Pyramid Lake Paiute Tribe

P.O Box 256, Nixon, NV 89424, Phone (775) 574-0101, EXT. 25

PUBLIC COMMENT

The Pyramid Lake Paiute Tribal Wetlands Program is posting for Public Comment:

The Northern Leopard Frog Management Plan

1st Draft

Purpose:

This management plan addresses the biology, ecology, and conservation of the Northern Leopard Frog. The goal is to provide a current summary of the health and distribution of Northern Leopard Frog populations throughout the region, and determine future management strategies for population expansion and reintroduction into ancestral ranges throughout the Pyramid Lake Reservation.

If you would like to receive a copy of the Northern Leopard Frog Management Plan please contact Wetland Specialist, Emily Hagler (Gibson) at 775-574-0101, EXT. 25

(or)

link to our Departments Water Quality Website for the Full PDF at: http://www.plptwq.org/northern-leopard-frog-management-plan

(or)

Submit your comments to:
Pyramid Lake Wetlands Program
Attn: Emily Hagler
PO Box 256
Nixon, NV 89424

Comments will be accepted through October 8, 2019 4:30 p.m.

Pyramid Lake Paiute Tribe
Natural Resources Department
Northern Leopard Frog Management Plan

Version 1.0
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Author – Emily Hagler
Review – Kameron Morgan

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Introduction

The northern leopard frog (*Lithobates pipiens,* previously *Rana pipiens*) is a widespread species that has experienced significant declines across most of its range, while remaining abundant in regions of the United States. The species has been extirpated from a majority of its historical range throughout the Tahoe-Pyramid Watershed and is known to inhabit only a limited number of sites of the Pyramid Lake Paiute Reservation (PLPR). Factors contributing to northern leopard frog (NLF) population declines include habitat destruction, disease, chemical contamination, acidification of water, increased ultraviolet light due to loss of the ozone layer, introduced non-native predators, over collection, a changing climate, hydromodification and other general environmental degradation. However, no one cause is known to be the primary factor behind population declines. Instead, it is expected that multiple site-specific factors are involved.

Habitat degradation and elimination are ongoing threats throughout the watershed and much of the species range. NLF habitat has been altered throughout the century, resulting in various degrees of degradation along a majority of the lower Truckee River corridor through the impacts of grazing, recreation, urban development and hydrologic alteration.

The most significant historical action being the construction of Derby Dam in 1905 and subsequent channelization of the lower Truckee River in 1962 by the U.S. Army Corps of Engineers (USACE), which resulted in changes to the natural hydrology of the lower river corridor. Derby Dam was constructed to divert water via the Truckee Canal for agricultural uses in the Carson River watershed, resulting in a drastic reduction of flows in the lower Truckee River. Furthermore, channelization of the river as a result of the Flood Control Act of 1954 caused extensive erosion in the riverbed, and increased flooding downstream from the channelized areas. Alterations to seasonal flooding patterns and reduced natural recruitment in the riparian plant community have led to extensive declines in the wildlife populations dependent on riverine habitat (Roodet al. 2003). Changes to the riparian corridor has severely affected local populations of NLFs. The NLF was historically one of the most visible and abundant amphibians throughout much of the U.S. and southern Canada. However, in some regions, including northern Nevada, it has now been almost completely extirpated. Collaborative and comprehensive management actions are necessary for the preservation of this species into the future.

This management plan was developed with the support of the U.S. Environmental Protection Agency (EPA), Region 9. The 2007 publication of *The Northern Leopard Frog (Rana pipiens): A Technical Conservation Assessment*, by the U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, Species Conservation Project, was used as a model in the development of this site-specific management plan. This is a “living” document directing tribal actions in attainment of established long-term goals. The after-mentioned written record represents the most current version by which the Pyramid Lake Wetland Program is guided in day-to-day operations, as well as in major decisions. Any changes, corrections or deletions must be directed to the Pyramid Lake Paiute Tribal Council for approval.

Goal

This management plan addresses the biology, ecology, and conservation of the NLF. The goal is to provide a current summary of the health and distribution of NLF populations throughout the region and determine future management strategies for population expansion and reintroduction into ancestral ranges throughout the PLPR.

Management Strategies

Federal Designations

The U.S. Fish and Wildlife Service (USFWS) was petitioned in 2006 and 2011 to add the western United States (U.S.) population of the NLF to the list of threatened species, protected under the Endangered Species Act (ESA). Under the ESA, animal populations that are discrete, significant and threatened can be considered for protection as a “distinct population segment” (DPS). Analysis of genetic data indicates that, while there are genetic differences among leopard frogs, the populations are not marked separately. Therefore, the western U.S. populations do not qualify as a DPS. The USFWS then evaluated the status of the entire species. While the species has experienced reductions in its historical range, particularly in the western U.S. and western Canada, the species is still considered to be widespread and relatively common in the eastern U.S. and eastern Canada. Threats at the species level do not indicate that the NLF is in danger of extinction, or likely to become so within the foreseeable future, throughout all or a significant portion of its range. It was determined by the USFWS in both these cases that listing was not warranted. Currently, there is no federal designation for the NLF.

State and Tribal Designations

The NLF has no special status (i.e., threatened or endangered) in most states where it occurs. However, the state of Nevada has several designations for the species. NLFs are listed a protected amphibian (NAC 503.075.2) by the State of Nevada. Additionally, the Nevada Bureau of Land Management classified the species as sensitive. Furthermore, the species was listed in the Nevada Wildlife Action Plan (2012, 2005) as a species of conservation priority. Furthermore, the PLPT has taken several actions to conserve the dwindling species; identifying the NLF as a species of concern in 2018, through resolution (PL 33-17).

Biology and Ecology

Description and Systematics

The NLF is a ranid frog of moderate size (5.1 to 9.0 cm snout-vent length), with brown or green background color, and two or three irregular rows of dark spots on the dorsum. It is also characterized by conspicuous dorsolateral ridges bordering the spots at the edge of the dorsum. Males have swollen thumbs on their forefeet, paired vocal pouches at the sides behind the head, which are visible when vocalizing, and are usually smaller than females in body size. Tadpoles of most frogs are difficult to identify without technical expertise. Tadpoles are brown, olive, or gray above and white below. The vent is located on the lower right side of the midline on the body near the tail fin. Leopard frog tadpoles can reach total snout-vent lengths of 3.4 inches (87 mm).

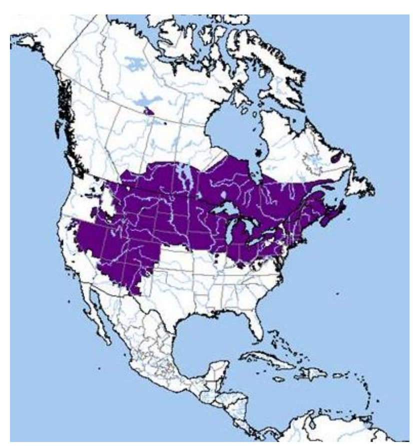

Figure 1: Historic Range of the NLF.

Distribution and Abundance

The NLF is a species of cooler climates, with a range that encompasses most of the northern states of the U.S. and stretches north into Canada (Figure 1). Table 1 (Appendix A) lists the states and provinces in which the NLF is found, historical abundance (if known), present abundance (if known), and the population trend (where known). While historically abundant throughout its range, the abundance and distribution of the species has retracted.

In the western U.S., the species has undergone major declines, suffering extinctions in some areas (Rorabaugh 2005). NLFs were once the most common and widespread species of amphibian in the state. In 1940, a study recorded leopard frog presence on the Truckee River as far upstream as Verdi and as far downstream as Willows Beach on the PLPR (Lindale 1940). In 2004, a survey on Truckee River amphibians found only one remaining population of NLFs, located on the PLPR between Wadsworth and Nixon (Panik & Barrett 1994). Surveys of the distribution of NLFs in Nevada suggest significant population losses statewide over the last 70 years. Hitchcock's (2001) resurvey of historically occupied sites across Nevada revealed leopard frogs at only 18 of 97 sites (Fig. 2, from Hitchcock 2001) with populations largely extirpated from the north-central and northwestern portions of the state. In Nevada, leopard frogs were once common along the Truckee, Carson, and Walker rivers; however, recent surveys have found only four occupied locations within these three watersheds. Today, populations are in decline, especially along the Truckee, Carson and Walker Rivers (Rogers & Peacock 2012).

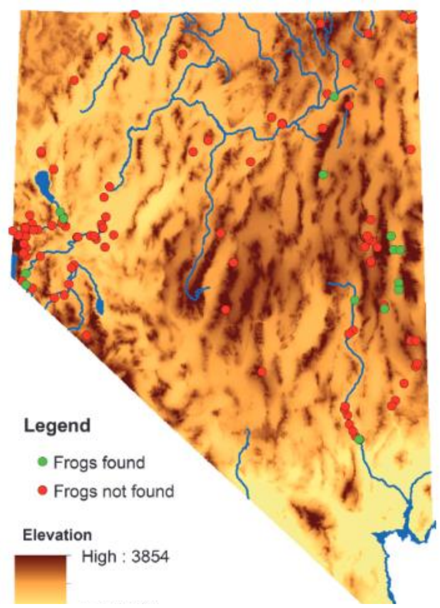

Figure 2: 2001 Hitchcock findings of NLFs in Nevada.

