – Conservation Area**,** CC – Conservation Covenant, ECA – Ecological Conservancy Area, ER – Ecological Reserve, FRIR – Fraser River Islands Reserve, MP – Municipal Park, NPR – National Park Reserve, PP - Provincial Park, RP - Regional Park, WHA - Wildlife Habitat Area. **Size range indicates protected area < 500 m to <1000 m in elevation.

Vicinity	Site	Type of Protection	Area (ha)
North Vancouver Island	Beacon Pond, Malcolm Island	WHA	3
	Marble River, near Alice Lake	WHA	4
	Marble River	PP	1,419
	Nimpkish River	ER	18
	Cape Scott	PP	22,294
	Brooks Peninsula [h]	PP	51,631
	TOTAL		75,369
Campbell River District Vancouver Island	Brewster Bridge, Brewster Lake	WHA	1.6
	Diver 1, west of Brewster Lake	WHA	4.7
	Martha 1, near Martha Lake	WHA	15.8
	Sorenson's Marsh, near	WHA	11.9
	Kendrick, near Gunpowder Creek	WHA	20.5
	Maquinna Point, Nootka Island	WHA	15.5
	TOTAL		70
South Vancouver Island	Swan Lake, near Ucluelet	WHA	18.6
	Corrigan, near Port Alberni	WHA	13
	Corrigan 6.5, near Port Alberni	WHA	37.6
	Cous Creek, near Port Alberni	WHA	10.7
	Flora, near Nitnat	WHA	3
	Noyse Plateau	WHA	52
	Upper Canoe Pass Creek, near Effingham Inlet	WHA	4.5
	Julia Passage 1, near Effingham Inlet	WHA	10.4
	Julia Passage 2	WHA	4.6
	Julia Passage 3	WHA	9.4
	Rosemond Creek, near Jordan Ridge	WHA	33
	Loss Creek W, near Jordan Ridge	WHA	26
	Loss Creek E	WHA	16
	McVicar Creek, near Jordan Ridge	WHA	9
	Pete Wolfe Ck, near Jordan Ridge	WHA	12
	Carmanah - Walbran	PP	16,450
	Cowichan River	PP	1,414
	Newcastle Island [h]	PP	336
	Englishman River [h]	PP	97
	Englishman River [h]	RP	207
	Goldstream Park [h]	PP	477
	Kennedy Lake	PP	241

Vicinity	Site	Type of Protection	Area (ha)
	Pacific Rim, West Coast Trail, Cape Beale, Long Beach	NPR	~ 27,900
	Strathcona	PP	**~ 43,800 - ~ 133,000
	Miracle Beach	PP	137
	Little Qualicum Falls	PP	440
	Rosewall Creek	PP	54.3
	Denman Island	CC	~ 191
	Westwood Lake Park, Nanaimo	MP	50
	Gulf Islands, Pender & Saturna	NPR	~ 3600
	Thetis Lake, Saanich	RP	834
	Francis King, Saanich	RP	200
	Rithet's Bog, Saanich	CA	42
	Goldstream, Saanich	PP	477
	TOTAL		97,207 – 186,407
Lower Mainland	Lynn Canyon, North Vancouver	MP	250
	Burnaby Lake, Burnaby	RP	3.11
	Douglas Island, Port Coquitlam	FRIR	187
	Minnekhada, Coquitlam	RP	175
	Golden Ears	PP	** 8,450 - 30, 500
	Silverdale Creek Wetlands, Mission	MP	46
	Sasquatch	PP	1217
	F.H. Barber, near Hope	PP	8.5
	Bridal Veil, Chilliwack	PP	32
	Cheam Lake Wetlands, Chilliwack	RP	107
	Cultus Lake, Chilliwack	PP	2729
	Willibrand Creek, Abbotsford	MP	41.5
	Clearbrook Trail, Abbotsford	MP	9.2
	Brae Island, near Langley	RP	69
	Latimer Park, Langley	MP	16.8
	Campbell Valley, Langley	RP	450.6
	Aldergrove Regional Park	RP	166.5
	Hawthorn Park, Surrey	MP	27.8
	Green Timbers Urban Forest, Surrey	MP	239.7
	Crescent Park, Crescent Beach	MP	46.8
	Delta Nature Reserve, Burns Bog	ECA	2042
	TOTAL		16,314 – 38,364
Sea-to-Sky Corridor	Alice Lake, Squamish	PP	396
	Brandywine Falls, near Whistler	PP	420
	TOTAL		816
Sunshine Coast	Smuggler Cove Marine, Sechelt	PP	185
	Sargeant Bay	PP	142

Vicinity	Site	Type of Protection	Area (ha)
	TOTAL		327
Entire B.C. Range	GRAND TOTAL		190,103 – 301,353

On the Lower Mainland, very little of the land base is protected, and much of it consists of small parks surrounded by urban and rural developments. Many of the known sites for the Northern Red-legged Frog are located within these parks and, even though the land is protected, habitat degradation and fragmentation occur (Waye 1999).

