Recovery Plan for the Northern Leopard Frog (*Lithobates pipiens*) in British Columbia

Prepared by Northern Leopard Frog Recovery Team

BRITISH COLUMBIA
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Ministry of Environment

December 2012

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This series presents the recovery strategies or recovery plans that are prepared as advice to the Province of British Columbia on the general strategic approach required to recover species at risk. Recovery strategies or recovery plans are prepared in accordance with the priorities and management actions assigned under the British Columbia Conservation Framework. The Province prepares recovery strategies to ensure coordinated conservation actions and meet its commitments to recover species at risk under the *Accord for the Protection of Species at Risk in Canada*, and the *Canada–British Columbia Agreement on Species at Risk.*

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Disclaimer

This recovery plan has been prepared by the Northern Leopard Frog Recovery Team, as advice to the responsible jurisdictions and organizations that may be involved in recovering the species. The British Columbia Ministry of Environment has received this advice as part of fulfilling its commitments under the *Accord for the Protection of Species at Risk in Cana*da, and the *Canada–British Columbia Agreement on Species at Risk*.

This document identifies the recovery strategies that are deemed necessary, based on the best available scientific and traditional information, to recover Northern Leopard Frog populations in British Columbia. Recovery actions to achieve the goals and objectives identified herein are subject to the priorities and budgetary constraints of participatory agencies and organizations. These goals, objectives, and recovery approaches may be modified in the future to accommodate new objectives and findings.

The responsible jurisdictions and all members of the recovery team 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 on the recovery team.

Success in the recovery 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 plan. The B.C. Ministry of Environment encourages all British Columbians to participate in the recovery of Northern Leopard Frogs.

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EXECUTIVE SUMMARY

The Northern Leopard Frog (*Lithobates pipiens*) is a medium-sized frog that reaches between 75 and 110 millimetres at maturity. Although it was once common across North America, its populations in western North America have declined precipitously since the 1970s. It was designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1998 and its status re-examined and confirmed in May 2000 and in April 2009. It is listed as Endangered in Canada on Schedule 1 of the *Species at Risk Act* (SARA). In British Columbia, the Northern Leopard Frog is ranked S1 (critically imperiled) by the Conservation Data Centre and is on the provincial Red list. The B.C. Conservation Framework ranks the Northern Leopard Frog as a priority 1 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 which requires special management attention to address the impacts of forest and range activities under the *Forest and Range Practices Act* (FRPA) and 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).

Although previously known to occur at numerous sites in southern B.C., the Northern Leopard Frog has declined to two populations. One is an extant remnant population in the Creston Valley Wildlife Management Area (CVWMA; CVWMA 2011) in the Lower Kootenay Ecological Drainage Unit. The primary breeding population at CVWMA is in the northern portions of the wildlife management area, in the Duck Lake area. The second population is a reintroduced population at Bummers Flats in the Upper Kootenay Ecological Drainage Unit near Cranbrook, a site that had historically been occupied by Northern Leopard Frogs in the 1980s. However, the population size is assumed to be extremely small and cannot be estimated as egg masses have not been found to date.

Biologically limiting factors impeding rapid recovery of Northern Leopard Frogs in B.C. include extremely small population size, low egg mass production each year, low resistance to chytridiomycosis, and potential effects of reduced genetic diversity. Historically, the primary threat was habitat destruction resulting from wetland draining and reclamation in the early to mid-1900s. Recently, the primary threat appears to be chytridiomycosis caused by the fungus Batrachochytrium dendrobatidis, which has been causing significant mortality in the CVWMA Northern Leopard Frog population and currently represents the single-most significant threat to the populations in B.C.

The population and distribution goals are to:

1. Prevent the extirpation of the Northern Leopard Frog in B.C. by maintaining and where feasible expanding the extant populations in the CVWMA and in Bummers Flats;
2. Establish two additional populations of Northern Leopard Frog in the historical range; and
3. In the long term[1], ensure the Northern Leopard Frog is well distributed in its historical range, occurring in all four Ecological Drainage Units: Columbia-Kootenay Headwaters, Upper Kootenay, Lower Kootenay, and Okanagan.

[1] It is not currently possible to provide a timeline for this long-term goal.

The recovery objectives for the next 10 years work towards achieving both the immediate and long-term population and distribution goals. The recovery objectives for Northern Leopard Frog are:

1. Restore and enhance habitat and augment the two extant populations as necessary with captive bred or captive reared animals of various life-stages to prevent extirpation of the Northern Leopard Frog in B.C.
2. Identify, protect[2], and restore suitable habitats; and mitigate threats and initiate stewardship in those habitats within the species' historical range that are:
    a) candidates for reintroduction locations; or
    b) within dispersal distance of an extant population.
3. Establish at least two additional populations of Northern Leopard Frog, one each in two of the Ecological Drainage Units in the historical range: Columbia-Kootenay Headwaters, Upper Kootenay, Lower Kootenay, and Okanagan.
4. Establish populations in captivity as an insurance against catastrophic population loss in the wild (assurance populations) and to preserve genetic diversity and provide source populations for reintroduction.
5. Address the knowledge gaps that currently constrain effective implementation of recovery efforts. Priority knowledge gaps currently identified are population level impacts of chytridiomycosis and mitigation strategies; genetic constraints on population recovery; population dynamics; quantification of population level impacts of threats, including pollution and invasive species; and effectiveness of population augmentation, reintroduction, and habitat restoration strategies.

RECOVERY FEASIBILITY SUMMARY

Without assistance, the Northern Leopard Frog may become extirpated in B.C. in the near future. However, the recovery team believes that the recovery of the Northern Leopard Frog in B.C. is feasible based on the criteria outlined below by the Government of Canada (2009):

Individuals of the wildlife species that are capable of reproduction are available now or in the foreseeable future to sustain the population or improve its abundance.

- Yes. Within the historical range of the species in B.C., there are two small populations of Northern Leopard Frogs. Breeding activity and reproductive output have been monitored annually since 2000. Although population size is limited, animals still exist and are available to improve the population growth rate and abundance. Translocation from other jurisdictions (e.g., Alberta) may also be an option provided genetic issues are considered.

Sufficient suitable habitat is available to support the species or could be made available through habitat management or restoration.

- Yes. There appears to be potentially suitable habitat for Northern Leopard Frogs in areas of their historical range in the Columbia-Kootenay, Upper and Lower Kootenay Ecological Drainage Units, although reintroduction habitat in the Okanagan might be limited. Initial

[2] Protection can be achieved through various mechanisms including: voluntary stewardship agreements, conservation covenants, sale by willing vendors on private lands, land use designations, and protected areas.

habitat restoration and reintroduction efforts, conducted between 2001 and 2005, have demonstrated limited success and can be further refined through adaptive management and experience from other jurisdictions.

Can the primary threats to the species or its habitat (including threats outside Canada) be avoided or mitigated.

- Yes. Most invasive species can be controlled or mitigated to some extent and habitat restoration and enhancement may reverse or mitigate natural systems modifications that have led to decline of Northern Leopard Frogs.
- Unknown. A potential exception to the statement above is mitigation of impacts of Bd, the fungus responsible for chytridiomycosis. This disease is thought to be responsible for amphibian declines around the globe but the cause of amphibian declines is complex and many factors may be involved. , The extent to which Bd can be mitigated is presently unknown.

Recovery techniques exist to achieve the population and distribution objectives or can be expected to be developed within a reasonable timeframe.

- Yes. Captive rearing, habitat restoration and reintroduction have all demonstrated initial success and the recovery team plans adaptive refinement of further efforts. A captive rearing program collected eggs from the wild at CVWMA Duck Lake population to be reared in captivity and released back to Duck Lake to augment the population and also to other sites as part of reintroduction efforts (Adama and Beaucher 2006). From 2001 to 2005, a total of 10,147 tadpoles (Gosner stage 30) and 14,487 metamorphs were released (Adama and Beaucher 2006). Habitat restoration has been carried out at the CVWMA in Leach Lake (2004) and in Corn Creek Marsh (2005), and frogs from the captive rearing program were released there to establish populations. Limited success has been observed at Leach Lake where migration from Duck Lake and release of captive reared frogs resulted in a breeding population until 2008, but no breeding has been observed since then. A reintroduction site was established at Bummers Flats, a site historically occupied by Northern Leopard Frogs prior to the 1980s. Between 2003 and 2005, a total of 493 tadpoles and 3639 metamorphs were released at Bummers Flats, and successful breeding was confirmed in 2007, 2008 and 2010 (Adama and Beaucher 2006; Houston 2008, 2009) and additional tadpoles from Duck Lake were introduced there in 2011. The recovery team now considers the Bummers Flat population a successful reintroduction site because of the continued evidence of breeding at the site.

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1 COSEWIC* SPECIES ASSESSMENT INFORMATION

Date of Assessment: April 2009
Common Name (population):** Northern Leopard Frog - Rocky Mountain population
Scientific Name:** *Lithobates pipiens*
COSEWIC Status: Endangered
Reason for Designation: Although previously found in many localities in southeastern British Columbia and the Okanagan, this frog has suffered severe declines in both distribution and abundance, and now exists in extremely small numbers at only a single native population in the Creston Valley.
Canadian Occurrence: British Columbia
COSEWIC Status History: Designated Endangered in April 1998. Status re-examined and confirmed in May 2000 and in April 2009. Last assessment based on an update status report.

***Committee on the Status of Endangered Wildlife in Canada.

****Common and scientific names reported in this recovery plan follow the naming conventions of the British Columbia Conservation Data Centre, which may be different from names reported by COSEWIC.

In Canada, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has divided Northern Leopard Frog (*Lithobates pipiens*) into three separate populations or designated units (DU). Populations in Manitoba, Ontario, Quebec, New Brunswick, Prince Edward Island, Nova Scotia, and Newfoundland, in the Canadian Shield, Great Lakes/St. Lawrence, Appalachian/Atlantic Coast and Carolinian faunal provinces were described as the Eastern population and are assessed as Not at Risk (COSEWIC 2009). Populations in Alberta, Saskatchewan, Northwest Territories, and Manitoba west of the Canadian Shield, were described as the Western Boreal/Prairie population and designated as a species of Special Concern. The designated unit of Northern Leopard Frog that occurs in B.C., the Rocky Mountain population (originally termed the Southern Mountain population), is listed as Endangered nationally by COSEWIC (COSEWIC 2009). The Endangered status was assigned because only a single native population remains and if immediate action is not taken “in all likelihood it will soon be extirpated” (Seburn and Seburn 1998).

2 SPECIES STATUS INFORMATION

Northern Leopard Frog[a]	
Legal Designation:	
FRPA:[b] Species of Risk OGAA:[b] Species of Risk	B.C. *Wildlife Act:*[c] Schedule A SARA Schedule: 1- E (2006)
Conservation Status[d]	
B.C. List: Red B.C. Rank: S1 (2007) National Rank: N5 (2000) Global Rank: G5 (2002)	
Subnational Ranks:[e]	
Canada	Alberta (S2S3), Labrador (S3S4), Manitoba (S4), New Brunswick (S5), Northwest Territories (SNR), Nova Scotia (S5), Ontario (S5), Prince Edward Island (S4S5), Quebec (S5), Saskatchewan (S3)
United States	Arizona (S2), California (S2), Colorado (S3), Connecticut (S2), Idaho (S3), Illinois (S5), Indiana (S2), Iowa (S5), Kentucky (S3), Maine (S3), Maryland (S4), Massachusetts (S3S4), Michigan (S5), Minnesota (S4), Missouri (S2), Montana (S1S3), Navajo Nation (S2), Nebraska (S5), Nevada (S2S3), New Hampshire (S3), New Jersey (SNR), New Mexico (S1), New York (S5), North Dakota (SNR), Ohio (SNR), Oregon (S1S2), Pennsylvania (S2S3), Rhode Island (S2), South Dakota (S5), Texas (S1), Utah (S3S4), Vermont (S4), Washington (S1), West Virginia (S2), Wisconsin (S4), Wyoming (S3)
B.C. Conservation Framework[f]	
Goal 1: Contribute to global efforts for species and ecosystem conservation.	Priority:[g] 4 (2009)
Goal 2: Prevent species and ecosystems from becoming at risk.	Priority: 6 (2009)
Goal 3: Maintain the diversity of native species and ecosystems.	Priority: 1 (2009)
Action Groups:	Compile Status Report; List under *Wildlife Act*; Send to COSEWIC; Planning; Habitat Protection; Habitat Restoration; Private Land Stewardship; Species and Population Management

[a] Data source: B.C. Conservation Data Centre (2012) unless otherwise noted.
[b] Species at Risk = a listed species that requires special management attention to address the impacts of forest and range activities under the FRPA (Province of British Columbia 2002) and/or the impacts of oil and gas activities under the OGAA (Province of British Columbia 2008) on crown land (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; B = breeding; 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. U.S. data from NatureServe (2010).
[e] Data source: NatureServe (2010).
[f] Data source: B.C. Ministry of Environment (2010b).
[g] Six-level scale: Priority 1 (highest priority) through to Priority 6 (lowest priority).

