Species Status Assessment Report

for the

Columbia Spotted Frog (*Rana luteiventris*) Great Basin Distinct Population Segment

U.S. Fish and Wildlife Service
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Executive Summary

In this Species Status Assessment (SSA), we evaluate the biological status of Columbia spotted frogs (*Rana luteiventris*) in the Great Basin both currently and into the future through the lens of the species' resiliency, redundancy, and representation. This SSA Report provides a comprehensive assessment of biology and natural history of Columbia spotted frogs and assesses demographic risks, stressors, and limiting factors. Herein, we compile biological data and a description of past, present, and likely future stressors (causes and effects) facing Columbia spotted frogs in the Great Basin.

Columbia spotted frogs are highly aquatic frogs endemic to the Great Basin, northern Rocky Mountains, British Columbia, and southeast Alaska. Columbia spotted frogs in southeastern Oregon, southwestern Idaho, and northeastern and central Nevada make up the Great Basin Distinct Population Segment (DPS; Service 2015, pp. 1–10). Columbia spotted frogs are closely associated with clear, slow-moving streams or ponded surface waters with permanent hydroperiods and relatively cool constant water temperatures (Arkle and Pilliod 2015, pp. 9–11). In addition to permanently wet habitat, streams with beaver ponds, deep maximum depth, abundant shoreline vegetation, and non-salmonid fish species have the greatest probability of being occupied by Columbia spotted frogs within the Great Basin (Arkle and Pilliod 2015, pp. 9–11, 15, 32).

Males become sexually mature usually at age 2 or 3 while females mature typically a year later (Reaser and Pilliod 2005, p. 561). Breeding occurs once a year in the spring for Columbia spotted frogs with timing being a factor of latitude, elevation, and annual weather (Reaser and Pilliod 2005, p. 560). Once they become adults, male Columbia spotted frogs have lower survival rates than females, possibly due to the smaller sizes attained by males making them more susceptible to predation (Turner 1962, p. 328; Licht 1974, p. 621, 625). While the oldest frogs documented were 12–13 years old, most males live 3–4 years and females typically survive 5–8 years (Reaser 2000, pp. 1161–1162; Bull 2005, p. 27). Adult Columbia spotted frogs feed day or night and are opportunistic feeders, consuming many types of insects, mollusks, and even other amphibians (Bull 2005, pp. 16–19; Reaser and Pilliod 2005, p. 561).

Monitoring efforts are being implemented throughout the range of the Columbia spotted frog in Idaho, Nevada, and Oregon. Extensive surveys and monitoring since 1993 have revealed that Columbia spotted frog populations are much more widespread than what was previously known (and at the time of Candidacy). While some sites and watersheds are no longer occupied, Columbia spotted frogs are well distributed as compared to the known historical distribution throughout southwestern Idaho and northeastern Nevada with isolated and disjunct populations in southeastern Oregon and central Nevada. Population estimates are available for six intensively surveyed sites across three states—population growth at three sites are positive, one site is stable, and two sites are declining (Pilliod *et al.* 2015b, pp. 13–14, 35). Most occupied sites harbor relatively few numbers of adult frogs and many populations are isolated from each other. Population genetic analyses have been conducted in Oregon and Idaho and have revealed genetic signals indicative of small isolated populations (Robertson and Funk 2011, pp. 5–9, 13; Robertson and Funk 2012, pp. 5–12), but these analyses have not been conducted for Nevada. The current condition of Columbia spotted frogs in the Great Basin DPS is due to a combination

of historical, geologic, climatic, and environmental events and more recent anthropogenic influences.

Columbia spotted frogs in the Great Basin have been impacted primarily by the effects of past habitat destruction and modification, which caused increased habitat fragmentation and isolation. Heavy use by livestock has been shown to be detrimental to Columbia spotted frog habitat. While livestock grazing occurs throughout the Great Basin, there is uncertainty regarding livestock grazing effects from a lack of monitoring data (Veblen *et al*. 2011, pp. 24–28, 39). Development of springs for livestock and agricultural purposes has occurred throughout the Great Basin; however, the status of Columbia spotted frog habitat as it relates to spring development is unknown. Mining has been shown to have local impacts to populations but has a relatively low influence on a rangewide basis. Beaver management can influence Columbia spotted frogs if trapping occurs in areas which are occupied by Columbia spotted frogs. Beaver harvest is monitored by the states at the county level; therefore, the impact from trapping is difficult to evaluate. Modification and destruction of Columbia spotted frog habitat from historical and current anthropogenic disturbances have contributed to the current fragmented and isolated nature (and subsequent genetic character) of Columbia spotted frog populations in the Great Basin.