The majority of the landbase of the Sunshine Coast and central south coast is zoned for forestry activities, but a number of new protected areas were created along the south central Coast in 2006-2007. The largest of these including Ugwiwey/Cape Caution Conservancy (102 km^2), Lockhard-Gordon Conservancy (245 km^2), Tsa-latl/Smokehouse Conservancy (378 km^2), Phillips Estuary/?Nacinuxw Conservancy (14 km^2), and Palemin/Estero Basin Conservancy (29 km^2). No surveys for the Northern Red-legged Frog have been done in these Parks but they do overlap with the species' extent of occurrence.

Forestry regulations and guidelines

The *Forest and Range Practices Act* provides some provisions for the protection of habitats of the Northern Red-legged Frog through regulations for pesticides and riparian widths and General Wildlife Measures contained in the Identified Wildlife Management Strategy. For example, regulations pertaining to riparian management require that buffer zones of undisturbed forest cover be retained around larger wetlands and streams. Smaller wetlands (<0.5 ha) used extensively by the Northern Red-legged Frog are not addressed by these provisions.

The Identified Wildlife Management Strategy contains guidelines for the protection and management of the Northern Red-legged Frog through the establishment of Wildlife Habitat Areas and associated General Wildlife Measures. Currently there are 23 Wildlife Habitat Areas for Northern Red-legged Frogs, totalling 336 ha on Vancouver Island (Table 5). Another 8 have been proposed for the Island, and inventory work on the Sunshine Coast may support the establishment of Wildlife Habitat Areas there (McConkey pers. comm. 2015). In addition, a number of Wildlife Habitat Areas in place for other species, such as Marbled Murrelets (*Brachyramphus marmoratus*), also protect habitat for Northern Red-legged Frogs.

Urban planning and protection initiatives

Municipal and regional governments in the Lower Mainland, Vancouver Island, and Sunshine Coast have prepared land use plans, by-laws, and zoning regulations, which offer some protection for wetland habitats. A set of province-wide Best Management Practices (BMPs) for amphibians and reptiles has been developed by the Ministry of Water, Land and Air Protection (Ovaska *et al.* 2003).

Conservation organizations, such as Ducks Unlimited, The Land Conservancy, Pacific Parkland Foundation and the Nature Trust of BC, have played an important role in acquiring, protecting and restoring wetlands and adjacent terrestrial habitats in southwestern British Columbia. Some projects, such as Cheam Lake wetlands, Codd Island Wetlands, Pitt-Addison Marsh, Burns Bog, and Blaney Bog, may be of sufficient size to protect both wetland and adjacent forest cover for the Northern Red-legged Frog.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Barbara Beasley completed a Ph.D. on the mating strategies of swallows at Simon Fraser University in 1994. She works as an independent biology consultant and part-time instructor at the Bamfield Marine Sciences Centre and Quest University. She coordinated a 3-year inventory project from 1997 to 2000 to assess the relative abundance of amphibian species in forests of different age as part of the Province of B.C.'s land-use planning process for Clayoquot Sound. Her long-term research involves documenting road mortality of amphibians, including the Northern Red-legged Frog, and testing the effectiveness of mitigation efforts. She recently founded the Association of Wetland Stewards for Clayoquot and Barkley Sounds, a charitable non-profit organization aimed at promoting amphibian conservation through research, monitoring and public education on the west coast of Vancouver Island.

COLLECTIONS EXAMINED

No specimens were examined but data were obtained from records held in the following institutions and accessed through the HerpNET data portal (http://www.herpnet.org) on 17 November 2013:

University of Alberta Museum of Zoology

University of Colorado Museum

Royal Ontario Museum, Toronto, Ontario

American Museum of Natural History, New York

University of Louisiana at Monroe

University of British Columbia Beaty Biodiversity Museum

Museum of Vertebrate Zoology, University of California, Berkeley

California Academy of Sciences, San Francisco

Smithsonian National Museum of Natural History, Washington, D.C.

Records from the Canadian Museum of Nature were sent by Michele Steigerwald. Kristiina Ovaska checked and confirmed that specimens for two questionable records held by the Royal British Columbia Museum were *Rana lutreiventris*, not *Rana aurora*.

Appendix 1. Breeding site occupancy of the Northern Red-legged Frog at wetlands in Metro Vancouver and the Fraser Valley in 2012.

Occupancy was assessed by inspecting each site for egg masses during the spring breeding period (N=119: 57 sites – species present, 62 sites – species not detected). A subset of sites that were sampled twice, each time by a different observer, was consistent in 94% of the instances (source: Malt unpubl. data 2013; figure used with permission).