3 SPECIES INFORMATION

3.1 Species Description

The Northern Leopard Frog is a medium-bodied frog that varies in size from 30 mm at metamorphosis to over 100 mm as an adult. It is characterized by numerous dark spots surrounded by a light-coloured halo against a green or brown background body colour. Two pronounced dorsal ridges run the length of its body (Figure 1).

Figure 1. Adult Northern Leopard Frog. (Photo credit: Barb Houston)

During the breeding season, male frogs emit a complex advertising call consisting of snores, chuckles, and grunts (Larson 2004). Eggs are laid in clusters (egg masses) of 600 to 7000 eggs and take 7–12 days to hatch (Corn and Livo 1989; Adama and Beaucher 2006). At hatching, tadpoles are approximately 11 mm in length and grow quickly, completing metamorphosis in 60–90 days (Adama *et al.* 2003). Sexual maturity is reached in two to three years at northern latitudes (Eddy 1976; Waye and Cooper 2000).

3.2 Populations and Distribution

Population and Distribution in North American

The Northern Leopard Frog is widely distributed throughout much of North America (Figure 2). Its range is from Nova Scotia across the continent to just west of the Rocky Mountains, and from Great Slave Lake to Arizona and New Mexico (Cook 1984; Stebbins and Cohen 1995).

Populations in central and eastern Canada appear to be stable; however, populations west of Ontario have undergone serious declines, particularly in British Columbia and Alberta (Roberts 1981; Stebbins and Cohen 1995; Seburn and Seburn 1998; Kendell 2003). A similar trend has also been observed in the western United States, as severe declines have been observed in Montana, Idaho, Washington State, Colorado, Arizona, California, Nevada, Oregon, Utah, and Wyoming (Corn and Fogleman 1984; Clarkson and Rorabaugh 1989; Panik and Barrett 1994; Stebbins and Cohen 1995; Koch *et al.* 1996; McAllister and Leonard 1996; Sredl 1997; Werner 2003).

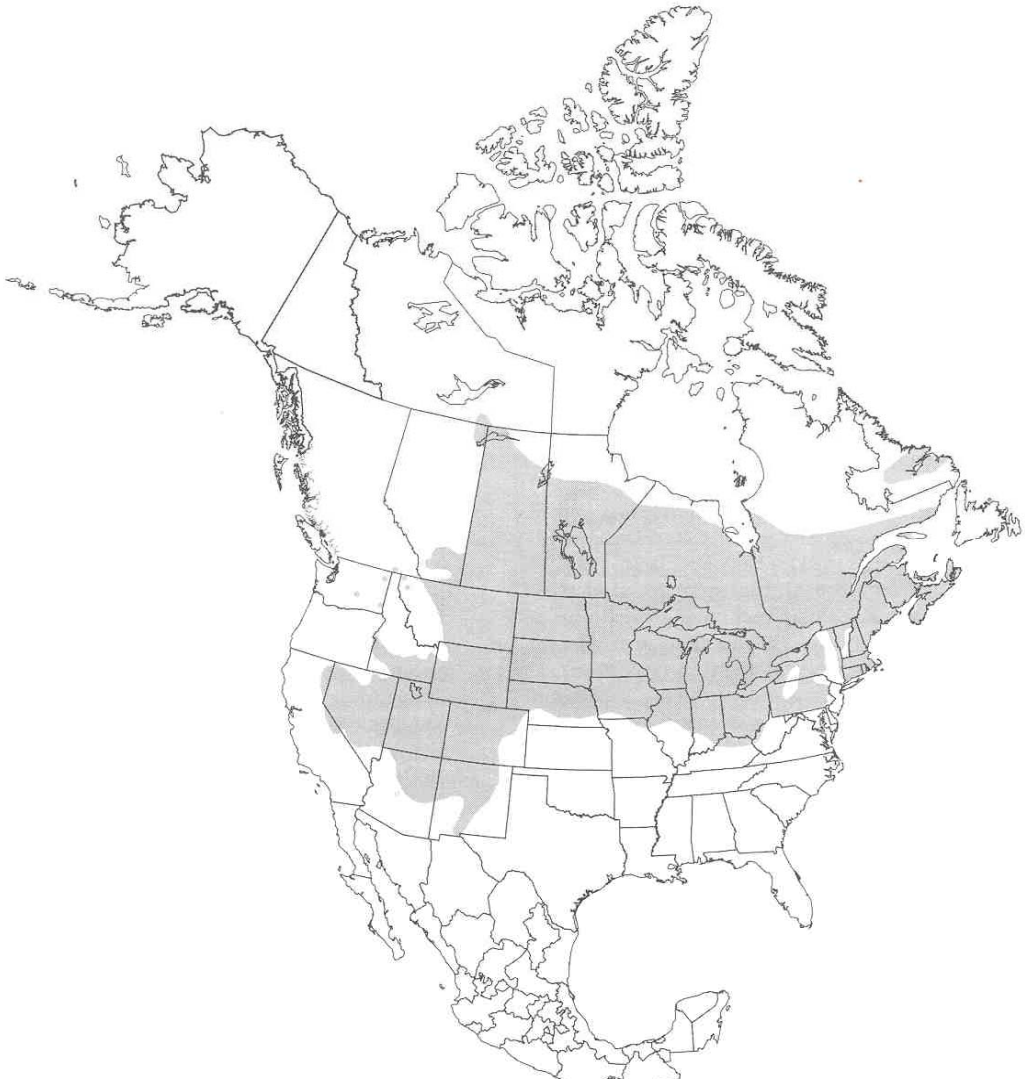

Figure 2. Current distribution of Northern Leopard Frogs in North America (from Kendell 2003, with permission).

Population and Distribution in Canada

Approximately half of the Northern Leopard Frog's global geographic distribution is in Canada (Figure 2). In B.C., the Northern Leopard Frog is currently restricted to only two locations in the southeast corner of the province. Populations in Alberta also appear to be somewhat isolated with distribution restricted to sites in the south and in the extreme northeast of the province (Kendell 2003). Distribution information for Saskatchewan is lacking but is thought to be fairly widespread occurring in isolated areas (Didiuk 1997). The Northern Leopard Frog is believed to be relatively common and widespread in southern Manitoba. In eastern Canada, the species continues to be relatively widespread.

Population and Distribution in B.C.

In B.C., the decline of the Northern Leopard Frog has been severe. The current index of area of occupancy is thought to be around 268 km^2 (COSEWIC 2009). Historically, the Northern Leopard Frog was known to occur in the Columbia-Kootenay Headwaters, Upper Kootenay, Lower Kootenay, and Okanagan Ecological Drainage Units (EDU)[3] (Matsuda *et al.* 2006). In the historic range , Northern Leopard Frogs had been reported at nine locations, but were undoubtedly more widespread (Figure 3, Table 1; Green and Campbell 1984). Annual surveys conducted between 1996 and 2001 failed to detect Northern Leopard Frogs outside a single 400-hectare wetland called Duck Lake in the Creston Valley Wildlife Management Area (CVWMA), near Creston (Orchard and Ohanjanian 1995; Ohanjanian and Teske 1996; Gillies and Franken 1999; Waye and Cooper 2000) in the Lower Kootenay Ecological Drainage Unit.

The population size at Duck Lake is inferred to be extremely small because only an average of 8.4 (range: 4–16) egg masses have been located annually (Adama and Beaucher 2006) even with substantial and constant search effort over these years. As with many species of frogs, detection probability can be low. However, Northern Leopard Frog male breeding calls are fairly audible over long distances, and surveys using a combination of call surveys and targeted visual surveys for egg masses have a reasonable probability of detecting breeding frogs in a given area. While Duck Lake has been surveyed constantly over the past decade, less effort has been expended over the surrounding areas. However, it is reasonable to assume that breeding population at Duck Lake is correlated closely with the number of egg masses detected annually, and is assumed to be less than 20 breeding females each year.

Attempts to expand the population at CVWMA have been made. Habitat restoration and reintroduction of captive reared Northern Leopard Frogs from eggs collected from Duck Lake has been attempted in the southern portions of CVWMA in Leech Lake and Corn Creek Marsh. Although Northern Leopard Frogs were detected at these sites a year or two after introductions, they are currently either extirpated or below detection levels.

A second population of Northern Leopard Frogs also exists that has been successfully reintroduced in Bummers Flats in the Upper Kootenay River Ecological Drainage Unit north of Cranbrook. Between 2003 and 2005, a total of 493 tadpoles and 3639 metamorphs were released at Bummers Flats, and successful breeding was confirmed in 2007, 2008 and 2010 (Adama and Beaucher 2006; Houston 2008, 2009). The recovery team considers the Bummers Flat population to currently be a successful reintroduction site because calling males and young-of-the year have been observed at the site for almost 5 years since the last reintroduction of captive reared frogs. The population size is assumed to be extremely small and cannot be estimated as egg masses have not been found to date.

[3] Ecological Aquatic Units of British Columbia (EAU BC) classifies freshwater systems at three spatial scales – Freshwater Ecoregions, Ecological Drainage Units, and River and Lake Ecosystems – based on measurable environmental features, processes and biological data. Freshwater Ecoregions are defined based on zoogeographic patterns in fish recolonization following the last glacial recession. Five Freshwater Ecoregions are identified in BC. Ecological Drainage Units are nested within Freshwater Ecoregions and take into account zoogeographic, climatic, and physiographic patterns that define freshwater systems. Ecological Drainage Units incorporate the known distribution of native freshwater fishes in BC. Thirty-six Ecological Drainage Units are identified in BC (Ciruna *et al.* 2007).

In the southern Okanagan, two Northern Leopard Frog observations were made in the 1940s in Osoyoos Lake but this population is extirpated (Seburn and Seburn 1998). It has been suggested that the population in Osoyoos Lake may have been introduced. Unfortunately, an attempt to verify this using mitrochondrial DNA from preserved museum specimens was unsuccessful (L. Friis, pers. comm. 2007). In the absence of clear evidence for introduction, the recovery team considers the Okanagan Ecological Drainage Unit to be within the historical native range of Northern Leopard Frogs in B.C. On Vancouver Island a population of Northern Leopard Frogs were recorded in 1976 and 1977 in Hamilton Marsh, near Parksville and the population was thought to be of captive animals that were released into the wild (Green 1978). The site on Vancouver Island is considered "introduced" as it is well outside the range of the Northern Leopard Frogs (Figure 3, Table 1). It is unknown whether this population still persists.