Nonnative fish and amphibian predators and pathogens occur within the range of Columbia spotted frogs. Nonnative fish and amphibian predators can eliminate or reduce populations or restrict movement of individuals, thus, increasing fragmentation and inhibiting metapopulation dynamics; therefore, predation by nonnative fish and amphibians is negatively impacting Columbia spotted frogs in the Great Basin. Nonnative fish and amphibian predators can also be vectors for parasites and pathogens (*e.g.*, chytrid fungus), which may increase susceptibility of individuals or populations to disease outbreaks or deformities leading to increased mortality rates. However, population-level effects of both pathogens and parasites have yet to be documented within the Great Basin; therefore, we conclude that disease is not negatively affecting Columbia spotted frogs in the Great Basin at this time but may in the future.

Climate change has and is expected to continue to affect Great Basin ecosystems; however, predictions are difficult to make and the impacts to Columbia spotted frog populations are not well documented (Fleishman *et al*. 2004, pp. 248–251; Botkin *et al*. 2007, pp. 227–234; Field *et al*. 2007, pp. 627–630). Many negative consequences of a changing climate are associated with amphibian species, and predictions indicate that impacts from climate change may be the greatest challenge to conserving amphibians in the future (Corn 2005, pp. 59–64). The current state of small fragmented populations of Columbia spotted frogs in the Great Basin DPS indicates populations are more vulnerable to extirpation due to loss of habitat from predicted climate related impacts (Corn 2005, pp. 59–64; Wilcox *et al*. 2006, pp. 857–862; Pilliod *et al*. 2015a, p. 19). Protecting or improving Columbia spotted frogs and their habitat so that they can adapt to expected changes in climate may be the most important conservation action (Chambers *et al*. 2004b, pp. 266–268; Seavy *et al*. 2009, pp. 331–333). Overall, we found that climate change research forecasts a drying pattern and a subsequent reduction in suitable habitat with additional isolation of populations; however, there is uncertainty about how these changes will play out at the population level and the future timeframe under which this will happen. While research has shown that current weather patterns are not influencing Columbia spotted frogs similarly across

the Great Basin DPS, this pattern could change if these climate influences become more synchronous, or the frequency, duration, and severity of extreme events such as drought increases across the Great Basin (Pilliod *et al*. 2015b , p. 17).

Conservation efforts are occurring in many areas across the range of the Columbia spotted frog. A 10-year Conservation Agreement and Strategy had been implemented in Nevada since 2003. Due to the success of the CAS in managing and conserving Columbia spotted frogs in Nevada, a revised 10-year agreement (2015–2024) was signed in February 2015. In 2006, a Candidate Conservation Agreement with Assurances was developed for a population in Idaho. An increase in monitoring has improved our knowledge of the distribution of the species as well as improved knowledge of demography in several populations. Ongoing management aimed to maintain or improve Columbia spotted frog habitat is occurring in many locations within the Great Basin. Improved grazing management (*e.g.*, reduced stocking rates, reduced utilization levels, rest rotation practices) in some locations has contributed to improved stream and riparian habitat in some areas. Creating ponded habitat has also improved numerous occupied sites throughout the Great Basin as well as other parts of the species range (Hossack *et al*. 2013a, pp. 1415–1418; Pilliod and Scherer 2015, pp. 20–21). Beaver are important in the creation of small pools with slow-moving water that function as habitat for frog reproduction and create wet meadows that provide foraging habitat and protective vegetation cover (Naiman *et al*. 1988, pp. 754–761; Cunningham *et al*. 2007, pp. 2520–2523; Pollack *et al*. 2014, pp. 279–289). Beaver management by the states will be important in the long-term survival of Columbia spotted frogs. All three states include Columbia spotted frog on their list of protected species.

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Introduction

Columbia spotted frogs (*Rana luteiventris*) are highly aquatic frogs endemic to the Great Basin, northern Rocky Mountains, British Columbia, and southeast Alaska. Three distinct major clades (a clade is a group of taxa sharing a closer common ancestry with one another than with members of any other clade) have been identified using mitochondrial DNA: Northern, Great Basin, and Utah (Figure 1; Funk *et al*. 2008, pp. 201–202). Columbia spotted frogs in southeastern Oregon, southwestern Idaho, and northeastern and central Nevada are considered part of the Great Basin Distinct Population Segment (DPS) (Figure 1; Funk *et al*. 2008, pp. 201–205; Service 2015, pp. 1–10). Columbia spotted frogs (*Rana luteiventris*) in the Great Basin DPS have been a candidate for Endangered Species Act (ESA) protection since 1993 (Service 1993, pp. 27260–27263).

