Saskatchewan
Prairie Conservation
Action Plan

Guide to Managing for Optimal Habitat Attributes:

Northern Leopard Frog

(*Lithobates pipiens* – Western Boreal/Prairie populations)

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ABOUT THIS GUIDE

A New Approach To Managing For Species At Risk

The intent of this guide is to determine local and landscape-scale habitat features that are optimal for species at risk at different life stages, as well as important non-habitat related beneficial management practices. As habitat for species at risk declines and threats to populations increase in jurisdictions outside Canada, it becomes critical to provide optimal conditions on what remains if we are to conserve or recover a species.

This First Approximation of the guide for Northern Leopard Frogs should be considered a living or dynamic document that will continually evolve. As our knowledge of prairie species at risk improves with research and monitoring, this guide will need to be periodically revisited and updated.

Who Should Use This Guide?

Most grassland species at risk in Saskatchewan exist on working agricultural lands that most often support grazing livestock and sometimes support annual or perennial crops. This guide provides habitat targets and non-habitat related beneficial management practices (BMPs) for land managers who may have the opportunity to aid in the conservation of species at risk on the land under their control. Additionally, the habitat targets and BMPs may be used by conservation organizations in designing results-based agreements with land managers.

The Environmental Benefit Index (EBI) is designed to be used by any stakeholder to prioritize sites and/or projects for conservation and recovery programs, or by land managers to evaluate the value of their property for a particular species.

How To Use This Guide

This guide is presented in two parts. The first part summarizes the important spatial and temporal needs of the species and presents habitat targets and non-habitat related BMPs. Habitat targets for the Northern Leopard Frog are presented at the site scale and categorized by the type of habitat required at different life stages. Site-scale targets are those attributes that the individual prefers at a certain time (e.g., overwintering, breeding, or foraging) or within a certain portion of their home range. Site habitat targets are most commonly physical vegetation, water, soil and/or topography parameters, but may also include such attributes as configuration of land cover or habitats, presence/absence of human infrastructure, etc. The rationale for each target or BMP is also provided so land managers can readily understand the relationship between the target and use of habitat by the species.

Guides have been prepared for individual species. Habitat targets for individual species give the land manager the choice of species they wish to benefit. Managing for a single species may result in habitat that is undesirable for another species. Conflicts between species are addressed in the EBI.

The second part of the guide presents an index that places values on the habitat targets and BMPs in combination with other considerations. An Environmental Benefit Index is a compound index that considers multiple environmental factors when determining an ecological outcome. EBIs can be used to evaluate and prioritize opportunities for conservation programs. An EBI is of considerable importance in determining priority sites to invest in, particularly when funds are limited.

The overall goal of the EBIs for species at risk habitat is to ensure maximum environmental value for an investment in results-based conservation programming. The EBI has several potential uses including:

- To geographically target the most important locations,
- To evaluate and rank candidate properties or projects for their environmental benefit,
- To rank the environmental benefit of candidate properties or projects by cost (or bid), and
- To evaluate projects over time to determine if environmental values are being improved or maintained, or to evaluate the efficiency of the investment over time.

EBIs were identified as a method to target programming and prioritize participation in the design of the Prairie Beef & Biodiversity program (Commission for Environmental Cooperation, 2013). EBIs were subsequently developed for the Greater Sage-Grouse (Ranchers Stewardship Alliance Inc., 2014), Piping Plover (SK PCAP, 2017), and Burrowing Owl (unpublished, 2017).

Northern Leopard Frog Identification

Size – Body length: 3.3-13.0 cm; recently metamorphosed Northern Leopard Frogs average 3.3-4.0 cm.

Features –Often green, sometimes brown or rarely golden frog with smooth skin and obvious dark spots surrounded with outer lighter rings on back; light cream-coloured or white belly; two light-coloured glandular ridges of skin (dorsolateral folds) running from behind the eyes down sides of the back; females are on average larger than males; males may possess swollen thumbs during the breeding season and use vocalizations to attract females during the breeding season.

Eggs –deposited in globular or irregularly globular masses (8-15 cm diameter). Eggs are usually small (2 mm), black on top with white underneath, and surrounded by 2-3 jelly envelopes that can be up to 6 mm thick. Once the eggs are deposited, the jelly envelopes surrounding them begin to swell. Egg masses may range from 600-7,000 eggs. Globular masses almost always occur in clusters, with several or many females laying eggs close together.

Larvae – can reach up to 12 cm total length prior to metamorphosis and their dorsal colour usually ranges from green to brown with small gold spots and a cream-coloured underbelly.

Call - in late April (a few days after ice out) to June, the male Northern Leopard Frog can be most easily heard calling after dark if weather (wind speed, air and particularly water temperature) is favourable. They may also call during the day if weather conditions after dark are not favourable. The call is a low snore followed by several low grunts and chuckles, sometimes described as sounding like a finger rubbed on a wet balloon. Calls are not loud, are difficult to hear at longer distances, and may be obscured by ambient noise.

To hear the call, visit:
https://www.naturewatch.ca/frogwatch/leopard-frog-3/

Where Do Northern Leopard Frogs Live?

The Northern Leopard Frog was formerly abundant and widely distributed across its range in North America. Declines in populations and numbers of individuals were noted in the 1970s and 1980s, especially in the western parts of the range. Since then, in Alberta the species occurs in small populations at isolated small areas. The species appears to be widely distributed throughout southern Saskatchewan, and to be widely distributed and abundant in southern Manitoba. Wide fluctuations in population size from year to year make it difficult to analyze population trends. Northern Leopard Frogs found in Manitoba, Saskatchewan, Alberta, and the Northwest Territories belong to the Western Boreal/Prairie populations. Figure 1 shows key habitat and occurrences of Northern Leopard Frog in southern Saskatchewan.