Migration and Movement

In fall, frogs migrate to overwintering sites in ponds, streams, inundated wetlands, and rivers. Fall migration of NLFs usually occur at night from mid-September through October, but appears to end by late October. At the overwintering area in the fall, disturbance of frogs causes them to swim directly into deep water, in contrast to their summer behavior in which they tend to return to shore. Frogs hibernate on lake bottoms, often under debris, and they tend to congregate near areas of high oxygen concentration such as the bottom of spillways (Merrell 1970). They may also excavate shallow pits on the bottom of sandy ponds as overwintering sites (Emery et al. 1972).

Habitat

NLFs require a diverse range of habitats in close proximity due to their complicated life cycles. Merrell and Rodell (1968) categorized three major habitat types: winter habitat (overwintering in lakes, streams, inundated wetlands and ponds), summer habitat (feeding by adults in upland areas), and tadpole habitat (up to three months spent as tadpoles in shallow breeding ponds). To understand the types of habitats used by NLFs, the habitat they use throughout various stages of their life history must be considered in all management approaches. Their complex movement patterns during the year must also be considered, including: habitat used for reproduction, natal dispersal, summer feeding ranges, fall migrations, and overwintering. It should also be recognized that the relevant published literature that characterizes NLF habitat comes from populations scattered across North America. Consequently, it is likely that differences in habitat use by NLFs exist regionally.

Breeding and Tadpole Habitat

Several extensive studies have been conducted throughout the U.S. of the life history of the NLF. Various research studies have shown that NLFs breed in mid-sized ponded wetlands that do not support fish populations, are generally disconnected from other bodies of water, and dry up during droughts. The most important habitats for breeding and tadpole development for NLF are semi-permanent to seasonal palustrine habitats that tend to last from 30 days to one year, with an open canopy, Werner and Glennemeier (1999), Merrell (1977). Palustrine systems with an unconsolidated bottom generally have a mud bottom and vegetative cover less than 30 percent, which is ideal conditions for tadpoles. Tadpoles require bodies of water with no overhead canopy and that are free of predaceous species (Kruse and Francis 1977, Hecnar and M'Closkey 1997a, Werner and Glennemeier 1999). These bodies of water should be reasonably shallow so that the sun can heat them to temperatures suitable for rapid development, especially at higher elevations where the growing season may be short. However, the ponds should not be too shallow because they can dry too rapidly for tadpoles to complete their 58 to 105-day larval period (Hammerson 1999).

Subadult and Adult Habitat

The NLF is one of the more terrestrial of the ranid frogs, using a considerable amount of upland habitat around breeding ponds. Following reproduction, adult NLFs move into upland habitat in which they may feed for the summer. The species tends to frequent grassy expanses in the summer when grass was from several centimeters to a half a meter in height. Many studies identified movements by this species of up to 3.0 km from water, and Dole (1971) notes that subadults move up to 5.2 km away from natal ponds.

In various locations across their range, subadult frogs, after completing their larval period, migrate across land to suitable feeding sites. The habitat through which successful dispersal occurs is not known completely. Frog movements among habitats and pond spacing are two of the most important factors to consider in management of NLFs, as both factors are likely to affect population density in this species greatly. The pattern of spacing of suitable breeding sites across the landscape and upland movements made by NLFs are both significant in colonization or recolonization of ponds, and the maintenance of healthy metapopulations.

Adult Overwintering Habitat

In the fall, subadult and adult frogs migrate to overwintering sites. Little is known of potential overwintering sites for NLFs; however, winter habitat is expected to be similar to that throughout the species' range. It is theorized that NLFs utilize bottoms of flowing streams and ponded wetlands (and possibly springs) that are large enough that they do not freeze solid in winter. However, there could be local adaptations to other suitable habitat of significance.

Overwinter mortality may be important for NLFs, as it is for other ranid frogs. Especially important is oxygen depletion at overwintering sites (Merrell and Rodell 1968, Bradford 1983), which accounts for the pattern of frogs to overwinter at inflow areas where oxygen saturated water is relatively abundant (Oldfield and Moriarty 1994). It may also be why they overwinter in streams, where oxygen saturation is typically higher than in ponded wetlands, and lakes. This further emphasizes the importance of permanently flowing streams, springs, and riparian buffers as overwintering sites in the region. Overwintering sites on the PLPR is unknown.

Food and Feeding Habits

Most of what is known about the food habits of tadpoles, subadults, and adult NLFs is anecdotal. NLF tadpoles are generalist herbivores, occasionally scavenging dead animals including conspecifics. Franz (1971) found that NLF tadpoles mostly ate various species of free-floating green algae and blue-green algae.

NLFs become carnivorous at metamorphosis, and are opportunistic insectivores with a propensity to consume anything that moves and is small enough to be swallowed, including smaller NLFs (Drake 1914, Linzey 1967, Merrell 1977, Miller 1978). They primarily eat insects: spiders, mollusks, crustaceans, and various other arthropods, coleopterans (beetles) and orthopterans (grasshoppers), but also dipterans (flies and associated groups), hemipterans (true bugs), and hymenopterans (wasps and their allies), Whitaker (1961), Drake (1914).

Breeding Biology

As soon as males leave overwintering sites, they travel to breeding ponds and call in shallow water of suitable wetland sites. Like many pond-breeding frogs, male NLFs attract females by breeding calls from specific locations within a breeding sight, with several males typically calling together to form a breeding chorus. Females come to males and breed at the calling sites. After breeding, females immediately leave the ponds while males stay in the chorus continuing to call, resulting in a preponderance of males at breeding ponded wetlands (Merrell 1977).

Specific sites used for calling and breeding have been described as being the warmest part of the pond, typically in water of 40 cm depth or less in an unshaded location with maximum exposure to sunlight (See PLPT Wetland QAPP). Daytime air temperatures are usually required to be greater than 20 °C for calling to begin.

NLFs show geographic variation in the timing of reproduction and egg-laying that is determined by various environmental cues. At lower elevations, NLFs began breeding in March, but at higher elevations, they often did not start breeding until April or May (Hammerson 1999). Eggs are laid within two to three days following the onset of chorusing (Corn and Livo 1989). In Northern Nevada, the timing of reproduction is uncertain, but calling has been heard in April at mid-elevation (~1200 m) ponds and as late as in May and June as observed by the PLPT Wetland Program. Annual precipitation, runoff, and temperatures heavily influence the timing of breeding on the PLPR.

The number of eggs laid in a clutch varies widely, even within a population. Eggs are deposited as single large round masses 5 to 13 cm in diameter, and they are black in color. Furthermore, they are attached to emergent vegetation such as sedges (*Carex* spp.) or rushes (*Scirpus* spp.). Eggs masses are attached to vegetation just below the surface in warm, shallow water from 7 to 25 cm deep, in areas that are exposed to the sun.

Hatching and time of metamorphosis varies geographically and attitudinally, dependent on environmental variables, especially temperature. Hatching occurs after 5 to 20 days' dependent on a host of ecological conditions including temperature, canopy, water depth and the local weather. Wright and Wright (1949) reported that tadpoles usually transformed in 60 to 80 days. Local baseline data of breeding biology on the PLPR has been inconclusive, more work in identifying influential factors is needed.

Population Demography

Current data on age to maturity, age at first reproduction, and age at death is inconclusive; very little is known about age-specific survival rates. Generally, NLFs do not become sexually mature until their first year following metamorphosis, and most are not sexually mature until their second year, sometimes longer other regions. Similarly, the average life expectancy of a NLF is unknown. Although Flower (1936) reported that a captive leopard frog lived for five years and 11 months, Leclair and Castanet (1987) found few frogs older than four to five years. It is reasonable to assume from these data that most NLFs, living in the wild, seldom reach their sixth year. It is also reasonable to conclude that female NLFs may breed two or three times during their lives, and no more than four times.

Community Ecology

Several studies have been conducted on NLFs and their role in amphibian communities (DeBenedictis 1974, Smith-Gill and Gill 1978, Woodward 1982, 1983, McAlpine and Dilworth 1989, Hecnar and M'Closkey 1998, Relyea and Werner 2000, Relyea 2001a, 2001b). Although no studies examining NLFs or their role in structuring the community have been completed in Nevada, PLPT Wetland Program staff have observed NLF tadpoles dominating in some semi-permanent wetlands during the spring and early summer, when bullfrogs are not present. Woodward (1982, 1983) found that temporary pond breeders were often superior competitors to permanent pond breeders, and that some temporary pond breeders ate tadpoles of permanent pond breeders (Woodward 1982). Although they are at a competitive disadvantage to temporary pond breeders, NLF tadpoles are better able to avoid predation because they tend not to move very much, as compared to tadpoles of temporary pond breeders. It has also been found that there are more tadpole predators in permanent ponds, thus explaining why NLFs have evolved this important behavioral trait.