The Species Status Assessment (SSA) framework is intended to be a review of the species biology and stressors to evaluate the species' current status and estimates its abundance and distribution into the future. The intent is for the SSA Report to be easily updated as new information becomes available and to support all functions of the Endangered Species Program from Candidate Assessment to Listing to Consultations to Recovery. As such, the SSA Report will be a living document upon which many other documents such as listing rules, recovery plans, and 5-year reviews will be based.

This SSA Report for the Columbia spotted frog is intended to provide the biological support for the decision on whether to propose to list the species as threatened or endangered and, if prudent and determinable, where to propose designating critical habitat. Additionally, the SSA Report is a biological report that provides a strictly biological review of the available information related to the biological status of Columbia spotted frogs within the Great Basin DPS. It is not a staff recommendation or a decision on whether this taxon should be proposed for listing as threatened or endangered under the ESA. That decision will be made by the Service Director after reviewing this document and all relevant laws, regulations, and policies, and the results of a proposed decision or decisions, will be announced in the *Federal Register*.

In this SSA Report we think about viability in terms of estimates of distribution and abundance now and into the future. To help us do this we characterize the species in terms of resiliency, redundancy, and representation.

Resiliency is defined as the ability of the species to withstand stochastic events. Resiliency is based on metrics of population health, for example, birth versus death rates, and population size. Healthy populations are more resilient and better able to withstand disturbances such as random fluctuations in birth rates (demographic stochasticity), variations in rainfall (environmental stochasticity), or the effects of anthropogenic activities.

Redundancy is defined as the ability of a species to withstand catastrophic events. Redundancy is based on spreading risk through the duplication and distribution of resilient populations across the range of the species. The greater the number of resilient populations a species has distributed over a larger landscape, the better able it can withstand catastrophic events.

Representation is defined as the ability of a species to adapt to changing environmental conditions. Representation is based on the breadth of genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the species' range. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human caused) in its environment. In the absence of species-specific genetic and ecological diversity information, such as is the case with Columbia spotted frogs in Nevada, we evaluate representation based on the extent of, and variability of habitat characteristics within, their geographical range.

In summary we evaluate the biological status of Columbia spotted frogs in the Great Basin both currently and into the future through the lens of the species' resiliency, redundancy, and representation. This SSA Report provides a comprehensive assessment of biology and natural history of Columbia spotted frogs and assesses demographic risks, stressors, and limiting factors. Herein, we compile biological data and a description of past, present, and likely future stressors (causes and effects) facing Columbia spotted frogs in the Great Basin. For a glossary of other terms used in this SSA Report, reference Appendix A.

Chapter 1

In this chapter, we will describe the taxonomy, distribution, and life-history characteristics of the species to include the individual, population, and species as a whole. A species' viability is largely influenced by its life history. The characteristics of a species that make it unique, such as its resource needs, trophic niche, population dynamics, and reproductive strategies, will heavily influence how it responds both physiologically and behaviorally to anthropogenic influences or natural phenomena in its current and future environments. Understanding these responses and the reasons for these responses is crucial for the successful management, conservation, and recovery of Columbia spotted frogs.

Taxonomy

Spotted frogs (*Rana pretiosa*) were first described by Baird and Girard (1853, pp. 378–379) and later split into two subspecies, *R. pretiosa pretiosa* and *R. pretiosa luteiventris* (Thompson 1913, pp. 53–56). The Service accepts species-specific genetic and geographic differences in Columbia spotted frogs based on Green *et al*. (1996, pp. 377–388; 1997, pp. 2–7), Bos and Sites (2001, pp. 1505–1511), and Funk *et al*. (2008, pp. 201–202), which define populations in western Washington and Oregon and northeastern California as Oregon spotted frogs (*R. pretiosa*) and the remainder of the populations as Columbia spotted frogs (*R. luteiventris*) (Figure 1; Funk *et al*. 2008, pp. 201–202). Based on further geographic and genetic characterization, Columbia spotted frogs in southwestern Idaho, southeastern Oregon, and northeastern and central Nevada are part of the Great Basin population of Columbia spotted frogs (Figures 1 and 2; Funk *et al*. 2008, pp. 201–202). It was previously thought that populations in northeastern

Oregon were part of the Great Basin population; however, Funk *et al*. (2008, pp. 201–202; Figures 1 and 2) found that these populations belong to the Northern population. A small population on the border of eastern White Pine County, Nevada, and western Toole County, Utah, has been determined to be part of the Utah population of Columbia spotted frogs through phylogenetic data (Funk *et al*. 2008, pp. 201–202; Figures 1 and 2). The Committee on Standard and Scientific Names recently changed the genus name for many North American frogs from *Rana* to *Lithobates*; however, Columbia spotted frogs maintained the genus name *Rana* (Crother 2012, pp. 20–21). We have carefully reviewed available taxonomic information to reach the conclusion that the species *R. luteiventris* is a valid taxon.

