Management Plan for the Northern Red-legged Frog (*Rana aurora*) in British Columbia

Prepared by B.C. Ministry of Environment

BRITISH COLUMBIA | Ministry of Environment

October 2015

About the British Columbia Management Plan Series

This series presents the management plans that are prepared as advice to the Province of British Columbia. Management plans are prepared in accordance with the priorities and management actions assigned under the British Columbia Conservation Framework. The Province prepares management plans for species that may be at risk of becoming endangered or threatened due to sensitivity to human activities or natural events.

What is a management plan?

A management plan identifies a set of coordinated conservation activities and land use measures needed to ensure, at a minimum, that the target species does not become threatened or endangered. A management plan summarizes the best available science-based information on biology and threats to inform the development of a management framework. Management plans set goals and objectives, and recommend approaches appropriate for species or ecosystem conservation.

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Disclaimer

This management plan has been prepared by the B.C. Ministry of Environment, as advice to the responsible jurisdictions and organizations that may be involved in managing the species.

This document identifies the management actions that are deemed necessary, based on the best available scientific and traditional information, to prevent Northern Red-legged Frog populations in British Columbia from becoming endangered or threatened. Management actions to achieve the goals and objectives identified herein are subject to the priorities and budgetary constraints of participatory agencies and organizations. The goal, objectives, and management approaches may be modified in the future to accommodate new objectives and findings.

The responsible jurisdictions have had an opportunity to review this document. However, this document does not necessarily represent the official positions of the agencies or the personal views of all individuals.

Success in the conservation of this species depends on the commitment and cooperation of many different constituencies that may be involved in implementing the directions set out in this management plan. The Ministry of Environment encourages all British Columbians to participate in the conservation of Northern Red-legged Frogs.

ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

The Northern Red-legged Frog is a medium-sized (7–10 cm) reddish-brown and black-speckled frog that gets its name from the translucent red undersides of its hind legs. Its range extends along the Pacific coast, west of the Coast and Cascade Mountains from southwestern British Columbia to northwestern California. In British Columbia, the Northern Red-legged Frog occurs mainly throughout the forested lowlands (< 1200 m elevation) of Vancouver Island, the adjacent Gulf Islands, along the mainland coast as far north as Kingcome Inlet, and in the Lower Fraser Valley to Hope. The Northern Red-legged Frog requires structurally complex wetlands (i.e., the ratio of emergent vegetation to open water) and forest habitats (i.e., abundant canopy cover, downed wood and litter) in a suitable spatial configuration to complete its life cycle.

The Northern Red-legged Frog (*Rana aurora)* was first designated as Special Concern by the Committee on the Status of Endangered Wildlife in Canada in 1999 and was re-examined and confirmed in 2002, 2004 and 2015 (Waye 1999, COSEWIC 2002, 2004, 2015). It is listed as Special Concern in Canada on Schedule 1 of the *Species at Risk Act* (SARA). In British Columbia, the Northern Red-legged Frog is ranked S3S4 (special concern, vulnerable to extirpation or extinction up to apparently secure) by the Conservation Data Centre and is on the provincial Blue list. The B.C. Conservation Framework ranks the Northern Red-legged Frog as a priority 1 under goal 2 (prevent species and ecosystems from becoming at risk) and as a priority 2 under goal 3 (maintain the diversity of native species and ecosystems). It is protected from capture and killing, under the B.C. *Wildlife Act*. It is also listed as a species that requires special management attention to address the impacts of forest and range activities under the *Forest and Range Practices Act* (FRPA) and/or the impacts of oil and gas activities under the *Oil and Gas Activities Act* (OGAA) on Crown land (as described in the Identified Wildlife Management Strategy).

A portion of the British Columbia population of Northern Red-legged Frogs occurs in densely human-populated areas where wetlands and forests continue to be lost and fragmented due to urban and agricultural development and road construction. Wetland habitats are drained and altered by development, water management projects, and possibly by aggregate extraction. Throughout most of the rest of the Northern Red-legged Frogs' range, habitats are modified as a result of logging. Introduced species (e.g., bullfrogs and sport-fish) and pollution have been shown to have detrimental effects on the development and growth rates of the species. Emerging diseases, such as chytridiomycosis, climate change, and UV-B radiation could exacerbate other threats and are topics of active research on declining amphibian populations around the world.

The management goal is to maintain self-sustaining and ecologically functioning populations of the Northern Red-legged Frog in occupied watersheds throughout its range in British Columbia.

The following are the priority short-term objectives:

1. Address knowledge gaps about the species distribution, relative abundance, and population ecology.
2. Protect key habitat such as aquatic (breeding), terrestrial (foraging), and interconnections (migration and dispersal) of Northern Red-legged Frogs across the distributional range.

3. Prevent the spread of introduced species (e.g., fish predators, bullfrogs, invasive plants) to breeding wetlands.
4. Reduce the levels of urban, agricultural, and forestry pollutants in terrestrial and aquatic habitats.
5. Prevent disease transfer by people and implement baseline disease monitoring.
6. Increase knowledge of the effectiveness of various mitigation strategies implemented to decrease population-level threat impacts.
7. Reduce gaps in our knowledge about the species vulnerability to emerging epidemic diseases and effects of climate change, and how these emerging threats may be synergistically magnified in altered habitats.
8. Increase public education and awareness to promote threat mitigation and population recovery efforts in human-altered areas where Northern Red-legged frogs persist or may have recently been extirpated.

Many elements of this management plan are already underway and need to be continued to manage ongoing threats. Increased collaboration is essential to address emerging threats and knowledge gaps, and to test the effectiveness of mitigation actions. Increased public education and involvement are critical to habitat protection, monitoring, and threat mitigation in habitats with significant human use.

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1 COSEWIC* SPECIES ASSESSMENT INFORMATION

Date of Assessment: November 2004
Common Name (population): Northern Red-legged Frog
Scientific Name: *Rana aurora*
COSEWIC Status: Special Concern
Reason for Designation: A large proportion of the known Canadian distribution of this species occurs in the densely populated southwestern part of British Columbia. Habitats are becoming increasingly lost and fragmented due to land conversions and other human activities. Introduced Bullfrog and Green Frog, which are spreading rapidly, have replaced this species at many sites and appear to adversely affect the use of wetland breeding sites and reproductive success. Populations of this species, and other amphibian species that require extensive habitat, are inherently vulnerable to habitat fragmentation, which can be expected to exacerbate isolation effects and local extinctions.
Canadian Occurrence: British Columbia
COSEWIC Status History: Designated Special Concern in April 1999. Status re-examined and confirmed in May 2002 and in November 2004. Last assessment based on an updated status report.

* Committee on the Status of Endangered Wildlife in Canada.

2 SPECIES STATUS INFORMATION

Northern Red-legged Frog[a]		
Legal Designation:		
FRPA:[b] Species at Risk OGAA:[b] Species at Risk	B.C. *Wildlife Act:*[c] Schedule A	SARA: Schedule 1– Special Concern (2005)
Conservation Status[d]		
B.C. List: Blue B.C. Rank: S3S4 (2010)	National Rank: N3N4 (2013)	Global Rank: G4 (2008)
Other Subnational Ranks:[e] Alaska: SNA; California: S2?; Oregon: S3S4; Washington: S4		
B.C. Conservation Framework (CF)[f]		
Goal 1: Contribute to global efforts for species and ecosystem conservation.		Priority:[g] 3 (2010)
Goal 2: Prevent species and ecosystems from becoming at risk.		Priority: 1 (2010)
Goal 3: Maintain the diversity of native species and ecosystems.		Priority: 2 (2010)
CF Action Groups:[f]	Compile Status Report; Monitor Trends; Planning; Send to COSEWIC; Habitat Protection; Habitat Restoration; Private Land Stewardship; Species and Population Management	

[a] Data source: B.C. Conservation Data Centre (2014a) unless otherwise noted.
[b] Species at Risk = a listed species that requires special management attention to address the impacts of forest and range activities on Crown land under the *Forest and Range Practices Act* (FRPA; Province of British Columbia 2002) and/or the impacts of oil and gas activities on Crown land under the *Oil and Gas Activities Act* (OGAA; Province of British Columbia 2008) as described in the Identified Wildlife Management Strategy (Province of British Columbia 2004).
[c] Schedule A = designated as wildlife under the B.C. *Wildlife Act*, which offers it protection from direct persecution and mortality (Province of British Columbia 1982).
[d] S = subnational; N = national; G = global; T = refers to the subspecies level; X = presumed extirpated; H = possibly extirpated; 1 = critically imperiled; 2 = imperiled; 3 = special concern, vulnerable to extirpation or extinction; 4 = apparently secure; 5 = demonstrably widespread, abundant, and secure; NA = not applicable; NR = unranked; U = unrankable.
[e] Data source: NatureServe (2014).
[f] Data source: B.C. Ministry of Environment (2010).
[g] Six-level scale: Priority 1 (highest priority) through to Priority 6 (lowest priority).

3 SPECIES INFORMATION

3.1 Species Description

The Northern Red-legged Frog (*Rana aurora*) has a brown or reddish-brown back marked with black speckles and spots. It has black bands across the upper surface of its legs and prominent dorso-lateral folds, which appear as small ridges, extending from behind the eye along each side of the body. A dark eye mask is bordered by a pale stripe along the upper jaw. The white throat, chest, and belly are often mottled with gray or black peppering. The undersides of the hind legs are translucent red, giving the species its common name. The groin area is flanked with yellowish-green and black blotches. Red often extends from the legs up the belly and chest. The extent of red varies among individuals and with age. Small juveniles may lack the red colour altogether or show only a faint reddish or yellowish tint on the underside of the legs. Adult females reach 100 mm in body length, and males reach 70 mm (Matsuda *et al.* 2006).

Tadpoles are light tan or greenish brown, and the trunk, tail, and fins are typically covered with brassy gold blotches or flecks. The tail is relatively short (about 1.5 times, or less, the length of the body), and the dorsal fin is relatively tall, giving tadpoles a stubby appearance. Eggs (each 3 mm in diameter not including the jelly coat) are laid in a large, loose jelly mass about the size of a cantaloupe (10–20 cm in diameter). A single mass contains 200 to 1100 eggs.

3.2 Populations and Distribution

Distribution
The Northern Red-legged Frog occurs along the Pacific coast west of the Coast and Cascade Mountains from southwestern British Columbia to northwestern California (Figure 1). A similar species, previously thought to be a subspecies, the California Red-legged Frog (*Rana draytonii*), occurs south of Mendocino County, California to Baja California, Mexico (Nussbaum *et al.* 1983). An isolated population of Northern Red-legged Frogs on Chichagof Island in southeastern Alaska is the result of a recent introduction (Hodge 2004). A small population on Graham Island in Haida Gwaii is probably also introduced (Ovaska *et al.* 2002).

Two-thirds of the global distribution of the Northern Red-legged Frog is in the United States with about one-third being in Canada, within the province of British Columbia (Figure 1). Northern Red-legged Frogs are found throughout Vancouver Island; the adjacent Gulf Islands in the Strait of Georgia and Johnstone Strait; and on the adjacent mainland, west of the Coast Mountains (Figure 2). On the mainland coast 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. Most occurrences are at low (< 500 m) elevations (Beasley *et al.* 2000; Wind 2003). The highest occurrence record in B.C. was at 1020 m (Wind 2003). The rugged coastal forests north of Powell River and along the Central Coast have not been surveyed systematically for amphibians, and the limits of this species on the mainland remain unknown (COSEWIC 2015). Vancouver Island comprises the bulk (> 50%) of the species' known Canadian range, which is disjunct from the rest of the range.

Figure 1. Range map showing global distribution of the Northern Red-legged Frog. Populations introduced to Haida Gwaii and Alaska are not shown. Source: International Union for Conservation of Nature, Conservation International, and NatureServe (2014).