Natural Predators

A variety of predators eat NLFs at all life stages. Most mortality occurred in the tadpole stage and was largely caused by predators, although overwintering mortality was important to subadults (i.e., recently metamorphosed tadpoles). Various early authors recorded the following as predators of tadpoles: waterfowl, garter snakes (*Thamnophis* spp.), water snakes (*Nerodia* spp.), fishes, leeches, and aquatic insects, including diving beetle larvae and adults (Dytiscidae), dragonfly larvae (Libellulidae), caddisfly larvae (Phryganeidae), backswimmers (*Notonecta* spp.), and giant water bugs (*Belostoma* spp.). Spiders (Lycosidae and Pisauridae) may also eat tadpoles (Merrell 1977).

Introduced Predators

Introduced predators have the capacity to overcome NLF populations since the frogs have not co-evolved with such predators. Bullfrogs are well known to cause the elimination of populations of ranid frogs, especially in the western U.S. and lower Truckee River, where bullfrogs have been widely introduced (Stebbins and Cohen 1995). Although NLFs and bullfrogs co-occur in parts of their range, in areas where bullfrogs and NLFs are not sympatric and in which bullfrogs have been introduced, NLFs have declined (Hammerson 1982, 1999). Bullfrogs directly predate all indigenous frog species and are opportunistic hunters. Consequently, the establishment of non-native populations of bullfrogs should be treated as a major management problem for the persistence of native frog populations.

Introduced predaceous fish known to occur in parts of the lower Truckee River include: rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta),* largemouth bass (*Micropterus salmoides*), sacramento perch (*Archoplites interruptus*), green sun fish (*Lepomis cyanellus*), and bluegill (*Lepomis macrochirus*). These species are known to eat tadpoles as well as frog eggs. NLFs have no natural defense against predaceous fish, the widespread establishment of these species is a serious issue. On the PLPR native and non-native predation fish inhabit the Truckee River corridor and have pioneered into developed wetlands adjacent to the Truckee River. Their influence on the current population distribution of NLFs is unknown. Predation fish also eat overwintering NLFs, which are extremely vulnerable (Emery et al. 1972).

Aquatic Invasive Species

There are several species and aquatic invasive species throughout the Truckee River system that have altered habitat conditions for the NLF. One species of concern for habitat distribution is the common carp (*Cyprinus carpio*). It is regarded as a pest fish because of its widespread abundance and because of its tendency to destroy vegetation and increase water turbidity by dislodging plants and rooting around in the substrate, causing a deterioration of habitat for species requiring vegetation and clean water (Cole 1905; Cahoon 1953; Bellrichard 1996; Laird and Page 1996). Available literature indicates common carp may destroy aquatic macrophytes directly by uprooting or consuming the plants, or indirectly by increasing turbidity and thereby reducing light for photosynthesis. Carp have had noted adverse effects on biological systems including destruction of vegetated breeding habitats used by both fish and amphibians, and an increase in turbidity.

Furthermore, as the PLPR is at the terminus of the watershed controlling aquatic invasive species source populations upstream of the PLPR boundary is convoluted. The Truckee River watershed spans 3,060 square miles, of which 2,300 square miles are in Nevada and the remaining are in California; it flows through four counties (Placer County, CA; Nevada County, CA; Sierra Country, CA; Washoe County, NV) Major tributaries to the Truckee River in California from the Lake Tahoe outlet and heading downstream include: Bear Creek, Squaw Creek, Cabin Creek, Pole Creek, Donner Creek, Trout Creek, Martis Creek, Prosser Creek, the Little Truckee River, Gray Creek, and Bronco Creek. Major lakes and reservoirs in the California part of the watershed include Lake Tahoe, Donner Lake, Independence Lake, Webber Lake, Boca Reservoir, Stampede Reservoir, Prosser Creek Reservoir, and Martis Creek Reservoir.[10] In the Lower Watershed, Steamboat Creek, which drains Washoe Lake, is the major tributary to the Truckee River. These factors all play a roll in the distribution and density of aquatic invasive species on the lower Truckee River.

Competitors

In amphibian assemblages, the most obvious stage at which competition occurs is the larval period.

Tadpoles of other amphibian species may have similar diets to those of NLFs, and so they may compete with each other for limited resources in typically confined breeding ponds. Interactions during this life stage have been emphasized in studies of amphibian competition.

On the PLPR, NLFs co-occur with bullfrogs, western mountain toads (*Anaxyrus boreas*), and pacific tree frogs (*Pseudacris regilla*), and may breed in the same or adjacent sites. These species may compete as larvae, but no studies of competition between these species have been done.

Parasites and Disease

Three basic types of diseases have been identified in amphibians: viruses, fungal infections, and bacterial infections. Viruses and fungal infections have been implicated in mass-mortality events. However, the bacterial diseases collectively called “red leg” has been reported to cause mass mortality events. The term ”red leg” may refer to the symptomology of a variety of different bacteria (Faeh et al. 1998) but is frequently associated with *Aeromonas hydrophila*. However, Carey et al. (1999) stated that they believed that bacterial infections were largely secondary to fungal and viral infections.

Specific types of irido viruses known as rana viruses can infect ranid frogs, and some amphibian declines have been attributed to these viruses (Jancovich et al. 1997, Daszak et al. 1999). Rana viruses are extremely lethal with 100 percent mortality in most cases. Tadpoles are most susceptible to these viruses, but all life stages can acquire the disease. Infected metamorphs die without apparent signs of infection, and infected adults show no overt signs but may display a general weakness. Secondary bacterial infections are common during rana virus infection.

Although a link between rana viral infections and amphibian declines is suspected, it is less clear than the link between chytridiomycosis and amphibian declines. Chytridiomycosis, a disease of anurans caused by a chytrid fungus (*Batrachochytrium dendrobatidis, BD*), and it has been found in NLFs (Carey et al. 1999). The extent of this disease and mortality rates in NLFs are unknown. The signs of chytridiomycosis are loss of the righting reflex, lethargy, and abnormal posture (Daszak et al. 1999). BD is known to exist within the upper watershed, it has yet to be determined the extent of its occurrence on the lower Truckee River.

Parasites also pose a significant threat to many amphibians. It is common for NLFs collected in the wild to have a high parasite load. There have been various field investigations of the parasites of this species. Fried et al. (1997) found that some parasites are particularly lethal to NLF tadpoles. Of particular interest are trematode parasites in the genus *Ribeiroia*, which have emerged as a potential cause of limb abnormalities in Pacific treefrogs (Sessions and Ruth 1990, Johnson et al. 1999) and western mountain toads (Johnson et al. 2001). It is not known if any of these parasites contribute to population declines in NLFs.

Conservation Status and Threats

Causes of Downward Trends

Habitat loss and fragmentation along the Truckee River have been caused by a variety of land uses, including urbanization, agricultural cropland, hydromodification, and construction of roads and trails. Any kind of habitat fragmentation in any locality, including construction in relatively pristine areas, can result in loss of important habitat. For example, many Truckee River tributaries and upstream reservoirs are used for fishing, which often results in heavy use of sites near or in wetlands, and construction of shelters, picnic areas, recreational beaches, campsites, restrooms, walkways, and other structures. Because wetlands are popular areas for recreation, a variety of wetlands are being converted from wetlands suitable for NLFs to other uses.

Because of the popularity of fishing within the Truckee River system and other mountainous areas of the western U.S., fish stocking is a widely used practice and is likely having a tremendous impact on amphibian populations. Stocking also occurs in ponds and lakes that were naturally fishless, especially reservoirs that flow into the Truckee River. Some of these waters are likely critical to successful frog reproduction, and stocking of non-native species in these locations is particularly harmful. Given that the introduction predaceous fish have a detrimental effect on native amphibian populations, federal and state agencies should review their current stocking practices to consider the implications for native amphibian assemblages.

Introduction of diseases (e.g., chytridiomycosis and ranavirus) is also a concern. Such diseases can be lethal to local populations and are probably transmitted through a number of vectors, including humans (e.g., on clothing, boots, waders), but it is not known precisely how they move from population to population. One common practice in the Truckee River, its tributaries, and reservoirs that might result in the introduction of disease is the extensive introduction of predaceous fish for sport anglers and the use of bait, which is frequently dumped into ponds and lakes following fishing. In addition, diseases can be transported on muddy boots if they have been in aquatic habitats containing frogs of any species. Many species of animals (e.g., bullfrogs) use ponds similar to the ponds that NLFs inhabit (Rumble et al. 2004), and they could transport diseases on their bodies as they move from pond to pond. Introduced pathogens make their way downstream and eventually enter the PLPR affecting tribal amphibian populations of which the extent is unknown.