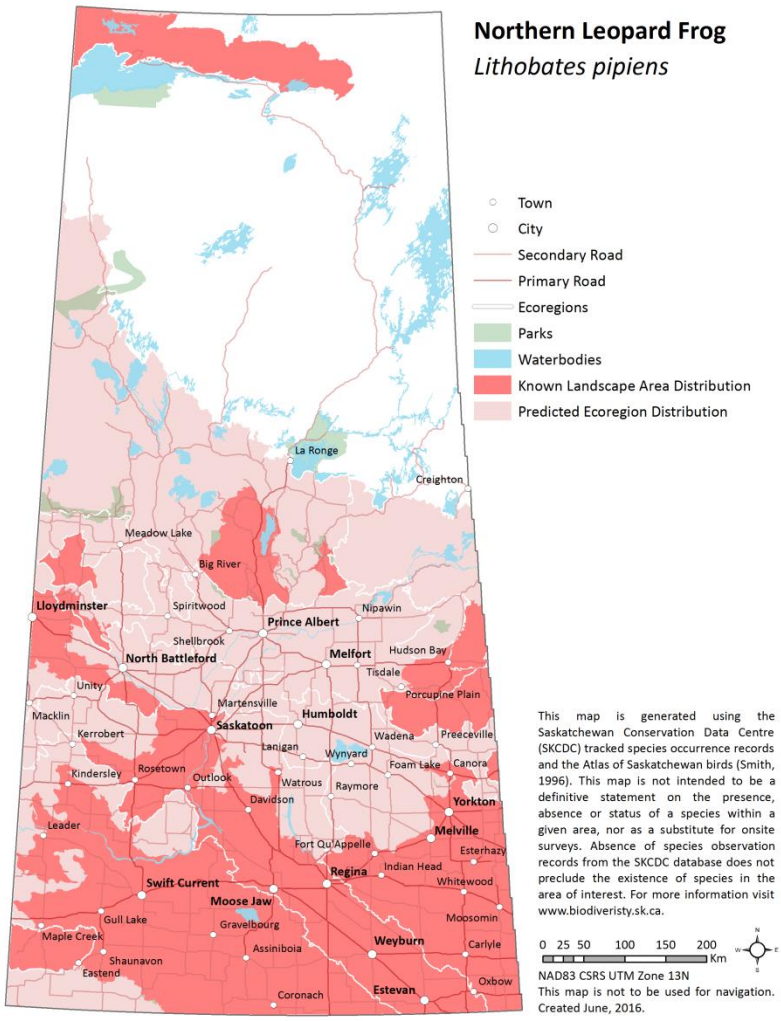

Figure 1. Range map of known and potential occurrences of Northern Leopard Frog (Saskatchewan Conservation Data Centre, 2017).

Behavior And Habitat Use In Canada

In the spring, Northern Leopard Frogs emerge from hibernation soon after the ice thaws on overwintering waterbodies. Males move to breeding sites prior to the females and begin calling, sometimes as early as mid-April and before the ice is fully gone from breeding sites. Females that are sexually mature and in breeding condition, are attracted by the calling males. These females will arrive at the breeding waterbodies days to weeks after males begin calling. Breeding occurs from late April into June. Emergence from winter dormancy and the onset of breeding is dependent on environmental variables, including air and water temperatures, depth of snowpack and winter ice thickness. Latitude and elevation also influence the timing of breeding. Generally, breeding takes place in spring after the water temperature rises above 7 to 10°C.

The female releases a globular mass of eggs and at the same time the male releases his sperm onto the eggs. Egg-laying sites are typically in shallow (generally between 15 and 75 cm deep) open water that receives direct sunlight in early morning and afternoon. Such habitat provides a thermal environment that optimizes growth and development of eggs and tadpoles. Submerged and emergent aquatic vegetation are important for egg mass attachment. Eggs are usually attached to submerged vegetation within 5-20 cm of the water surface. Eggs and tadpoles have temperature dependent development. Eggs can take anywhere from 4 to 30 days to hatch and tadpoles typically reach metamorphosis in 60-90 days depending on water temperature. Tadpole development is also influenced by the presence of predators, density, and disease.

Tadpoles are primarily herbivorous, feeding on leaf-litter detritus and filamentous algae. However, invertebrates are also commonly eaten, and cannibalism and scavenging are well-documented for tadpoles of this species. Upon metamorphosis, young frogs eat mainly insects and other invertebrate prey. Invertebrate prey size becomes larger as frogs mature and adult frogs have been known to occasionally eat small vertebrates including mice, birds, snakes and other frogs, in addition to the normal diet of insects, spiders, worms, snails, slugs, and fish.

After metamorphosis, young frogs spend much of their time foraging near the edge of breeding waterbodies in areas with available prey and sufficient cover; but long distance and mass migrations to larger waterbodies have been observed. Young-of-the-year frogs disperse from their breeding waterbodies (typically 2 km but can be as much as 8 km). Young frogs may not become sexually mature until two to three years after metamorphosis.

As air and water temperatures drop, frogs move to overwintering waterbodies, which must not freeze to the bottom (sufficient depth, flow or groundwater influx) and must be well-oxygenated. Photoperiod and frog physiology likely also affect when hibernation is triggered.

Mortality is very high during the egg, tadpole and overwintering young of year life stages. Only about 1% of eggs mature into adult frogs. Mortality of adults can occur during the fall and winter as a result of predation, desiccation, and inability to find appropriate hibernacula (i.e., freezing and anoxia) as well as due to a lack of sufficient energy stores of fat and/or disease.

Predators of Northern Leopard Frogs include snakes, mink, turtles, herons, raccoons, and numerous other animals. Eggs are preyed upon by leeches, dragonfly larvae, etc. Tadpoles may be preyed upon by other frogs, waterfowl, fish, snakes and predacious aquatic invertebrates.

Northern Leopard Frogs utilize movement corridors during seasonal migrations (to and from breeding, foraging, and overwintering habitat) or while dispersing. They tend to favour wet meadows, wetlands, or riparian areas that have a higher moisture level within the soil and atmospheric moisture resulting in a more humid microclimate, compared to surrounding habitats. Research associated with relocation of egg masses of Northern Leopard Frogs indicates that they are genetically programmed to move in a specific direction from the breeding waterbody to the overwintering waterbody.

Field observations of Northern Leopard Frogs suggest that the frogs may prefer feeding, loafing and basking in open and semi-open habitats with short vegetation. Tall grass and thick vegetation afford needed protection from hot and dry weather, as well as cover from predators. Shorter grass height may improve foraging efficiency, and allow Northern Leopard Frogs to more easily disperse and move about.

Through their lifecycle, Northern Leopard Frogs require specific habitats for breeding, foraging, overwintering and habitat corridors. In some cases specific habitat requirements may overlap spatially. For example, breeding and overwintering can occur in the same pond with adjacent habitat that supports foraging behaviour. However, often these habitats are separated from one another, by up to 2 km. Importantly, habitat corridors provide the critical link connecting these habitats.

Figure 2 illustrates some of the main habitat preferences and avoidances for Northern Leopard Frog.