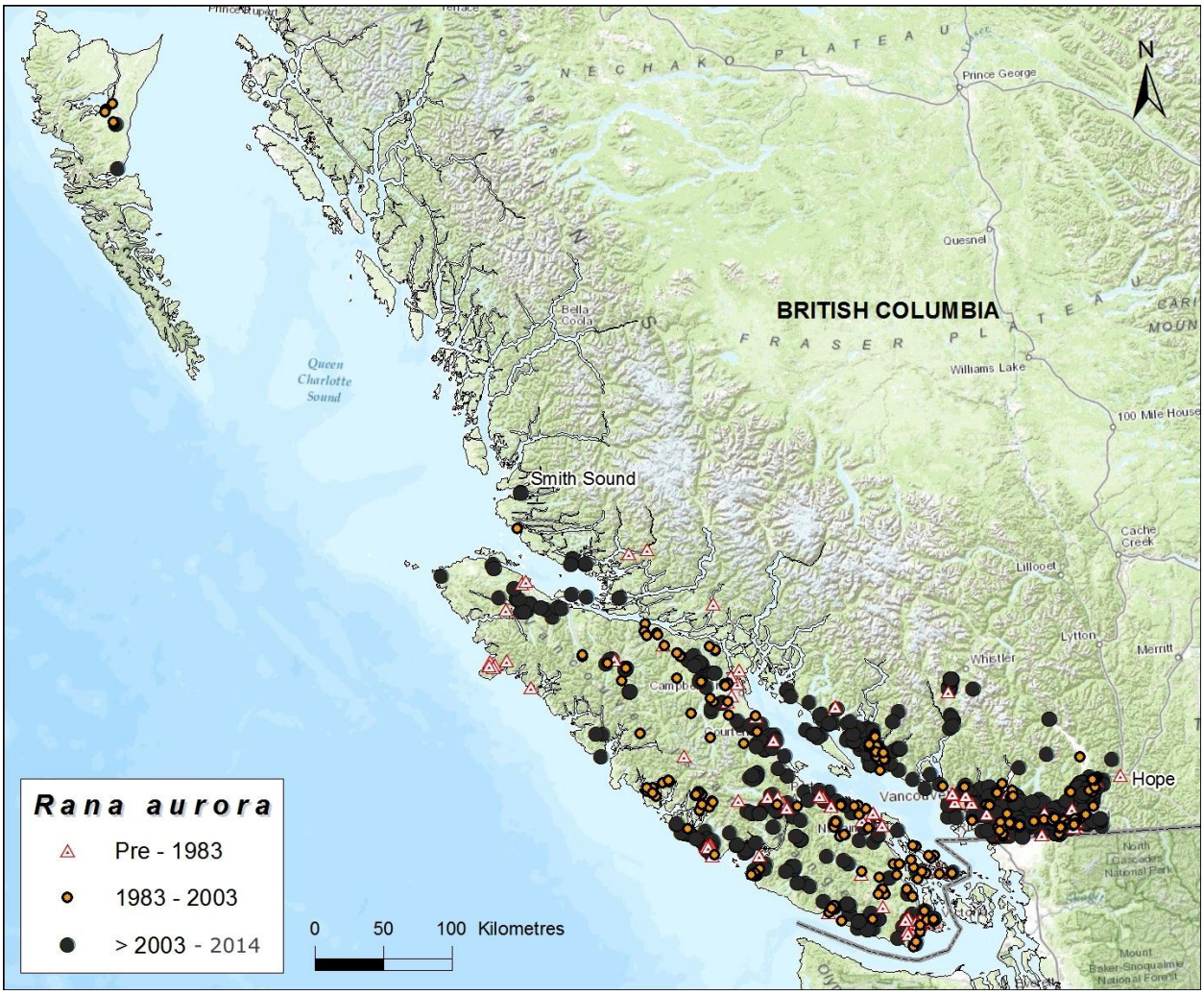

Figure 2. Canadian distribution of the Northern Red-legged Frog over three time periods to note changes that were related to increased survey effort over time. Observations include all life stages as well as populations on Haida Gwaii that are currently considered introduced. Records are from data compiled for COSEWIC in 2014. Map prepared by J. Wu, COSEWIC Secretariat, Environment Canada.

The extent of occurrence in Canada is estimated to be 75,625 km^2, based on a minimum convex polygon containing all known occurrences within the species native range (COSEWIC 2015). Haida Gwaii is not included because the species was probably introduced there (Ovaska *et al*. 2002). This estimate is based on records derived from museum collections, published and unpublished research reports and datasets, and incidental observations compiled for COSEWIC in 2014. The extent of occurrence is an indicator of the range of the species and includes areas at high elevation (> 1100 m) and within the ocean that are unsuitable habitat for the species.

Following the COSEWIC methodology, the Index of Area of Occupancy (IAO) was calculated by placing grid cells (2 x 2 km) on all known occurrences compiled for COSEWIC in 2014. The IAO was estimated to be 2,588 km^2 which is likely an underestimate, as search effort is incomplete (COSEWIC 2015).

Numerous inventories have documented the presence/not detected status of Northern Red-legged Frogs in different parts of its B.C. range (Table 1). Most reported that populations of Northern Red-legged Frogs were widespread and relatively common (found in 40% or more of the wetlands searched). Inventories that included numerous sites at higher elevations (> 500 m) found lower levels of occurrence (found in only 13–26%) (Beasley *et al.* 2000; Wind 2003). Not all wetlands were used for breeding, so surveys that focused only on finding egg masses may have missed the occurrence of adults. For example, Wind (2008) 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 opened up the canopy around some of the ponds (see discussion on logging threats).

Table 1. Frequency of occurrence of Northern Red-legged Frogs (at various life stages) found during wetland inventories. Note: numerous additional surveys exist as part of environmental assessments or other projects but have not been included in this table. See COSEWIC (2015) for a more thorough list.

Location (& land tenure)	Time period	No. of wetlands searched	Frequency of occurrence	Report/Source
Lower Mainland				
Fraser Lowlands (Provincial & Private)	Late 1990s	94	50% (all stages)	Haycock and Knopp (1998)
Fraser Lowlands (Provincial & Private)	2010–2011	43	47% (breeding)	Pearson (2010, 2011)
Metro Vancouver & Fraser Lowlands (Provincial & Private)	2012	119	48% (breeding)	Malt (2013)
Sea-to-Sky Corridor				
Alice Lake, Pinecrest & Brandywine (Provincial)	2007–2010	55	60% (all stages)	Malt (2011)
Sunshine Coast				
Sechelt Peninsula (Provincial & Private)	2010–2011	4	100% (breeding)	Mitchell *et al.* (2012)
Powell River (Provincial & Private)	2010–2011	6	66% (breeding)	Mitchell *et al.* (2012)
Texada Island (Provincial & Private)	2010–2011	9	44% (breeding)	Mitchell *et al.* (2012)
Vancouver Island				
Northeast Island	2002	85[a]	13% (all stages)	Wind (2003)
North-Central Island Forest District (Provincial)	2006–2012	58	45% (breeding)	B.C. Ministry of Environment (2012)
Campbell River Forest District (Provincial)	2006–2012	35	40% (breeding)	B.C. Ministry of Environment (2012)
Clayoquot Sound 6 watershed planning units (Provincial)	1998–1999	148	26% (all stages)	Beasley *et al.* (2000)
Tofino – Ucluelet & Long Beach area Pacific Rim National Park (Federal, Provincial & Private)	2008–2014	45	89% (all stages)	Beasley (2011); B. Beasley, unpublished data, 2012–2014
SE Vancouver Island (Provincial & Private)	2002	78[a]	23% (all stages)	Wind (2003)

Location (& land tenure)	Time period	No. of wetlands searched	Frequency of occurrence	Report/Source
South Island Forest District (Provincial)	2006–2012	104	57% (breeding)	B.C. Ministry of Environment (2012)
Nanaimo Lakes (Private)	2007	68	62–74% (adults)[a] 4–19% (breeding)[b]	Wind (2008)

[a] Wind (2003) searched 113 and 122 small wetlands in the north and southeast parts of Vancouver Island, respectively, including ephemeral ones that were dry. This table includes only the wetlands with water at the time of the survey, so they can be compared to other surveys.
[b] Range indicates the pre-timber harvest (first) and post-timber harvest (second) values for ponds.

Population Trends

The species is apparently secure across its global range. However, there have been population declines in the southern portion of the species range in California (Jennings and Hayes 1994), and in the Willamette Valley, Oregon (Blaustein *et al.* 1995; Pearl 2005) and potentially the Rogue Valley, Oregon (Pearl 2005). It appears to remain relatively common in at least some areas of Washington State (Adams *et al.* 1998; Adams *et al.* 1999), including human-modified landscapes (Richter and Azous 1995; Ostergaard *et al.* 2008).

In British Columbia, long-term population monitoring has been initiated in the past 2–6 years in different regions: the west coast of Vancouver Island (Beasley 2011), the Sunshine Coast, Texada Island and Lower Mainland (Mitchell *et al.* 2012), and the Fraser Valley (Pearson 2012). There are no declining trends observed from these surveys so far. There have been a few local declines and disappearances documented in other ways. Occupancy surveys and environmental assessments over the past 5 years (Malt 2013; Robertson Environmental 2013) indicate Northern Red-legged Frogs have disappeared from parts of Delta, Ladner, and Tsawwassen where they were abundant in the 1960s (Rithaler 2002, 2003a). Salvage reports compared to post-construction monitoring at one wetland at Pinecrest in the Sea-to-Sky Corridor showed there was an estimated population decline of 73–92% over 3 years as a result of highway construction and road mortality (Malt 2012). Intensive search effort and no detections at Stanley Park since the 1970s indicate that the species is extirpated there (Stanley Park Ecology Society 2010). There appear to be fewer Northern Red-legged Frogs at wetlands on the Saanich Peninsula since American Bullfrogs have invaded them in comparison with wetlands where there are no American Bullfrogs (K. Ovaska, pers. comm., 2014; D. Fraser, pers. comm., 2014).

Population Size

The best available information on population sizes of Northern Red-legged Frogs in B.C. comes from surveys of the number of egg masses (an index of the number of breeding females) at various breeding sites throughout the species range. There were over 16,000 egg masses counted at 197 wetlands in the past 10 years (COSEWIC 2015). These surveyed wetlands comprise less than half of the known occurrences (COSEWIC 2015). The number of breeding adults is at least double the number of egg masses, assuming that there is at least one male for every female that laid eggs. Licht (1969) and Calef (1973a) caught 3–6 times more adult males than the number of egg masses at their study sites. Thus, it is reasonable to assume that the total population of adult Northern Red-legged Frogs in B.C. is well over 32,000 and likely closer to 100,000.

The highest egg mass 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 and 618, respectively; Julia Passage in Barkley Sound – 445) (B.C. Ministry of Environment 2012; B. Beasley, unpublished data, 2012–2014). 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). Such large populations were uncommon. About 80% of the ponds surveyed had less than 100 egg masses, and 35% had less than 10 (B.C. Ministry of Environment 2012). It is possible that smaller counts represent isolated small but persistent populations. More likely, they comprise portions of larger populations spread among multiple breeding ponds, as found in other species of amphibians (Marsh and Trenham 2001). If so, population sustainability may depend on interconnections across the landscape within the 4–5 km distance that Northern Red-legged Frogs can move (Hayes *et al.* 2001; Hayes *et al.* 2007).

3.3 Needs of the Northern Red-legged Frog

The Northern Red-legged Frog lives within B.C.'s Coastal Western Hemlock (CWHdm, CWHds, CWHmm, CWHvh, CWHvm, CWHwh, CWHxm) and Coastal Douglas-Fir (CDFmm) biogeoclimatic units (B.C. Ministry of Land, Water and Air Protection 2004). Northern Red-legged Frogs require both aquatic breeding habitats and terrestrial habitats in a suitable spatial configuration to complete the different phases of their life cycle.

Aquatic Habitat

The Northern Red-legged Frog breeds in a variety of permanent and temporary freshwater bodies, including potholes, ponds, ditches, springs, marshes, margins of large lakes, and slow-moving portions of rivers (Blaustein *et al.* 1995 and references therein). In the Puget Lowlands, Washington State, the most common wetlands where this species was found had shallow slopes and a southern exposure; these habitat attributes together explained 63% of the variation in wetland occupancy (Adams 1999). Also in Washington State, Ostergaard (2001) found the species present more often in wetlands with greater extent of emergent vegetation and forest cover in the surrounding area. Egg masses were most numerous in ponds with over 30% forest cover within 200 m from the shore. 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 water areas of larger waterbodies (Beasley *et al.* 2000). McConkey (pers. comm., 2010) noted the presence of beaver dams at several of the most productive wetland sites used by Northern Red-legged Frogs for breeding. He suggested that beavers may have an important role in creating and augmenting wetland habitats by increasing water depths, extending hydroperiods, and influencing aquatic vegetation communities.