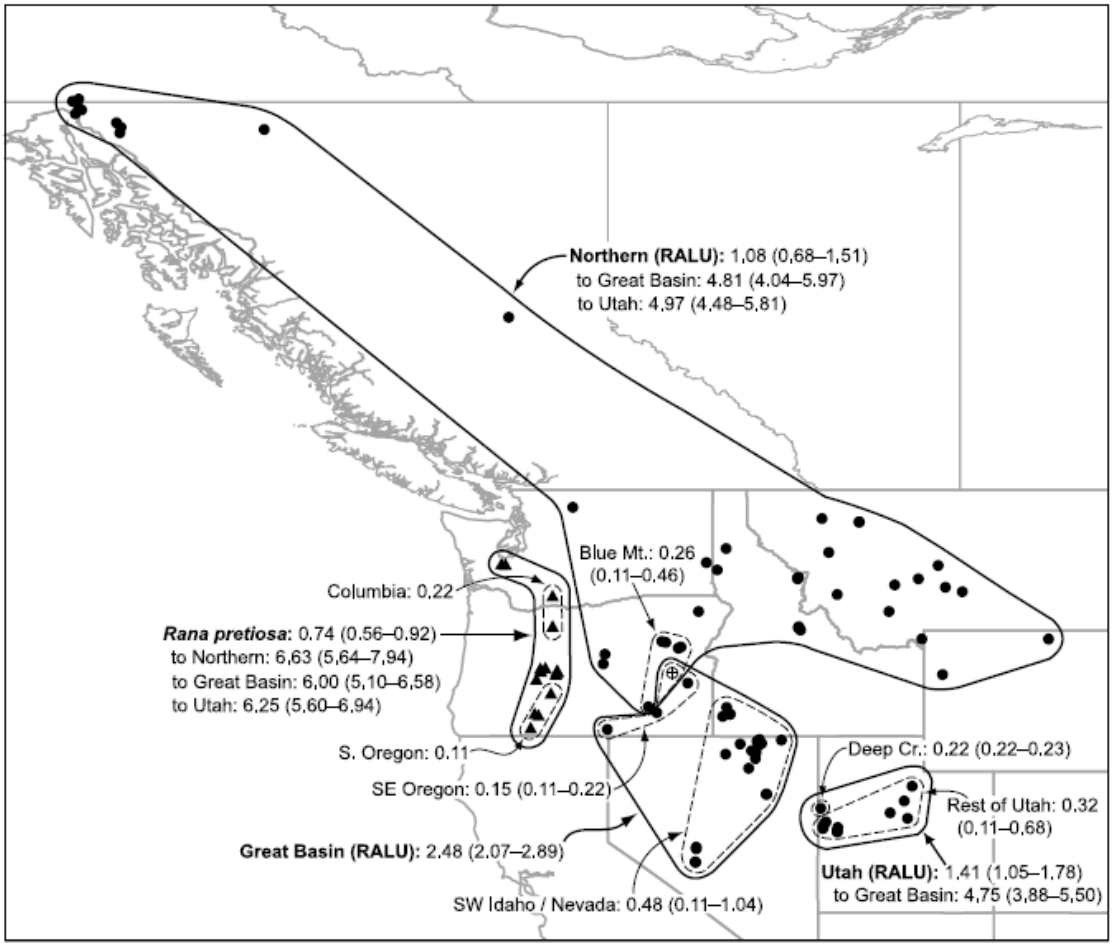


Fig. 3. Geographic distribution of major clades (solid black lines) and nested clades (dashed lines) identified in the phylogenetic analyses, with mean percent corrected sequence divergence (and ranges in parentheses) shown within and among clades. Clade names correspond to those used in Fig. 2 and Tables 1–3. Triangles = *R. pretiosa*; circles = *R. luteiventris*. The open circle with a cross is Kingsbury Gulch (site 59), where haplotypes from the northern clade and Great Basin clade were found.

Figure 1. Geographic distribution of Oregon spotted frogs (*Rana pretiosa*) and Columbia spotted frogs (*Rana luteiventris*; Funk *et al*. 2008, p. 202). Reprinted with permission. The Kingsbury Gulch site (open circle with a cross) has subsequently been identified as being part of the Northern Clade (Robertson and Funk 2012, p. 5).