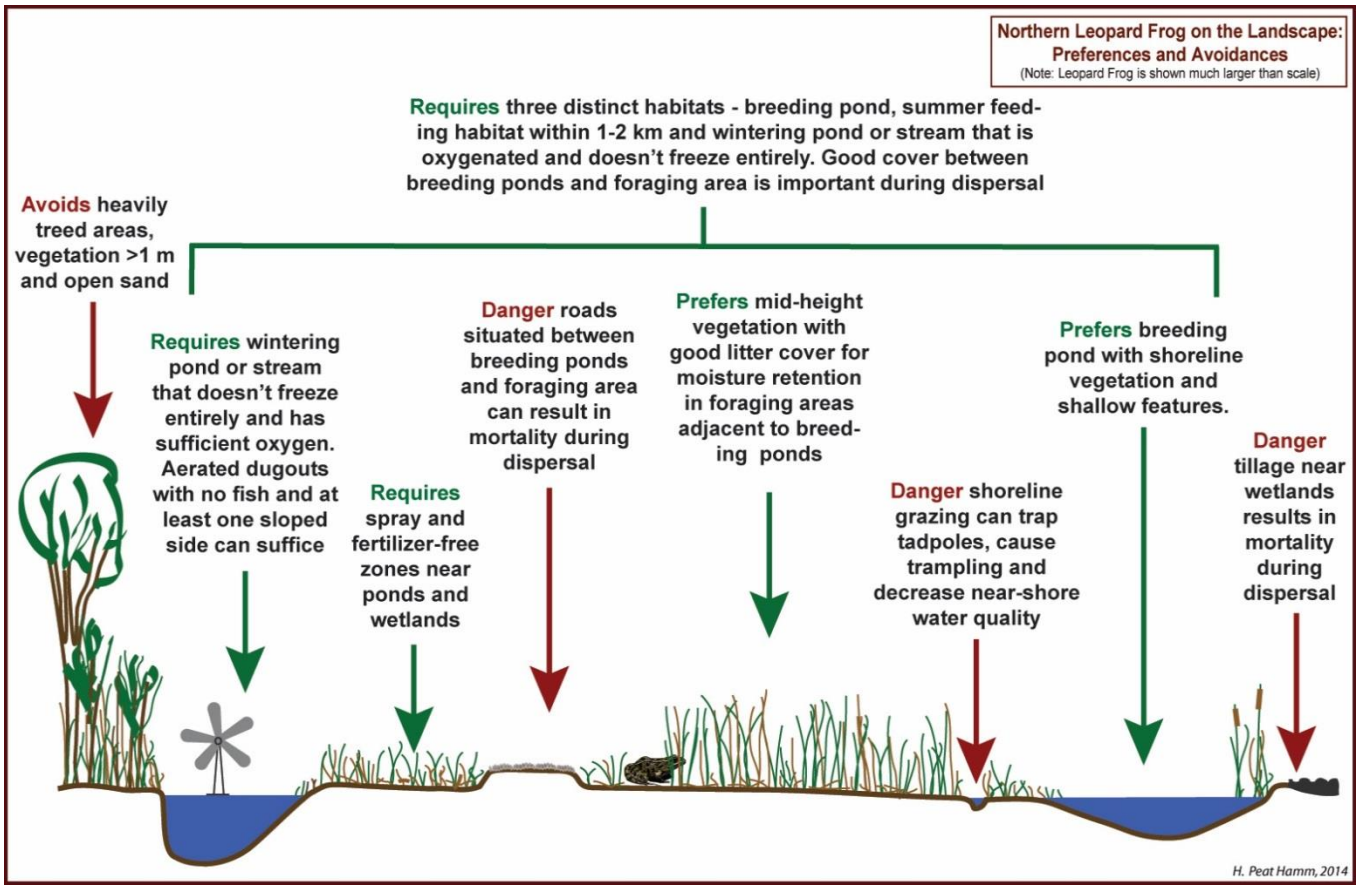

Figure 2. Habitat Diagram for Northern Leopard Frog (Peat Hamm, H. 2017).

Threats To Northern Leopard Frog In Canada

Most declines in Northern Leopard Frog populations are often associated with habitat loss, degradation, and fragmentation. The varied habitat requirements of this species make it particularly vulnerable to such changes. Removal or modification of even one of the required habitat types, or habitat fragmentation/barriers (i.e., loss of habitat corridors) may make the landscape unsuitable for the frog's lifecycle. In addition to habitat threats, direct impacts may occur to populations from disease, water contaminants, and predation.

DISEASE

Disease outbreaks have historically occurred in amphibian populations, including die-offs due to *Ranavirus* in southern Saskatchewan. Other possible diseases on the Prairies include chytridiomyosis, red leg disease, various water mould diseases and infections by trematode cysts. Stocked fish may also be a vector for pathogens spread via the fish or water they were transported and introduced with into the stocked pond. Biocides and other chemicals can result in reduced fitness of amphibians making them more susceptible to pathogens and parasites.

WETLAND LOSS

Wetland loss is likely the main threat to Northern Leopard Frogs. Not only does this have a direct impact on necessary habitat, as breeding waterbodies, overwintering grounds and movement corridors are destroyed and movement corridors dry out, but it is an indirect impact, as destruction of marsh and wetland habitat reduces the filtering capacity of the landscape and thereby reduces the water quality in the remaining functional wetlands.

INVASIVE SPECIES

Introduced fish can cause local extirpation by preying on all life stages of Northern Leopard Frogs during both the breeding and overwintering periods. Stocked fish may also be a vector for pathogens spread via the fish or the water in which they were transported.

Northern Leopard Frogs may use habitat that has grass or vegetation over 1 m in height less frequently than shorter grass. Certain invasive plant species such as reed canary grass can dominate naturally structured vegetation and make it less suitable for the frogs.

DOMESTIC GRAZERS

Grazing cattle and other livestock with unrestricted access to riparian areas and littoral zones can degrade these areas and trample egg masses and Northern Leopard Frogs. Impacts are dependent on the season of access. Siltation on shorelines can smother frog eggs by impeding membrane respiration. Grazers can impact water quality from erosion, sedimentation, urine and fecal material. High-intensity grazing decreases the litter layer, allowing increased drying of the soil surface, and making it more difficult for the frogs to travel great distances from water sources. High-intensity grazing also reduces the habitat for insect prey.

Livestock grazing can also be beneficial and used as a management tool to enhance the habitat of the Northern Leopard Frog. Grazing animals can be used to control the density and height of vegetation, and limit woody species encroachment in riparian areas. Reduced vegetation height may increase prey availability for frogs by bringing insects and other prey into reach and managed grazing of emergent plants may help maintain open water areas, along the shoreline, that can improve breeding habitat. In addition, desirable heterogeneity of vegetation structure and litter abundance can be produced using livestock grazing as a management tool.

WOODY SPECIES ENCROACHMENT

Northern Leopard Frogs use a variety of habitats but typically avoid heavily treed areas, but may use the edges of these areas. Generally, as the proportion of forest in an area increases, Northern Leopard Frog occurrence decreases. This species will be more likely to occur in or near a forested area if it is fragmented because the frogs preferentially move into and use the open areas.

Woody vegetation, including both trees and shrubs, surrounding overwintering or breeding habitat traps snow and blocks sunlight, thereby slowing the warming of water in spring. Cooler water extends the period frogs stay in dormancy, extends the time eggs take to hatch and extends the time tadpoles take to complete their metamorphosis.

ENVIRONMENTAL CONTAMINANTS -PESTICIDES AND FERTILIZERS

Northern Leopard Frogs are sensitive to pollutants. Pesticides have been documented to negatively affect Northern Leopard Frog adults and tadpoles directly and indirectly due to suppression of the immune system, interference with hormone production which affects the sexual development of frogs, increased infection, and subsequent mortality. In addition, biocides and other chemicals can affect Northern Leopard Frogs indirectly by impacting their food supply.

Fertilizer applications, if allowed to run off into waterbodies, can be detrimental to Northern Leopard Frogs. Fertilizer increases eutrophication (excess of nutrients), resulting in increased algal growth, which in turn can result in increased snail populations (which feed on algae). Aquatic snails also play an essential role in the life cycles of trematode parasites. More snails in the system mean a higher rate of trematode survival and therefore infestation on amphibian larvae, including frogs.

ROADS AND OTHER LINEAR DEVELOPMENTS

Most Northern Leopard Frogs disperse from breeding waterbodies after metamorphosis and may cross roads when moving between seasonal habitats placing them at risk of being struck by vehicles. Mortality due to traffic has been documented as far as 1.5 km from breeding waterbodies in marshy areas. The proximity of seasonal habitats to roads and higher road volume leads to a higher the risk of road mortality.