Temporary wetlands have reduced levels of predation on all amphibians, including Northern Red-legged Frogs, due to the absence of fish, and have higher water temperatures compared to larger, deeper, permanent waterbodies (Adams 2000). These conditions are conducive to rapid larval development and survival. Temporary wetlands must persist at least until mid-summer for successful metamorphosis (Nussbaum *et al.* 1983). Within breeding sites, egg masses are usually attached or anchored to emergent graminoids (rushes, sedges, and grasses), shrubs (hardhack,

sweet gale), and submergent vegetation (*Potomogeton, Nuphar*) in semi-exposed areas in shallow water (average depth 32 cm) (Richter and Azous 1995). Oviposition sites typically have little water flow and receive sunlight for at least a part of the day (Storm 1960; Licht 1969, 1971). Less often, egg masses are deposited in deeper water (Calef 1973a) and in partial shade (Beasley 2011).

Northern Red-legged Frog tadpoles feed on epiphytic algae and use relatively dense vegetation as cover (Nussbaum *et al.* 1983). Important habitat elements for tadpoles include herbaceous and emergent vegetation (rushes and sedges) and submerged downed wood. In general, habitat characteristics within waterbodies are more important than waterbody size for determining the likelihood of a waterbody being used as breeding habitat by a Northern Red-legged Frog (Beasley 2011; B.C. Ministry of Environment 2012).

Terrestrial Habitat

Northern Red-legged Frog metamorphs remain around the edges of breeding ponds for short periods (days to weeks) before dispersing (Licht 1969, 1986). In the fall, juveniles have been observed more than 0.5 km from the nearest known breeding site (Pearl 2005; Beasley 2008). There is some evidence that newly metamorphosed amphibians (of other species) select forested habitat over open fields when emigrating from breeding ponds (Walston and Mullin 2008). Important features of suitable terrestrial habitat include the presence of a closed canopy to maintain cool and moist microclimate, uncompacted soil, coarse woody debris, and undisturbed leaf litter (Aubry and Hall 1991; Haggard 2000; Schuett-Hames 2004). Juveniles often occupy relatively moist, densely vegetated riparian microhabitats (Licht 1986; Twedt 1993).

At least some adults appear to leave breeding sites relatively soon after the breeding period and move substantial distances (commonly 1.5 km to over 4 km from breeding pools) (Hayes *et al.* 2001, 2007) through forests (Nussbaum *et al.* 1983; Licht 1986; Gomez and Anthony 1996; Beasley 2008). During summer, adults have been found along streambanks, in moist riparian areas (Hayes *et al.* 2001; Chan-McLeod and Moy 2007), and small temporary wetlands (Golder Associates Ltd. 2008). At one northern California site, adults tended to use microhabitats adjacent to standing water rather than remaining in standing water (Twedt 1993). Moist cover in riparian areas, seeps, and small densely vegetated wetlands offers individuals the opportunity to forage, hydrate, and be sheltered from predators during hot, dry summer months. Gomez and Anthony (1996) found the highest abundance of Northern Red-legged Frogs in deciduous forest compared to coniferous stands; however, this was likely correlated with their capturing more in riparian habitats compared to upslope habitats. Greater numbers have been trapped in coniferous stands of moderate moisture than in drier stands in the Oregon and Washington Cascades (Aubry and Hall 1991; Bury *et al.* 1991). Two studies found Northern Red-legged Frog adults more frequently in older managed forest stands (Aubry and Hall 1991; Aubry 2000), but other terrestrial studies have not documented clear preferences for any stand age in managed and unmanaged forests (Bury *et al.* 1991; Bosakowski 1999).

In British Columbia, distribution records and anecdotal observations suggest that the species is commonly found in second-growth forests, and 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.

Abundant precipitation allows frogs to travel away from moist summer refuges throughout the forested environment and across more exposed areas such as clearcuts (Chan-McLeod 2003) and roads (Beasley 2006). Most long-distance movements happen on rainy nights in the spring (April to June) and fall (September to early November) (Beasley 2008). Adults tend to move in the direction of breeding ponds in the fall (Beasley 2008).

Little is known of the specific requirements for overwintering sites except that Northern Red-legged Frogs are not freeze-tolerant so they need a refuge from below-freezing temperatures (Waye 1999). Overwintering likely occurs on the forest floor and possibly at the bottom of ponds (Licht 1969). Chan-McLeod (2003) found one adult overwintering in a stream bank. Adults in southern parts of the species' range can remain active through winter (Nussbaum *et al.* 1983; Twedt 1993). Adults in low elevation areas of coastal British Columbia are also observed active in winter and begin breeding in January or February (Beasley, pers. comm., 2015).

3.4 Ecological Role

Amphibians, in general, play important roles in the ecosystem both as consumers of invertebrates and as prey for birds, mammals, and other larger organisms. Tadpoles graze on epiphytic algae and microorganisms growing on detritus. Experiments in enclosures indicated that feeding by Northern Red-legged Frog tadpoles altered both the composition and abundance of periphyton in a way that could initiate seasonal succession of periphyton and have widespread effects within food webs (Dickman 1968). Tadpoles are eaten by fish, Roughskin Newts (*Taricha granulosa*), Northwestern Salamanders (*Ambystoma gracile*), giant water bugs (Belostomatidae), larval diving beetles (Dytiscidae), and dragonflies (Calef 1973b; Licht 1974). Juvenile and adult Northern Red-legged Frogs consume various small insects, arachnids, and mollusks (Licht 1986). Larger adults are able to take larger food items, including juvenile conspecifics and salamanders (Licht 1986; Rabinowe *et al.* 2002). Garter snakes, herons, raccoons, and other vertebrates prey on juvenile and adult Northern Red-legged Frogs (Licht 1974, 1986; Gregory 1979).

Ecosystem imbalances resulting from population declines are easy to imagine because the Northern Red-legged Frog plays an important role in food webs, decomposition processes, and the transfer of nutrients between aquatic and terrestrial environments.

3.5 Limiting Factors

Limiting factors are generally not human induced and include characteristics that make the species less likely to respond to management/conservation efforts.

Like all amphibians, Northern Red-legged Frogs face a number of limiting factors related to their anatomy, physiology, and life history. They lay anamniotic eggs that must stay wet in the position where they are placed, are easily damaged in water currents, and are vulnerable to anoxic conditions at warm temperatures, as well as moulds and other water-transferred diseases. The reported lower thermal tolerance for Northern Red-legged Frog embryos is 3.5ºC, well

above freezing, and the maximum thermal tolerance is 21ºC (Licht 1971). Persistent spring snowpacks delay the onset of the breeding season and may delay embryonic development. Eggs and larvae develop more quickly in relatively warm water. As ectotherms with no protective cover to prevent them from drying out on land, their ability to survive extreme temperatures and drought depends on being able to find cool, moist habitats. Air temperature and precipitation have a strong influence on activity levels and timing of migration movements, foraging, predator avoidance, digestion, growth, sexual maturity and breeding. Their biphasic life requires both aquatic and terrestrial habitats, which exposes them to a wide diversity of predators and parasites. Northern Red-legged Frogs breathe and take up moisture through their skin, a trait that exposes them to pollutants in air, soil and waterbodies.

Some members of Northern Red-legged Frog populations move distances up to 4.8 km from breeding sites (Hayes *et al.* 2007) presumably as a result of competition and the distribution of resources (food, water, cover). As suitable habitats become spread far apart, migration distances increase and so does mortality associated with encountering unsuitable habitats, such as non-forested areas and roads (Hayes *et al.* 2008). High fidelity to breeding sites causes the Northern Red-legged Frog to cross the same risky landscape features repeatedly. Urban and agricultural development and roads that destroy or alter migration routes may negatively affect a population even though the overall landscape appears suitable (Hayes *et al.* 2008). Thus, the species' propensity to migrate and its high fidelity to breeding sites are limiting factors that make it vulnerable to threats.

4 THREATS

Threats are defined as the proximate activities or processes that have caused, are causing, or may cause in the future the destruction, degradation, and/or impairment of the entity being assessed (population, species, community, or ecosystem) in the area of interest (global, national, or subnational) (adapted from Salafsky *et al.* 2008). For purposes of threat assessment, only present and future threats are considered.[1] Threats presented here do not include limiting factors,[2] which are presented in Section 3.5.

For the most part, threats are related to human activities, but they can also be natural. The impact of human activity may be direct (e.g., destruction of habitat) or indirect (e.g., introduction of invasive species). Effects of natural phenomena (e.g., fire, flooding) may be especially important when the species is concentrated in one location or has few occurrences, which may be a result of human activity (Master *et al.* 2012). As such, natural phenomena are included in the definition of a threat, though they should be considered cautiously. These stochastic events should only be considered a threat if a species or habitat is damaged from other threats and has lost its resilience. In such cases, the effect on the population would be disproportionately large compared to the effect experienced historically (Salafsky *et al.* 2008).

[1] Past threats may be recorded but are not used in the calculation of threat impact. Effects of past threats (if not continuing) are taken into consideration when determining long-term and/or short-term trend factors (Master *et al.* 2012).
[2] It is important to distinguish between limiting factors and threats. Limiting factors are generally not human induced and include characteristics that make the species or ecosystem less likely to respond to recovery/conservation efforts (e.g., inbreeding depression, small population size, and genetic isolation).

4.1 Threat Assessment

The threat classification below is based on the IUCN-CMP (World Conservation Union–Conservation Measures Partnership) unified threats classification system and is consistent with methods used by the B.C. Conservation Data Centre. For a detailed description of the threat classification system, see the Open Standards website (Open Standards 2014). Threats may be observed, inferred, or projected to occur in the near term. Threats are characterized here in terms of scope, severity, and timing. Threat "impact" is calculated from scope and severity. For information on how the values are assigned, see Master *et al.* (2012) and table footnotes for details. Threats for the Northern Red-legged Frog were assessed for the entire province (Table 2).

Table 2. Threat classification table for Northern Red-legged Frog in British Columbia.

Threat #[a]	Threat description	Impact[b]	Scope[c]	Severity[d]	Timing[e]
1	Residential & commercial development	Low	Small (1–10%)	Extreme (71–100%)	High
1.1	Housing & urban areas	Low	Small (1–10%)	Extreme (71–100%)	High
1.2	Commercial & industrial areas	Negligible	Negligible (<1%)	Extreme (71–100%)	High
1.3	Tourism & recreation areas	Negligible	Negligible (<1%)	Serious (31–70%)	High
2	Agriculture & aquaculture	Negligible	Negligible (<1%)	Serious (31–70%)	High
2.1	Annual & perennial non-timber crops	Negligible	Negligible (<1%)	Serious (31–70%)	High
2.3	Livestock farming & ranching	Negligible	Negligible (<1%)	Serious (31–70%)	High
3	Energy production & mining	Negligible	Negligible (<1%)	Serious (31–70%)	High
3.2	Mining & quarrying	Negligible	Negligible (<1%)	Serious (31–70%)	High
3.3	Renewable energy	Negligible	Negligible (<1%)	Unknown	High
4	Transportation & service corridors	Medium	Large (31–70%)	Moderate (11–30%)	High
4.1	Roads & railroads	Medium	Large (31–70%)	Moderate (11–30%)	High
4.2	Utility & service lines	Negligible	Negligible (<1%)	Unknown	High
5	Biological resource use	Low	Restricted - Small (1–30%)	Moderate (11–30%)	High
5.3	Logging & wood harvesting	Low	Restricted - Small (1–30%)	Moderate (11–30%)	High
6	Human intrusions & disturbance	Negligible	Negligible (<1%)	Slight (1–10%)	High
6.1	Recreational activities	Negligible	Negligible (<1%)	Slight (1–10%)	High
7	Natural system modifications	Low	Small (1–10%)	Moderate (11–30%)	High
7.2	Dams & water management/use	Low	Small (1–10%)	Moderate (11–30%)	High
8	Invasive & other problematic species & genes	High - Medium	Pervasive - Large (31–100%)	Serious - Moderate (11–70%)	High
8.1	Invasive non-native/alien species	High - Medium	Pervasive - Large (31–100%)	Serious - Moderate (11–70%)	High

Threat #[a]	Threat description	Impact[b]	Scope[c]	Severity[d]	Timing[e]
8.2	Problematic native species	Medium - Low	Restricted - Small (1–30%)	Serious - Moderate (11–70%)	High
9	Pollution	Low	Small (1–10%)	Moderate - Slight (1–30%)	High
9.1	Household sewage & urban waste water	Unknown	Unknown	Moderate - Slight (1–30%)	High
9.2	Industrial & military effluents	Negligible	Negligible (<1%)	Moderate (11–30%)	High
9.3	Agricultural & forestry effluents	Low	Small (1–10%)	Moderate - Slight (1–30%)	High
9.5	Air-borne pollutants	Unknown	Unknown	Moderate - Slight (1–30%)	High
11	Climate change & severe weather	Unknown	Pervasive (71–100%)	Unknown	High
11.1	Habitat shifting & alteration	Negligible	Negligible (<1%)	Unknown	High
11.2	Droughts	Unknown	Pervasive (71–100%)	Unknown	High
11.3	Temperature extremes	Unknown	Pervasive (71–100%)	Unknown	High
11.4	Storms & flooding	Unknown	Small (1–10%)	Unknown	High

[a] Threat numbers are provided for Level 1 threats (i.e., whole numbers) and Level 2 threats (i.e., numbers with decimals).