Extrinsic Threats

There are a number of potential threats to the continued viability of NLFs in the PLPR region. Although it is difficult to say which of these is most important, it is believed that risk factors threatening NLFs fall into three main categories: 1) landscape-scale processes that threaten the viability of populations, 2) direct threats of mortality from various non-indigenous biotic agents, and 3) water quality degradation.

Landscape scale changes such as loss and fragmentation of breeding habitat, disruption of migratory pathways, and loss or alteration of over-wintering sites, may have caused range-wide declines in NLFs. However, there is a lack of detailed data necessary to document these changes over the last 100 to 200 years of European settlement in the western U.S., and particularly on Tribal trust lands.

Livestock can have significant impacts on wetland and riparian vegetation and aquatic communities, including damage to streamside vegetation, increased sedimentation as a consequence of resulting erosion, and more rapid movement of water through stream systems where riparian vegetation is no longer present to stem water flow. The effects are a further reduction of water resources available to amphibians and a loss of effective habitat. While the lower Truckee River is closed to grazing and is fenced accordingly, on occasion cattle grain access to the river corridor through downed fences, gates left open, and through tribal allotments.

Human development of wild lands has been shown to affect amphibian populations negatively at the regional scale (e.g., Hecnar and McCloskey 1996). Lehtinen et al. (1999) showed that habitat fragmentation from development activities lowered amphibian species richness at 21 glacial lakes in Minnesota, where the NLF was the most abundant anuran. These authors found that amphibian species richness at ponds declined with distance from other ponds and with increased road density, both common results of urbanization. They also found that species richness declined as urban land use increased at all spatial scales, implying that increasing levels of urbanization should lead to decreased species richness, no matter the scale at which development takes place. They recommended that land management plans address landscape changes caused by urbanization and attempt to minimize such changes.

The expansion of development on formerly wild private/public land is a factor in current NLF population densities in the Truckee River Watershed. The loss of wild land has been extensive throughout the Truckee River region and is likely to continue into the foreseeable future. It is likely that urbanization has a negative effect on the lower Truckee River. Furthermore, human growth on nearby private land impacts tribal lands, upstream growth puts additional pressure on the watershed, with potentially detrimental impacts to local herpetofauna. Consequently, it is believed that habitat on the PLPR has become increasingly important to amphibians and wildlife in general.

The effects of introduced organisms on amphibians are extensively documented, and a review of this literature is beyond the scope of this management plan. In the case of the NLF, the effects of introduced predaceous fish and bullfrogs have already been discussed. Also relevant is the impact of diseases. Many organisms visit frog ponds, ungulates and other mammals, waterfowl, fishes, various species of insects, and doubtless others (Rumble et al. 2004), and they could move these diseases around the landscape, as could humans.

The complex life cycle of amphibians and the permeability of their skin make them especially susceptible to ecotoxicological agents (Cooke 1981, Duellman and Trueb 1986, Bishop 1992, Hall and Henry 1992). Diana and Beasley (1998) offered a concise review of toxicant studies in amphibians, including brief summaries of studies on polychlorinated biphenyls (PCB), benzene, phenol, crankcase oil, mercury, cadmium, lead, hydrogen ions (acidification), aluminum, nitrate fertilizers, trichlopyr, triazine herbicides, phenoxy herbicides, dipyridyl herbicides, glyphosate (found and tested in Roundup®), pyrethroids, cholinesterase- inhibiting insecticides, carbamate insecticides, organophosphorus insecticides, organochlorine insecticides, and rotenone. Collective results indicated that the number of common toxicants introduced into the environment constituted an enormous amount of chemical pollution and likely contributed to amphibian declines around the world. Breeding ponds used by NLFs collect all manner of toxicants from runoff, and are almost certainly exposed to these agents at all points in their life cycle. While the use of these toxicants is minimal on the PLPR, it should be addressed.

It is problematic to fully discuss the meaningful relationship between water quality issues and NLFs along the Truckee River as a whole. It is not possible to summarize the types of toxicants to which this species may be exposed without writing an extensive review of water quality throughout the region, which is beyond the scope of this document. However, we can more generally summarize the ecotoxicological hazards to which NLFs may be exposed. The following factors contribute to poor water quality in wetland habitats, frequented by NLFs:

Pesticides: One of the most studied classes of ecotoxicological agents. Throughout the upper Truckee River region, various pesticides are used, the most common being 2, 4-D Amine, Escort®, Plateau®, and Roundup®. Unfortunately, pesticide use is one of the more difficult inputs to study. However, many of the commonly used pesticides have short half- lives, usually from one week to 30 days. If used judicially, they may be more or less safe, but this depends on individual applicators. No region-wide statistics exist on the extent of the use of pesticides, and it is beyond the scope of this document to compile such data.

Fertilizers: Hecnar 1995 looked at the effects of fertilizers on NLFs. In this study, NLF tadpoles were exposed to chronic and acute doses of ammonium nitrate fertilizer. In acute tests, tadpoles suffered severe weight loss. In chronic tests, tadpoles not only lost weight, but there were mortalities as well. The NLF was the most severely affected of the species tested, which included American toads, boreal chorus frogs, and green frogs. Hecnar (1995) pointed out that the differential mortality of the species tested would likely cause shifts in species composition in free- living communities of amphibians. While fertilizer effects may not be significant in much of the PLPR. Upstream runoff from croplands, lawns, and golf courses affect anuran on the PLPR as it travels downstream.

Mining/metals: Mining has been practiced in parts of Northern Nevada and within the PLPR for at least 150 years. Although this activity has become less prolific in recent years, residue from abandoned mining sites continues to adversely affect many drainages. Mining causes acidification of water and leads to metals- laden effluent from mines and smelter sites (including surrounding soils) into receiving waters. Some authors have found devastating effects of mining on local herpetofauna, long after mines have closed (Porter and Hakanson 1976). Before 1900, mercury was used during the milling of ores from the Comstock Lode throughout many areas in the Truckee River Watershed. Steam Boat Creek is a tributary severely affected by mercury and other metals contamination, which originates at Washoe Lake where mills used mercury for gold and silver until the late 1800s. Mercury has since spread downstream of Washoe Lake, settling in the sediments in the lower Truckee River and Pyramid Lake.

From 2002-2005, Darell Slotton (UC Davis) and the Tribe conducted a preliminary assessment study of mercury bioaccumulation in Pyramid Lake and the lower Truckee River. Total and methylmercury were investigated in water, bottom sediments, invertebrates, small fish and large fish. Testing of water and bottom sediments in both Pyramid Lake and the Truckee River indicated that the upper Truckee River to be the primary source of total and methylmercury to Pyramid Lake. Furthermore, elevated levels of mercury in fish tissue samples were found to exceed EPA criteria.

Cattle grazing: Cattle produce considerable amounts of waste that run into waterways. Waste that may run off into amphibian breeding ponds. Grazing by cattle affects water quality (Buckhouse and Gifford 1976), water chemistry (Jefferies and Klopatek 1987), and water temperature (Van Velson 1979). The changes are subtle over time (Elmore and Beschta 1987), but they profoundly alter aquatic ecosystems (Kauffman and Krueger 1984). High levels of cattle grazing activity in and around frog breeding ponds leads to substantial increases in the levels of nitrates, and fecal coliform bacteria in these ponds. Tadpoles collected in a heavily polluted pond used by cattle in Lawrence County, South Dakota, had deformed mouthparts and irritated skin (Smith unpublished data 1998). Reaser (2000) found that cattle grazing influenced the decline of the Columbia spotted frog (*Rana luteiventris*) at a study site in Nevada. Ross et al. (1999) recommended that cattle be fenced out of sensitive wetlands in Nevada to conserve these frogs. No one, however, has investigated the specific agents causing amphibian declines in grazed areas. Excluding cattle from key breeding ponds used by this species, upstream drainages, and the surrounding upland habitat could mitigate impacts.

Sedimentation: Sedimentation can also run into waterways due to erosion from a variety of sources. Road cuts are sources of sedimentation; cattle are known to cause erosion by trampling and overgrazing streamside vegetation and slopes. Recent large fires throughout the PLPR could also contribute to sediment load in nearby waterways. Additionally, historical hydromodification of the river corridor has resulted in large scale sedimentation throughout the lower Truckee River and has had a tremendous impact on indigenous fish and amphibian population. Sedimentation can result in the covering of eggs resulting in their inability to preform gas exchange pertinent to egg development.

Water quality factors leading to limb malformations: Additionally, the reduction of water quality has the potential to affect amphibians, and NLFs appear to be more sensitive to many of these agents than most amphibians that have been studied. Because the Truckee River watershed and PLPR contain large and heterogenous ecosystems, it would be incredibly difficult to assess the potential impact of any of these agents on NLF's region-wide without an extensive watershed-wide study. The most important local water quality considerations are likely to be contributed to cattle, input of pesticides into streams and breeding ponds, mining and smelting and associated pollutants, and runoff from roadways (including sedimentation).