In addition to being barriers to movement, roads can also contribute to pollution (e.g., road salts, oils, dust control agents, fuels and lubricants and other substances from vehicles). Road salts, for example, can travel nearly 200 m from roads into wetlands contaminating amphibian habitat and

possibly causing malformation of larvae. Traffic noise can also interfere with breeding choruses of frogs.

OTHER

Forage harvesting - High mortality has been observed in alfalfa fields during summer mowing operations.

Prescribed Burning- Large, denuded areas can present physical barriers to the movement of amphibians because of lack of vegetative cover which increases Northern Leopard Frog vulnerability to predation and meteorological conditions. Prescribed burns should only be done during winter months when amphibians are inactive, should be avoided in riparian areas and a minimum 20 m unburned buffer should be maintained around wetlands. Small patch burns in amphibian habitat should have minimal impact on amphibian habitat.

Pipeline Construction - Entrapment is common during construction of pipelines and other excavations.

Urban development - can result in widespread habitat loss and pollution (roads/yard chemicals) and change the hydrology—overland and underground water flows—of an area, causing remaining natural water sources to dry earlier than usual, before amphibian larvae can complete their metamorphosis. Urban development may lead to roadkill and collection pressure. Overall, urban development often results in widespread habitat loss, degradation and fragmentation.

Stormwater management ponds can become a habitat sink or ecological trap due to high levels of pollutants, frequent drying or sudden inundation, lack of natural emergent and riparian vegetation, and narrow buffer of cover vegetation. Stormwater ponds are often proximate to roads. Therefore, the risk of mortality may be high for amphibians occupying these ponds.

Cultivation – Removing large tracts of upland (native grassland, aspen parkland or ephemeral wetlands) for the purposes of annual crop production renders habitat unsuitable for frog foraging and dispersal.

Renewable Energy – The large footprint of solar panels renders habitat unusable by frogs. Noise from wind turbines can interfere with calling.

Large dams – the timing of water releases can flood oxbows and other ponds along watercourses impacting egg hatching and larval habitat. Conversely, the withholding of spring floodwaters can change hydrological regimes downstream of the dam rendering breeding sites unusable.

HABITAT REQUIREMENTS OF NORTHERN LEOPARD FROG IN CANADA

The critical dates related to the various habitats required by Northern Leopard Frogs are listed in Table 1.

Table 1. Critical dates of habitat use in Saskatchewan.

Life Stage	Critical dates for SK
Breeding	Late April to June. At higher elevations and latitudes, breeding occurs later in the season. Eggs take ~ 4 - 30 days to hatch.
Metamorphosis	Late July to September. 60 to 90 days after hatching.
Dispersal of Young of Year	Late July to September.
Foraging	Adults – May to early October; Young of Year – Late July to early October.
Overwintering	Early October to April. Move to overwintering waterbodies and eventually into hibernation.

Because of the complex, multi-habitat needs of Northern Leopard Frogs, the landscape features required relate in part to the proximity of breeding, foraging, overwintering and corridor habitat. All habitats are required. Preferred habitat features for overwintering, breeding and foraging are presented in the following sections.

Features Of Overwintering Habitat Of Northern Leopard Frogs

Overwintering habitat includes waters that are deep enough that they do not freeze to the bottom in winter, or that are spring fed or flow and hence do not freeze entirely over during winter. A key feature of overwintering sites is that they are well-oxygenated; these are often permanent waterbodies such as streams or ponds. The influence of springs and groundwater in both still and moving water can help maintain water temperatures keeping the ice from freezing to the bottom and the water from becoming anoxic due to thick ice cover. Additionally, sites where sun exposure in spring facilitates ice melt help frogs emerge from dormancy. Known habitat characteristics include:

- Waterbodies that do not freeze to bottom in winter - natural or constructed waterbodies of sufficient depth (>4 m deep) or flow to prevent ice from freezing to the bottom (e.g., lakes, streams, rivers) with a goal of maintaining water temperatures between 2^{o} and 4^{o} C.
- Water quality - oxygenated (naturally or via aerator) and cold. Dissolved oxygen levels can be as low as 5 ppm but ideally 7-10 ppm and temperature of 1-4°C. Areas with high oxygen saturation include streams, rivers, springs, bottom of spillways and stream inflow areas of wetlands and other waterbodies.

- Slope of waterbody on at least one side needs to be moderate enough for direct sunlight to reach the water throughout the day to facilitate ice melt and emergence of frogs from dormancy.
- Shoreline would ideally be free of trees and shrubs or other features (e.g., spoil piles) that will catch snow and shade water, thereby preventing sunlight from reaching the water in the spring. At least the south side of the waterbody needs to be free of obstruction of sunlight.
- Overwintering sites with connectivity to other necessary habitats and not separated by roads. Frogs will travel up to 2km to get to a breeding site.

Features Of Breeding Habitat Of Northern Leopard Frog

Breeding habitat includes waterbodies that have emergent vegetation and relatively shallow features near-shore. These may be permanent waterbodies or seasonal waterbodies that dry up later in summer. The shoreline and emergent aquatic vegetation provides protection from predators and unfavorable weather, and provides a surface on which to attach eggs. Northern Leopard Frogs may also use quiet bays of larger waterbodies, oxbows, and backwaters of rivers for breeding. Known habitat characteristics of breeding habitats include:

- Frogs typically prefer to breed in clean, clear water.
- Slope of waterbody on at least the south side needs to be moderate enough for direct sunlight to reach the water throughout the day.
- Water temperature in the littoral zone in mid-May higher than 10^{o}C, and ideally higher than 20^{o}C at mid-day.
- Shoreline would ideally be free of trees and shrubs or other features (e.g., spoil piles) that will catch snow and shade water, thereby preventing sunlight from reaching the water in the spring. At least the south side of the waterbody needs to be free of obstruction of sunlight.
- Water levels in the deepest part of the littoral zone ideally between 30 and 45 cm. Water depth maintained at least until frogs reach metamorphosis (into August), although some drawdown is tolerable. An influx of cold water, such as from a water release from a dam in summer, could delay development.
- Undisturbed riparian areas and aquatic vegetation until eggs hatch and tadpoles reach metamorphosis.
- Waterbody supports emergent vegetation in the littoral zone.
- Waterbody surround by permanent cover extending ideally at least 200 m from the shore to protect water quality.
- Riparian area ideally rates Healthy according to Saskatchewan's riparian health protocols to protect water quality.
- Riparian zone free of invasive plants - Northern Leopard Frogs may not use habitat that has vegetation over one metre in height, but this may depend on the density of

vegetation. Some invasive plants can dominate naturally structured vegetation and make it less suitable. Dense, tall native vegetation can also hinder habitat suitability for frogs.

- A typical breeding site might be 30 to 60 m diameter and 1.5 to 2.0 m deep at its deepest point.
- Breeding sites with connectivity to other necessary habitats, and not separated by roads.