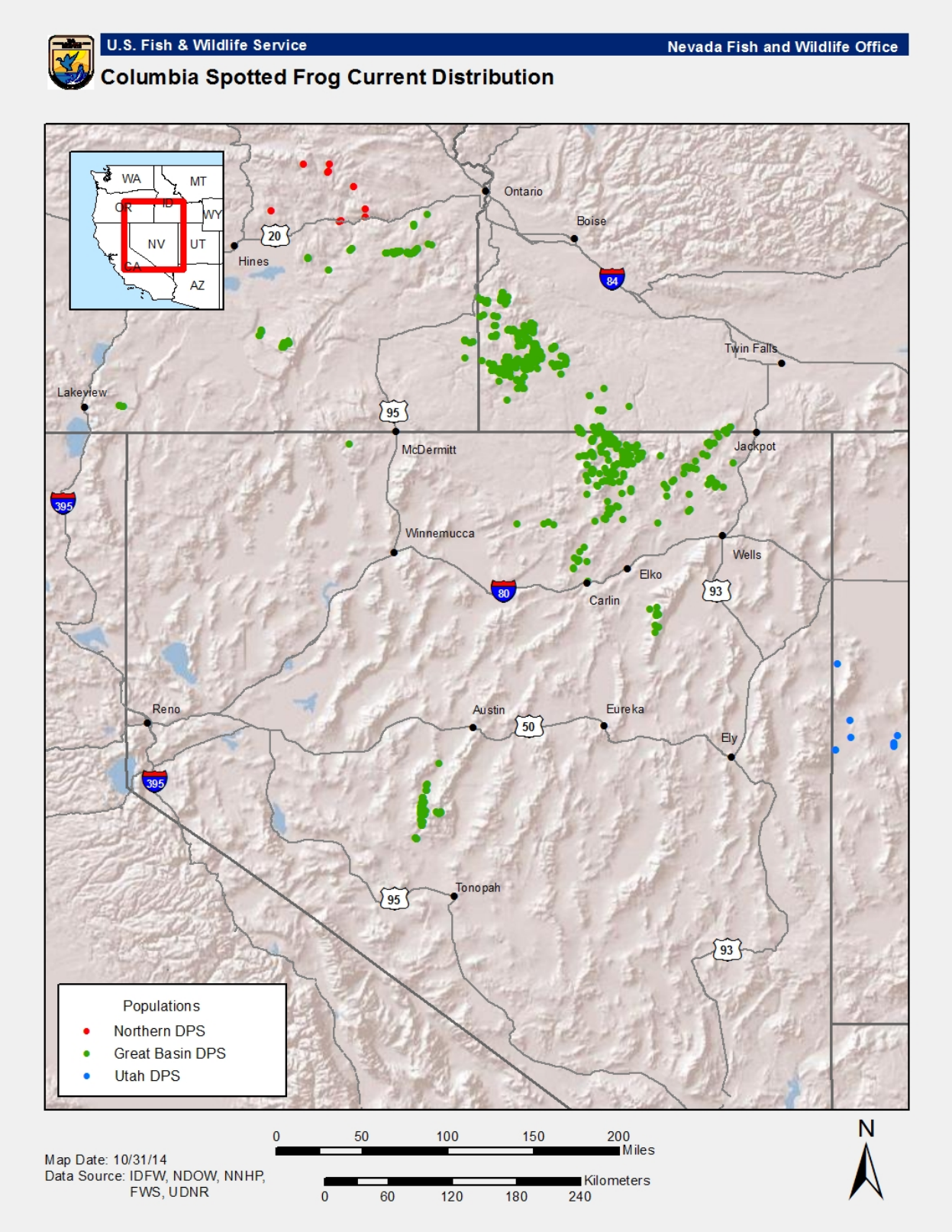


Figure 2. Current range of the Columbia spotted frog, Great Basin DPS, southern edge of the Northern DPS, and western edge of the Utah DPS.