[b] **Impact** – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each threat is based on severity and scope rating and considers only present and future threats. Threat 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%). Unknown: used when impact cannot be determined (e.g., if values for either scope or severity are unknown); Not Calculated: impact not calculated as threat is outside the assessment time (e.g., timing is insignificant/negligible [past threat] or low [possible threat in long term]); Negligible: when scope or severity is negligible; Not a Threat: when severity is scored as neutral or potential benefit.

[c] **Scope** – Proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%; Negligible < 1%).

[d] **Severity** – Within the scope, the level of damage to the species from the threat that can reasonably be expected to be affected by the threat within a 10-year or 3-generation timeframe. For this species a generation time of 4 to 6 years (COSEWIC 2015) was used resulting in severity being scored over a 12- to 18-year timeframe. 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 $\geq$ 0%).

[e] **Timing** – High = continuing; Moderate = only in the future (could happen in the short term [< 10 years or 3 generations]) or now suspended (could come back in the short term); Low = only in the future (could happen in the long term) or now suspended (could come back in the long term); Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

4.2 Description of Threats

The overall province-wide Threat Impact for this species is High.[3] The highest scored threat to Northern Red-legged Frogs is considered to be species introductions (such as, bullfrogs, predatory fish, *Batrachochytrium dendrobatidis*) followed by direct road mortality due to increasing transportation demands within its range in B.C. (Table 2). Details are discussed below under the Threat Level 1 headings.

IUCN-CMP Threat 1. Residential & commercial development

1.1 Housing & urban areas – low impact

Part of the species' range (~6%) overlaps the most human-populated and fastest growing parts of the province in the Lower Fraser Valley and on southern and eastern Vancouver Island (Hectares BC 2011). Housing development is expected to double over the next 20–30 years in areas such as the Fraser Valley and Squamish-Lillooet Regional Districts (Fraser Valley Regional District 2004; Squamish-Lillooet Regional District 2008). Although growth strategies include goals to create higher densities within urban containment areas, some sprawling development is expected to continue (Urban Futures 2007; Capital Regional District 2008; Metro Vancouver 2010). Approximately 20% of the species known occurrences in British Columbia are in areas within 1 km of existing residential or commercial development (COSEWIC 2015) and it is expected that at least 5% of those will be affected by expanding urban development in the next 10 years.

Where urban development occurs, there will be a reduction in the amount and quality of breeding, foraging, migration, and dispersal habitats required throughout the life cycle of the Northern Red-legged Frog. Wetlands are drained, forests cleared, and soil paved over to create land suitable for building (Minton 1968; Boyle *et al.* 1997). Although the provincial *Water Act* and Riparian Area Regulation protects some wetlands and riparian areas (e.g., 5 m buffers around streams with fish habitat), habitat will be irreversibly lost, and what is left will be further fragmented. Fragmentation restricts movements between foraging and breeding habitats and dispersal between 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 many 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." 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.

[3] The overall threat impact was calculated following Master *et al.* (2012) using the number of Level 1 Threats assigned to this species where Timing = High or Moderate. This includes 1 High-medium, 1 Medium, and 4 Low (Table 2).The overall threat considers the cumulative impacts of multiple threats.

Malt (2013) conducted systematic surveys to assess the breeding occupancy at wetlands within municipalities throughout Metro Vancouver and the Fraser Valley in the spring of 2012. Egg masses of Northern Red-legged Frogs were present at 48% of the sites. 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 (Malt 2013). These results fit with trends of amphibian population decline with habitat losses observed in the U.S. Pacific Northwest (Hayes *et al.* 2008 and citations within).

1.2 Commercial & industrial areas – negligible impact

Industrial areas are expanding in Sumas, Abbotsford, Langley, Surrey, Maple Ridge, and Burnaby, as well as Langford and other areas (K. Welstead, pers. comm., 2011) but the increased industrial footprint over the next 10 years is expected to take up a very small area relative to the species range and occurrences.

1.3 Tourism & recreation areas – negligible impact

Expanding recreation and tourism development is expected to affect less than 1% of the species range and occurrences. Ski hills are developed at higher elevations than where the species normally occurs. Golf course development may affect Northern Red-legged Frog populations in positive ways (D. Fraser, pers. comm., 2014) depending on how they are constructed and managed. Golf courses create wetlands suitable for amphibian breeding and can contribute significant amounts of habitat in urban settings (Colding *et al.* 2009). However, the hydroperiods of constructed wetlands need to be managed to reduce the incidence of bullfrogs (Boone *et al.* 2008; see threat 8.1). Golf courses that retain natural forest and shrub patches associated with creeks and drainage ditches, and provide cool, moist habitats for foraging and security cover are better suited for Northern Red-legged Frogs but many urban golf courses are highly manicured lawn habitats that are not suitable for this species.

IUCN-CMP Threat 2. Agriculture & aquaculture

2.1 Annual & perennial non-timber crops – negligible impact

Historically the draining of wetlands for agriculture, such as Sumas Prairie in the Fraser Valley, had an impact on Northern Red-legged Frog populations; however, the species persists in remnant patches of forest and wetland habitats within and adjacent to agricultural fields throughout the Fraser Valley and Greater Vancouver Regional Districts. In a few places agriculture is becoming more intensive shown by activities such as increased greenhouse construction and greater water use (K. Welstead, pers. comm., 2011) however, most of the Agricultural Land Use Inventories summaries indicate that greenhouses comprise a very minor component of the Agricultural Land Reserve (ALR) (D. Trotter, pers. comm., 2015). Further drainage of wetlands and removal of forest and shrub cover that would reduce breeding and foraging habitat is expected to affect less than 1% of the species occurrences (D. Fraser, pers. comm., 2014).

Currently, as much as half of the Agricultural Land Reserve (ALR) in parts of the Lower Mainland and on Vancouver Island is forested (D. McConkey, pers. comm., 2014; D. Trotter pers. comm., 2015). It is important to note, over the long term, much of this land could become converted to farmland as pressure for local food production increases and the provisions that protect wetlands and other waterbodies, such as the Riparian Areas Regulation, would not apply within the ALR (D. McConkey, pers. comm., 2014).

2.3 Livestock farming & ranching – negligible impact

Livestock farming and ranching occurs on less than 1% of the area occupied by Northern Red-legged Frogs. These activities degrade habitat to varying degrees depending on the practices. Infrastructure that is created for feedlots and to house livestock, such as at sites around Mountain Slough and Maria Slough in Harrison-Agassiz (K. Welstead, pers. comm., 2011), impedes movements to breeding sites and reduces the amount of terrestrial habitat available for foraging. Livestock may trample vegetation needed for egg laying and cover from predators in and around breeding ponds, and with poor management practices, contribute to degradation of water quality by increasing nutrient loads from fecal wastes. Agricultural practices that retain wetlands with forested buffers, and exclude livestock from portions of wetland habitat during breeding periods have less negative effect on breeding habitat quality. Maintaining riparian connections between breeding ponds and foraging forested habitat is essential for populations to persist in areas with livestock activity.

IUCN-CMP Threat 3. Energy production & mining

3.2 Mining & quarrying – negligible impact

Mining operations for aggregate materials (sand, gravel, crushed stone) exist in or near almost all B.C. towns and there are mining projects (including gold extraction) near known Northern Red-legged Frog localities in Agassiz, Lake Eric, Mission, Chilliwack, Sumas Mountain, and Ucluelet (Beasley 2011; K. Welstead, pers. comm., 2011). Mining removes vegetation, and soil within the extraction area, and can have hydrological influences on nearby wetland breeding habitats. Mining can lower groundwater levels, divert water flow, intercept surface water, increase evaporation rates, and increase turbidity and temperature of water flowing into adjacent wetlands (Frazer *et al.* 1996). Abandoned flooded quarries are used as breeding habitat (Beasley 2011) but survival of offspring developing in these habitats has not been studied. Despite increasing demand for materials for future housing developments (Fraser Valley Regional District 2009), less than 1% of the species range and occurrences are expected to be affected by mining in the next 10 years.

3.3 Renewable energy – negligible impact

Although Independent Power Projects (IPPs) are expected to proliferate along river systems on the Lower Mainland and Vancouver Island and wind farms are planned for Vedder Mountain and Nahwitti River, the total footprint over the next 10 years on the area inhabited by Northern Red-legged Frogs is likely to be very small (< 1%). The severity of impact of these projects is unknown. IPPs divert water and alter the hydrology of watersheds but the effects on lowland wetland habitats used by breeding Northern Red-legged Frogs are unknown. IPPs that require the

removal of tree canopy cover expose frogs to greater risk of dehydration but effects will be site-specific depending on the extent of canopy removal and the spatial distribution of the remaining aquatic and terrestrial habitat.

IUCN-CMP Threat 4. Transportation & service corridors

4.1 Roads & railroads – medium impact

Roads occur in such high density that 44% of the known occurrences of the Northern Red-legged Frog in B.C. are within 500 m of roads (COSEWIC 2015). At elevations less than 500 m, across the species' range, 94% of the landscape is within 5 km of a road, 77% is within 1 km, and 36% is within 100 m of a road (Hectares BC 2014). Road networks continue to expand. Two major highway expansion projects occurred recently within the area occupied by Northern Red-legged Frogs on the Lower Mainland (i.e., Port Mann Highway 1 Expansion and South Fraser Perimeter Road), and more are expected in the next 10 years.

Roads pose a threat to Northern Red-legged Frog populations in a variety of ways. Roads are often constructed in lowland areas near or through wetlands where they displace aquatic breeding habitat and cause direct mortality to adults and juveniles trying to migrate and disperse. 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 where a total of 695 individual Northern Red-legged Frogs were salvaged before construction (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). 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 function of installed underpasses and barriers does not improve (Malt 2012).

Road mortality of Northern Red-legged Frogs has also been documented on Highway 4 near Coombs (Blood and Henderson 2000), Nanaimo Lakes Road in Nanaimo (Wind 2012a), 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 2012a), and Wake Lake near Duncan (Wind 2012a). It is unknown how much unreported road mortality occurs, but it is likely to be high given the extensive road network across the province. 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. Until there is further research to test and improve the effectiveness of mitigation practices, amphibian road mortality will remain a continuing threat to this species (Ovaska *et al.* 2004).

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 2008). Roads also alter drainage patterns and often create ponds in adjacent ditches that attract breeding adults (Beasley 2011), exposing them and their offspring to the suite of negative impacts associated with roads. Roads are a source of sedimentation and pollution, such as road salts, oils, lubricants, tire residues, heavy metal contamination, and other vehicle-associated

chemical products, which are carried in runoff and accumulate in ponds and ditches. These sources are considered under Threat 9 – Pollution.