Features Of Foraging Habitat Of Northern Leopard Frog

Foraging habitat includes a variety of sites usually within 1 to 2 km of the breeding pond that provide habitat for prey of Northern Leopard Frogs. Known habitat characteristics of foraging habitat include:

- Ideally, at least 200 m of permanent cover adjacent to breeding waterbody for foraging.
- Riparian area ideally rates Healthy according to Saskatchewan's riparian health protocols. Riparian vegetation is important as protective habitat for foraging Northern Leopard Frogs and as habitat for prey.
- The general preference is for areas with mid-height vegetation (15–30 cm), to provide adequate shade and allow for visual identification of prey, but with a variety of vegetation heights and densities (heterogeneity of structure).
- Northern Leopard Frogs typically avoid areas that are treed, have vegetation over 1 m tall, or are open and sandy.
- Moderate amount of litter for the Ecosite - litter is important for maintaining soil moisture, which frogs need in order to keep hydrated when they are away from their pond habitat. They have the ability to obtain moisture from the soil through "seat patches", and higher soil moisture enables them to forage at greater distances from water.
- Emergent vegetation in the littoral zone that is neither dense nor sparse which allows for both production and detection of prey.
- Water that is 50 cm or deeper adjacent to the littoral zone where adult frogs can avoid predators.

Features Of Corridor Habitat Of Northern Leopard Frog

Seasonal habitats are ideally all found within and adjacent to the same waterbody. However, this is not always the situation. Corridor habitat includes habitats that allow Northern Leopard Frogs to move safely and effectively between seasonal habitats to complete their life cycle. Suitable habitat corridors should exist between overwintering and breeding sites; between breeding and foraging sites; and between different breeding sites to allow for dispersal and expansion of the population. Young frogs may disperse as far as 8 km from the breeding site. Corridors enhance genetic diversity of Northern Leopard Frog populations by allowing them to find new mates in neighbouring areas and to find new habitat if local natural resources or

environmental conditions become unfavourable. Suboptimal corridor habitat may be traversed at night or during wet conditions. Known characteristics of habitat corridors include:

- Watercourses and adjacent riparian vegetation are often used as corridors connecting seasonal habitats.
- Unique habitat features such as gullies and spring fed areas (seeps) with lush vegetation may benefit migrating or dispersing frogs.
- A variety of open or semi-open areas with vegetation varying in density and height.
- Moderate amount of litter for the Ecosite - litter is important for maintaining soil moisture, which frogs need in order to keep hydrated when they are away from their pond habitat. They have the ability to obtain moisture from the soil through "seat patches".

Optimal habitat targets are listed in Table 1. Many of these habitat targets may be created through management of disturbance (i.e., grazing, controlling livestock access to water, or water level manipulation) on the land.

Table 1. Optimal habitat targets for Northern Leopard Frog.

HABITAT	TEMPORAL SCALE	HABITAT TARGET
Overwintering Habitat	Early October - late April	Waterbody with inflow or throughflow of water, or standing water >4m deep
		Dissolved oxygen content of water 8 ppm or higher
		Waterbody free of trees or shrubs, spoil piles or other features near enough to the shoreline to shade the water especially in early morning. Banks sloped at 20° (36%) or lower. At least the south side of the waterbody sloped and free of obstruction of sunlight
		Cobble or clay substrate on bottom of standing waterbody with low amounts of organic matter
		Waterbody surrounded by at least 10 m of permanent cover of grass and/or forbs
		Total dissolved solids <250 ppm
		Riparian Area Assessment = Healthy
Breeding Habitat	Late April - September	Depth of water in the deepest part of the littoral zone 30 – 45 cm
		Water levels and hydroperiod near natural and standing water maintained through July into mid-August. No large influxes or drawdowns of water during the breeding period

HABITAT	TEMPORAL SCALE	HABITAT TARGET
		Water temperature in littoral zone 20^{o} – 30^{o}C at mid-day
		Sparse or intermediate densities (Classes 5 – 10 density distribution from SK PCAP Rangeland Health Assessment manual) of emergent vegetation
		Waterbody free of trees or shrubs, spoil piles or other features near enough to the shoreline to shade the water especially in early morning. Banks sloped at 25^{o} (47%) or lower. At least the south side of the waterbody sloped and free of obstruction of sunlight
		Waterbody surrounded by at least 200 m of permanent cover of grass and/or forbs
		Total dissolved solids <250 ppm
		Riparian Area Assessment = Healthy
Foraging Habitat	May - October	Intermediate density (Classes 8 – 10 density distribution from SK PCAP Rangeland Health Assessment manual) of emergent vegetation
		Water depth >50 cm adjacent to littoral zone
		Minimum of 200 m of permanent cover of grasses and/or forbs adjacent to breeding pond
		Vegetation adjacent to breeding pond between 15 and 30 cm in height
		Patchiness / heterogeneity of vegetation height and density
		Moderate amounts of litter for the Ecosite. Litter patchy in distribution
Corridor Habitat	April - November	Lush vegetation and moist soil occurring in association with the following features: gullies, seeps, riparian corridors, ephemeral streams etc.
		Vegetation height and density, and amount of litter vary to provide open and semi-open areas (heterogeneity)
		Moderate amounts of litter for the Ecosite. Litter patchy in distribution

OTHER MANAGEMENT PRACTICES FOR NORTHERN LEOPARD FROG

There are numerous management issues unrelated to the habitat characteristics of seasonal habitats that should be taken into consideration when managing for Northern Leopard Frogs. These beneficial management practices are:

- Exclude frogs from pipeline or other excavation areas, using temporary barrier fences, salvage. Use provincial setback guidelines for Northern Leopard Frog when excavating.
- Avoid placing dugouts in wetlands. In dry years, the water drains into the dugout and breeding habitat is eliminated. A dugout on the periphery of a wetland may not have a significant enough effect on hydrology to impact breeding habitat.
- Mow as early as possible – before dispersal of young of the year from the breeding pond. High mortality has been observed in alfalfa fields during summer mowing operations. Grazing in fields next to riparian areas is preferred over mowing and haying operations
- No/minimal disturbance by off-highway vehicles in riparian zone - mortality due to traffic has been documented as far as 1.5 km from breeding waterbodies in marshy areas
- Avoid the use of bluestone (copper sulfate) in dugouts and other stock watering ponds. It may break down the algae which will reduce the oxygen content of the water.
- Avoid stocking waterbodies with game fish or ornamental pond fish and avoid releases of species such as carp, goldfish and bullfrogs which compete with Northern Leopard Frog and spread pathogens. Both the introduced species and the water they are transported in may carry pathogens.
- Avoid collecting Northern Leopard Frogs, larvae or eggs for any purpose except relocation or translocation. Collection of frogs and eggs for research, commercial and recreational purposes is considered a historic threat to the species.

ENVIRONMENTAL BENEFIT INDEX (EBI) FOR NORTHERN LEOPARD FROG HABITAT

Criteria And Scoring

The EBI was developed by compiling comprehensive categories of criteria based on available knowledge, such as Northern Leopard Frog population and habitat research, as well as species recovery strategy documents.

The EBI begins with two screening criteria. These criteria are either met, in which case the user continues to the next criterion, or not met, in which case the property or potential project is eliminated from further consideration. The remaining criteria are grouped by seasonal habitat.

A scoring system was devised for the EBI. Each criterion is weighted out of 200, 100, 50, or 30 based on relative importance to the species.

The total scores are calculated based on the following formula:

EBI=
((1)(2)+(3.1+3.2+3.3+3.4+3.5)+(4.1+4.2+4.3+4.4+4.5)+(5.1+5.2)+6+7+8+9)

The EBI result may then be divided by the costs of the proposed project or the bid for the project to determine cost effectiveness. The cost to achieve the habitat requirements could include added management, added infrastructure or inputs or lost opportunities.