Furthermore, recent concern over climate change and corresponding loss of the ozone layer has prompted investigations of the effects of increasing levels of ultraviolet light on limb deformities in NLFs. Elevated levels of ultraviolet light can cause hind limb malformations in the laboratory (Ankley et al. 1998) and in the field (Ankley et al. 2000), but the significance of these results for NLF populations in natural situations remains unclear.

Inherent Vulnerability

The NLF is inherently vulnerable to disturbance factors for a number of reasons. On the PLPR, NLFs are periodically found on the riverbanks and near the mouth of the river; however, they are largely observed in a few wetlands near Wadsworth, NV, including on a tribal land assignment. It has been observed that there are many vulnerabilities in these locations that need to be addressed through management. Considering the after mentioned vulnerabilities of NLFs will assist in the management and recover of the species as on the lower Truckee River:

1. **Use of small ponds for reproduction.** NLFs use small (usually less than 5 ha) ponds and wetlands in which to breed (Merrell 1968, 1977, Collins and Wilbur 1978, Corn and Livo 1989, Hammerson 1999). It is imperative that management actions take into consideration the distribution of small ponds across the landscape.

2. **Need for fishless ponds for reproduction.** In much of their range, NLFs selectively breed in small, fishless ponds, and the introduction of predatory fish to such ponds is a well-known threat to

this species. Yet federal and state agencies introduce such fish throughout the Truckee River system. Because the PLPT does not manage the upper watershed, it is unlikely that fish introductions can be discontinued entirely. In addition, accidental or intentional introductions of predatory fish by the public will probably be difficult to prevent. A public information campaign to inform the public of the harm of accidental or intentional introduction of predatory fish into fishless ponds might help to reduce the frequency.

3. **Use of upland habitats for summertime foraging.** NLFs use moist upland habitats surrounding breeding ponds for summertime foraging. Preserving the lower Truckee River corridor is essential to preserving foraging habitat for the NLF. Encroachment from urbanization threatens these habitats, preserving existing habitat and improving degraded habitat, is vital to the preservation and recovery of the species.

4. **Highly permeable skin.** The skin of freshwater amphibians is highly permeable (Duellman and Trueb 1986). Consequently, toxins can be readily absorbed through the skin. Since NLFs serve as prey items for many species, the accumulation of toxins in their body tissues can have repercussions throughout the food web. In this sense, NLFs might serve as a key indicator species in ecosystems in which they occur. It is possible that population size and health of NLFs might indicate overall ecosystem health. However, there appears to be little work on the presence of toxins in NLFs in the wild.

5. **Susceptibility to introduced diseases.** NLFs are susceptible to various diseases. Chytridiomycosis is an emerging disease and, as such, may not be considered an intrinsic threat. Ranavirus, however, has probably always been a threat to NLF populations (Jancovich et al. 1997, Carey et al. 1999, Daszak et al. 1999).

6. **Necessity of overland migration routes between seasonal habitats and to reach and colonize new ponds.** NLFs move across the landscape for many reasons, including dispersal of metamorphs, summer movements associated with feeding, and migrations to and from overwintering sites (Dole 1967, Dole 1965b, Merrell 1977). The routes followed include wet meadows, wetlands, tall grass, and riparian corridors. These corridors can be affected by habitat degradation from a variety of causes.

Pyramid Lake Conservation and Management of the NLF

Implications and Conservation Elements

The following factors, in rough order of priority, should be considered when restoration planning is conducted focused on conserving NLFs on the PLPR:

- protection of known and potential breeding sites.
- control of introduced predaceous fish and bullfrogs.
- protection of overwintering sites.
- control of introduced infectious diseases.
- monitoring and protection of water quality.
- protection of migratory and dispersal pathways.
- Implementation of stream buffers

- Incorporate NLF habitat requirements in future restoration project
- other factors.

Prioritization is uncertain since risk factors will vary from site to site and are not completely known in many cases. Beyond the first two items, which are of nearly equal importance, the order of the list is highly speculative. What is not speculative, however, is the fact that all these factors have affected NLFs at study sites throughout North America, and likely impact PLPR populations.

Protection of Known and Potential Breeding Sites

The preservation of PLPR wetland resources is vital to provide protection for the species. While most PLPR wetlands are monitored annually, further protective and restorative commitments are needed to protect species specific habitat for NLFs on tribal lands. Specifically, relatively small (less than 5 ha) seasonal and semi-permanent wetlands used throughout the summer as foraging habitat must be protected (Semlitsch 1998, 2000a). Although Semlitsch (1998) refers to upland habitat as a buffer zone, it is more appropriately referred to as core habitat area and should be protected as such. Dole (1965a, 1965b) showed that NLFs typically used a home range of about 68 to 503 m^2, but his work does not provide guidance for how much upland core area should be protected to conserve an entire population, because some of the population will have home ranges farther from the breeding wetlands than other members of the population. Implementing conservation buffers in these areas is a management tool for conserving potential breeding sites.

Control of Predaceous fish

Introduced non-native predaceous fish have been clearly implicated in the decline of anuran (Bovbjerg 1965, Brönmark and Edenhamn 1994, Hecnar and M'Closkey 1997b), ongoing fisheries management by various species is beyond the scope of this management plan. It is difficult to resolve the conflict between fishing management priorities and the need to protect populations of NLFs and other amphibians. Fish found in desirable wetlands they might be safely removed using electroshock, but only when NLFs are not in the pond at the same time. If frogs use ponds for breeding and overwintering, it would be difficult or impossible to use this technique without damaging the frog population. In addition, ponds without frogs but with fish may become good frog habitat if fish were to be removed.

Coordination with regional federal and state agencies to collaboratively manage predacious fish is valuable to holistic management. U.S. Fish and Wildlife Services (USFWS) electroshock the lower Truckee River annually from Derby Dam to Marble Bluff. This strategy has removed large quantities of predation fish from the lower Truckee River. The continuation and expansion of these and similar practices can remove pressure on the species. Additionally, partnering with the Pyramid Lake Fisheries Department to annually drain wetlands with actively managed hydrology controlled by hatchery operations can result in the removal of predaceous fish and other aquatic invasive species.

Protection of overwintering sites

Overwintering mortality can be high at times in ranid frogs (Bradford 1983). It is important that overwintering sites be identified and protected. Unfortunately, no work has been done on the PLPR to survey, map or monitor overwintering sites. Without such specific investigations, further management actions to protect overwintering habitats are compromised. Mapping these habitats is cumbersome and costly, various simplified monitoring is encouraged to identify these ecological niches.

Control of introduced infectious diseases

All modes of transmission of infectious diseases are not known. It has been inferred that diseases can travel on any animal agent, including humans, from pond to pond. It is therefore assumed that limitation of travel by humans from pond to pond is desirable, but impractical. Animals are thought to be vectors; more research is necessary to determine their roles in the spread of diseases. Monitoring and reporting any occurrence of a disease in any anuran on the PLPR as part of management will improve conservation efforts.

Upon further examination of local infectious diseases if was concluded that the occurrence interval on the Truckee River is unknown. However, after communicating with the University of Nevada, Reno Herpetologist (Jamie Voylers) it was indicated that they are present in the watershed. Continuous monitoring and repeated laboratory screening is necessary for early detection.

Water quality

Water quality has major effects on amphibians, as we have discussed. Ponds, especially those known to have breeding or overwintering populations of frogs, should be monitored for water quality. Particularly those in close proximity to sources of pollutants, those where herbicides and pesticides may be used to control noxious weeds. It is recommended that all wetlands be sampled to PLPT Water Quality QAPP standards annually.

Protection of migratory and dispersal pathways

Dole (1965b, 1967, 1971) and Merrell (1977) found that leopard frogs use many routes and habitats for migration and dispersal, including wet meadows, tall grass, and riparian corridors. Habitat destruction and road construction interrupt these pathways, and it is likely that grazing does so as well. We suggest that these movement corridors be afforded protection, but there are no detailed studies that examine the management of such areas. It will be necessary to understand the landscape to manage migratory pathways. Also needed is basic knowledge of how frogs move among suitable breeding ponds.

Tools and practices

Considerations for inventory and monitoring

Comprehensive inventory and monitoring plans on a Reservation-wide scale, as well as establishing partnerships with upstream agencies is essential. Most importantly, staff must determine specific localities where NLFs are found within the PLPR by conducting basic inventories. Inventory can be simple, such as call survey, visual encounter surveys, egg mass surveys and drift fence pitfall traps monitoring that determine the presence or absence of breeding choruses across a landscape. It can be thorough as well, such as quadrant transect surveys, patch surveys, radio transmitter monitoring, toe clipping, passive integrative tag monitoring, and aquatic funnel trapping to determine the effective population sizes at sites where frogs are found. Depending on the monitoring techniques, some information on relative abundance can be gathered.

Regardless of monitoring strategy an extent, precise location data should be entered into a Geographical Information Systems (GIS) database, and data should be maintained and updated on a regular basis, so managers always have access to the most recent information.