4.2 Utility & service lines – negligible impact

The transmission corridor in Morris Valley will be twinned in the near future, and all IPPs have transmission lines but the area affected in the next 10 years will be less than 1% of the Northern Red-legged Frog range. The severity of the threat is "unknown." Although tree canopy cover is cleared, shrubs are maintained for habitat. Herbicides and wood preservatives are applied only as spot treatments under BC Hydro's Pest Management Plan so they should have little effect. Exposure to electromagnetic fields (EMF) affects amphibian development in laboratory studies (e.g., Severini *et al.* 2003; Grimaldi *et al.* 2004) but the severity of the threat in the field is unknown.

IUCN-CMP Threat 5. Biological resource use

5.2 Gathering terrestrial plants – negligible impact

Harvesting sphagnum moss from wetlands has the potential to interrupt the daily activity of breeding adults in the spring and juveniles and adults in the summer when these life stages spend time basking and foraging in moist sphagnum mats around the edges of boggy ponds (B. Beasley, unpublished data, 2012–2014). Moss harvesting occurs on less than 1% of the species range, thus the impact of this threat at the population level is assessed as negligible.

5.3 Logging & wood harvesting – low impact

Approximately 80% of the area over 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 last 20 years (13%) and between 20 and 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, we would expect 5% of the species range would be cut in the next 10 years. Recent development plans on the coast set a sustainable rate of cut at about 1% of the timber harvesting land base (THLB) per year (D. McConkey, pers. comm., 2014). It is difficult to know the THLB over the next 10 years for the range of the Northern Red-legged Frog, but if 50% of the managed over 140 year-old forest is within the THLB and will be logged in the next 10 years, then 1.5%[4] of the area occupied by Northern Red-legged Frogs will be harvested over the next 10 years. This is an underestimate because maturing forests of 50 years in age, not just those over 140, are currently being logged.

Wildlife Habitat Areas (WHAs) have been established to protect 336 ha of forest and wetland habitats for 23 breeding populations of Northern Red-legged Frogs on Crown Land on Vancouver Island (B.C. Ministry of Environment 2009). The area protected by WHAs represents less than 0.02% of the species range. Protection measures for wildlife habitat on private forestry lands, which cover large tracts of the species' habitat on southern Vancouver Island and the Lower Mainland, are currently undertaken on a voluntary basis only.

[4] Calculation based on 0.01/yr X 10 years X 0.5 X 0.29.

Vegetation removal and road building associated with logging can lead to changes in watershed hydrology that may affect the suitability of wetlands for breeding. Some wetlands have increased hydroperiods post-logging (Wind 2008) 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 2008). 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. Modeling 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 breeding, as well as 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 coastal B.C. In fact, small wetlands are usually not identified on maps (Beasley *et al.* 2000; Wind 2008).

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. 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 depend on 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, provide sufficient habitat protection and connectivity. Thresholds to meet Northern Red-legged Frog population needs over the long term are uncertain but retention in patches of 0.8 to 1.5 ha in stream locations were recommended based on telemetry studies (Chan-McLeod and Moy 2007).

IUCN-CMP Threat 6. Human intrusions & disturbance

6.1 Recreational activities – negligible impact

The increasing human population in B.C. is associated with increased recreational activity such as “mudbogging” with all-terrain vehicles (ATVs), mountain biking, horseback riding, and dog walking. These activities can trample habitat features, particularly vegetation used for cover, as attachment sites for egg laying, and as foraging surfaces. There have been anecdotal reports of extensive damage to Northern Red-legged Frog breeding and foraging habitats caused by mountain biking in some areas of the Lower Mainland, but this impact is concentrated on a very small focused area of the species’ range (P. Govindarajulu, pers. comm., 2015). All recreational

activities combined are estimated to affect less than 1% of the Northern Red-legged Frog population in B.C. Locating recreational trails and access roads away from breeding ponds would mitigate this threat.

IUCN-CMP Threat 7. Natural system modifications

7.2 Dams & water management use – low impact

Human use alters water flow patterns from their natural range of variation in several ways that affect the habitat and breeding success of Northern Red-legged Frogs. Historically the draining of wetlands for agriculture, such as Sumas Prairie in the Fraser Valley, would have had a tremendous impact on Northern Red-legged Frog populations, but these habitat losses are not considered in the current estimation of ongoing threats. Still, it is important to recognize that current populations are remnants of much larger historic populations. 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 wetland breeding habitat (Hawkes 2005). Other impoundments that affect populations of Northern Red-legged Frogs include Buttle Lake and Campbell River (> 695 ha of wetlands and > 5000 ha of land flooded) (BC Hydro Fish and Wildlife Compensation Program 2011) and Elsie Lake (72 ha of wetlands and 672 ha of land flooded) (Wind 2012b). The ongoing impacts of impoundments result from fluctuations in water levels and flow rates within the waterbodies that attract breeding frogs. For example, water levels at Division Reservoir in Jordan River Watershed fluctuates as much a 9.6 m during the breeding period for Northern Red-legged Frogs (Hawkes 2005). Females usually attach egg masses to plant stems at depths of 0.3 to 2 m beneath the surface of the water (Beasley 2011). If water depths and vegetation structure allow for laying, then subsequent water fluctuations create surges that dislodge eggs, washing them into poorer locations for embryo development. Alternatively, eggs and/or larvae become stranded if water levels drop too much before development is complete. Similar detrimental effects of water fluctuations have been noted at quarries excavated into the groundwater table (Beasley 2011), stormwater catchment structures (Ostergaard *et al.* 2008), and marshes managed for waterfowl (K. Welstead, pers. comm., 2011).

Flood control structures have been beneficial in protecting existing Northern Red-legged Frog habitats but are in need of maintenance. Many dykes in the Lower Mainland are old and need to be replaced such as the dykes at Minnekhada Regional Park and Codd Wetland (K. Welstead, pers. comm., 2011). Failure to replace these structures could lead to inundation of salt water that would destroy the freshwater habitat of Northern Red-legged Frogs.

IUCN-CMP Threat 8. Invasive & other problematic species & genes

8.1 Invasive non-native/alien species – high to medium impact

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). *Bd* has been detected on Northern Red-legged Frogs sampled throughout the province

but no outbreaks of Chytridiomycosis have been reported for the species (Richardson *et al.* 2014). However, another Ranid frog species in B.C.has had mortality linked to the disease. It is hypothesized that the catastrophic decline of the Northern Leopard Frog (*Lithobates pipiens*) was caused by Chytridiomycosis (Voordouw *et al.* 2010). Conditions that lead to disease outbreaks are not well understood. Chytridiomycosis infects the keratinized tissue in the skin of adults and the mouthparts of larvae (Rachowicz and Vredenburg 2004). It is thought that the infection may interfere with osmoregulation and electrolyte balance leading eventually to cardiac arrest (Voyles *et al.* 2009). Antimicrobial peptides appear to play a role in resisting infection (Rollins-Smith *et al.* 2003; Rollins-Smith and Conlon 2005). 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 (see Farrer *et al*. 2011). 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).

Other pathogenic microorganisms infecting amphibians include *Aeromonas* bacteria, which cause red-leg disease in stressed animals; various pathogenic iridoviruses; and *Saprolegnia*, a water mould that affect the egg stages of many amphibians. It is likely that all these waterborne diseases are present in British Columbia although no systematic surveys have been conducted. *Aeromonas* has been detected in captive *Ranid* frogs during limited disease testing, and frogs with potential red-leg disease have been observed in the field (P. Govindarajulu, pers. comm., 2015). It is extremely difficult to detect iridoviruses during disease surveys, and the virus is rarely detected during testing of captive animals; although eggs masses with potential *sparolegnia* infestations have been observed in the field, the pathogen has not been confirmed with laboratory testing (P. Govindarajulu, pers. comm., 2015). These diseases are easily spread between amphibian populations by humans if precautions are not taken. Awareness of the necessary precautions is high among amphibian researchers but low among other people, such as recreational users, who move between wetlands.

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 2004; 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.*, 2015). Occupancy modeling predicts that Bullfrogs will overlap most of the range of the Northern Red-legged Frog in the Lower Fraser Valley in another 70 years (R. 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 Langford 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; P. Govindarajulu, pers. comm. 2014).

The introduction and spread of American Bullfrogs (*Lithobates catesbeiana*) are thought to have contributed to declines of Northern Red-legged Frog populations throughout its range; however, there is uncertainty about how strong their effect has been (Pearl *et al.* 2005; Adams *et al.* 2011). Adult bullfrogs prey on all life stages of Northern Red-legged Frogs and bullfrog tadpoles compete with and can cause a reduction in the rates of development and growth of Northern Red-legged Frog tadpoles (Govindarajulu 2004). Red-legged Frog tadpoles reduced their activity and increased the time spent in shelters when exposed to Bullfrogs or their chemical cues (Kiesecker and Blaustein 1997, 1998; Govindarajulu 2004). However, survivorship to metamorphosis was not affected by the presence of bullfrog tadpoles alone. Survivorship was only reduced if the tadpoles were exposed to both larval Bullfrogs and a fish predator (Kiesecker and Blaustein 1998).

In some situations in British Columbia, such as Stanley Park and Delta, the American Bullfrog seems to have completely displaced Northern Red-legged Frogs (Rithaler 2002, 2003a; Stanley Park Ecology Society 2010), likely as a result of combined population-level effects 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, appears to have contributed to the expansion of populations of American Bullfrogs and Green Frogs and the disappearance of the Northern Red-legged Frogs from particular wetlands (R. Rithaler, pers. comm., 2014). In other areas, Northern Red-legged Frogs seem to persist in wetlands with American Bullfrogs at least over the short term but at reduced numbers (e.g., Trevlac Pond in Victoria) (P. Govindarajulu, pers. comm., 2014; D. Fraser, pers. comm., 2014). Northern Red-legged Frogs do have breeding refuges in ephemeral or temporary pools, while American Bullfrogs and introduced fish are restricted to permanent waterbodies.

Stocking of non-native sport fish has been a common practice throughout the range of the Northern Red-legged Frog in B.C. (Wind 2004; Freshwater Fisheries Society of B.C. 2014). Non-native fishes such as bass (*Micropterus*), sunfish (*Lepomis*), and perch (*Perca*) 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 about 20 years ago (S. Silvestri, pers. comm., 2014). Fish prey on Northern Red-legged Frog larvae and can reduce populations, unless wetland habitats are complex enough to provide refuge for frogs (Adams *et al.* 2011). Several studies have shown negative associations of Northern Red-legged Frogs with the presence of non-native fish (Adams 1999, 2000; Pearl *et al.* 2005).

There has been a rapid spread of invasive plants, such as reed canarygrass *(Phalaris arundinacea)* and purple loosestrife *(Lythrum salicaria)* in coastal B.C. Reed canarygrass occurs in wetlands throughout the Lower Mainland and the southeast side of Vancouver Island (> 10% of the Northern Red-legged Frog range). Secondary plant compounds, known as tannins, in purple loosestrife increased mortality of American Toad (*Anaxyrus americanus*) tadpoles (Maerz *et al.* 2005). Dense, tall stands of reed canarygrass appeared to limit oviposition habitat of Oregon Spotted Frog (*Rana pretiosa*) (Kapust *et al.* 2012). Large amounts of decaying grass, which may be typical in dense stands of reed canarygrass, reduced survival of Wood Frog

(*Lithobates sylvatica*), Pickerel Frog (*Lithobates palustris*), American Toad, and Cope's Gray Treefrog (*Hyla chrysoscelis*) in mesocosm studies (Rittenhouse 2011). No studies have looked for these effects on Northern Red-legged Frogs yet.