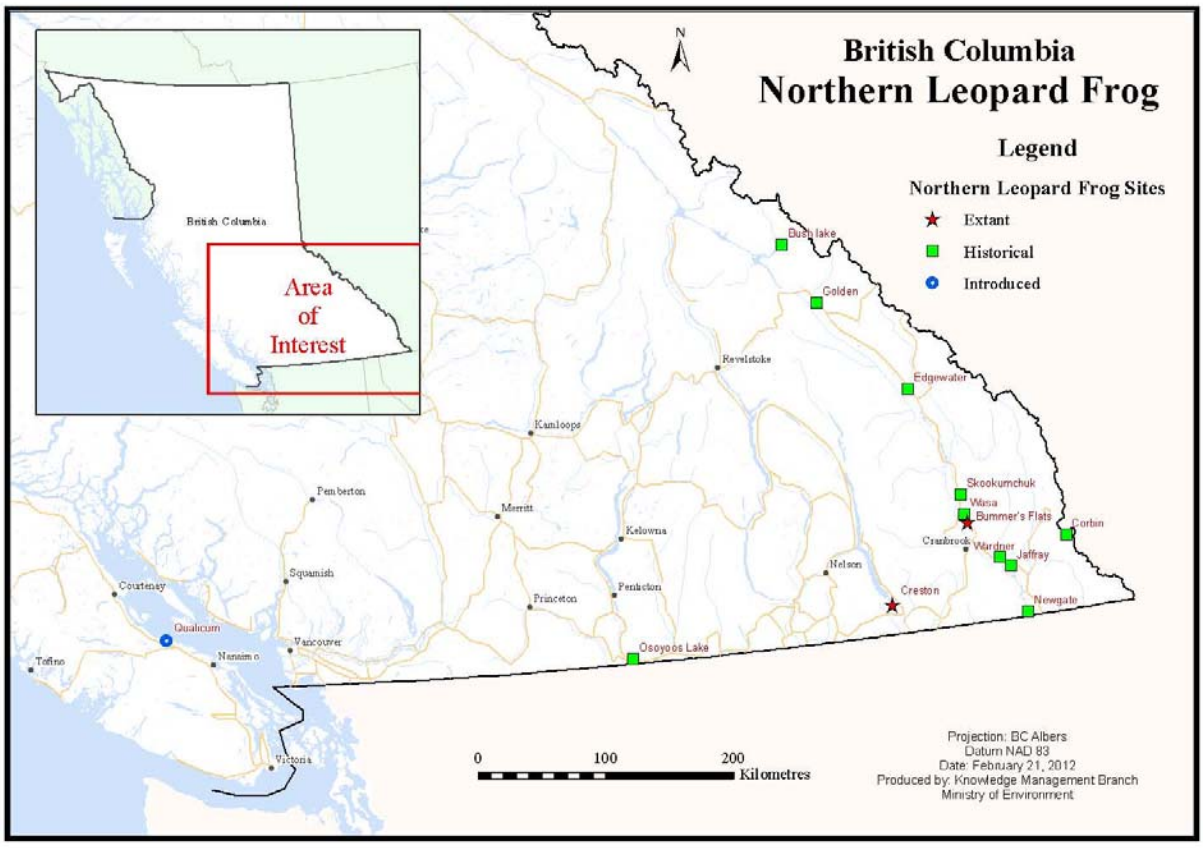

Figure 3. Historical and present distribution of Northern Leopard Frogs in British Columbia. The population on Vancouver Island is considered "introduced" as it is well outside the range of the Northern Leopard Frogs. The two extant populations include the remnant population in CVWMA near Creston and the reintroduced population at Bummers Flats north of Cranbrook. All other populations are historical and no Northern Leopard Frogs have been detected in recent surveys.

Table 1. Locations of recently documented Northern Leopard Frog populations in B.C.

Location	Status	Description	Land tenure
CVWMA, near Creston Lower Kootenay EDU	Extant	• Native population • Area ~400 ha • Population estimate: potentially < 30 breeding adults on average	Wildlife Management Area on provincial crown land
Bummers Flat, north of Cranbrook Upper Kootenay EDU	Extant	• Reintroduced population • Area ~1104 ha • Population estimate: unknown, probably very small	First Nations (3-4ha), Crown land (~857ha), Nature Trust (~242ha fee simple)
Hamilton Marsh, near Qualicum Beach, Vancouver Island	Unknown probably extirpated	• Introduced	Municipal Park, Crown land, Private land

3.3 Needs of the Northern Leopard Frog

3.3.1 Habitat and Biological Needs

The Northern Leopard Frog requires three distinct habitats: (1) breeding and tadpole rearing habitat; (2) foraging habitat; and (3) overwintering habitat (Merrell 1977; Hine *et al.* 1981; Waye and Cooper 2000; Adama and Beaucher 2006). Suitable habitat is also required to allow animals to move between these seasonal habitats. While none of the habitat types are particularly unique, their spatial juxtaposition is extremely important. As the Northern Leopard Frog seem to use the same traditional seasonal habitats year after year, maintaining the suitability and protection of these habitats and corridors is critical to the long-term survival of the species.

Breeding and Rearing Habitat

From early April to mid-June, Northern Leopard Frogs aggregate at their natal ponds to breed (Adama and Beaucher 2006). Egg masses are laid in the warmest areas of the breeding pond in shallow open water (< 50 cm deep) or in sparsely vegetated openings in cattail (*Typha* spp.) marshes that are exposed to the sunlight (Merrell 1977; Hine *et al.* 1981; Corn and Livo 1989; Gilbert *et al.* 1994; Waye and Cooper 2000; Adama and Beaucher 2006). These sites often occur in eutrophic (dense algal growth due to high nutrient conditions) wetland settings in association with cattail marshes (Hine *et al.* 1981; Waye and Cooper 2000). Although ample habitat may be present, Northern Leopard Frogs are philopatric (returning to their birth place) and the breeding sites are small and localized. Adama and Beaucher (2006) estimated the size of the two traditional breeding areas within the 400-hectare Duck Lake (CVWMA) to be 0.7 and 2.2 hectares based on repeated presence and documented egg masses at these particular sites over the years (95% kernel density function) (Rodgers and Carr 1998).

Water quality parameters are important habitat elements for amphibian larvae. Optimal pH for most freshwater animals is between 6.5 and 9.0 (Boyd and Tucker 1998) and pH recorded at Northern Leopard Frog breeding sites in Alberta and B.C. has been in this range (Seburn and Seburn 1998; Kendell 2002; Adama and Beaucher 2006). The pH values outside the optimal range can be detrimental to respiration, excretion, and development (Schlichter 1981; Boyd and

Tucker 1998; Whitaker 2001). Dissolved oxygen (DO) levels are important during early stages of development in amphibians (Burggren and Just 1992), but as ranid larvae progress through metamorphosis lungs develop that enable the larvae to gulp air and tolerate low levels (< 2 ppm) of DO (Wassersug and Seibert 1975; Noland and Ultsch 1981; Ultsch *et al.* 1999; Adama *et al.* 2004). DO at the breeding sites in the CVWMA ranged from 7.31 to 13.45 ppm (D. Adama, unpublished data) and seem suitable for successful completion of metamorphosis in Northern Leopard Frog tadpoles. As metamorphosis takes up to 90 days, water permanence during the summer months is essential.

Foraging Habitat

Northern Leopard frog tadpoles are assumed to be planktivores (filter feeders on algae, copepods and other invertebrates from the water column) and detritivores (feeders on decaying matter, algal growth, and microbial films from the wetland bottom and submerged surfaces) like most ranid larvae. However, variation in food resources or foraging habitat selection in the tadpole stages is not well characterized. In experimental studies, inadequate nutrition in the tadpole stages can result in smaller size at metamorphosis and prolong the developmental process (Steinwascher and Travis 1983; Pandian and Marian 1985; Kupferberg 1994; Beck 1997; Browne *et al.* 2003), which in turn can be detrimental to post-metamorphic survival and reproductive fitness (Smith 1987; Semlitsch *et al.* 1988; Goater 1994; Altwegg and Reyer 2003). Protein is an important dietary element for ranid larvae (Somsueb and Boonyaratpalin 2001; Adama *et al.* 2004; Martinez *et al.* 2004) but availability and limitation of protein in the diet of wild tadpoles is not clearly understood.

Post-metamorphic Northern Leopard Frogs feed primarily on insects (Drake 1914; Whitaker 1961; Linzey 1967; Miller 1978; McAlpine and Dilworth 1989; Collier *et al.* 1998). While insect densities are likely an important aspect of their life history and reflect habitat conditions, this aspect of terrestrial amphibian ecology has not been well researched. Summer habitat for Northern Leopard Frogs includes terrestrial and/or semi-aquatic habitat that are relatively open such as the edge of wetlands, moist meadows, and fields, where they can readily forage on insects (Cook 1984; Burggren and Just 1992). Low vegetation (5–30 cm tall) within a short distance of deeper water (> 1 m) provides ideal foraging habitat and escape habitat (Adama and Beaucher 2006). Areas that are either heavily grazed or thick with dense tall vegetation, such as reed canarygrass (*Phalaris arundinacea*), are avoided (Merrell 1977; Adama and Beaucher 2006). Summer foraging habitat is often closely associated with or close to the spring breeding habitat. Upon metamorphosis, young frogs will travel distances of up to 5 km from the breeding pond to foraging areas (Dole 1965; Merrell 1977; Seburn and Seburn 1998).

Overwintering Habitat

Northern Leopard Frogs overwinter underwater in well-oxygenated waterbodies such as at the bottom of ponds, streams, and rivers (Emery *et al.* 1972; Cunjak 1986; Ultsch *et al.* 2000), or less commonly in underground burrows and caves (Parris 1998; Waye and Cooper 2000). For survival underwater, it is important that the waterbodies are well oxygenated and that they do not freeze to the bottom (Manion and Cory 1952; Hine *et al.* 1981; Ultsch *et al.* 2000; Stewart *et al.* 2004). Dissolved oxygen levels recorded at overwintering sites in the CVWMA were 10.5 ppm and 12.2 ppm (D. Adama, unpublished data). Substrate does not appear to be a factor as frogs will either burrow into mud or lie exposed on rocky substrate (Emery *et al.* 1972; Cunjak 1986;

Ultsch *et al.* 2000). The distance between the spring breeding habitat and the foraging habitat to the overwintering habitat is typically less than 2 kilometres (Hine *et al.* 1981; Waye and Cooper 2000; Adama and Beaucher 2006).

Transitional Habitat
Northern Leopard Frogs migrate between overwintering habitat and breeding habitat in late winter and spring and between their summer habitat and overwinter habitat in late summer and fall (Dole 1965, 1971; Merrell and Rodell 1968; Merrell 1977; Seburn *et al.* 1997; Waye and Cooper 2000). If necessary, animals will cross a variety of unsuitable and suitable habitat types including roads, meadows, agricultural lands, sparse forests, or watercourses to move between their seasonal habitats (Seburn *et al.* 1997; Waye and Cooper 2000). Frogs may experience higher mortality rates during these migrations, such as being killed on roads, higher predation rates, and risk of desiccation. The fragmentation of the seasonal habitat by unsuitable or high risk habitats such as roads can be detrimental to amphibian populations (Houlahan *et al.* 2000; Carr and Fahrig 2001).

3.3.2 Ecological Role

Amphibian larvae play an important role in wetland ecosystems. As primary consumers, they can have a significant effect on nutrient cycling in wetland ecosystems (Seale 1980). Because of their amphibious life cycle, frogs transport nutrients and minerals between the aquatic and terrestrial components of the ecosystem (Seale 1980). Adult frogs are effective predators of insects, worms, spiders, and other small invertebrates.

3.3.3 Limiting Factors

In B.C., the Northern Leopard Frog is inferred to be at a critically small adult breeding population size, based on the number of egg masses detected each year. Between 1999 and 2009, an average of 8.4 (range: 4–16) egg masses have been located annually in the CVWMA (Adama and Beaucher 2006) even with substantial and relatively constant search effort over these years. Such small population sizes are vulnerable to extirpation due to demographic stochasticity and chance factors.