Columbia spotted frogs in Nevada, southwestern Idaho, and most populations in the southeastern Oregon portion of the Great Basin are geographically separate from the remainder of the species (Figures 1 and 2; Funk *et al*. 2008, p. 204). The largest of Nevada's three population areas is the Jarbidge-Independence Range in Elko and Eureka Counties as well as southern Owyhee and Twin Falls Counties, Idaho. A smaller population of Columbia spotted frogs is located in the Ruby Mountains about 80 kilometers (km) (50 miles (mi)) south of the Jarbidge-Independence Range population. However, these two populations are isolated by lack of suitable habitat and hydrologic connectivity. The Toiyabe Mountains population is isolated nearly 320 km (200 mi) southeast of the Ruby Mountains and Jarbidge-Independence Range populations and represents the southern-most extremity of its range (Figures 1 and 2). The Owyhee population of Columbia spotted frogs appears to be widely distributed throughout southwestern Idaho (Owyhee County) and southeastern Oregon (Malheur County). Scattered populations also occur in northern Nevada (Humboldt County) and southeastern Oregon (Lake, Malheur, and Harney Counties), but these populations are generally small, with a few exceptions, and appear to be isolated from each other and from other populations in southwestern Idaho and northeastern Nevada by either natural or human-induced habitat disruptions (Robertson and Funk 2011, pp. 5–9; Robertson and Funk 2012, p. 6).

All four Great Basin populations are geographically isolated and separate from the main continuous Northern population of Columbia spotted frogs in the central mountains of Idaho by the Snake River Plain and adjacent lowlands in eastern Oregon. The Owyhee population in southwestern Idaho is approximately 125 km (75 mi) from the Northern population in central Idaho. Occupied habitat in the Northern population is characterized generally by conifer forests and high elevation lake environments within the Blue Mountains and Middle Rockies Ecoregions IDFW 2005, pp. 1–13; ODFW 2006, pp. 112–132) while habitat for the Great Basin population is characterized by sagebrush steppe and their associated stream and pond environments within the Owyhee Uplands, Northern Basin and Range, and Central Basin and Range Ecoregions (IDFW 2005, pp. 1–13; ODFW 2006, pp. 204–221; NDOW 2012a, pp. 84–85). However, Columbia spotted frog populations within the Northern and Great Basin DPSs converge in east-central Oregon in the vicinity of State Highway 20. In this area, Columbia spotted frogs from the Northern and Great Basin populations are in close proximity to each other (Figures 1 and 2; Robertson and Funk 2012, pp. 6, 20). Furthermore, the Great Basin population is both hydrologically and geographically separated from isolated populations in Utah (Figures 1 and 2). The population in the Ruby Mountains (Lahontan Basin) is approximately 145 km (90 mi) from the West Desert population (Bonneville Basin) near Ibapah, Utah. As detailed below, geographic isolation of the Great Basin population is supported by genetic analyses.

Three earlier genetic studies were conducted on Columbia spotted frogs, which have improved our knowledge of the distribution and genetic structure of the species (Green *et al*. 1996, pp. 374–390; Green *et al*. 1997, pp. 1–8; Bos and Sites 2001, pp. 1499–1513). The strongest genetic evidence that Columbia spotted frog populations in the Great Basin are genetically discrete from other Columbia spotted frogs comes from Funk *et al*. (2008, pp. 198–210) who examined mitochondrial DNA (mtDNA) sequence variation throughout the extant range of Columbia spotted frogs. These data indicate three distinct major clades (a clade is a group of taxa sharing a closer common ancestry with one another than with members of any other clade): Northern, Great Basin, and Utah (Figure 1; Funk *et al*. 2008, pp. 201–202). The three clades are nearly as

divergent from each other as they are from Oregon spotted frog, a closely related but separate species (Funk *et al*. 2008, p. 202). Additionally, within each major clade, well-defined nested clades are also evident. The Great Basin clade has two well-defined nested clades in southwestern Idaho-Nevada and southeastern Oregon (Figure 1; Funk *et al*. 2008, p. 202). This area of southeastern Oregon has been identified as a natural zone of hybridization for other species, such as butterflies and birds (Remington 1968, pp. 321–428). These two nested clades are also the most divergent among the nested clades indicating the effects of small isolated populations in southeastern Oregon (Funk *et al*. 2008, p. 205). The authors also found one location in east-central Oregon where there is an overlap between the Northern and Great Basin clades (Figure 1; Funk *et al*. 2008, p. 204). However, a more recent study using microsatellite markers found that this site (Kingsbury Gulch) belongs in the Northern clade (Robertson and Funk 2012, p. 5).

Species Description

Ranids typically are characterized as slim-waisted, long-legged, smooth-skinned jumpers with webbed hind feet and usually with a pair of dorsolateral folds (glandular folds) that extend from behind the eyes to the lower back (Figures 3–4). Adult Columbia spotted frogs measure between 5 and 10 centimeters (cm) (2 and 4 inches (in)) from snout to vent, with females being larger than males (Bull 2005, pp. 20–22; Tait 2007, pp. 17–18). Dorsal colors and pattern include light brown, dark brown, or gray, with small spots (Figures 3–4; Stebbins 2003, pp. 66, 229–230). Ventral coloration can differ among geographic population units and may range from yellow to salmon; however, very young individuals may have quite pale, almost white, ventral surfaces (Figure 5; Stebbins 2003, pp. 66, 229–230). The throat and the ventral region are sometimes mottled (Figure 5). The head may have a dark mask with a light stripe on the upper jaw, and the eyes are turned slightly upward (Figures 3–4). Adult male frogs have swollen thumbs with darkened bases (Figure 6; Stebbins 2003, pp. 66, 229–230).