Call Surveys

The simplest and most commonly used practice to survey amphibian populations is the call survey (Berrill et al. 1992, Peterson and Dorcas 1994, Zimmerman 1994, Bishop et al. 1997, Bonin et al. 1997, Lepage et al. 1997, Johnson 1998, Mossman et al. 1998). Call surveys may be set up a number of ways, including traveling along transects randomized by habitat, at locations specified along a roadway, and other methods. On the PLPR, the Wetland Program staff has carried out call surveys by first surveying during daytime hours for ponds in which NLFs may occur. Investigators then visit potential breeding ponds at night to listen for breeding choruses of frogs. Number of individuals in the chorus is then estimated by auditory means: 1) a few individuals calling sporadically, but calls widely spaced in time; 2) several individuals calling but field staff are usually able to discern individual calls; and 3) a full chorus. Usually, ponds are visited at least three times during the breeding season to verify whether the pond is being used during breeding. See Amphibian Monitoring Standard Operating Procedures.

Depending on the species, call surveys can be an excellent way to survey and monitor frogs, but not all anurans are easily surveyed by this method. The calls of some frog species vary in volume geographically. NLFs have low volume calls that may be hard to hear, NLFs call sporadically and at very low volume in the lower Truckee River region. Consequently, they have cautioned the use of call surveys to survey or inventory the species on the PLPR. Instead conduct call surveys as a prelude to more specific surveys. Bonin et al. (1997) have also advised against the use of the technique to quantitatively assess the extent of frog declines over several years. Auditory techniques, such as audio strip transects (Zimmerman 1994), automated data loggers (Peterson and Dorcas 1994), or advanced acoustic monitoring (Rand and Drewry 1994), could be evaluated in the future for their efficacy on the PLPR before using them as monitoring tools. It is recommended that daytime visual searches, in the active season (May through October, depending on weather and elevation), are conducted to find NLFs unless other monitoring tools have proved their effectiveness.

Visual Encounter Surveys

Herpetologists for many years have used visual searches in suitable habitat to find amphibians. This is frequently the most productive way to search for amphibians and, if properly quantified, is a suitable technique to survey and monitor many species (Crump and Scott 1994). Proper quantification of search effort involves recording the amount of time spent actively searching, not including time spent traveling, taking photos, etc.; this technique is known as the visual encounter survey. Investigators simply approach a survey area and walk around the area searching for the species of interest, possibly flipping suitable cover objects. After a pre-determined period of time, the search is halted and results (number of specimens encountered) are recorded. Refer to PLPT Wetland QAPP for detailed techniques.

The use of visual encounter surveys to find subadults, adults, and metamorphs after the breeding season and to search for developing tadpoles using dipnets swept through shoreline vegetation is also recommended. However, this method results in presence/ absence data only. Sometimes tadpoles are obvious using this technique, but sometimes they cannot be found at sites where metamorphs are found later in the season. During the breeding season, Wetland Program staff has found that NLFs are cryptic and hard to locate either by sight or by sound. The tadpoles may also be hard to find because they are hiding in dense cover. Wetland Program staff have experienced difficulty attaining accurate counts of NLFs because they can be present in large numbers (e.g., hundreds of tadpoles or metamorphs) or are otherwise hard to count (e.g., several individuals jump and escape simultaneously). Given that failure to see frogs during a single survey is not proof of absence, it is recommended to survey a site at least three times, preferably including at least one visit during breeding and after suspected metamorphosis of tadpoles, before recording NLF absence. Crump and Scott (1994) cover the assumptions and limitations of the visual encounter technique, reference this material if questioning the applicability of the technique to a specific survey area.

Egg Mass Surveys

Another survey method in monitoring NLFs is egg mass survey (Corn and Livo 1989, Werner et al. 1999, Crouch and Paton 2000). In this type of survey, investigators visit wetlands that are suspected to have breeding populations of NLFs to search for egg masses. As described in the *Breeding Biology* section, eggs are laid in clumps on submerged vegetation slightly below the water. Since a single female lays each clump, simply counting all egg masses found in a pond gives an estimate of the number of females using the pond for reproduction. If a 1:1 sex ratio is assumed, the total breeding population size can be estimated. However, it is important to recognize that not all females are likely to breed during a given year, the sex ratio may not be 1:1, and there will be an undetermined number of sexually immature individuals in the population. In addition, egg mass surveys require training because it is often difficult for non-specialists to identify NLF eggs.

Drift Fences and Pitfall Trap Monitoring

Drift fences and pitfall traps can be installed and periodically monitored to assess the abundance of amphibians at a study site (Corn 1994). Drift fences can also be installed at breeding sites, completely encircling the site and trapping every individual entering or leaving the site (Dodd and Scott 1994). Drift fences are long fences made of sheet metal and placed flush to the ground such that amphibians cannot climb over or burrow under the fence. Pitfall or funnel traps are placed along the fence to trap amphibians moving along the fence. In our experience, it can be difficult to train non-herpetologists to install drift fences properly, and it is recommended that a herpetologist be consulted and survey teams be properly trained if drift fences are to be used. We believe that the primary use of drift fences would be for studies of NLF breeding ponds or studies of movement in the species, not as a routine method of survey. Drift fences can be costly, both in terms of materials and construction effort, but once installed they can be cheaply and easily operated.

Quadrant and Transect Surveys

Upland habitats can be quantitatively sampled using quadrat sampling (Jaeger and Inger 1994), transect sampling (Jaeger 1994a), and patch sampling (Jaeger 1994b). Each of these techniques relies on sampling various sizes and shapes of plots to determine how many amphibians occur per unit area of sampled habitat. Of all the techniques discussed, these are the only techniques that can provide information on the number of animals per unit of habitat.

Patch Surveys

Patch sampling (Jaeger 1994b) refers to the sampling of patches where frogs are more likely to occur, which in the case of NLFs should be habitat near breeding wetland ponds, along streams, or in riparian corridors. One general drawback to patch sampling is that the habitat is not randomly sampled because habitats that investigators think lack frogs are not sampled. However, as long as the data are not presented as being a random sample of all possible habitats, patch sampling is an appropriate tool to survey amphibians.

Patch sampling can be combined with quadrat or transect sampling. During the breeding season, NLFs are concentrated at wetland ponds, but following breeding they are dispersed in upland habitat and may be more difficult to locate (although it may still be expected that frogs will be found near ponds, streams, or riparian areas). Therefore, areas near wetland, streams, and in riparian zones can be selected as patches. To systematically sample these areas, researchers might restrict searches to areas immediately adjacent to ponds (for example, the 200 m area as discussed under Intrinsic vulnerability, along streams, and in riparian corridors. They can then conduct quadrat or transect samples (quadrats are square plots while transects are long strip-like plots; some researchers make little distinction between the two), in these patches to assess the numbers of adult frogs using these habitats. These combined techniques could result in an assessment of frog density around breeding wetland ponds, along streams, and in riparian corridors following the breeding season.

Radio Transmitter Monitoring

Any technique that allows the hand capture of specimens can be used in conjunction with marking techniques as part of a larger study on breeding or movement patterns. Amphibians can be marked and tracked using a variety of devices including radiotransmitters (Richards et al. 1994), radioactive tags (Ashton 1994), toe clipping (Green 1992), and passive integrated transponder (PIT) tags.

Radiotracking has been used on larger animals for a number of years, but with miniaturization of transmitters, it been successfully used on amphibians in the field, including ranid frogs (Rathbun and Murphey 1996, Lamoureux and Madison 1999, Mathews and Pope 1999, Bull 2000, Bull and Hayes 2001) and NLFs in particular (Waye 2001). The technique is time-consuming and expensive, requires detailed training of investigators, and may require invasive surgery to install transmitters. However, it is the best way available to obtain detailed information on the movement of animals in the field.

Radio tags have also been used to monitor amphibian movements in the field (Ashton 1994) and. Radio tags are particularly useful for small organisms that cannot be tracked using radio-transmitters. The tags can be detected from up to 5 m by scintillation counters (Semlitsch 1998), so they can be used to find specific locations of frogs where a restricted movement area is expected. Although this technique is available, there are concerns over handling of the tags, health effects on frogs with implanted tags, and environmental effects that may argue against studies using radio tags.

Toe Clipping

Toe clipping has long been used to mark various animals in the field and is best used in conjunction with recapture surveys to roughly track NLFs over time. Green (1992) outlines a basic pattern for numbering frogs using toe clipping. When effectively used in conjunction with other sampling techniques, toe clipping can be used to monitor the movements of individuals and to derive a mark-recapture estimate of population density using a number of open population estimators given in Krebs (1999). Deriving a mark-recapture estimate of population size at most ponds would require marking and recapturing large numbers of NLFs. Since toe clipping is invasive, it should not be used unless it is part of a determined effort to monitor frog movements or to derive population estimates. Toe clipping, when done in conjunction with basic sampling, is simple and inexpensive to implement.