Recent genetic work has shown that the Duck Lake (CVWMA) population has low genetic diversity when compared with other populations in western North America (Hoffman and Blouin 2001, 2004; Wilson *et al.* 2008); this is presumed to be due to the small number of breeding individuals and inbreeding arising from this small population size. The reduced genetic diversity arising from small population size is called a genetic bottleneck and has been described for other populations of wild frogs (e.g., Andersen *et al.* 2004). The effects of genetic bottlenecks include reduced fitness (vigour and growth) or abnormal development (Dunham *et al.* 1999) or disease susceptibility (see section 4.2 re: IUCN threat classification #8) . However, in some studies, genetic “bottlenecks” have not resulted in any measurable effects on populations. For example, Zeisset and Beebee (2003) could find no evidence of significant genetic “bottleneck” effects in Marsh Frog (*Rana ridibunda*) populations in two areas of Great Britain despite a founder population of only 12 individuals**.**

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 in the area of interest (global, national, or subnational) (Salafsky *et al.* 2008). For purposes of threat assessment, only present and future threats are considered[4]. Threats presented here do not include biological features of the species or population such as inbreeding depression, small population size, and genetic isolation; or likelihood of regeneration or recolonization for ecosystems, which are considered limiting factors[5].

For the most part, threats are related to human activities, but they can be natural. The impact of human activity may be direct (e.g., destruction of habitat) or indirect (e.g., invasive species introduction). Effects of natural phenomena (e.g., fire, hurricane, flooding) may be especially important when the species or ecosystem is concentrated in one location or has few occurrences, which may be a result of human activity (Master *et al.* 2009). As such, natural phenomena are included in the definition of a threat, though should be applied 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, and is thus vulnerable to the disturbance (Salafsky *et al.* 2008) so that this type of event would have a disproportionately large effect on the population/ecosystem compared to the effect they would have had historically.

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 and the B.C. Conservation Framework. For a detailed description of the threat classification system, see the CMP website (CMP 2010). 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.* (2009) and table footnotes for details.

To assess scope of the threats, threats were considered at the extant population at Duck Lake (CVWMA), the reintroduced population at Bummers Flats, and at two candidate locations[6] (one in the Kootenay area and one in the Columbia area) for population re-introduction as supported by the Population and Distribution Objectives (Section 5.1). Threats for the Northern Leopard Frog were assessed for the entire province (Table 2).

[4] 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.* 2009).
[5] 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.
[6] It is not yet known if Northern Leopard Frogs will actually be re-introduced into these areas. These two candidate locations were chosen only to help represent the type and extent of threats to Northern Leopard Frog.

Table 2. Threat classification table for the Northern Leopard Frog in British Columbia.[7]

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Stress[e]
1	Residential & commercial development	Low	Small	Slight	High	
1.1	Housing & urban areas	Low	Small	Slight	High	Habitat loss
1.3	Tourism & recreation areas	Low	Small	Slight	High	Habitat loss
2	Agriculture & aquaculture	Medium	Large	Moderate	High	
2.1	Annual & perennial non-timber crops	Medium	Restricted	Serious	High	Habitat loss
2.3	Livestock farming & ranching	Medium	Large	Moderate	High	Habitat degradation; Accidental mortality; Increased predation
3	Energy production and mining	Unknown	Small	Unknown	High	
3.2	Mining and quarrying	Unknown	Small	Unknown	High	Habitat degradation
3.3	Renewable energy	Unknown	Small	Unknown	Moderate	Habitat degradation
4	Transportation & service corridors	Low	Restricted	Moderate	High	
4.1	Roads & railroads	Low	Restricted	Moderate	High	Direct mortality
6	Human intrusions & disturbance	Unknown	Large	Unknown	High	
6.1	Recreational activities	Unknown	Pervasive	Unknown	High	Habitat degradation; Accidental mortality
6.3	Work & other activities	Low	Large	Unknown	High	Habitat degradation; Accidental mortality
7	Natural system modifications	Medium-Low	Large	Moderate - Slight	High	
7.1	Fire & fire suppression	Medium-Low	Large	Moderate - Slight	Moderate	Habitat degradation; Direct mortality
7.2	Dams & water management/use	Low	Large	Slight	High	Habitat loss
7.3	Other ecosystem modifications	Not Calculated	Large	Serious	Insignificant /Negligible	Habitat degradation; Direct mortality

[7] Severity of the threats was scored based on the best judgment of the Northern Leopard Frog Recovery Team in the absence of published information.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Stress[e]
8	Invasive & other problematic species & genes	Very High	Pervasive	Extreme	High	
8.1	Invasive non-native/alien species	Very High	Pervasive	Extreme	High	Habitat degradation; Direct mortality
8.2	Problematic native species	High	Large	Serious	High	Habitat degradation; Direct mortality
9	Pollution	Medium	Large	Moderate	High	
9.2	Industrial & military effluents	Unknown	Large	Unknown	High	Direct and indirect mortality
9.3	Agricultural & forestry effluents	High-Medium	Pervasive	Serious-Moderate	High	Direct and indirect mortality
11	Climate change & severe weather	Unknown	Pervasive	Unknown	Moderate	
11.2	Droughts	Unknown	Pervasive	Unknown	Moderate	Habitat degradation; Direct mortality

[a] **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 timeframe (e.g., timing is insignificant/negligible or low as threat is only considered to be in the past); Negligible: when scope or severity is negligible; Not a Threat: when severity is scored as neutral or potential benefit.
[b] **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%).
[c] **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 three-generation 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%).
[d] **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.
[e] **Stress** – the condition or aspect (key ecological, demographic, or individual attribute) of the conservation target that is impaired or reduced by a threat (e.g., directly or indirectly results from human activities).

4.2 Description of the Threats

The overall province-wide Threat Impact for this species is Very High[8]. The Very High and High threats include invasive and other problematic species and genes, and natural systems modifications respectively (Table 3). Historically, the primary threat was habitat destruction resulting from wetland draining and reclamation in the early to mid-1900s. Recently, the primary threat appears to be chytridiomycosis caused by the fungus *Batrachochytrium dendrobatidis* (Bd; Berger and Speare 1998; Longcore *et al.* 1999), which has been causing significant mortality in the CVWMA Northern Leopard Frog population (Adama and Beaucher 2006; Voordow *et al.* 2010) and currently represents the single-most significant threat to the populations in B.C. Details are discussed below under the IUCN Level 1 headings.

IUCN # 1. Residential and commercial development
Historically, wetlands could have been drained and filled in for residential and commercial development but the extent of this or the impact on Northern Leopard Frog populations has not been documented. Currently, a few houses and residences are distributed adjacent to the CVWMA and there is a campground in one candidate re-introduction location in the Kootenays). There are some impacts to the Northern Leopard Frog population arising from these existing developments and the maintenance of these areas but these impacts are thought to be low. There are currently no known plans for further residential or commercial development either around CVWMA, Bummers Flats or the two candidate reintroduction sites. The probability of such development in the next 10 years is assumed to be low in the absence of further information.

IUCN # 2. Agriculture and aquaculture
The magnitude, scale, and duration of habitat alterations during human settlement in the last few centuries are important, as well as more subtle changes to the habitat matrix such as wetland succession or changes to community composition. Worldwide, habitat destruction and alteration pose the most significant threats to amphibians (Alford and Richards 1999; Lehtinen *et al.* 1999; Semlitsch 2000, 2003; Blaustein and Kiesecker 2002; IUCN *et al.* 2004). During the 1900s, thousands of hectares of valley-bottom wetland were converted to agricultural land in the Creston Valley. This eliminated vast areas of wetland habitat for Northern Leopard Frogs. This historic threat is acknowledged here but not used to calculate current impact of this threat.

Amphibians have typically been considered classic species models for the concept of the meta-populations (Alford and Richards 1999; Marsh and Trenham 2001; Storfer 2003), where subpopulations blink in and out of existence based on stochastic and spatial factors. However, there is emerging evidence that quality of habitat between breeding sites may be of greater importance in affecting distribution and abundance (Smith and Green 2005; Richter-Boix *et al.* 2007). Northern Leopard Frogs are considered capable dispersers, with reported movements of up to 5.2 km (Dole 1971). Currently, the network of dykes, steep-banked rivers, and intervening

[8] The overall threat impact was calculated following Master *et al.* (2009) using the number of Level 1 Threats assigned to this species where Timing = High or Moderate. This includes 1 Very High, 1 High, 2 Medium, 2 Low, and 3 unknown (Table 3).

agricultural land fragment habitats likely hinders access to seasonal habitats, limits dispersal, and increases mortality. At the CVWMA, Northern Leopard Frogs have no option other than to travel across agricultural land to access overwintering sites (M.A. Beaucher, unpublished data), making them more vulnerable to predation and more exposed to agricultural chemicals (e.g., pesticides and herbicides). The severity of this threat at the CVWMA location is thought to cause serious negative population level effects. Similar threats also exist at the two candidate re-introduction locations where there is cultivation of hay, although the extent of this might be limited compared to CVWMA.

Livestock farming (cattle grazing) is present at both current Northern Leopard Frog locations, will be an issue at all future re-introduction locations in the Upper and Lower Kootenay Ecological Drainage Units, and could even be an issue in the Columbia-Kootenay headwaters Ecological Drainage Unit depending on the specific location. The threats arise from direct trampling of frogs in upland foraging areas; loss of vegetation cover due to overgrazing thereby potentially increasing predation rates on foraging frogs; trampling and habitat deterioration of shoreline habitats; and potential trampling hazard at overwintering sites. However, cattle grazing has been shown to be an effective tool to control excessive cattail development, especially when combined with water level management (Kostecke *et al.* 2004). When seedlings and young cattails without extensive rhizomes are grazed, the stem density of the colony can be reduced and grazing can also reduce densities of some upland successional vegetation, including invasive reed canarygrass (P. Ohanjanian, pers. comm., 2010), potentially improving the quality of the upland foraging areas for Northern Leopard Frog.

Although the severity of the threats from agricultural activities can be serious, these threats can be mitigated to some extent at extant locations and be mitigated or avoided in future re-introduction sites.

IUCN #3. Energy production and mining

There are very preliminary discussions for wind energy plans in the Creston Valley, and for independent power projects in the Old Goat River Channel on Duck Creek, which are all in the vicinity or within the CVWMA (M.A. Baucher, pers. comm. 2011). There is a limestone processing plant (IMASCO) near the CVWMA that could affect water acidity if it expands or alters its current practices. These potential threats are recorded here for completeness but their impact is unknown.

IUCN #4. Transportation and service corridors

Recent surveys at CVWMA have documented Northern Leopard Frogs being killed while crossing a road as they were migrating to and from their overwintering habitat (Waye and Cooper 2000; Adama and Beaucher 2006; Houston 2010a). For example, in one night of observation at CVWMA, an adult and a young-of-the-year were killed in 500 m stretch of road with only two cars using the road (Houston 2010a). Additional monitoring in fall 2011 provided similar results, indicating that road mortality could have population level impacts on the small population of Northern Leopard Frogs at CVWMA (B. Houston, unpublished data). Amphibian road mortality causing population level impacts has been documented in other published studies (Carr and Fahrig 2001; Bouchard *et al.* 2009).

Roads are present at both extant Northern Leopard Frog locations and will be present to some extent at reintroduction locations in the future. Although roads can currently be very detrimental to Northern Leopard Frog populations, mitigation measures such as road closures during critical times or other mitigation measures may be possible and are currently being investigated. Therefore, the threat is scored as low impact over the ten year time frame of assessment because the mitigation measures are expected to be effective in reducing current mortality, and because this threat will be evaluated and minimized at future reintroduction sites.

IUCN #6. Human intrusions and disturbance

The wetlands where the Northern Leopard Frogs are currently found and candidate reintroduction sites are used regularly for waterfowl hunting and fishing activities. Most of these areas are also managed wetlands, and there are some disturbances arising from people working in the wetlands maintaining pumps, weirs, and other water control devices. The extent of the impact on Northern Leopard Frogs from this human intrusion is currently unknown. If the intrusion is occurring in areas of high Northern Leopard Frogs use, such as favoured foraging or overwintering sites, it could have a population level impact. It is recorded here as a potential threat that needs to be assessed for reintroduction site selection.