Figures 3 and 4. Columbia spotted frogs (*Rana luteiventris*) from the Toiyabe Mountains population in central Nevada (Figure 3; Used with permission: Joel Sartore/joelsartore.com) and southwestern Idaho (Figure 4).

Figure 5. Ventral view of an adult Columbia spotted frog from the Toiyabe Mountains population in central Nevada.

Figure 6. A male Columbia spotted frog showing the swollen thumb.

Habitat

Columbia spotted frogs are highly aquatic and are closely associated with clear, slow-moving streams (lotic) or ponded (lentic) surface waters with permanent hydroperiods and relatively cool midday water temperatures between 6–24˚ Celsius (C) (43–75˚ Fahrenheit (F)) (Munger *et al*. 1996, p. 8; Reaser 1997a, pp. 32–33; Reaser and Pilliod 2005, p. 561; Welch and MacMahon 2005, p. 477; Arkle and Pilliod 2015, pp. 9–11). Habitat with permanent hydroperiods accounted for 83 percent of all detections made within the Great Basin (Arkle and Pilliod 2015, p. 13). In addition to permanently wet habitat, Arkle and Pilliod (2015, pp. 9–11, 15, 32) also found that lotic habitats, particularly streams with beaver ponds, deep maximum depth (greater than 0.5 m), abundant shoreline vegetation, and non-salmonid fish species (*e.g*., speckled dace *Rhinichthys osculus*) have the greatest probability of being occupied by Columbia spotted frogs within the Great Basin. Lotic habitats generally have greater habitat connectivity and more permanent hydroperiods as compared to isolated ponds (Arkle and Pilliod 2015, pp. 9–11, 15, 32). Deeper habitats tend to be associated with more permanent hydroperiods, are important for escape cover from predators, and are vital for overwintering habitat (Arkle and Pilliod 2015, pp. 9–11, 15, 29). Emergent shoreline vegetation provides: (1) quality foraging areas; (2) cover from predators; (3) areas for thermoregulation; (4) egg mass deposition areas; (5) and larval rearing habitat (Arkle and Pilliod 2015, pp. 9–11, 16). Occupied habitat with non-predatory fishes represents habitats with permanent hydroperiods and at least temporary connectivity with other waterbodies (Arkle and Pilliod 2015, pp. 9–11, 15, 29).

Reproducing populations have been found in habitats characterized by springs, floating vegetation, and larger bodies of pooled water with permanent hydroperiods (*e.g.*, oxbows, lakes, stock ponds, beaver-created ponds, seeps in wet meadows, backwaters) (Reaser and Pilliod 2005, pp. 560–561; Hossack *et al*. 2013a, pp. 1415–1416; Figures 7–11). Hossack *et al*. (2013a, p. 1415) reported that larger breeding sites (ponds greater than 0.15 ha) with permanent hydroperiods and low human impacts explained much of the variation in population growth across the entire range of Columbia spotted frogs. Pilliod and Scherer (2015, pp. 14, 45) also found more egg masses as ponds increased in size at the Sam Noble Springs site in southwestern Idaho.

Columbia spotted frogs occur in areas with relatively harsh winter conditions making overwintering habitat an important requirement for survival. Important components of overwintering habitat include areas which do not freeze completely, adequate dissolved oxygen levels, and limited risk from predation and scouring (Bull and Hayes 2002, pp. 142–146). A deep silt or muck substrate may be required for Columbia spotted frog hibernation and torpor (a state of lowered physiological activity, usually occurring during colder months) (Bull 2005, p. 12; Reaser and Pilliod 2005, p. 561). Columbia spotted frogs will use areas where water does not freeze, such as spring heads and undercut streambanks with overhanging vegetation (Bull 2005, p. 12; Reaser and Pilliod 2005, p. 561; Hatch *et al.* 2002, p. 30); however, they can overwinter underneath ice-covered streams and ponds (Bull and Hayes 2002, p. 143; Tattersall and Ultsch 2008, pp. 122–123; Hatch *et al.* 2002, p. 29). Winter can be a time of high mortality further emphasizing the importance of habitat connectivity, permanent hydroperiods, adequate depth and dissolved oxygen (Bull and Hayes 2002, pp. 143–146; Hatch *et al*. 2002, pp. 25–26).