The range of possible scores for candidates that pass the screening criteria is quite wide. The lowest possible total score is 305 and the highest possible score is 1930. When evaluating candidate properties for a project or program, it may be possible to divide the scores into more general High, Moderate and Low priorities. There are many uses for a general ranking. For example, a more general ranking could be used to determine the total cost of implementing results-based programming on all high priority sites.

SCREENING CRITERIA

1. The area of consideration supports a current or recent presence of Northern Leopard Frogs, because they tend to return to natal sites. It is also important to ensure optimal habitat for source populations of Northern Leopard Frog.
   Yes=1, No=0.

2. The area of consideration is free of, or distant (>200m) from paved roads or high traffic volume gravel roads. Paved roads can attract frogs to the warmth, and traffic noise may interfere with calling.
   Yes=1, No=0.

OVERWINTERING HABITAT CRITERIA

3. Of the three main types of habitat required by the Northern Leopard Frog, overwintering habitat is the most critical. It has the most specific requirements and is the most limited in supply.

   3.1. Adult frogs overwinter in the bottom of waterbodies, or portions of waterbodies, whether standing (lentic) or flowing (lotic) water, that normally do not freeze to the bottom. Moving water or deep water are more likely to maintain water temperatures high enough to prevent freezing. The goal is to maintain the temperature of the water between 2 and 4^{0}C. **(Max 200 points)**

State of Water

200	A water body with an inflow or throughflow of water overwinter. This may be a river or creek, or a springfed wetland or constructed impoundment.
100	A standing waterbody more than 4 m deep.
50	A standing waterbody between 1.7 and 4 m deep.

   3.2. Overwintering frogs breathe through their skin. Therefore, the oxygen content of the water at the bottom of the waterbody must be high enough in winter to meet the oxygen requirement of the overwintering Northern Leopard Frog. Research shows that frogs of many species are not present when oxygen levels are below 5 ppm. Saturation levels of dissolved oxygen in cool water can be in excess of 10 ppm. Flowing water tends to have higher dissolved oxygen in winter than standing water. Adequate oxygen levels can also be indicated by the presence of small fish such as stickleback and fathead minnows. **(Max 200 points)**

Dissolved Oxygen in Winter

200	>8 ppm; or flowing water and small fish present
150	6.6 to 8.0 ppm
100	5.0 to 6.5 ppm

3.3. The waterbody requires direct sunlight for thawing ice, melting snow and warming water so frogs can emerge from dormancy and should not be shaded. Based on shadow cast, shrubs under 1 m in height should be at least 3 m back from shoreline to allow direct sunlight on water. Likewise, woody vegetation 1 to 2 m high should be at least 6 m away from shoreline, and full sized trees should be approximately 50 m from shoreline. Based on the angle of sunlight in April in southern Saskatchewan, the bank of a waterbody needs to be 20° (36%) or lower in slope to allow for direct sunlight throughout the day. **(Max points 100)**

Habitat Quality – Direct Sunlight

100	Free of trees and shrubs, free of spoil piles or other features that limit direct sunlight on the water, banks sloped at 20° (36%) or lower
50	At least the south side of the waterbody free of trees and shrubs, spoil piles or other features that limit direct sunlight on the water, banks sloped at 20° (36%) or lower at least on the south side
0	Sunlight blocked on all sides of the water body by woody vegetation, spoil piles or other features, or all banks steeper than 20° (36%) slope

3.4. Underwater substrate is important as it relates to the ability of the waterbody to retain water and to support dissolved oxygen levels overwinter. Substrate is more important for standing water than for flowing water. **(Max points 100)**

Substrate under Water

100	Cobble or clay with low amounts of organic material
50	Sand or silt with low amounts of organic material
30	Organic materials (vegetation or debris)

3.5. Salinity, turbidity, sediments, nitrates, phosphates and other nutrients in overwintering waterbodies may impact frog survival by increasing vegetation and organic matter, and thereby reducing the dissolved oxygen content of the water. Healthy riparian areas or vegetative buffers can help filter runoff from adjacent soils and reduce the amount of minerals and nutrients entering the water.

Habitat Quality – Winter Water Quality

100	Waterbody surrounded by permanent cover of grass and/or forbs; and Total dissolved solids <250 ppm; and Riparian Health Assessment = Healthy
50	Waterbody surrounded by cropland but with a minimum 10m vegetated buffer; and Total dissolved solids <1000 ppm; Riparian Health Assessment = Healthy or Healthy with Problems
0	Any of the following: Waterbody surrounded by cropland without a vegetated buffer; or Total dissolved solids >1000 ppm; or Riparian Health Assessment = Unhealthy

4. Optimal breeding habitat in standing water includes shallow wetlands that retain water to mid-August at minimum. These would typically be Class III or IV wetlands (Class III - Seasonal Ponds and Lakes are characterized by shallow marsh vegetation, which generally occurs in the deepest zone. These wetlands are typically dominated by emergent wetland grasses, sedges and rushes. They are usually dry by midsummer. Class IV - Semi-permanent Ponds and Lakes are characterized by marsh vegetation, which dominates the central zone of the wetland, as well as coarse emergent plants or submerged aquatics, including cattails, bulrushes and pondweeds. These wetlands frequently maintain surface water throughout the growing season.)

   Features along rivers that provide optimal habitat include slumps and terraces, sandbars, oxbows, beaver ponds, and ponds adjacent to rivers.

   Water depth and temperature are the most critical parameters for breeding habitat.

   4.1. Ideally, eggs masses need to be at least 15 cm under water until they hatch. **(Max points 100)**

Water Depth at Deepest Part of Littoral Zone

100	30 to 45 cm
50	45 to 75 cm
25	<30 cm or >75 cm

   4.2. The length of time that eggs take to hatch varies depending on water temperature in the shallow littoral zone where they are laid. Hatching can take as little as 4 days in temperature of 25^{o}C or higher, and as long as 30 days in temperatures of 10^{o}C or lower. Eggs die in temperatures of 2.5^{o}C or lower. Higher temperatures are optimal because the longer eggs take to hatch, the higher the risk that they will be killed by predators, siltation, trampling, ultraviolet light, Saprolegnia infection etc. Large or fast fluctuations in temperature will also kill eggs. **(Max points 100)**

Water Temperature in the Littoral Zone at mid-May

100	>20°C
50	10 – 20°C
30	2.5 – 10°C
0	<2.5°C

4.3. When eggs masses are laid, they are deposited on emergent vegetation below the surface of the water. Egg attachment keeps the eggs in warm, shallow water that favours embryo and tadpole development. Without emergent vegetation to attach egg masses to, eggs might be washed up on shore or drift into cooler water. Shallow water with emergent vegetation at least around the edges of the waterbody limits the types of predators that can access the eggs and reduces the chance that eggs will be found by predators. **(Max points 100)**

Habitat Quality – Emergent Vegetation

100	Sparse or intermediate emergent vegetation (Classes 5 – 10 density distribution from SK PCAP Rangeland Health Assessment manual)
50	Dense, shorter native vegetation such as sedges
0	Dense, tall vegetation such as cattails, reed canary grass, or flowering rush; or waterbody denuded of vegetation.