IUCN #7. Natural system modifications

Fire has been used in the past at CVWMA and potentially at Bummers Flats, and the two candidate reintroduction sites to control vegetation and manage biofuel loads. If the fires should occur in upland foraging areas at a time of high use by Northern Leopard Frogs, this practice could have a serious impact on the population. In addition to direct mortality from the fire, the loss of vegetation cover following burning could decrease cover for the frogs and increase predation risk. The use of fire to manage vegetation has decreased in recent years. Currently, fire is not being used in CVWMA for vegetation control, but may in the future; however, if the timing of burning could be scheduled for early spring before movements or dispersal across land (M.A. Beaucher, pers. comm., 2010) the impacts from fire could be mitigated.

Modification of hydrology is one of the more important threats faced by Northern Leopard Frogs. Historical habitat destruction from the construction of hydroelectric reservoirs in southeastern B.C. has had negative consequences on Northern Leopard Frogs in B.C. The creation of the Mica Reservoir along the upper Columbia, north of Golden, B.C., and of the Libby Reservoir along the Kootenay River near the U.S.-Canada border eliminated Northern Leopard Frog populations and vast areas of habitat. As a result of both the Libby Dam and extensive dyking along the Kootenay River, the natural hydrological regime has greatly altered successional trajectories of wetlands in the CVWMA (Wilson *et al.* 2004).

As a result of the compartmentalization of the wetlands, water levels must be managed actively to maintain habitat suitability within the CVWMA, on Bummers Flats, and at the candidate reintroduction locations. If water levels are managed inappropriately during the year without considering the seasonal habitat requirements of Northern Leopard frogs, it could lead to impacts such as lack of water at traditional breeding sites, stranding of egg masses, and inundation of cold water during the tadpoles growing season. Over time the neglect of water management

could also result in loss of habitat, such as the invasion of dense stands of cattails resulting in little remaining shallow open water habitat suitable for breeding.

Since the reclamation of wetlands in the Creston Valley, the construction of dykes and water control structures in the 1970s has further isolated wetlands into discrete compartments, thus fragmenting habitats (Province of British Columbia 1974; Wilson *et al.* 2004). Additionally, water level management associated with wetland reclamation for agriculture includes several river channels and creeks being rerouted for flood control that eliminates or alters movement corridors from breeding areas to overwintering habitat. However, the ability to control water levels in the marshes also has positive aspects. It allows managers to provide an adequate amount of water for breeding and to maintain it through to metamorphosis. Furthermore, before dyking, water levels at the south end of Kootenay Lake fluctuated greatly, preventing the development of submergent vegetation communities, which are prime Northern Leopard Frog habitats.

Currently, changes to the *1938 Kootenay Lake Order* that regulates the storage of water in Lake Koocanusa and the flow of Kootenay River are being considered. These changes, which are referred to as VarQ or variable discharge, are proposed to accommodate White Sturgeon (*Acipenser transmontanus*), Bull Trout (*Salvelinus confluentus*), and Salmon (*Oncorhynchus* spp.) stocks in the United States, under its *Endangered Species Act*. Currently the water level requirements of the Northern Leopard Frog are not part of the considerations, and changes to water level management to accommodate these other species might result in negative impacts on the quality of Northern Leopard Frog habitats and connectivity among seasonal habitats.

Overall, dams and water management can have both positive and negative impacts on extant and reintroduced populations. Often water management activities have subtle effects that influence natural processes such as wetland succession and in turn influence community structure and habitat suitability for the Northern Leopard Frog. This issue needs to be addressed both as a threat and as a knowledge gap to develop effective recommendations for water level management for the benefit of Northern Leopard Frogs.

IUCN #8. Invasive and other problematic species and genes

There is strong evidence that *Batrachochytrium dendrobatidis* (Bd), a fungal disease responsible for chytridiomycosis, is causing increased juvenile and adult Northern Leopard Frog mortality (Adama and Beaucher 2006; Voordouw *et al.* 2010). Chytridiomycosis is a skin disease of amphibians caused by the Bd fungus that infects the epidermis of amphibians, consuming keratinized tissue in the skin of adults (Berger *et al.* 1998; Pessier *et al.* 1999), and the mouth parts of larvae (Fellers *et al.* 2001; Parker *et al.* 2002; Rachowicz and Vredenburg 2004). The disease, first described in 1998 (Berger *et al.* 1998), has been implicated in the decline of amphibians around the globe (Longcore *et al.* 1999; Daszak *et al.* 2003; Weldon *et al.* 2004; Speare and Berger 2005). The mechanism of mortality is not well understood, but it is thought that the infection may interfere with osmoregulation and electrolyte balance leading eventually to cardiac arrest (Voyles *et al.* 2009). Alternatively, lethal toxins released by the fungus may be absorbed by frogs (Berger *et al.* 1998; Parker *et al.* 2002; Blaustein *et al.* 2005). Antimicrobial peptides appear to play a role in resisting infection (Rollins-Smith *et al.* 2003; Rollins-Smith and Conlon 2005).Whether Bd is an endemic pathogen that has increased in virulence or impacts due to changes in environmental and other cofactors or if Bd is an introduced pathogen/pathogenic

strain remains hotly debated (Weldon *et al*. 2004; Farrer *et al*. 2011). It has been suggested that the emergence of chytridiomycosis may be linked to global factors such as climate change (Pounds *et al.* 2006). For the purposes of this threat assessment Bd is treated as a globally emerging introduced pathogen.

The low genetic variation in the Northern Leopard Frogs found at Creston compared with other populations in western North America (Hoffman and Blouin 2001, 2004) could also be contributing to higher disease susceptibility in this population (Dunham *et al.* 1999). On rare occasions frogs have been observed to clear themselves of Bd infections (Voordouw *et al*. 2010). However, chytridiomycosis makes the frogs lethargic, which may make them more susceptible to native and introduced predators even if they were able to eventually clear themselves of this infection.

The presence of Bd is one of the most important factors threatening the persistence and recovery of the Northern Leopard Frog in B.C. Bd has been present in the CVWMA since at least 1999 (Waye and Cooper 2000). It is highly lethal to adult and juvenile Northern Leopard Frogs and it is likely a major factor in the decline of the population (Adama and Beaucher 2006).Bd has also been detected at Bummers Flats, and in some sites in the Lower Kootenay and Columbia-Kootenay headwaters EDUs (B. Houston, unpubl. data), but its impact on amphibian populations there is not known. Bd has been detected in co-occurring Columbia Spotted Frogs (*Rana luteiventris*), although chytrid-associated mortality has not been observed in this species which has led to the speculation that Columbia Spotted Frogs could serve as a reservoir host of Bd (Adama and Beaucher 2006).

Additionally, there is the potential that people moving among these and other wetlands could unknowingly move pathogens such as Bd on their waders and field gear. While Bd is thought to be present in many of these wetlands, strain and virulence differences are currently unknown. The introduction of a novel pathogen or strain can have devastating impacts on the Northern Leopard Frog population, so the potential for humans to vector this threat is recorded here. To help prevent the introduction of pathogens, researchers use disinfection protocols when moving between wetlands (B. Houston, pers. comm., 2010).

Predation of amphibian larvae by stocked/introduced fish, as well as predation of overwintering frogs by some introduced fish species (e.g., bass), pose a significant threat to many pond breeding amphibians (COSEWIC 2000; Gebhart and Roberge 2001; Wind 2003; B. Houston, pers. comm., 2010). A fish inventory conducted in the breeding ponds at CVWMA reported an abundance of introduced fish including Largemouth Bass (*Micropterus salmoides*), Brown Bullhead (*Ameiurus nebulosus*), Yellow Perch (*Perca flavescens*), and Pumpkinseed (*Lepomis gibbosus*) (Gebhart and Roberge 2001). Introduced species such as these can be detrimental to species of pond breeding amphibians and may be suppressing the population in the CVWMA

In addition to introduced species, native species and pathogens can also pose a threat to Northern Leopard Frogs. Substantial egg and larval mortality due to common water mould (*Saprolegnia* sp.) was responsible for significant egg mortality in Northern Leopard Frog egg masses in the CVWMA in 2001. This outbreak was associated with unusually high water levels and, as a result, egg masses were laid in decaying grass in an upland meadow in 15 cm of water up to 50

m from the traditional breeding pond. While this fungus is not typically considered to be an infectious agent, under certain environmental conditions, catastrophic egg mortality by *Saprolegnia* has been reported in other amphibians (Banks and Beebee 1988; Kiesecker and Blaustein 1997; Robinson *et al.* 2003).

Ranavirus, a member of the Iridovirus family, has been attributed to declines in some amphibians (Daszak *et al.* 1999). Very little is known about the origin of viral strains, and if they are endemic or introduced. This virus was detected in captive reared Northern Leopard Frogs in BC in 2002; however, no mortality was associated with the disease (Adama *et al.* 2003). Currently, this virus is not being tested for at any of Northern Leopard Frog locations in B.C. and it is unknown what impacts, if any, it may have on extant populations.

The encroachment of dense stands of cattails and the introduced reed canarygrass reduces the suitability of shoreline and upland habitat for breeding and foraging. Positive results have been observed when these wetland compartments in the CVWMA are managed actively to control succession. Mowing of cattails has been successful in creating Northern Leopard Frog breeding habitat (Adama and Beaucher 2006). The gradual ingrowth of native cattails and a rapid explosion of water shield (*Brasenia schreberi*) due to water and flood management appear to be having a detrimental effect on the suitability of Northern Leopard Frog breeding sites in the CVWMA. Purple loosestrife (*Lythrum salicaria*) was observed for the first time at Bummers Flats in 2009 (Ohanjanian and Wigle 2009), and would have similar effects as reed canary grass.

The invasive aquatic Eurasian water-milfoil (*Myriophyllum spicatum*) has been detected in the Kootenay River adjacent to the CVWMA wetlands, but to date, it has not been detected in the wetlands (B. Houston, pers. comm., 2010). There is a danger that recreational boaters may unknowingly transfer Eurasian water-milfoil into the wetlands when they move boats between the Kootenay River and the CVWMA wetlands. Due to the invasive nature of the Eurasian water-milfoil and its ability to efficiently disperse, it can have adverse impacts on the ecosystem. Since it can reproduce rapidly through vegetative fragmentation, it would take only a few fragments on an engine motor to become transferred to wetlands. Eurasian water-milfoil has migrated farther north along the Kootenay River and while its impact on the Northern Leopard Frog is unknown, it will not be long before it appears in the wetland compartments, if not already present (M.A. Beaucher, pers. comm., 2010). How these invasive plants will affect habitat suitability for Northern Leopard Frogs is unknown.

Overall, this threat category, in particular the presence of Bd, may pose the most significant threat to the recovery of Northern Leopard Frogs in B.C. It is also the threat that may be the most difficult to manage or mitigate.

IUCN #9. Pollution

Northern Leopard Frog habitat in Bummers Flats and candidate reintroduction habitat in the Columbia area is adjacent to a railway corridor. Possible contamination of ponds from cargo carried for many decades along this route has not been examined. Furthermore, waste from the lead/zinc Sullivan Mine at Kimberley, B.C., was used as ballast in beds of railway lines that run near Bummers Flats and some candidate reintroduction locations. The extent of this use, as well

as possible leaching of heavy metals into adjacent waterbodies from this ballast, may present a threat and should be investigated.

Various agricultural pollutants are toxic to amphibians or mimic estrogenic compounds. There is evidence that agro-chemicals contribute to amphibian population declines across North America (Rouse *et al.* 1999; Hayes *et al.* 2002; Relyea 2005). Pollution of aquatic habitats could occur through run-off from agricultural areas and through medium- to long-range atmospheric transport. The extensive literature on the impact of agricultural chemicals on amphibians has been summarized elsewhere (Hayes *et al*. 2006). In addition to the mortality and growth effects of agro-chemicals, in the St. Lawrence Valley, Quebec, a high incidence of hind-limb deformities in metamorphosing frogs, including the Northern Leopard Frog, was associated with run-off from agricultural lands exposed to pesticides (Ouellet *et al.* 1997; Harris 1998a, 1998b). Eutrophication of wetlands caused by manure and other nutrient inputs leads to increases in intermediate host populations of the trematode parasite *Rebeiroia sp.*, which in turn increases the incidence of amphibian limb deformities (Johnson and Chase 2004).