Passive Integrated Transponder Tagging

Passive integrated transponder (PIT) tags can be used to mark individuals as well. These are small glass rods, usually no more than 10 mm in length, that are inserted under the skin. A device reads uniquely coded numbers from the tags when waved over the marked individuals. Marking NLFs as part of a detailed movement or population study in this manner would provide detailed habitat selection data. Pit tags and the reader are expensive to purchase, but they are much less expensive than radio-transmitters and do not have the safety issues associated with radioactive tags. Pit tags can be inserted subcutaneously on the dorsal surface, and have been used successfully other species.

Aquatic Funnel Trapping

Aquatic funnel trapping is a technique that can be used to detect the presence of NLF tadpoles in breeding ponds. Various types of funnel traps are described in Adams et al. (1997). These traps are placed in ponds, where tadpoles swim into them and are captured. The traps are checked on a frequent basis, and tadpoles are identified and released. The materials used are not expensive (minnow traps), but they need to be checked daily or every few days during the tadpole growing season. Additional training is necessary for this technique, because non-specialists often find it difficult to differentiate the various tadpoles found throughout the PLPR.

Inventory and Monitoring Program on the Pyramid Lake Paiute Reservation

Amphibian monitoring on the PLPR began in 2018 and resulted in the development of this management plan. The following components are best management practices and techniques that frame the basis of all effective amphibian monitoring programs. Each of the following should be evaluated annually to determine whether program activities are meeting management goals:

1) **Sampling design:** Consult a professional herpetologist who can suggest appropriate habitat to monitor and who can dedicate time in the field. It is suggested that agencies monitor only sites that were known to have populations of frogs at the start of the monitoring efforts. Although it is of interest to know the number of occupied versus unoccupied breeding sites in an inventory effort, it is believed that abundance trends would most easily and efficiently be tracked by starting the monitoring program with several sites that have frogs. If frogs are no longer found on one of these sites during the monitoring period, the site should continue to be monitored for potential recolonization.

   It is not necessarily always clear what types of waterbodies NLFs will occupy. The PLPT Wetland Program has found them in temporary muddy water holes, degraded wetlands, relatively pristine small ponds with emergent vegetation (possibly their preferred habitat), river banks and adjacent riparian habitat, and at lake margins with emergent vegetation. By identifying sites where NLFs occur, management can monitor these sites for signs of decline through time. More sophisticated studies, or simple experience over time, might assist in the creation of new habitat, or to conserve appropriate habitat for the species.

2) **Historical surveys:** The best way to start a monitoring plan would be to review historical records of occurrence, as it is instructive to compare historical data to current data. Historically, occupied localities are revisited to determine presence or absence of the target species, and to examine general trends in distribution. Although presence/absence data lack statistical precision, the results are illustrative nonetheless. Field staff (Rorabaugh 2005) have used historic surveys to describe trends in distribution over time, as have we in this assessment. Simple hand capture or auditory surveys would suffice to determine presence or absence of the species at these sites, but we caution that several surveys may have to be conducted at a historical site before the species can be declared absent. If new surveys at several historical sites do not contain new records, there is reason to be concerned that frogs may be in decline in the region.

3a) **Preliminary surveys:** Techniques used to start a monitoring program can be very simple. Smith et al. (1996a, 1996b, 2004) found that NLFs could be inventoried using auditory surveys, but this required a trained ear, excellent hearing, and patience. In general field surveys conduct auditory surveys for three minutes at each site. However, Wetland Program staff has found that NLFs are very cryptic in chorusing behavior, and they may not call for long periods of time. When auditory surveys are used, trained observers visit several breeding ponds a night during the spring breeding season (April to July, depending on elevation and weather), listening for 15 minutes at each site. However, lack of calling does not necessarily indicate the absence of frogs, and it is believed that each site should be visited at least three times before concluding that there are no NLFs at the site. Auditory surveys cannot be used to determine successful reproduction. What can be determined, is that a breeding chorus was found at specific sites during the breeding season. See Wetland QAPP for Standard Operating Procedures for calling surveys.

3b) **Condition encounter surveys:** NLFs are more easily detected later in the active season (June to October, depending on weather and elevation), when subadults and adults may be found at the edges of wetlands basking in the sun. They are easily observed with simple visual searches. Again, a single observation at a site is sufficient to score there is a presence of the species at the site; comparatively, sites must be visited at least three times without positive identifications for frogs to be considered absent. However, visual surveys are expanded to gather more specific species data. See Wetland QAPP standard operating procedures for capture and processing. Collecting the pertinent data on life cycle stage, development, average length, average weight, percent algae present, percent detritus, Geographical Positioning System (GPS) location, water temperature, water depth, substrate type, Gosner Stage, Rosgen habitat type, bankfull width, and wetted perimeter. Observations turned into encounter rates can subsequently be used in simple statistical analyses of abundance and condition through time.

4) **Sampling of tadpoles:** Tadpoles can be sampled in various ways, including dipnets and various aquatic traps. The Wetland Program staff has had difficulty collecting tadpoles using dipnets in the thick emergent vegetation in which they occur. Tadpoles are difficult to identify, and it is likely that misidentification can happen. This could compromise data if done incorrectly. When using dipnets

to sample tadpoles, diseases could easily be transferred from pond to pond if dipnets are not properly disinfected (see item 6 below). Disinfect all nets and field material when changing survey sights.

5) **Geographical Information Systems (GIS):** All data should be entered into the GIS database. Various authors (Hayek and McDiarmid 1994, Juterbock et al. 1994, Fellers 1997) discuss the use of GIS in herpetofaunal studies. GIS is a universal system used for many applications. By spatially logging data managers can identify threats, improve buffer management and compare data to similar habitats. GIS is a powerful tool to be utilized in species specific management.

6) **Number of sampling sites:** There is no consensus on the number of sites that should be monitored across a region to examine trends in abundance, and there is no standard used among studies, herpetological or otherwise. However, Hayek and Buzas (1997) determined from theoretical considerations that a sample size of 20 should be adequate to infer biologically meaningful results from most biological data sets. Monitoring all wetlands where amphibians have been located. However, we should also note that any statistical textbook (e.g., Sokal and Rohlf 1994, Zar 1998) will point out that sample sizes should be as high as reasonable. Many factors will influence the number of ponds to be monitored, including size of the management area, number of suitable wetlands, funding, personnel, weather and staff time restraints.

7) **Disease Monitoring:** Monitoring and reporting all diseases and pathogens observed during inventory and assessment is a significant component. Swabing all captured anuran regardless of the species will assist in identifying these threats. Procedures for sampling pathogens utilizing swab samples should follow the best management practices of the laboratory the samples will be processed at. If processing laboratory is changed, methods needs to be readdressed.

8) **Disinfection of sampling gear:** The Primary technique, simple visual surveys, typically requires walking around a pond. Observers are less likely to be working in and out of the water on such a survey, than they would on surveys that require use of waders or dipnets. This should reduce the chance of transmission of disease from pond to pond, but we also recommend disinfection of field boots. As a standard protocol for amphibian survey and monitoring, investigators should sterilize boots and other gear between survey sites with a solution of 10 percent standard household bleach (1:10 by volume) by completely soaking the gear in this solution for at least 10 seconds, then rinsing it with distilled water and allowing it to dry in the sun prior to use. This technique should minimize the chance of introducing diseases to disease-free ponds. A current and detailed discussion of standard operating procedures for disinfecting field gear can be found online through the Declining Amphibian Population Task Force (http://www.open.ac.uk/daptf/).

Population and Habitat Management

Few scientific papers have addressed management of amphibians, fewer still have looked at ranid frog management, and none have done so specifically for NLFs. Semlitsch (2000a) is the most extensive review of the amphibian management literature available. Through the review of available literature, the Wetland Program can identify population and habitat needs for the NLF.

Microhabitat variables such as herbaceous cover, downed wood, and litter depth appear to be more important than broad-scale stand features. Amphibians better tolerate habitats that provide a variety of near-ground cover because these habitats provide a broad range of microclimates that allow effective behavioral thermoregulation and avoidance of desiccation. Also, scattering this type of disturbance around the landscape is beneficial. Several amphibian species use riparian corridors as migration pathways, and it is expected that the wider they are and the more connected NLF breeding ponds are to these riparian zones, the better off populations of NLFs will be. Additionally, roadways can isolate populations or reduce their size, sometimes even if these roadways are low or no-use roadways. This might be less of a problem for the NLF because they are known to migrate long distances under less than ideal conditions. However, heavily used roads may result in substantial mortality of migrating frogs. On the PLPR road mortality is unknown and thought to be minimal.