8.2 Problematic native species

All legal fish stocking in the range of the Northern Red-legged Frog is done with native Rainbow Trout (*Oncorhynchus mykiss)* and Cutthroat Trout (*Oncorhynchus clarkii*), most of which are sterilized through a pressure shocking technique that causes them to become triploid (S. Silvestri, pers. comm., 2014). Some sites receive non-sterilized brood stock. Northern Red-legged Frogs are not deterred from breeding in ponds that have Coho and Cutthroat Trout (B. Beasley, unpublished data, 2012–2014) but little is known about the ultimate productivity of sites with fish. Fish prey on Northern Red-legged Frog larvae (Licht 1974) and can reduce populations unless wetland habitats are complex enough to provide refuges for frogs. K. Ovaska (unpublished data, 2013–2014) observed that when water level goes down at Fairy Lake the tadpoles are forced into fish habitat and predation pressure is extreme. Native fish can also carry and potentially introduce diseases, such as Saprolegnia and iridioviruses (Mao *et al.* 1999), that reduce the hatching success and survival of Northern Red-legged Frogs.

IUCN-CMP Threat 9. Pollution

9.1 Domestic & urban waste water – unknown impact

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 the early development (Vitt *et al.* 1990). Chemicals are readily absorbed through amphibian skin and jelly coatings of eggs. In particular, sediment metals and chloride from road salts are known to be toxic to ranid embryos and larvae (Snodgrass *et al.* 2008). Many compounds found in wastewater are endocrine disrupters but the effects of these are unknown. The scope of the threat of urban waste water is unknown because of a lack of data for urban areas in British Columbia. In Portland, Oregon, Holzer (2014) found fewer amphibians in ponds with high levels of nitrate, a common pollutant in ponds within the city.

9.2 Industrial & military effluents – negligible impact

Pulp mill effluents and heavy metals and other chemicals and sediments released from mining are possible threats but occur in a negligible portion of the species range.

9.3 Agricultural & forestry effluents – low impact

The Northern Red-legged Frog is exposed to various pollutants related to agriculture within the Lower Fraser Valley. Organochlorine pesticides were applied widely to the Fraser Valley in the 1970s (Finizio *et al.* 1998) but are no longer available for purchase (D. Trotter, pers. comm., 2015). These have been 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; M. Pearson, pers. comm., 2011) and residues may remain in soils and waterbodies (Top 1996; Environment Canada 2011a). Glyphosate is used on non-organic farms for blackberry control along fences, for

field preparation in the spring, on Round-up Ready corn, and sometimes directly along waterways (M. Pearson, pers. comm., 2011; Environment Canada 2011a). Glyphosate sales may have expanded substantially due to increased sales of Round-up ready corn (D. Trotter, pers. comm., 2015). The levels of nitrate, nitrite, and phosphate in runoff and groundwater leachate may increase in the Fraser Valley if livestock densities increase and if manure is used inappropriately (Schindler *et al.* 2006; Environment Canada 2011b; D. Trotter, pers. comm., 2015).

Many of these agricultural pesticides and fertilizers are known to be toxic to amphibians, causing mutagenic effects, developmental abnormalities (Bonin *et al.* 1997) and larval mortality 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). The hatching success of Northern Red-legged Frog eggs experimentally set in agricultural ditches around Sumas Prairie was strongly depressed compared to those 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 byproducts from agricultural fertilizers in the Willamette 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). Atrazine is known to act as an endocrine disruptor that causes feminization of male Leopard Frogs (*Rana 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). 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). The Health Canada Pest Management Regulatory Agency does annual re-evaluations on pesticides and will consider phase-out or increased limits to application rates and timing practices where data exists showing negative impacts (D. Trotter, pers. comm., 2015).

The Northern Red-legged Frog is also exposed to herbicides used in silvicultural practices. As most of the species range is subject to forestry, up to 30% is expected to be under intensive silvicultural management, where herbicides may be used over the next 10 years. Laboratory studies indicate that a herbicide, called 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).

Amphibians, in general, are sensitive to the effects of glyphosate herbicides that are also used in forestry for site preparation and conifer release (Govindarajulu 2008). Although application guidelines protect most waterbodies and riparian areas, these herbicides may be sprayed over dry creeks and temporary ponds (P. Sowden, pers. comm., 2011). Population decline has been noted as a result of exposure to agricultural and forestry effluents (Orchard 1992; De Solla *et al.* 2002a), but the species persists in ponds and ditches on the edges of agricultural fields (D. Knopp, pers. comm., 2013) and in logging blocks.

9.5 Air-borne pollutants – unknown impact

Pollutants including heavy metals, solvents, and fuel burning by-products have been listed in air shed studies of the Georgia Basin area (Environment Canada and U.S. Environmental Protection Agency 2014), but their impact is unknown. 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 (*Rana draytona*) (Davidson *et al.* 2002).

IUCN-CMP Threat 11. Climate change & severe weather

11.1 Habitat shifting & alteration – negligible impact

The majority of the species range is within the Coastal Western Hemlock biogeoclimatic zone, which is expected to expand over the next 35 years mainly to higher elevations (Wang *et al.* 2012). The Coastal Douglas-fir biogeoclimatic zone (currently 0.25 million ha, about 6% of the species range ≤ 500 m elevation on Vancouver Island) will shrink 19% from its current extent in some areas 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. They could, for example, move to higher elevations as temperatures warm, but this is uncertain, given that the species is usually found lower than 500 m on relatively flat terrain. Models predict that limited dispersal ability will increase the vulnerability of amphibians to changes in climate in Europe (Araújo *et al.* 2006) and the same may be expected for amphibians in British Columbia.

11.2 Droughts – unknown impact

As temperatures rise and weather events become more extreme with climate change, models predict wetter winters and drier summers within the species range (Compass Resource Management 2007). 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 waterbodies become ephemeral ponds that have fewer fish, Northwestern Salamanders, and American Bullfrog, which all require permanent water for successful larval rearing and are significant predators on Northern Red-legged Frog tadpoles. There are potential negative consequences as well. Droughts may cause ephemeral wetlands to have shorter hydroperiods than the time required for Northern Red-legged Frog larva to complete development and metamorphosis (O'Regan *et al.* 2014; see discussion under Threat 11.3 Temperature extremes).

11.3 Temperature extremes – unknown impact

The mean average temperature across B.C. is expected to rise between 3 and 4.8ºC by 2080 (Compass Resource Management 2007). A model that looked at 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). Hayes *et*

al. (2008) postulated that, because Northern Red-legged frog embryos have a low critical thermal maximum body temperature, they could be vulnerable to thermal pollution from urban runoff coupled with warming effects of climate change. Extreme fluctuations in temperature, freezing in spring, or too much warmth too early could be detrimental to embryos. The severity depends on how much and how quickly the temperature changes over the next three generations (12–18 years).

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 larva 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 the availability of periphyton food to a level that kept pace with the increased metabolic demands of tadpoles. There was no mortality in the experiment because thermal maximums were not exceeded and the hydroperiod was long enough for the tadpoles to metamorphose. O'Regan *et al.* (2014) predict that, if exposed to more variable and faster drying than the conditions simulated in the experiment, 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 higher levels of eutrophication in warmer water receiving agricultural, industrial and urban runoff (particularly in the Fraser Lowlands). American Bullfrogs are a warm water species so higher temperatures would likely increase their rate of invasion and productivity (Compass Resource Management 2007). Warmer waters could also lead to the range expansion of native and exotic warm-water fishes (Chu *et al.* 2005; Rahel and Olden 2008) and increase predation pressure. Finally, exposure to UV-B radiation could increase if water levels drop and cause slower growth and development in embryos (Belden and Blaustein 2002).

11.4 Storms and flooding – unknown impact

Rising sea levels and an increase in the frequency and intensity of storms are predicted as part of our changing climate. The combination could cause coastal wetlands to be waterlogged repeatedly with salt water (Beckmann *et al.* 1997). Salinity greater than 4.5% is known to be lethal to embryos of Northern Red-legged Frogs (Hayes *et al.* 2008).

5 MANAGEMENT GOAL AND OBJECTIVES

5.1 Management Goal

The management goal is to maintain self-sustaining and ecologically functioning populations[5] of the Northern Red-legged Frog in occupied watersheds throughout its range in British Columbia.

5.2 Rationale for the Management Goal

The management goal is set to prevent the status of the Northern Red-legged Frog from becoming worse (i.e., shifting from Special Concern to Threatened). Northern Red-legged Frog populations still persist through much of the species' B.C. range, and are locally abundant at some sites. The goal is set to provide resiliency and redundancy of populations to hedge against unpredictable threats, such as emerging diseases (possibly exacerbated by habitat degradation), that have been responsible for dramatic declines in amphibian populations around the world. Resiliency allows a population to adapt and redundancy builds a buffer against localized extinction. The goal is to ensure ecological representation of populations and protect genetic diversity that may help them adapt to changing climatic conditions. We currently lack the data and models to set quantifiable population and distribution targets.

5.3 Management Objectives

The following are the priority short-term objectives:

1. Address knowledge gaps about the species distribution, relative abundance, and population ecology.
2. Protect key habitat such as aquatic (breeding), terrestrial (foraging), and interconnections (migration and dispersal) of Northern Red-legged Frogs across the distributional range in B.C.
3. Prevent the spread of introduced species (e.g., fish predators, bullfrogs, invasive plants) to breeding wetlands.
4. Reduce the levels of urban, agricultural, and forestry pollutants in terrestrial and aquatic habitats.
5. Prevent disease transfer by people and implement baseline disease monitoring.
6. Increase knowledge of the effectiveness of various mitigation strategies implemented to decrease population-level threat impacts such as road mortality.
7. Reduce gaps in our knowledge about the species vulnerability to emerging epidemic diseases and effects of climate change, and how these emerging threats may be synergistically magnified in altered habitats.

[5] Self-sustaining means a population can persist without human intervention over the long term; ecologically functioning means a population is large enough to perform its ecological roles as predators, prey, hosts for parasites, structural engineers, etc., within ecosystems.

8. Increase public education and awareness to promote threat mitigation and population recovery efforts in human-altered areas where Northern Red-legged frogs persist or may have recently been extirpated.

6 APPROACHES TO MEET OBJECTIVES

6.1 Actions Already Completed or Underway

The following actions have been categorized by the action groups of the B.C. Conservation Framework (B.C. Ministry of Environment 2010). Status of the action group for this species is given in parentheses.

Compile Status Report (complete)

- COSEWIC report completed (COSEWIC 2004). An updated COSEWIC status report is in draft form and the anticipated assessment date is April 2015.

Send to COSEWIC (complete)

- Northern Red-legged Frog assessed as Special Concern (COSEWIC 2004).

Planning (in progress)

- B.C. Management Plan completed (this document, 2015).

Monitor Trends (in progress)

- Inventories completed in various parts of the range (Haycock and Knopp 1998; Beasley *et al.* 2000; Wind 2003, 2008; Madrone Environmental 2009; Beasley 2011; Malt 2011, 2013; B.C. Ministry of Environment 2012; Mitchell *et al.* 2012) to better understand patterns of distribution and habitat use and support land-use planning. No inventories have been done north of the Sunshine Coast.
- Known localities of breeding habitat for Northern Red-legged Frogs have been mapped and are available through the Species Inventory Web Explorer and the B.C. Species and Ecosystem Explorer (B.C. Conservation Data Centre 2014b).
- Population monitoring by counting egg masses is ongoing at wetlands in at least three areas: (1) within and around the Long Beach Unit of Pacific Rim National Park Reserve (Beasley 2011); (2) at wetlands used by Oregon Spotted Frog in the Fraser Valley (Pearson 2010, 2011, 2012); and (3) at Little Campbell River in Surrey (A. Baylis, pers. comm., 2014).
- Wetlands in the Greater Victoria area were inventoried in 1998–1999 to determine the relative distribution of Northern Red-legged Frogs and Bullfrogs (P. Govindarajulu, unpublished data, 1998–1999).
- B.C. Frogwatch promotes, initiates and supports ongoing Citizen Science monitoring programs on public and private land.
- Unpublished literature review done on the effects of non-native predators on aquatic ecosystems (Wind 2004).
- Experimental study done to assess the impacts of Bullfrogs on development, growth, and survival of Northern Red-legged frog tadpoles in artificial ponds (Govindarajulu 2004).

- Experimental study done to assess the impacts of temperature variability and *Bd* on growth and survival of Northern Red-legged Frog tadpoles in mesocosms (Hamilton *et al.* 2012).
- Experimental study done to assess the impacts of increased temperatures and shorter hydroperiods on the rate of development and survival of tadpoles in artificial ponds (O'Regan *et al.* 2014).
- Model developed to predict the vulnerability of tadpoles based on their thermal physiology under climate change scenarios (Gerick *et al.* 2014).