Creston Valley is a highly developed agricultural area supporting annual cereal and oilseed crops, perennial forage crops and dairy farming. A channel in the CVWMA that is used by Northern Leopard Frogs for overwintering receives run-off from agricultural fields, and the private land through which the Northern Leopard Frogs migrate to and from this overwintering habitat is sprayed with pesticide. Many pesticides which have been shown to have detrimental effects on amphibians including Atrazine and glyphosate (Hayes *et al.* 2002, 2003) are used in the Creston Valley (Masse and Miller Consulting and Morrow Environmental Consultants Inc. 2006).

There are three studies that have examined various water quality parameters in the vicinity of the Northern Leopard Frog population in the CVWMA. In 2004, a single Duck Lake site was sampled for pesticide residues in surface water as part of a larger Canada wide pesticide surveillance study (Murray *et al*. 2004). All assessed pesticide residues were below detection levels in this study, although it is not possible to draw inferences given the extremely small sampling effort and lack of replication. In 2006, sediment samples from Duck Lake were examined and five chemical residues including, aminomethylphosphonic acid (AMPA), dichloro-diphenyl-trichloroethane degradation products (DDTs), quintozene, triallate and polybrominated diphenyl ethers (PBDEs), were identified in sediment samples as being of potential concern (Masse and Miller Consulting and Morrow Environmental Consultants Inc. 2006). In 2008, a single “snap-shot” survey was conducted in the drainage ditches and sloughs of the Creston Valley, and analysed for water quality parameters including physical parameters such as pH and conductivity, and biological and bioactive parameters such as nitrogen compounds, phosphorus, heavy metals, bacteria, and pesticides (Ministry of Environment 2008). This study showed high levels of phosphorous, turbidity and suspended solids, higher than acceptable values for enterrococci in many sample sites, and low dissolved oxygen levels below acceptable limits for both instantaneous and long term availability for aquatic life in almost all the ditches. Although pesticide levels were below reporting limits, the authors recommended that these results should not be considered conclusive given the time of year when the sampling occurred, low sampling effort, the absence of surfactant analyses, and the high detection levels

set in the analyses. Taken together these studies highlight a number of issues that might be of concern with respect to impacts on Northern Leopard Frog habitat quality.

In addition to agricultural pesticides, some of the wetlands and surrounding area at Bummers Flats and other sites that could be suitable for reintroduction could be sprayed for mosquito control. Malathion which is often used to control adult mosquitoes has been shown to be toxic to amphibians (Relyea *et al.* 2005; Budischak *et al.* 2008). *Bacillus thuringiensis israelensis* (*Bti*) is often used to control larval mosquitoes and is assumed to be harmless to amphibians, but a case of complete disappearance of larval amphibians following *Bti* use was documented in the Okanagan (C. Bishop, pers. comm., 2008).

The current information and studies indicate that Northern Leopard Frogs could be exposed to a number of pesticides, and detrimental water quality factors and that the overall threat posed by pollution to the recovery of Northern Leopard Frogs could be significant. However, quantitative data are not available at this time but this threat should be addressed as a high priority knowledge gap.

IUCN #11. Climate change and severe weather

Climate change as a result of global warming threatens all aspects of biodiversity (IPCC 2002). However, the role of global warming on amphibian declines has received little attention (Beebee 2002; Carey and Alexander 2003) and there is little agreement on the impacts that climate change has had or will have on amphibians (Araujo *et al.* 2006; Pounds *et al.* 2006). If climate models such as those presented by the IPCC (2002) are correct, it is not unrealistic to anticipate that the impacts on amphibians will be significant. However, addressing climate change in the context of the recovery of the Northern Leopard Frog is not possible at present.

Most authors agree that amphibian declines are complex and that multiple factors may be at play, involving indirect causal relationships and synergistic interactions among several environmental variables (Alford and Richards 1999; Collins and Storfer 2003; Beebee and Griffiths 2005; Blaustein and Dobson 2006). Examples include complex relationships between climate, UV-B exposure, and pathogen outbreaks (Kiesecker *et al.* 2001; Blaustein *et al.* 2003; Pounds *et al.* 2006). Addressing the complex nature of amphibian decline will be challenging (Wilcox 2006).

In general, the climate change modelling prediction is for increasing temperature and increased summer water stress (although annual precipitation is projected to increase) for the Columbia and Kootenay regions (Murdock *et al.* 2007). If climate change leads to droughts within the range of Northern Leopard Frogs, this might result in the loss of breeding and foraging habitat in the shallow margins of wetlands. In addition, water demands for competing human uses such as irrigation and ranching could exacerbate the effects of drought in these wetlands. At this time the severity of these effects on population dynamics of Northern Leopard Frogs is unknown and it is not possible to estimate impacts.

5 RECOVERY GOAL AND OBJECTIVES

5.1 Population and Distribution Goals

The population and distribution goals are to:

1. Prevent the extirpation of the Northern Leopard Frog in B.C. by maintaining and where feasible expanding the extant populations in the CVWMA and in Bummers Flats;
2. Establish two additional populations of Northern Leopard Frog in the historical range; and
3. In the long term[9], ensure the Northern Leopard Frog is well distributed in its historical range, occurring in all four Ecological Drainage Units: Columbia-Kootenay Headwaters, Upper Kootenay, Lower Kootenay, and Okanagan.

5.2 Rationale for the Population and Distribution Goal

The immediate goal is to prevent the extirpation of the one extant remnant population in the CVWMA and the one population that was reintroduced at Bummers Flats as part of recovery efforts. Both populations are at critically low numbers, and extensive efforts are essential to prevent these populations from disappearing. Currently there is limited understanding of why these populations remain at critically low numbers even with extensive population augmentation using captive-reared frogs, and why these populations do not expand into apparently suitable habitat available within migration distance at both sites. An understanding of these factors is necessary before viable population size can be quantitatively estimated.

Within the next 10 years, the second goal is to establish at least two additional populations. The intent for additional populations is that they will be established within the Northern Leopard Frog's historical range in two of the four possible Ecological Drainage Units: Columbia-Kootenay Headwaters, Upper Kootenay, Lower Kootenay, and Okanagan (Ciruna *et al.* 2007). The reason for establishing populations in different Ecological Drainage Units is to expand the range of the Northern Leopard Frog to all the areas where it was historically found and to buffer against catastrophic loss in any one Ecological Drainage Unit. Ideally, reintroduction sites will be chosen where the meta-populations consisting of a number of connected subpopulations (< 10 km apart) can be established. Population modelling shows that the meta-population configuration has a higher probability of persistence than a single population with the same number of individuals (Tischendorf 2007). In addition to the biological reasons stated above for selecting a reintroduction site, it is important to note that the selection of a site is also constrained by non-biological reasons such as availability of sites, land-tenure issues, stakeholder consultations, etc.

Potential reintroduction sites within the historic range of the Northern Leopard Frog in southeastern B.C. include marshes distributed over a 150 km length of the Upper Columbia River (Columbia Wetlands Stewardship Partners 2008) within the Columbia-Kootenay Headwaters Ecological Drainage Unit collectively referred to as the Columbia Marshes in this document. Flood plain wetlands and ponds along the Kootenay River about 15 km upstream of

[9] It is not currently possible to provide a timeline for this long-term goal.

the CVWMA within the Lower Kootenay Ecological Drainage Unit also contain potential reintroduction sites and are referred to as the Yaqan Nuki wetlands in this document. It is not yet known where Northern Leopard Frogs may be re-introduced within either of these areas, nor how much of it is suitable habitat for the species. Detailed habitat suitability analysis has not been completed for the entire historical range of the Northern Leopard Frog but it is thought that reintroduction habitat in the Okanagan Ecological Drainage Unit might be limited due to intensive human use.

The third and ultimate long-term goal is to establish additional populations so that there is at least one population in each of the four Ecological Drainage Units that historically had Northern Leopard Frogs: Columbia-Kootenay Headwaters, Upper Kootenay, Lower Kootenay, and Okanagan. Over the next 5–10 years, knowledge gaps on the establishment and persistence of reintroduced populations will be addressed. Until these knowledge gaps are addressed and effective methods of population reintroduction and establishment designed, it is not possible to quantify or provide a timeline for the achievement of this long-term goal.

Downlisting of this species from Endangered to Threatened would require an increase in the index of area of occupancy to > 500 km^2 and the number of extant stable populations from 2 to >5 and the total number of mature individuals in any one population is > 250 animals (COSEWIC 2011). This may be achievable if the long-term goal is realized.

5.3 Recovery Objectives

The recovery objectives for the next 10 years work towards achieving both the immediate and long-term population and distribution goals. The recovery objectives for Northern Leopard Frog are:

1. Restore and enhance habitat and augment the two extant populations as necessary with captive bred or captive reared animals of various life-stages to prevent extirpation of the Northern Leopard Frog in B.C.
2. Identify, protect[10], and restore suitable habitats; and mitigate threats and initiate stewardship in those habitats within the species' historical range that are:
    c) candidates for reintroduction locations; or
    d) within dispersal distance of an extant population.
3. Establish at least two additional populations of Northern Leopard Frog, one each in two of the Ecological Drainage Units in the historical range: Columbia-Kootenay Headwaters, Upper Kootenay, Lower Kootenay, and Okanagan.
4. Establish populations in captivity as an insurance against catastrophic population loss in the wild (assurance populations) and to preserve genetic diversity and provide source populations for reintroduction.
5. Address the knowledge gaps that currently constrain effective implementation of recovery efforts. Priority knowledge gaps currently identified are population level impacts of chytridiomycosis and mitigation strategies; genetic constraints on population recovery; population dynamics; quantification of population level impacts of threats,

[10] Protection can be achieved through various mechanisms including: voluntary stewardship agreements, conservation covenants, sale by willing vendors on private lands, land use designations, and protected areas.

including pollution and invasive species; and effectiveness of population augmentation, reintroduction, and habitat restoration strategies.

6 APPROACHES TO MEET OBJECTIVES

6.1 Actions Already Completed or Underway

Recovery actions for the Northern Leopard Frog in B.C. have been underway for several years. Actions listed below have been categorized by the action groups of the Conservation Framework. Status of the action group for this species is given in brackets.

Compile Status Report (complete)

- Status reports completed (COSEWIC 2000, 2009).
- Three region-wide amphibian surveys were conducted in the Central and East Kootenay regions over the past decade to inventory historical Northern Leopard Frog locations (Ohanjanian and Teske 1996; Gillies and Franken 1999; Ohanjanian *et al.* 2006).
- Population monitoring has been ongoing since 1997 at CVWMA (Waye and Cooper 2000; Adama and Beaucher 2006; Davidson 2006a, 2006b; Houston 2008, 2009, 2010a). The use of radio telemetry has provided information on Northern Leopard Frog movements and habitat use (Waye and Cooper 2000).
- Amphibian surveys have been conducted on Reserve Lands adjacent to the Bummers Flats in 2005, 2007, and 2009. Tissue samples have been provided for two studies that explore the phylogenetic relationship of Northern Leopard Frogs from different regions: one study focuses on North America (Hoffman and Blouin 2001, 2004) while the other focuses on Canada (Wilson *et al.* 2008).

Send to COSEWIC (complete)

- Status report was sent to COSEWIC and the Northern Leopard Frog was designated as Endangered (COSEWIC 2000). In 2009, it was re-assessed but its status remained unchanged (COSEWIC 2009).