Yet to be discussed in this report, is the importance of local population dynamics and metapopulation dynamics. Like many species, pond-breeding amphibian populations are connected across the landscape; with each pond serving as a population, and all populations of all ponds existing as one, or several, metapopulations. Each pond may be more or less isolated, depending on how far each is from other ponds, the predilection of frogs to migrate from pond to pond, the tendency of young to disperse from natal ponds, the risks associated with inter-pond migration, and the philopatry of subadult and adult frogs. Without detailed studies of the genetics and movement patterns of frogs at given sites, it is difficult to know whether there is a high degree of within-population genetic variability (i.e., most genetic variability is found within a population or pond), or a high degree of among-population genetic variability (i.e., most genetic variability is found among ponds). In the former case, conservation of one or a few breeding ponds and surrounding upland habitat conserves most of the genetic variability within the metapopulation. In the latter case, more ponds must be conserved to maintain a high degree of genetic diversity within the metapopulation. In either case, the safest way to conserve high genetic diversity is to maintain as many ponds and their surrounding upland core area as possible, with numerous inter-pond migration and dispersal corridors. This reduces the chance of the whole population becoming extinct due to an unforeseen stochastic event, and facilitates recolonization of local extirpations by dispersers from neighboring ponds.

Wetland Program Amphibian Monitoring Structure

The PLPT Wetland Program assumes the responsibility of monitoring the distribution of NLFs on the PLPR. The program is dedicated to the restoration and preservation of NLF and habitat in which it is dependent on. The program will work with land managers both on and off the PLPR to recover populations of the species. Actions to be implemented include: the fencing of critical habitat, active bullfrog removal and management, education and outreach, disease and pathogen prevention, and continuous monitoring. Furthermore, the program will seek opportunities to expand the current range of the species through collaborations with outside agencies, foundations and local non-profits.

Table 1: Outlines the information needs of the Wetland Program to further guide and inform management for the establishment of best management practices to preserve NLF subpopulations on the PLPR. Furthermore, identifying potential partners and mechanisms of implementation.

Information needs to guide future management of metapopulations of northern leopard frogs on the PLPR			
Category	Subcategory	Management Action	Potential Partners
Survey and Monitoring	Breeding Accordance	Call Surveys	University of Nevada, Reno
	Breeding Success	Egg Mass Surveys	Southern Nevada Water Authority, Environmental Resources Division
	Presence/Absence	Visual Encounter Survey	Arizona Game & Fish Department
	Distribution/Density	Mark Recapture	
	Population Estimate	Drift Fence & Transect Survey	
		Quadrant & Transect Survey	
		Patch Survey	
		Toe Clipping	
		Aquatic Funnel Trapping	
Mapping of Habitat	Overwintering & Upland Habitat	Patch Survey	ESRI
	Breeding Habitat	Toe Clipping	Bureau of Indian Affairs
	Movement/Migration Corridor	Quadrant & Transect Survey	Patagonia
	Habitat Characterization	Radio Transmitter Monitoring	Pyramid Lake Range Program
	Lifecycle Ecological Niche Needs	Passive Integrative Tagging and Monitoring	Pyramid Lake Aquatic Invasive Species Program
		Aquatic Funnel Trapping	Pyramid Lake High School
		Vegetation Surveys	
		Outreach and Education	
Predacious Fish	Presence/Absence	Survey/Monitor	Pyramid Lake Fisheries Department
	Distribution/Density	Manual Removal, Netting	USFWS
	Severity of Habitat Impact	Electroshocking	Pyramid Lake Aquatic Invasive Species Program
	Method of Predation	Screens	Pyramid Lake High School
	Stage Specific Vulnerabilities	Minnow trapping	The Nature Conservancy
		Outreach and Education	

Aquatic Invasive Species	Species Specific Data	Survey/Monitor	Pyramid Lake Fisheries Department
	Distribution/Density	Manual Removal, Netting	Pyramid Lake Aquatic Invasive Species Program
	Extent of Impact	Electroshocking	The Nature Conservancy
	Rick/Threat Analysis		
Grazing	River Corridor Trespass	Education and Outreach	Pyramid Lake Rangeland Program
	Tribal Allotment Grazing	Holistic Land Management	Bureau of Indian Affairs
	Wetland Grazing	Enclosure Fence Condition Inventory	Pyramid Lake Cattlemen's Association
	Vandalism	Include NLF Habitat Needs in Revised Grazing Management Plan	
	Nutrient Loading	Water Quality Monitoring	
	Sensitive Habitat Mapping and Protection	Habitat Mapping and Protection	
	Erosion	Outreach and Education	
Physiological Abnormalities	Disease	Screen of Disease	Nevada Department of Environmental Protection
	Pollution/ Water Quality	Survey Chemical Use on PLPR	U.S. Environmental Protection Agency
	Limb Malformation	Monitor and Report Malformations	University of Nevada, Reno
	Chemical application	Monitor and Report Abnormal Behavior and Posture	National Wildlife Health Center
		Establish Buffer Zone	Pyramid Lake Aquatic Invasive Species Program
		Outreach and Education	Pyramid Lake Water Quality Program
		Monitor Water Quality	Pyramid Lake High School
			The Nature Conservancy

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Appendix A:

Table 1. Historic and current abundance and population trends for the NLF across its range in North America. See **footnotes** for references.

State or Province	Historical Abundance	Present Abundance	Population Trend
Alberta	Unknown[1]	Uncommon[1,2,3]	**Declining[1,2,3]**
Arizona	Uncommon[4]	Uncommon[4]	**Declining[4]**
British Columbia	Unknown	Unknown	**Unknown**
California	Extralimital?[5,6]	Uncommon[3]	**Declining[3]**
Colorado	Unknown	Uncommon[7,8,9]	**Declining[7,8,9,10]**
Connecticut	Unknown	Unknown	**Unknown**
Idaho	Unknown	Uncommon[11]	**Declining[11]**
Illinois	Unknown	Common[12]	**Stable[12]**
Indiana	Common[13]	Uncommon[13,14]	**Declining[13,14]**
Iowa	Common[15]	Uncommon[15]	**Declining[15]**
Kentucky	Unknown	Unknown	**Unknown**
Maine	Unknown	Unknown	**Unknown**
Manitoba	Unknown	Unknown	**Unknown**
Massachusetts	Unknown	Unknown	**Unknown**
Michigan	Uncommon[16]	Unknown	**Declining[16]**
Minnesota	Common[17]	Common[17]	**Declining[17]**
Montana	Unknown	Uncommon[18,19]	**Declining[18,19]**
Nebraska	Unknown	Unknown	**Unknown**
Nevada	Unknown	Unknown	**Unknown**
New Brunswick	Unknown	Common[20]	**Stable[20]**
New Hampshire	Unknown	Unknown	**Unknown**
New Mexico	Unknown	Unknown	**Declining[37]**
New York	Unknown	Unknown	**Unknown**
Newfoundland	Extralimital[21,22]	Unknown	**Unknown**
North Dakota	Unknown	Unknown	**Unknown**
Northwest Territories	Unknown	Uncommon[23]	**Unknown**
Nova Scotia	Unknown	Unknown	**Unknown**
Ohio	Unknown	Common[24]	**Stable[24]**
Ontario	Unknown	Unknown	**Unknown**
Pennsylvania	Unknown	Unknown	**Unknown**
Quebec	Unknown	Unknown	**Unknown**
Saskatchewan	Unknown	Unknown[25]	**Unknown[25]**
South Dakota	Unknown[26]	Common[26,27,28,29,30]	**Unknown[26]**
Utah	Unknown	Unknown	**Unknown**
Vermont	Unknown	Unknown	**Unknown**

Washington	Uncommon[31]	Uncommon[31]	**Declining[31]**
West Virginia	Unknown	Unknown	**Unknown**
Wisconsin	Common[32]	Common[32]	**Declining[32,33,34,35]**
Wyoming	**Unknown**	**Unknown**	**Declining[3,11,36]**

If no reference is given, the data are unknown for the various provinces and states that are listed.

References: 1 = Russell and Bauer (1993); 2 = Roberts (1992); 3 = Stebbins and Cohen (1995); 4 = Clarkson and Rorabaugh (1989); 5 = Bury and Luckenbach (1976);

6 = Jennings and Hayes (1994); 7 = Hammerson (1999); 8 = Hammerson (1982); 9 = Cousineau and Rogers (1991); 10 = Corn and Fogleman (1984); 11 = Koch and

Peterson (1995); 12 = Mierzwa (1998); 13 = Minton (1998); 14 = Brodman and Kilmurry (1998); 15 = Lannoo (1994); 16 = Collins and Wilbur (1979); 17 = Moriarty

(1998); 18 = Werner et al. (2004); 19 = Reichel (1996); 20 = McAlpine (1997); 21 = Buckle (1971); 22 = Green and Campbell (1984); 23 = Fournier (1997); 24 = Orr et

al. (1998); 25 = Didiuk (1997); 26 = B. Smith, personal observation; 27 = Peterson (1974); 28, 29, 30 = Smith et al. (1996a, b; 1998); 31 = Leonard et al. (1999); 32 =

Mossman (1998); 33, 34 = Hine et al. (1975, 1981); 35 = Dhuey and Hay (2000); 36 = Baxter and Stone (1985); 37 = C.W. Painter unpublished data 2006.