Habitat Protection and Private Land Stewardship (in progress)

- Approximately 16% of the species' documented occurrences are within parks and other protected areas (COSEWIC 2015). The total amount of area available for Northern Red-legged Frogs in protected areas within these parks and ecological reserves is 1564 km^2 below elevations of 500 m and 2677 km^2 at elevations below 1000 m (COSEWIC 2015). Most known occurrences occur below 500 m. There is less protected land in the southeastern quarter of Vancouver Island and the Lower Mainland than other parts of the species range. Brandywine Falls Provincial Park was tripled in size in 2010 to 420 ha to include habitat for Northern Red-legged Frogs (B.C. Parks 2015) in compensation for habitat loss during the Highway 99 realignment.
- There are currently 23 Wildlife Habitat Areas (WHAs)[6] for Northern Red-legged Frogs, totaling 336 ha on provincial Crown land under the *Forest and Range Practices Act* (FRPA) (B.C. Ministry of Environment 2014a). All occur on Vancouver Island where another 8 have been proposed. Inventory work on the Sunshine Coast may support the establishment of WHAs there as well (D. McConkey, pers. comm., 2015). In addition, a number of low elevation WHAs established for other species, such as Marbled Murrelets (*Brachyramphus marmoratus*), also protect habitat for Northern Red-legged Frogs.
- The B.C. Integrated Wildlife Management Strategy (IWMS) originally recommended that Northern Red-legged Frog WHAs should consist of a core wetland network plus a 30 m riparian reserve zone (RRZ) of adjacent upland habitat and an additional 20 m riparian management zone (RMZ) beyond the core area. They suggested that the networks should include small ephemeral or perennial wetlands that were "unclassified" (each < 0.5 ha). This design was meant to provide breeding habitat free of predatory fish, and protection of wetland habitats. The WHA delineation strategy has been updated based on inventory results, effectiveness monitoring, and ease of implementation (D. McConkey, pers. comm., 2010). The revised strategy includes the following: use of egg mass counts as indicators of relative population abundance to determine important breeding areas, regardless of the riparian class of the waterbody; enhanced protection of riparian habitats surrounding important breeding areas for both classified and unclassified wetlands that would receive either no mandatory no-harvest boundary or only a 10 m wide RRZ under the *Riparian Management Area Guidebook*[7]; a 50 m RRZ and no RMZ around the core area of the wetland; and a default 20 m RRZ as a default buffer width on each side of the stream to all

[6] Wildlife Habitat Areas (WHAs) for Northern Red-legged Frogs, as outlined in the IWMS species Account (B.C. Ministry of Water, Land and Air Protection 2004), maintain aquatic and riparian breeding habitats not addressed by the *Riparian Management Area Guidebook* (B.C. Ministry of Forests 1995) or through landscape-level planning.
[7] Lakes with riparian classes L3 and L4 and wetlands with riparian classes W3 and W4 do not receive default RRZs even though they are larger than 0.5 ha and other classified waterbodies have default RRZs of only 10 m widths.

streams connecting to the core wetland. This updated design is more likely to maintain natural microclimates and terrestrial foraging opportunities, facilitate initial dispersal of emerging juveniles, and potentially protect overwintering habitats. Eliminating RMZs from WHA design consideration also simplifies management by eliminating the need for harvesting prescriptions within RMZs.

- *Best Management Practices for Amphibians and Reptiles in Urban and Rural Environments in British Columbia* (Ovaska *et al.* 2004) and *Develop with Care 2014: Environmental Guidelines for Urban and Rural Land Development in British Columbia* (B.C. Ministry of Environment 2014b). Best management practices (BMPs) provide guidelines and specific measures that developers and local governments can use to protect or restore habitats for these animals.
- *Small Wetland and Amphibian Assessment Field Card* (Wind and Beese 2008): a tool developed for Western Forest Products Inc., based on information from the Nanaimo Lakes area of southeastern Vancouver Island. The field card helps forestry professionals identify breeding habitats and prioritize areas for retention.
- Clayoquot Sound Watershed Plans protect much of the amphibian habitat in Clayoquot Sound within watershed reserves designed to protect rare and sensitive ecosystems (Clayoquot Sound Technical Planning Committee 2006).
- 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. Developers are required to follow by-laws, mitigate impacts, and protect wildlife habitat, where possible.
- Municipality of Delta developed detailed "In-Stream Works Windows" designed to protect amphibians and their habitats in riparian areas (Rithaler 2003b).
- Conservation organizations such Ducks Unlimited, Nature Trust of B.C., The Land Conservancy, and Saltspring Island Conservancy are actively 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.
- Wetland creation projects completed to compensate for lost Northern Red-legged Frog habitat at BC Hydro reservoirs (Wind 2012b; Tuttle 2013) and along the Sea-to-Sky Highway (Squamish River Watershed Society 2012).
- Other wetlands created by Saltspring Island Conservancy (2014) and The Urban Biodiversity Enhancement and Restoration (UBER) Project at Haliburton Community Organic Farm in Victoria (P. Govindarajulu, pers. comm., 2014). Effectiveness monitoring of constructed wetlands is in progress or needed.
- *Canadian Environmental Assessment Act*. The species is considered part of 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., This has led to numerous salvages at various municipal and private project sites (e.g., City of Abbotsford 2005; Blair 2007; Golder Associates Ltd. 2007; EBA 2011; EcoDynamic Solutions 2011).
- Study initiated to monitor wetlands pre- and post-harvest to determine the effectiveness of riparian retention in forests of the Nanaimo Lakes area (Wind 2008).

- Study completed to examine habitat use by radio-tagged adults within logged areas (with variable retention) on Vancouver Island (Chan-McLeod 2003; Chan-McLeod and Moy 2007).
- B.C. Frogwatch promotes, initiates and supports ongoing amphibian stewardship programs on public and private land.
- B.C. Wildlife Federation ongoing programs: Wetlandkeepers and the Wetland Institute encourage wetland stewardship on public and private land across B.C.
- Association of Wetland Stewards for Clayoquot and Barkley Sounds ongoing programs promote stewardship of wetlands and surrounding forests where there are large populations of Northern Red-legged Frogs on public and private land near Ucluelet, B.C.

Species and Population Management (in progress)

- *Hygiene Protocols for Amphibian Fieldwork* to prevent disease transmission (B.C. Ministry of Environment 2008).
- B.C. *Wildlife Act* prevents harm to individual Northern Red-legged Frogs. Salvage at development sites and any research that involves handling animals, requires a permit under the B.C. *Wildlife Act*.
- The impact of introduced bullfrog on Northern Red-legged Frogs assessed (Govindarajulu 2004), and a number of outreach materials are available for educating the public about the negative effects of this introduced predator, how to prevent its spread, and how to mitigate its impacts (The Bullfrog Project – website, presentations, bookmarks, and brochures).
- Road kill and the effectiveness of tunnels and other mitigation structures monitored in several places (Chambers 2007; Beasley 2008; Materi 2008; Malt 2012; Wind 2012a).
- Survey done to assess the prevalence of *Batrachochytrium dendrobatidis* (*Bd*) in amphibians in B.C. (Richardson *et al.* 2014); provides baseline information needed for developing a plan to deal with this potential emerging threat to amphibians in B.C.
- Literature review done on the known effects of glyphosate-based herbicides used in silviculture on amphibians (Govindarajulu 2008).
- Assessment done of the effects of agricultural run-off in ditches used by breeding at one site, Sumas Prairie, in the Fraser Valley (de Solla *et al.* 2002a, 2002b).
- B.C. Wildlife Federation, North Shore Wetland Partners, Association of Wetland Stewards for Clayoquot and Barkley Sounds, and other local natural history clubs and non-profit organizations provide ongoing educational programs on what the public can do to help conserve amphibian habitats, which includes those of Northern Red-legged Frogs.
- Vancouver Aquarium *Frogs Are Forever* exhibition provides information on the global amphibian declines and what people can do to reverse it.
- Uu-a-thluk and Aboriginal Funds for Species at Risk developed *A Guide to Species at Risk on Land in the Nuu-chah-nulth Territories*, which includes information about Northern Red-legged Frogs and how to protect their habitats.
- In March 2013, the B.C. government approved legislative changes to implement mandatory Integrated Pest Management (IPM) use of pesticides on private landscaped areas recommended by the Special Committee on Cosmetic Pesticides (B.C. Ministry of Environment 2013). These IPM requirements are being phased in over time. The benefits of IPM in terms of reduction in chemical pollution can be expected to have a positive effect on Northern Red-legged Frogs but these effects may be difficult to measure and estimate.

6.2 Recommended Management Actions

The Management Actions and Implementation Schedule table provides guidelines for implementation of efforts to address threats, and to achieve the management objectives for Northern Red-legged Frogs in B.C. The table serves as a guideline for the development of detailed work plans for individual projects.

Table 3. Recommended management actions and implementation schedule for the Northern Red-legged Frog.

Obj. #	Conservation Framework action group	Recommended management action	Measure of success	Threat[a] or concern addressed	Priority[b] (Status)	Timeline
1	Monitor Trends, Species Management	Collect information about species occurrence and habitat, with emphasis on observations of roadkill and mass mortality. Ensure information is captured and made publicly available through appropriate tools (Frogwatch, SPI, CDC).	Maps and data of potential and current breeding sites across the range are available, with historical and current information on habitat condition, population changes and impact of threats noted at each location. Maps of roadkill and mass mortality sightings.	Knowledge Gap; Threat 4.1	Essential (ongoing)	2015 ongoing
1	Monitor Trends	Inventory and monitor selected sites in undeveloped and developed locations to assess distributions and population fluctuations.	Data on population size and dynamics to enable setting targets/thresholds for population management, resilience and long-term stability	Knowledge Gap	Essential (ongoing at one site from 2007)	
1	Monitor Trends	Use radio-telemetry and mark-recapture to clarify habitat use, movement patterns, and site fidelity in all seasons (including winter) with respect to quality and configuration in natural and modified habitats.	Data on Northern Red-legged Frog habitat use and preference patterns to enable setting targets/thresholds for habitat protection size and spatial arrangements (WHAs and other protected areas).	Knowledge Gap	Beneficial	complete prior to next COSEWIC assessment
1	Species Management	Conduct genetic studies to investigate population structure and quantify gene flow among populations.	Information on gene flow among populations (movement vs. fragmentation) and potential consequences of small and divided population structure.	Knowledge Gap	Beneficial	complete prior to next COSEWIC assessment in 2025
1	Monitor Trends	Conduct a population viability analysis to clarify population endangerment at selected sites that have numerous and/or high impact threats.	Information on population viability available, which may enable the setting of trigger points for specific management action implementation (e.g., population augmentation).	Knowledge Gap	Beneficial	complete prior to next COSEWIC assessment in 2025
2	Habitat Protection & Private Land Stewardship	Identify priority sites for securement and identify land ownership of these sites.	Maps of high priority sites for protection on private and public lands.	Knowledge Gap	Essential (ongoing)	2015-ongoing
2	Habitat Protection & Private Land	Secure wetland complexes with long-hydroperiod temporary ponds suitable for breeding Northern Red-legged Frogs but not	Increased protection of identified sites with evidence of long-term population persistence.	All Threats, especially	Necessary	ongoing and as opportunities