Planning (in progress)

- Recovery plan completed (this document, 2012).
- A draft survey manual describing field sampling protocols has been developed (Adama and Davidson, in prep.).
- A two part draft reintroduction strategy document is in progress. The first part, which is a literature review and assessment of reintroduction methods, is completed. The second part, which is an action plan for reintroduction of Northern Leopard Frogs, will be completed in the next two years.

Species and Population Management (in progress)

- A communication strategy was written to provide a framework and direction for communication between the recovery team and a wide variety of audiences (Ohanjanian 2003).
- A fish inventory was carried out in the CVWMA to identify piscine predators (Gebhart and Roberge 2001).
- A captive rearing and reintroduction program from 2001 to 2005 released a total of 10,147 tadpoles (Gosner stage 30) and 14,487 metamorphs to various sites in CVWMA (Adama and Beaucher 2006).
- As part of the captive rearing and reintroduction program, a reintroduction site was established at Bummers Flats, a site historically occupied by Northern Leopard Frogs prior to the 1980s. Between 2003 and 2005, a total of 493 tadpoles and 3639 metamorphs were released at Bummers Flats, and successful breeding was confirmed in 2007 and 2008 (Adama and Beaucher 2006; Houston 2008, 2009).
- Protocols for captive rearing (Wind 2002) and disease control between the wild and captive populations (Beaucher 2001) were developed.
- Water quality and benthic sediments were collected and assessed for agricultural contaminants in areas that support Northern Leopard Frogs in the CVWMA (Masse and Miller Consulting and Morrow Environmental Consultants Inc. 2006).
- Tissue samples from Northern Leopard Frogs and other co-occurring amphibians have been collected to determine the prevalence of Bd in the CVWMA and Bummers Flats (Voordouw *et al.* 2010).
- Communication between the recovery team and veterinarians, amphibian epidemiologists, and other disease experts is ongoing.
- Feasibility study completed in 2008 for potential reintroduction within Lower Kootenay Band Reserve Lands (Ohanjanian *et al.* 2008).
- Reconnaissance level habitat assessment of potential reintroduction sites for Northern Leopard Frog in the Upper Kootenay and Upper Columbia (Houston 2010b).
- Captive assurance colony established at the Vancouver Aquarium in the spring of 2009. Assurance colonies maintain a small representative population of highly endangered Northern Leopard Frog Frogs in captivity as an insurance against complete and catastrophic loss of the wild population.

Habitat Restoration (in progress)

- Habitat enhancement was conducted in the Duck Lake area in 2003 to improve water control to a breeding site.
- Habitat restoration has been carried out at the CVWMA in Leach Lake (2004) and in Corn Creek Marsh (2005).
- Various water control structures have been replaced to ensure proper water level management at breeding sites within the CVWMA (Beaucher 2006, 2009).

Habitat Protection (in progress)

- Wetlands on Ktunaxa lands have been assessed for habitat suitability (Ohanjanian and Beaucher 2005).

- Bummers Flats summary document of surveys and habitat assessment prepared for meetings with land managers (Ohanjanian and Houston 2008).

Existing Protection

In B.C., the Northern Leopard Frog occurs on lands that are afforded some level of protection by a variety of means. The main population, at Creston, is located in the 7000-ha CVWMA. The CVWMA was established by the B.C. legislature under the *Creston Valley Wildlife Act* (1968) for "wildlife conservation, management and development… and, in particular, as a waterfowl Management Area" (Province of British Columbia 1974). The *Creston Valley Wildlife Act* has legal authority to set management objectives.

In addition, the RAMSAR Convention, an intergovernmental treaty, recognized the CVWMA as a wetland of international importance in 1994, and the area is also an Important Bird Area (IBA) and an Important Amphibian and Reptile Area in Canada (IMPARA) (Beaucher 2009).

The Bummers Flats reintroduction site, totalling approximately 1104 ha, is comprised of three administrative bodies:

1. St. Mary's Band Indian Reserve (I.R. 6) where Northern Leopard Frog habitat will be protected as required by the federal *Species at Risk Act*. Total area of permanent water is approximately 3–4 ha; with an additional 14–20 ha of meadow inundated by the Kootenay River during and after high water in June.
2. Conservation lands purchased by the B.C. Ministry of Environment. Approximately 857 ha are held in fee simple by the Province of B.C. The B.C. Ministry of Environment (MOE) will remain the administrative authority for this land in perpetuity (B. Yeates, pers. comm. 2008). Although managed under the Parks and Protected Areas division of MOE, these lands do not have the same degree of protection as lands managed under the *Parks Act*. As such, activities such as mining could be considered on these conservation lands (B.C. Ministry of Environment 2009). However, as the conservation lands constitute a major riparian area along the Kootenay River, this is unlikely to occur.
3. The Nature Trust[11] holds the title (fee simple) to North Bummers Flats (Eastern Kootenays Conservation Properties 2007). The size of this property is 242.8 ha and the management agency is B.C. Ministry of Environment (Nature Trust 2010).

There are additional wetlands within the estimated dispersal distance of 5.2 km (Dole 1971) from Bummers Flats that also are afforded some level of protection. These are Wasa Sloughs (78.5 ha) and the Cherry Creek property (726 ha, of which approximately 20 ha is wetland), both owned by the Nature Trust and administered by the B.C. Ministry of Environment. The Wildlife Habitat Area (Bummers 1: 4-071) established for Long-billed Curlew (*Numenius americanus*) that consists of 53.1 ha may not contain a significant amount of Northern Leopard Frog habitat but still offers some habitat protection by managing forestry and range activities within the migration distance of the Northern Leopard Frog (P. Ohanjanian, pers. comm., 2010).

[11] The Nature Trust of British Columbia is a leading land conservation organization that manages ecologically significant land in order to protect the natural diversity of wildlife and plants, and their critical habitats.

Within the potential reintroduction areas in southeastern B.C. available protection includes federal land protected as the Columbia National Wildlife Area (about 1000 ha), and provincial land, designated as the Columbia Wetlands Wildlife Management Area (approximately 16,969 ha) (Province of British Columbia 2010).

Northern Leopard Frogs are protected under the *Wildlife Act*, against direct and intentional harm to the animals. The habitats utilized by Northern Leopard Frogs are not directly protected by legislation but provisions under the *Fish Protection Act*, the *Integrated Pest Management Act* and Regulation, Riparian Areas Regulation (RAR), and the *Forest and Range Practices Act* (FRPA) may provide some protection against habitat loss and degradation which indirectly benefits Northern Leopard Frogs. Northern Leopard Frog is identified as a species at risk under the Government Action Regulations (GAR) of FRPA, which enables the establishment of Wildlife Habitat Areas and General Wildlife Measures (GWMs) for protection from potential impacts from forestry or range use activities. None of these regulations protect the required connectivity and juxtaposition of seasonal Northern Leopard Frog habitats over the landscape.

6.2 Recovery Planning Table

The recovery actions presented in Table 3 follow the B.C. Conservation Framework action groups (B.C. Ministry of Environment 2010). These actions address threats or limiting factors to the recovery of the Northern Leopard Frogs in British Columbia or address the knowledge gaps that currently hamper effective planning, implementation or effectiveness monitoring of recovery actions.

Table 3. Recovery planning table for Northern Leopard Frog in British Columbia.

Objective	Conservation Framework action group	Approaches to meet objectives	Threat or concern addressed[a]	Priority[b]	Performance measure
1, 2	Planning; Species and Population Management	<u>Population monitoring</u> 1. Write a standardized monitoring protocol for each site. 2. Monitor the extant and reintroduced populations on an ongoing basis using standardized monitoring protocols. 3. Review and refine existing monitoring protocols.	Threats: All Limiting Factors: All	Essential	1. Standardized annual monitoring protocol written and implemented for all sites. 2. Collated annual summary of number of calling males, egg masses, young-of-year number and condition (size). 3. Population trends updated annually.
1,4	Species and Population Management;	<u>Quantification of threat impacts on population parameters and reduce mortality</u> 1. Quantify the impact of threats (very high - high impact - Invasive Species; medium impact - Agriculture, Natural Systems Modification and Pollution) on population parameters to prioritize threat mitigation activities. 2. Assess extent of road mortality, especially at CVWMA and investigate ways to reduce this mortality. 3. Implement mitigation measures to reduce mortality from threats as indicated by research on quantifying and prioritizing threat mitigation.	Threats: 1, 2, 4, 6–8	Essential	1. Prioritized list of threats to be addressed at each site. 2. Threat mitigation implemented when possible. 3. Road mortality reduction plan implemented through seasonal road closures or other methods. 4. Effectiveness monitoring of mitigation measures implemented.

Objective	Conservation Framework action group	Approaches to meet objectives	Threat or concern addressed[a]	Priority[b]	Performance measure
1, 2, 3,4	Planning; Species and Population Management	<u>Population augmentation and conservation</u> 1. Prepare a population augmentation and reintroduction strategy to identify objectives, infrastructure requirements, delivery mechanisms, and biological constraints (e.g., genetic, habitat, and animal husbandry). 2. Work with zoos/aquariums to establish captive assurance population(s) as a contingency. 3. As the assurance population matures, assess the potential for the assurance population to be a source of eggs/tadpoles for population augmentation and reintroductions. 4. Augment extant population at CVWMA and Bummers Flats as necessary. 5. Reintroduce and facilitate establishment of additional Northern Leopard Frog populations at a minimum of 2 additional sites in the next 10 years. 6. In the long term establish a minimum of one Northern Leopard Frog population in each one of the four historical ecological drainage units.	Threats: All; Limiting Factors: Small population size and genetic isolation	Essential	1. Population augmentation and reintroduction action plan completed. 2. A minimum of 2 zoo/aquarium facilities participating in assurance population management. 3. Population augmentation implemented as recommended by action plan. 4. Northern Leopard Frog populations increasing at extant sites. 5. Northern Leopard Frog populations established at additional sites.
1, 2	Private Land Stewardship; Habitat Protection; Habitat Restoration	<u>Maintain and improve the suitability of seasonal habitats</u> 1. Communicate and coordinate the Northern Leopard Frog habitat needs with the CVWMA, Ducks Unlimited, BC Parks and Protection Branch, the Nature Trust, private landowners, and other land managers to manage seasonal habitats for the species.	Threats: 1, 2, 4, 6–8	Essential	1. Northern Leopard Frog habitat management and conservation MOUs or stewardship agreements established with land mangers on sites with extant populations and potential reintroduction sites.
1,2,3	Private Land Stewardship; Habitat Protection; Habitat Restoration	<u>Identify, secure, and restore reintroduction habitats and maintain habitat connectivity</u> 1. Assess habitat suitability at potential reintroduction sites and develop a prioritized list of reintroduction sites. 2. At the high priority sites, conduct detailed habitat analysis to facilitate Northern Leopard	Threats: All Limiting factors: Small population size	Essential	1. Habitat assessment completed at a minimum of 2 reintroduction sites within 2 years. 2. Habitat restoration completed at a minimum of 2 reintroduction sites (may be ongoing work). 3. A prioritized list of other

Objective	Conservation Framework action group	Approaches to meet objectives	Threat or concern addressed[a]	Priority[b]	Performance measure
		Frog reintroduction and population establishment. At these sites, identify opportunities for habitat enhancement/restoration. 3. Identify potential connectivity sites among existing subpopulations and among reintroduction sites. 4. Assess options for protection such as stewardship, land purchases, and conservation covenants. 5. Develop a prioritized list of connectivity sites based both on effectiveness for population expansion and cost of acquisition/protection to enable the recovery team to respond rapidly to opportunities as they arise. 6. Work with collaborators, private landowners, land managers, all levels of government, NGOs, stewardship organizations, Ktunaxa, the Secwepemc, and Okanagan First Nations to secure these lands for Northern Leopard Frog reintroductions either through land purchase or partnership/stewardship agreements. 7. Develop and implement habitat restoration and enhancement plans at candidate reintroduction sites to facilitate Northern Leopard Frog population establishment. 8. Increase public concern, support, and participation in Northern Leopard Frog reintroduction efforts by conducting public education and outreach events, including developing Northern Leopard Frog Recovery website in collaboration with BC Frogwatch.			reintroduction sites compiled for future reintroductions beyond the 10 years of this recovery plan.
4, 5	Species and Population Management	<u>Chytridiomycosis mitigation strategy</u> 1. Continue testing for chytridiomycosis in Northern Leopard Frog and other amphibians in the CVWMA, Bummers Flats and at	Threat: 8	Essential	1. Chytridiomycosis mitigation measures implemented if possible. 2. Mortality due to chytridiomycosis and Bd prevalence in the population