4.4. The waterbody requires direct sunlight for melting snow and warming water and should not be shaded, particularly the littoral zone where emergent vegetation needs to grow and egg masses are deposited. Based on shadow cast, shrubs under 1 m in height should be at least 3 m back from shoreline to allow direct sunlight on water. Likewise, woody vegetation 1 to 2 m high should be at least 6 m away from shoreline, and full sized trees should be approximately 50 m from shoreline. Based on the angle of sunlight in May in southern Saskatchewan, the bank of a waterbody needs to be 25° (47%) or lower in slope to allow for direct sunlight throughout the day. **(Max points 100)**

Habitat Quality – Direct Sunlight

100	Free of trees and shrubs, free of spoil piles or other features that limit direct sunlight on the water, all banks sloped at 25° (47%) or lower
50	At least the south side of the waterbody free of trees and shrubs, spoil piles or other features that limit direct sunlight on the water, banks sloped at 25° (47%) or lower at least on the south side
0	Sunlight blocked on all sides of the water body by woody vegetation, spoil piles or other features, or all banks steeper than 25° (47%) slope

4.5. Salinity, turbidity, sediments, nitrates phosphates and other nutrients in overwintering waterbodies may impact frog survival. Healthy riparian areas or vegetative buffers can help filter runoff from adjacent soils and reduce the amount of minerals and nutrients entering the water. Salinity, as measured by total dissolved solids, is an important water quality parameter for Northern Leopard Frogs. They can tolerate very high salinity levels. However, levels in excess of 4000 ppm have been shown to significantly reduce survival and retard development of frog tadpoles. Levels of 600 ppm have been shown to cause abnormalities in frog embryos. Most freshwater systems have salinity levels under 250 ppm. However, in Saskatchewan some wetlands that occur on Solonetzic (saline) soils have high salinity levels.

High nutrient loadings support vegetation growth which can become too dense for tadpoles to use. High nutrient loadings also support snails which are the vector for trematodes which parasitize tadpoles.

Habitat Quality – Water Quality

100	Waterbody surrounded by at least 200 m of permanent cover of grass and/or forbs; and Total dissolved solids <250 ppm; and Riparian Health Assessment = Healthy
50	Waterbody surrounded by cropland but with a minimum 10 m vegetated buffer; and Total dissolved solids <1000 ppm; Riparian Health Assessment = Healthy or Healthy with Problems
0	Any of the following: Waterbody surrounded by cropland without a vegetated buffer or adjacent to a construction zone, intensive livestock operation or other development; or Total dissolved solids >1000 ppm; or Riparian Health Assessment = Unhealthy

FORAGING HABITAT CRITERIA

5. Both tadpoles and adult frogs require habitat in which to forage for food. This habitat may include littoral zones (of particular importance for tadpoles), riparian areas or upland habitat. It is not presently thought that the availability of prey is a limiting factor for Northern Leopard Frog.

    5.1. Emergent vegetation is necessary to produce food for Northern Leopard Frog tadpoles and to provide hiding cover for the tadpoles to evade predators. Young of the year adults tend to stay near or in the breeding pond and also require emergent vegetation. Dense or tall vegetation eliminates basking opportunities and acts as a wall to Northern Leopard Frog. Adult frogs require deeper water that they can use to avoid predators. **(Max points = 100)**

Habitat Quality – Emergent Vegetation and Water Depth

100	Intermediate emergent vegetation (i.e., Classes 8 – 10 density distribution from SK PCAP Rangeland Health Assessment manual;); and water deeper than 50 cm adjacent to littoral zone or riparian area
50	Sparse or patchy shorter native vegetation such as sedges; and water deeper than 20 cm adjacent to littoral zone or riparian area
0	Dense emergent vegetation, dense cattails or invasive species such as reed canary grass, northern loosestrife or flowering rush; or only shallow water available.

    5.2. About 80% of adult frogs forage within 100 m of the breeding waterbody. Therefore, perennial cover is required adjacent to breeding waterbodies for foraging. This vegetation cover may be riparian or upland vegetation. Sparse short vegetation facilitates movement and prey detection, whereas dense, tall vegetation facilitates predator avoidance and prey production. **(Max points = 100)**

Habitat Quality – Riparian and Upland Habitat

100	200 m to 2 km of permanent cover adjacent to breeding waterbody; vegetation generally between 15 and 30 cm in height; heterogeneity (patchiness) of vegetation height and density
50	100 to 200 m of permanent cover adjacent to breeding waterbody; vegetation generally less than 15 cm in height or greater than 30 cm in height; heterogeneity (patchiness) of vegetation height and density
30	<100 m of permanent adjacent to breeding waterbody; and / or homogenous vegetation height and density

6. The configuration of the three primary types of habitat (overwintering, breeding and foraging) is important to the success of Northern Leopard Frog survival and reproduction. The further frogs need to travel between habitats, the less likely they are to survive.

Habitat Configuration

200	Breeding and overwintering habitat, along with foraging habitat for tadpoles and young of the year, occur in the same waterbody, or are separated by less than 100 m; and Perennial cover for foraging extends more than 200 m from the breeding waterbody.
100	Breeding and overwintering habitat is separated by 100 to 500 m; and Perennial cover for foraging extends more than 100 m from the breeding waterbody.
50	Breeding and overwintering habitat is separated by more than 500 m; or Perennial cover for foraging extends for less than 100 m from the breeding waterbody.

7. Ideally, overwintering and breeding habitat occur in the same waterbody with optimal foraging habitat adjacent to that waterbody and extending to at least 200 m , and all habitats can be managed as one unit.

Habitat Management

200	All three types of primary habitat are within the area of consideration and controlled by a single land manager
100	The three types of primary habitat are controlled by more than one land manager, but are within close proximity (500 m) and suitable corridor habitat exists between habitats
50	The three types of primary habitat are controlled by more than one land manager, and are further than 500 m apart, or suitable corridor habitat does not exist between habitats

8. Young frogs may disperse as far as 8 km from the breeding waterbody. In order to facilitate dispersal to new areas, suitable corridor habitat must exist. If overwintering, foraging and breeding habitats are separated by more than 200 m, suitable corridor habitat must exist to connect these habitats.

Habitat Corridors

100	Lush vegetation and moist soils in gullies, seeps, riparian corridors, ephemeral or permanent watercourses are present between seasonal habitats; the vegetation and litter component of these areas are heterogenous in structure and amount
50	Lush vegetation and moist soils in gullies, seeps, riparian corridors, ephemeral or permanent watercourses are present between seasonal habitats ; the vegetation and litter component of these areas are homogenous in structure and amount
0	No suitable corridor features

9. Interaction with other species at risk (SAR): Other SAR may exist in the area. The presence of optimal Northern Leopard Frog habitat may have a positive, negative or neutral effect on the other SAR found in the area of consideration. (**Max points 30**)

Interaction with other Species at Risk

30	Northern Leopard Frog habitat contributes positively to other area SAR.
0	Northern Leopard Frog habitat has no impact on other area SAR.
-30	Northern Leopard Frog habitat has a negative impact on other area SAR

EBI= ((1)(2)+(3.1+3.2+3.3+3.4+3.5)+(4.1+4.2+4.3+4.4+4.5)+(5.1+5.2)+6+7+8+9)

REFERENCES

Adama, D., and K. Kendell. 2004. Rearing *Rana pipiens* for Conservation: Two Approaches to Captive Rearing. In T.D. Hooper, ed. Proc. of the Species at Risk 2004 Pathways to Recovery Conf. March 2-6, 2004, Victoria, B.C. Species at Risk 2004 Pathways to Recovery Conference Organizing Committee, Victoria, BC. 14pp.