Obj. #	Conservation Framework action group	Recommended management action	Measure of success	Threat[a] or concern addressed	Priority[b] (Status)	Timeline
	Stewardship	suitable for bullfrogs or fish, especially if surrounded by suitable riparian habitat.		8.1, 8.2		arise
2	Habitat Protection & Private Land Stewardship	Work with provincial, municipal, and regional governments to incorporate habitat protection into Official Community Plans, watershed plans, rezoning subdivisions, development permitting processes, and riparian bylaws.	Increased number of Official Community Plans, watershed plans, and other planning documents, across the range of the species that describe adequate provisions for protecting Northern Red-legged Frog habitats.	All Threats	Essential	ongoing and as opportunities arise
2	Habitat Protection & Private Land Stewardship	Work with First Nations to identify and implement habitat stewardship on reserves and within new treaty lands.	Increased number of identified sites on First Nations lands considered secure/protected.	All Threats	Necessary	ongoing and as opportunities arise
2	Habitat Protection & Private Land Stewardship	Work collaboratively with Parks and other conservation land holders and adjacent private landowners to protect habitats adjacent to protected areas to increase conservation and meta-population benefits for long term sustainability.	Increased number of secured/protected sites on private lands adjacent to protected areas and parks.	Threats 1.1, 4.1, 5.3, 7.2, 9.3	Necessary	ongoing and as opportunities arise
2	Habitat Protection & Private Land Stewardship	Collaborate with local Land Trusts and the Agricultural Land Commission to develop landowner agreements and covenants to protect Northern Red-legged Frog habitats on private lands, in particular hobby farms, agricultural land reserve and forests.	Increased number of identified sites on private lands with signed stewardship agreements with landowners or official land covenants protecting Northern Red-legged frog Frog habitat and populations.	Threats 1.1, 4.1, 5.3, 7.2, 9.3	Essential (ongoing)	ongoing and as opportunities arise
2	Habitat Protection & Private Land Stewardship	Work with the Ministry of Transportation and other agencies involved in road construction to develop strict policies that prevent road construction through or near wetland complexes and productive breeding sites.	Effective reduction in new roads and developments impinging on Northern Red-legged Frog habitat (monitored by reduction in salvage).	Threat 4.1	Essential	ongoing and as opportunities arise
2	Habitat Protection & Private Land Stewardship	Establish WHAs at sites with viable populations, especially those that are at risk of degradation. Work with government planners and companies to incorporate Northern Red-legged Frog habitat needs into	Maximized regional area allocation for WHA establishment and long-term sustainability of populations. Best management practices (BMPs) applied to Northern Red-legged Frog habitats within	Threats 1.1, 4.1, 5.3, 7.2, 9.3	Essential (ongoing)	ongoing and as opportunities arise

Obj. #	Conservation Framework action group	Recommended management action	Measure of success	Threat[a] or concern addressed	Priority[b] (Status)	Timeline
		watershed-level forest development plans and silviculture prescriptions.	lands under forestry prescriptions.			
3	Species and Population Management	Adopt policy and laws to prevent the release and intentional stocking of introduced species.	Policy and laws established to prevent the spread of fish predators, bullfrogs, and other introduced species.	Threat 8.1	Necessary	2015 (ongoing, as required and as opportunities arise).
3	Species and Population Management	Undertake focused introduced species control as required in high priority areas (e.g., high ecological value, high probability of success).	Documented successful eradication at priority sites (if needed) and successful prevention of range expansion of introduced species.	Threat 8.1	Essential	2015 (ongoing, as required and as opportunities arise).
3	Species and Population Management	Continue to educate people about the negative impacts of introduced species, and provide information on preventing introduction and range expansion of introduced species.	Increase in the number of people who recognize the impacts of introduced species and actively prevent introductions.	Threat 8.1	Beneficial	2015 (ongoing, as required and as opportunities arise).
3	Species and Population Management	Provide training and support local naturalist groups to conduct surveillance to detect early arrival of introduced species before they become established.	Increase in number of known breeding sites under surveillance and stewardship to manage for introduced species.	Threat 8.1	Essential	2015 (ongoing, as required and as opportunities arise).
3	Species and Population Management	Provide training and support to stewardship groups involved in introduced species control.	Increase in the number of sites with active introduced species control efforts. Database developed of surveillance, detections, and actions taken to remove bullfrogs and other introduced aquatic predators.	Threat 8.1	Beneficial	2015 (ongoing, as required and as opportunities arise).
4	Habitat Protection	Work with the Ministry of Agriculture to develop Beneficial Management Practices	Strategy/policy for managing pesticide and fertilizer runoff into Northern Red-	Threat 9.3	Beneficial	By 2016

Obj. #	Conservation Framework action group	Recommended management action	Measure of success	Threat[a] or concern addressed	Priority[b] (Status)	Timeline
		that reduce the impacts of pesticides and fertilizers and control runoff into Northern RLF habitat.	legged Frog habitats.			
4	Habitat Protection	Work with the Pest Management Regulatory Agency, municipal governments and non-governmental organizations such as the Canadian Cancer Society to restrict use of pesticides and fertilizers as a means to reduce runoff pollution to Northern Red-legged Frog habitats.	Restrictions on pesticide use implemented, for example municipalities that have reduced cosmetic use of pesticides.	Threat 9.3	Beneficial	When feasible
4	Habitat Protection	Promote implementation of BMPs for no-spray buffers and other means to filter out contaminants before they reach ponds and wetlands.	BMPs established to prevent or reduce runoff pollution of Northern Red-legged Frog habitats.	Threat 9.3	Beneficial	When feasible
4	Habitat Protection	Test the impact of contaminants to determine the ones with the greatest impact, and facilitate the development of alternatives or mitigation measures for these focal contaminants.	Quantification of contaminant levels under field conditions and their impact on population numbers and sustainability of Northern Red-legged Frog populations.	Knowledge Gap; Threat 9.3	Necessary	2016 to 2018 start
5	Species and Population Management	Require (through the permitting process) biologists and other people working in aquatic environments to adhere to hygiene protocols that prevent disease and parasite transmission.	Hygiene protocol adopted and used by people working in aquatic environments.	Threat 8	Essential (ongoing)	2015 and ongoing
5	Species and Population Management	Implement educational programs to increase awareness about how recreational users and other people frequenting wetlands can prevent spreading disease and parasites on boats, footwear, and other paraphernalia.	Increased awareness about wildlife disease transmission by humans.	Threat 8	Necessary	2015 and ongoing
5	Species and Population Management	Implement baseline disease and parasite monitoring in collaboration with B.C. and Canadian wildlife disease agencies, and other surveillance programs to understand potential emerging disease threats to Northern Red-legged Frogs.	Baseline data on wildlife disease prevalence and distribution in B.C.	Threat 8	Essential (ongoing)	2015 and ongoing
6	Habitat	Initiate population-level monitoring to	Population monitoring established at a	Knowledge	Essential	2015–

Obj. #	Conservation Framework action group	Recommended management action	Measure of success	Threat[a] or concern addressed	Priority[b] (Status)	Timeline
	Protection, Species and Population Management	provide a baseline population trend against which to assess the effectiveness of management and mitigation measures.	few key sites.	Gap		ongoing
6	Habitat Protection, Species and Population Management	Support collaboration of university and government researchers, forest companies, developers, urban planners among others to enable the effectiveness monitoring population management and threat mitigation actions and also quantifying threat impacts at the population level.	Increased number of research projects examining effectiveness of mitigation options that eventually lead to improved conservation and protection of Northern Red-legged Frogs.	Threats 1, 4, 5, 8, and 9. Knowledge gaps	Essential	2015–ongoing
6	Habitat Protection	Test the effectiveness of current Identified Wildlife Measures, WHAs, and WMAs and to improve habitat protection measures and refine targets for retention of riparian reserves, downed wood, and other habitat elements.	Improved mitigation measures for threats facing Northern Red-legged Frogs.	Knowledge Gap, Threats 1, 4, 5, 8, and 9	Essential	2015–ongoing
6	Habitat Protection, Species and Population Management	Test the effectiveness of BMPs, especially riparian leave strips and green corridors in allowing persistence in urban environments.	Population monitoring established at a few key sites with riparian leave strips and green corridors to assess population persistence and sustainability.	Knowledge Gap; Threats 1, 4, 5, 8, and 9	Necessary	2015–ongoing
6	Habitat Restoration	Test the effectiveness of creating temporary ponds and adding complexity to permanent ponds as breeding refuges from bullfrogs and predatory fish.	Population monitoring established at a few key sites; constructed pond sites to assess population persistence and sustainability.	Knowledge Gap; Threat 8.1	Essential	2015–ongoing
6	Species and Population Management	Test the effectiveness of tunnel underpass systems in safely connecting habitats and track the costs of installation, maintenance, and monitoring over the long term.	Population monitoring established at a few key sites tunnel underpass sites to assess maintenance of population connectivity, persistence and sustainability, and an estimate of ongoing maintenance costs of these tunnel structures.	Knowledge Gap; Threat 4.1	Essential (ongoing)	2015–ongoing
7	Species and Population Management	Obtain baseline data on presence and effects of amphibian diseases and monitor for infectious disease, at strategic sites across the	Baseline data on presence and effects of amphibian diseases, especially Chytridiomycosis.	Knowledge Gap; Threat 8.1	Essential (ongoing)	2015–ongoing

Obj. #	Conservation Framework action group	Recommended management action	Measure of success	Threat[a] or concern addressed	Priority[b] (Status)	Timeline
		range of the species.				
7	Species and Population Management	Model the potential effects of climate change on Northern Red-legged Frogs to predict future distribution patterns and potential impacts.	Research collaborations developed to model climate change effects and synergistic effects to predict future distribution patterns.	Knowledge Gap; Threat 11	Beneficial	2015–ongoing
7	Species and Population Management	Initiate collaborations with research institutions within B.C. and across the species range to look at synergistic effects of emerging diseases, climate change, and human modification of habitats.	Research collaborations developed to assess synergistic effects of emerging disease, climate change, and human modification of habitat.	Knowledge Gap; All Threats, especially 8.1 and 11	Beneficial	2015–ongoing
8	Private Land Stewardship	Evaluate existing materials and develop new educational products where necessary to deliver a coordinated multi-species public awareness campaign on amphibian conservation and threat mitigation, and wetland preservation and restoration, to promote Northern Red-legged Frog population management and persistence in human-altered habitats.	Effective educational programs delivered.	All Threats	Essential (ongoing)	2015–ongoing
8	Private Land Stewardship	Support stewardship groups implementing outreach programs to increase awareness of amphibian conservation issues including threats, stewardship options, BMPs, and encouraging the establishment of stewardship agreements in residential areas, agriculture, forestry, etc.	Change in awareness and level of support for habitat protection as measured by attitude surveys. Increase in the number of people involved in stewardship of wetlands within the range of the species.	All Threats	Essential (ongoing)	2015–ongoing

[a] Threat numbers according to the IUCN-CMP classification (see Table 2 for details).
[b] Essential (urgent and important, needs to start immediately); Necessary (important but not urgent, action can start in 2–5 years); or Beneficial (action is beneficial and could start at any time that was feasible)

7 MEASURING PROGRESS

Performance indicators provide a way to define and measure progress toward achieving the management (population and distribution) goals and objectives. Performance indicators have been integrated into the Management Action Table in Section 6.2.

8 EFFECTS ON OTHER SPECIES

Generally, the proposed activities will maintain habitats for other native wildlife and help ensure the integrity of natural communities and ecological processes. The Northern Red-legged Frog is present at all sites where the endangered Oregon Spotted Frog (*Rana pretiosa*) occurs in B.C. and the two species are believed to co-exist without interference (Licht 1969, 1974, 1986). The Northern Red-legged Frog uses riparian and terrestrial habitats that overlap to some extent with the threatened Coastal Giant Salamander (*Dicamptodon tenebrosus*) and the Western Toad (*Anaxyrus boreas*), a species of special concern. There are many differences in the strategies required for recovery and management of these four species, however all can benefit from work done to engage the public, raise awareness about general threats to amphibians, and increase habitat protection.

Any potential mortality to small mammals (shrews) and invertebrates associated with research techniques (pitfall trapping) used to do research and monitoring should be minimized by checking traps frequently and providing escape strings for small mammals. There are no known risks of disease transfer to other species. The potential for the spread of introduced species during surveys and monitoring can be minimized by following appropriate hygiene protocols.

Wetland restoration and the creation of temporary wetlands targeted at the recovery of Northern Red-legged Frogs benefits a number of other taxa including providing habitat for birds and bats. The implementation of riparian buffers and management zones around streams as part of the Northern Red-legged Frog habitat protection measures can lead to ecosystem benefits such as reduced sedimentation in streams, and migration corridors for many other taxa. In general, management efforts targeted at Northern Red-legged Frogs, which use aquatic and terrestrial habitats and are members in the mid-trophic levels of the food web, not only have positive effects on many other species but also lead to ecosystem benefits.

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