Objective	Conservation Framework action group	Approaches to meet objectives	Threat or concern addressed[a]	Priority[b]	Performance measure
		potential reintroduction sites to understand disease dynamics. 2. Communicate with experts on amphibian diseases and keep up with the current literature to develop a better understanding of disease dynamics and population level impacts. 3. When sufficient research information becomes available in the literature and through expert advice, develop a chytridiomycosis abatement strategy focused on Northern Leopard Frog recovery in B.C.			decreased.
4	Species and Population Management	<u>Genetic isolation</u> 1. Investigate the taxonomic status of western genetic units of the species, e.g., if they are distinguishable and unique compared to other genetic units within the range of the species. 2. Assess evolutionary significant units and identify suitable stocks for reintroduction into the former range in B.C. 3. Investigate the effects of inbreeding and outbreeding depression with respect to reintroduction.	Limiting Factors: Genetic isolation and small population size	Beneficial	1. Genetic factors constraining Northern Leopard Frog recovery identified and if possible mitigated.
4	Species and Population Management	<u>Species-specific habitat requirements</u> 1. Research habitat use and requirements of Northern Leopard Frogs to identify reintroduction habitat and inform restoration activities for extant populations or reintroduction locations. 2. Assess the role that habitat loss has played in the decline of Northern Leopard Frogs. Reconstruction of the pattern and rate of habitat loss may help to explain the original decline and inform habitat restoration activities. 3. Quantify impact of threats currently scored as "unknown impact" in the Threats	Knowledge Gap	Beneficial	1. Report on Northern Leopard Frog habitat use. 2. Utilization of this information to guide habitat analysis and restoration for Northern Leopard Frog reintroduction and population expansion activities.

Objective	Conservation Framework action group	Approaches to meet objectives	Threat or concern addressed[a]	Priority[b]	Performance measure
		Classification Table (Table 2) 4. Use Traditional Ecological Knowledge when available and applicable.			
4	Species and Population Management	<u>Population ecology and dynamics</u> 1. Estimate stage-specific mortality rates and clarify what is preventing the expansion of the extant population. 2. Initiate Capture-Mark-Recapture (CMR) analysis and radio-telemetry research to estimate population parameters. 3. Conduct population elasticity, sensitivity, and other data analysis as appropriate to determine which life-history parameter has the most influence on population growth rate. 4. Use insights from the population modelling to assess which life-stages are most effective in population augmentation and reintroduction efforts.	Threats: All Limiting Factor: small population size	Essential	1. Report on Northern Leopard Frog population dynamics and modelling published. 2. Utilization of the knowledge and insight in guiding population augmentation and reintroduction activities.
4	Population Management	<u>Reintroduction strategies</u> 1. Assess the most effective life-stages for introduction that lead to population persistence in reintroduced population. 2. Develop an economic model that balances the costs of captive rearing each life-stage against the most effective life-stage for reintroduction to optimize cost-effectiveness of projects establishing additional populations.	Limiting Factors: Small population size	.Essential	1. Information on the most cost-effective reintroduction methods for Northern Leopard Frogs in B.C. This information will be incorporated into the population augmentation and reintroduction strategy document.
1, 2, 3, 4	All	<u>Fundraising and public relations</u> 1. Review, revise and implement communications strategy as necessary. 2. Work with the CVWMA interpretive program to inform visitors about the only remnant population of Northern Leopard Frogs in B.C. and to increase the conservation profile of the frog in the public perception. 3. Develop a Northern Leopard Frog website for B.C.	All threats and limiting factors	Necessary	1. Public concern for Northern Leopard Frog recovery increased. 2. Public education events, signage, and website developed and implemented. 3. Research collaborations established to address knowledge gaps. 4. Multi-stream funding to support recovery actions for Northern Leopard Frogs.

Objective	Conservation Framework action group	Approaches to meet objectives	Threat or concern addressed[a]	Priority[b]	Performance measure
		4. Contact and inform adjacent landowners of recovery efforts to gain support and cooperation for implementing activities. 5. Initiate strategic collaborations with academia to facilitate research to address knowledge gaps. 6. Initiate, plan, and conduct fundraising efforts to implement recovery actions listed above such as establishment of assurance populations, habitat acquisition, restoration, and enhancement.			

[a] Threat numbers according to the IUCN-CMP classification (see Table 1 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 INFORMATION ON HABITAT NEEDED TO MEET RECOVERY GOAL

Sufficient suitable habitat is available to support the species or could be made available through habitat management or restoration through most of the species range except potentially in the Okanagan. Initial habitat restoration and reintroduction efforts, conducted between 2001 and 2005, have demonstrated success. The extent to which various threats operate in this potential habitat, the specific micro-habitat requirements, and the requirement for connectivity between seasonal habitats is currently incompletely understood. This has been identified as a knowledge gap that requires attention and actions to address this knowledge gap are outlined in Table 3.

As habitat does not appear to be spatially limiting and threats within this habitat require further investigation, a formal description of the biophysical attributes of survival and recovery habitat or geospatial description is not being described at this time. A schedule of studies has not been included in this document as actions to maintain and enhance occupied (survival) habitat and to determine appropriate relocation sites and connection (recovery) habitat are included in Table 3.

7.1 Description of Survival/Recovery Habitat

It is recommended that survival habitat be defined as the habitat that is necessary for the persistence of the species at occupied sites which currently includes the two extant locations: CVWMA and Bummer's Flat. It is recognized that these two locations will only achieve the first population and distribution goal and are insufficient to meet the two other population and distribution goals for the species. Recovery habitat is also required and can be defined as habitat where the species is reintroduced or translocated (introduced) into the Northern Leopard Frog's historical range. Reintroduction sites will need to be determined before recovery habitat can be described. Northern Leopard Frogs need a variety of habitats (e.g., breeding and rearing, foraging, overwintering and their connecting habitats). Although specific biophysical attributes are not described here, a general description of the habitat requirements for Northern Leopard Frog can be found in Section 3.3.1 "Habitat and Biological Needs".

8 MEASURING PROGRESS

The success of the recovery program will be determined primarily through monitoring of the Northern Leopard Frog population. If population monitoring indicates that the population is stable or increasing, then the immediate population and distribution goal for Northern Leopard Frog will have been met.

The recovery plan will be reviewed in five years to assess progress and to identify additional approaches or changes that may be required to achieve recovery.
The performance indicators presented below provide a way to define and measure progress toward achieving the immediate population and distribution goal. The following will be used to evaluate progress by 2016:

- The Northern Leopard Frog in British Columbia is still extant (Objective 1).

- Two additional self-sustaining populations, one each in two of the four basins in the historical range: Upper Columbia, Upper Kootenay, Creston Valley, and south Okanagan have been established (Objectives 2, 3 and 4).
- Key knowledge gaps that currently constrain effective implementation of recovery efforts have been initiated (Objective 5).

Performance measures are listed for each objective as they relate to specific actions in Table 2.

9 EFFECTS ON OTHER SPECIES

Maintaining and restoring wetland habitat to recover the Northern Leopard Frog in B.C. will benefit other wetland species and promote wetland conservation. The Northern Leopard Frog shares habitat with a number of species at risk (Table 4); however, before habitat enhancement/restoration prescriptions are implemented, potential impacts to non-target species must be investigated and addressed. This should be done in consultation with the responsible agencies (e.g., Department of Oceans and Fisheries (DFO), B.C. Ministry of Environment (MOE)) and input from First Nations and the general public should be sought.

Competitive interactions between Northern Leopard Frogs and other sympatric species are not well understood. Evidence from a single field experiment suggests that Northern Leopard Frogs may displace Columbian Spotted Frog when the two species occur together (Dumas 1964); however, other data suggest that this conclusion may be inaccurate (Werner 2003).

The reintroduction or translocation of Northern Leopard Frogs has the potential to spread diseases between and among wild and captive populations. A disinfection protocol (B.C. Ministry of Environment 2008) has been established to prevent the spread of chytridiomycosis. Research on chytridiomycosis (and other diseases) and consultation with wildlife veterinarians will provide additional insight into disease prevention and control.

Table 4. Species at risk whose habitats may overlap with Northern Leopard Frog (B.C. Conservation Data Centre 2012).

Species[a]	**Status**[b]	**Importance of site**
American Avocet *Recurvirostra Americana*	Red-listed	Migration corridor; accidental breeder
American Bittern *Botaurus lentiginosus*	Blue-listed	Breeder. Present in Bummers Flats, reintroduction site
American White Pelican *Pelecanus erythrorhyncos*	Red-listed Species at Risk	Foraging non-breeder
Bobolink *Dolichonyx oryzivorus*	Blue-listed	Breeder
Forster's Tern *Sterna forsteri*	Red-listed	Only nesting colony in B.C.
Great Blue Heron	Blue-listed	Three breeding colonies in

Species[a]	Status[b]	Importance of site
Ardea herodias Herodias	Species at Risk	Creston Valley
Sandhill Crane *Grus Canadensis*	Species at Risk	Migration corridor; breeder
Short-eared Owl *Asio flammeus*	Blue-listed Species at Risk COSEWIC Special Concern	Breeder
Western Grebe *Aechmophorus occidentalis*	Red-listed	One of only three nesting colonies in B.C.
Horned Grebe *Podiceps auritus*	COSEWIC Special Concern	Breeder in CVWMA
Western Screech-Owl *Megascops kennicottii macfarlanei*	Red-listed Species at Risk COSEWIC Endangered	Breeder
Yellow-breasted Chat *Icteria virens*	Red-listed Species at Risk COSEWIC Endangered	Present in CVWMA in some years; breeding possible, but unconfirmed
Olive-sided Flycatcher *Contopus cooperi*	Blue-listed COSEWIC Threatened	Possible breeder on CVWMA
Lark Sparrow *Chondestes grammacus*	Red-listed	Unconfirmed breeder on CVWMA
Western Toad *Anaxyrusboreas*	COSEWIC Special Concern	Breeder in CVWMA and Bummers Flats, reintroduction site
Western Painted Turtle *Chrysemys picta*	Blue-listed COSEWIC Special Concern	Breeding in CVWMA and Bummers Flats, and most other potential reintroduction sites
Monarch *Danaus plexippus*	Blue-listed COSEWIC Special Concern	Present in Bummers Flats, reintroduction site
Dione Copper *Lycaena dione*	Red-listed	Present in Bummers Flats, reintroduction site
White Sturgeon, *Acipenser transmontanus*, Columbia River population	Red-listed COSEWIC Endangered	Present in Kootenay River in CVWMA
Burbot *Lota lota*	Red-listed	In Kootenay and Columbia Rivers
Long-billed curlew *Numenius americanus*	Blue-listed COSEWIC special concern	Present in Bummer's Flats and could overlap Northern Leopard Frog foraging and transitional habitat
Lewis's Woodpecker *Melanerpes lewis*	Red-listed COSEWIC Endangered	Present in Bummer's Flats and could overlap Northern

Species[a]	Status[b]	Importance of site
		Leopard Frog foraging and transitional habitat
Double-crested cormorant *Phalacrocorax auritus*	Blue-listed	Nest and forage in CVWMA
Townsend's big-eared bat *Corynorhinus townsendii*	Blue-listed	Present in Bummers Flats and also potentially CVWMA

[a] The Northern Leopard Frog in B.C. does not occur in an ecological community or ecosystem that is considered to be at risk.
[b] Status is for B.C. except when noted as COSEWIC.

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