Alberta Sustainable Resource Development. 2003. Status of the Northern Leopard Frog in Alberta: update 2003. Alberta Sustainable Resource Development, Fish and Wildlife Division, and Alberta Conservation Association, Wildlife Status Report No. 9 (Update 2003), Edmonton, Alberta. 61 pp.

Bradford, D.F. 1983. Winterkill, oxygen relations, and energy metabolism of a submerged dormant amphibian, Rana muscosa. Ecology **64**(5): 1171-1183.

CEC. 2013. Prairie Beef and Biodiversity: A Payment for Ecosystem Services Program Design for Ranches on Natural Grasslands in Canada. Montreal, Canada. Commission for Environmental Cooperation. 29 pp.

COSEWIC. 2009. COSEWIC assessment and update status report on the Northern Leopard Frog *Lithobates pipiens*, Rocky Mountain population, Western Boreal/Prairie populations and Eastern populations, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 69 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Cottonwood Consultants Ltd. 1986. An overview of reptiles and amphibians in Alberta's grassland and parkland natural regions. Prepared for World Wildlife Fund Canada (Wild West Program), Toronto, ON. 63+ pp.

Dodd, C.K. 2013. Frogs of the United States and Canada, 2-vol. set. JHU Press.

Environment Canada. 2013. Management Plan for the Northern Leopard Frog (Lithobates pipiens), Western Boreal/Prairie Populations, in Canada. Species at Risk Act Management Plan Series. Environment Canada, Ottawa. iii + 28 pp.

Environment Canada. 2009. Petroleum Industry Activity Guidelines for Wildlife Species at Risk in the Prairie and Northern Region. Canadian Wildlife Service, Environment Canada, Prairie and Northern Region, Edmonton Alberta. 64p.

Hine, R. L., B. L. Les, and B. F. Hellmich. 1981. Leopard Frog populations and mortality in Wisconsin, 1974-1976. Department of Natural Resources, Madison, Wisconsin, 39 pp.

Karraker, N.E. 2007. Are embryonic and larval green frogs (*Rana clamatans*) insensitive to road deicing salt? Herpetological Conservation and Biology 2(1):35-41.

Kendell, K. 2002. Survey protocol for the Northern Leopard Frog. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Report No. 43, Edmonton, AB. 30 pp.

Kendell, K., Stevens, S., and D. Prescott. 2007. Alberta Northern Leopard Frog Survey, 2005. Technical Report, T-2007-001, produced by Alberta Conservation Association, Edmonton, Alberta, Canada. 18 pp + App. Accepted by ACA Report Series.

Larson, K.A. 2004. Advertisement call complexity in Northern Leopard Frogs, *Rana pipiens*. Copeia 2004(3): 676–682. doi: 10.1643/CH-03-247R2.

Merrell, D.J. 1970. Migration and gene dispersal in Rana pipiens. Am. Zool. 10(1): 47-52.

Merrell, D.J. 1977. Life history of the Leopard Frog, *Rana pipiens*, in Minnesota. *In* Occasional Papers. Bell Museum of Natural History, Minneapolis, Minnesota. p. 22.

Michalsky, S. and H. Peat Hamm. 2009. Prairie Species at Risk Beneficial Agricultural Practices Pilot Project – A State of Knowledge. Report, Fact Sheets and Databases. Manitoba Habitat Heritage Corporation: Winnipeg.

Ministry of Environment, Fish, Wildlife and Lands Branch. April 2017. Activity Restriction Guidelines for Sensitive Species. Regina, Saskatchewan.

MWPARC. 2009. Prescribed Fire Use and Important Management Considerations for Amphibians a nd Reptiles within the Midwest. 10 pp.
https://www.mwparc.org/products/fire/PARC_Prescribed_Burning_Guidelines_Final_Edition_10-11-09.pdf

PCAP SK. 2017. Guide to managing for optimal habitat attribute: Piping Plover (*Charadrius melodus circumcinctus)* 24pp.

Saskatchewan Prairie Conservation Action Plan (PCAP). 2008. Streams and Small Rivers Riparian Health Assessment Workbook. ISBN: 978-0-9809462-2-2.

Saskatchewan Prairie Conservation Action Plan (PCAP). 2008. Riparian Health Assessment for Lakes, Sloughs and Wetlands.
http://www.pcap-sk.org/rsu_docs/documents/Lakes_Sloughs_and_Wetlands-Blue.pdf

Peat Hamm, Heather. 2017. Saskatchewan Species at Risk Farm Program Workbook. Simply Agricultural Solutions: Saskatoon. 179 + v pp.

Pearson, Kim. 2018. Ecosystem Scientist, Parks Canada. Personal Communications regarding habitat features appropriate for Northern Leopard Frogs transplanted from Grasslands National Park to Waterton Lakes National Park.

Ranchers Stewardship Alliance Inc. 2014. Prairie Beef & Biodiversity Program: Results-based Module for Greater Sage Grouse. 19pp.

Randall, L.A., Chalmers, L.D., Moehrenschlager, A., and Russell, A.P. 2014. Asynchronous breeding and variable embryonic development period in the threatened Northern Leopard Frog (Lithobates pipiens) in the Cypress Hills, Alberta, Canada: conservation and management implications. The Canadian Field-Naturalist 128(1): 50-56.

Seburn, C.N.L., D.C. Seburn and C.A. Paszkowski. 1997. Northern leopard frog (*Rana pipiens*) dispersal in relation to habitat. Pp. 64–72. *In* Green, D.M. (Ed.), Amphibians in Decline: Canadian Studies of a Global Problem. Herpetological Conservation, Number 1, Society for the Study of Amphibians and Reptiles, St. Louis, Missouri.

Schiesari, L., E.E. Werner, and G.W. Kling. 2009. Carnivory and resource-based niche differentiation in anuran larvae: implications for food web and experimental ecology. Freshw. Biol. **54**(3): 572-586.

Sommers, Marcus, Lea A. Randall, and Robert MR Barclay. "Effects of environmental variables on the calling behaviour of Northern Leopard Frogs (Lithobates pipiens) in Alberta." *Canadian Journal of Zoology* ja.

Stevens, S.D, D. Page, and D.R.C. Prescott. 2010. Habitat suitability index for the Northern Leopard Frog in Alberta: model derivation and validation. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Report No. 132, Edmonton, AB. 16 pp.http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=552

Sutton, W. B. 2004. The Ecology and Natural History of the Northern Leopard Frog, Rana pipiens Schreber, in West Virginia. Thesis submitted to The Graduate College of Marshall University. 110 pp.

Wagner, G. 1997. Status of the Northern Leopard Frog (Rana pipiens) in Alberta. Alberta Environmental Protection, Wildlife Management Division, Wildlife Status Report No. 9, Edmonton,