Figure 7. Columbia spotted frog habitat in the Warner Ranch area, Toiyabe Mountains population in central Nevada. A natural stream channel is seen on the left and human created ponds on the right.

Figure 8. Human created pond, Toiyabe Mountains population in central Nevada. Deep water, abundant emergent vegetation, and floating vegetation provide high quality year round habitat for all lifestages of Columbia spotted frog.

Figure 9. Columbia spotted frog habitat associated with a beaver dam complex in Green Mountain Creek, Ruby Mountains population in northeastern Nevada.

Figure 10. Human created pond at Sam Noble Springs, Owyhee population, southwestern Idaho.

Figure 11. Typical Columbia spotted frog habitat in Dry Creek, southeastern Oregon.

An estimated 71 percent of all known currently occupied habitat for Columbia spotted frogs in the Great Basin occurs on federally-managed lands. The Humboldt-Toiyabe National Forest (HTNF) in Nevada is the only national forest which has occupied Columbia spotted frog habitat within the Great Basin DPS. Occupied habitat on BLM-managed lands include the Elko and Battle Mountain District Offices in Nevada; Lakeview, Burns, and Vale District Offices in Oregon; and Jarbidge, Bruneau, and Owyhee Field Offices in Idaho. The Service's Malheur National Wildlife Refuge in south central Oregon currently has multiple areas with occupied habitat. Columbia spotted frogs occur on the Yomba-Shoshone Reservation in central Nevada and the Duck Valley Indian Reservation straddling the border of Nevada and Idaho (2.1 percent). There is abundant suitable habitat on both reservations which have not been surveyed. The States manage approximately 3.3 percent of occupied habitat, and nearly 23 percent of known occupied habitat occurs on private lands including a substantial amount in southwestern Idaho. Much of the private lands within the Great Basin occur near permanent water sources and have not been surveyed indicating the potential importance of private lands in conserving Columbia spotted frogs (Arkle and Pilliod 2015, p. 18).

Life History

Males become sexually mature 1–2 years earlier than females, usually at age 2 or 3 (greater than 4.5 cm for males and 6.0 cm for females) (Reaser and Pilliod 2005, p. 561). Columbia spotted frogs employ a scramble mating system in which males race for access to females and there is little opportunity for female choice or male combat (Greene and Funk 2009, p. 244). Breeding occurs once a year in the spring for Columbia spotted frogs with timing being a factor of latitude, elevation, and annual weather (Reaser and Pilliod 2005, p. 560). Consecutive year breeding has been documented in females in northeastern Oregon (Bull 2005, p. 27). Females lay eggs once minimum daily water temperatures are between 2.5–12.9 C (36.5–55.2 F) and average daily water temperatures are between 9.6–16 C (49.3–60.8 F) (Bull and Shepard 2003, p. 109; Tait 2007, p. 8). Females lay one egg mass consisting of 150–2,400 eggs, usually in the warmest areas of a pond, and typically in shallow water (10–20 cm; 4–8 in) (Bull and Shepherd 2003, pp. 109–112; Bull 2005, pp. 8, 11; Reaser and Pilliod 2005, p. 560; Pearl *et al*. 2007a, pp. 87–89). Eggs generally hatch between 8–21 days after being laid depending on water temperature, and tadpoles usually metamorphose by mid- to late summer; however, they have been observed in the tadpole stage as late as October (Bull 2005, p. 7; Reaser and Pilliod 2005, p. 560). There is no evidence of overwintering in the tadpole stage (Reaser and Pilliod 2005, p. 560). Successful egg production and the viability and metamorphosis of Columbia spotted frogs are dependent on habitat variables such as hydroperiod, temperature, depth, and pH of water; cover; and the presence or absence of predators (Munger *et al*. 1996, p. 8; Reaser 1997b, pp. 21–22; Bull 2005, p. 7; Reaser and Pilliod 2005, pp. 561–562). Once they become adults, male Columbia spotted frogs have lower survival rates than females, possibly due to the smaller sizes attained by males or behavioral differences particularly during the breeding season, making them more susceptible to predation (Turner 1962, p. 328; Licht 1974, p. 621, 625). While the oldest frogs documented were 12–13 years old, most males live 3–4 years and females typically survive 5–8 years (Reaser 2000, pp. 1161–1162; Bull 2005, p. 27). Female growth rates are higher than males with sexual dimorphism occurring in frogs at 2 years of age (Bull 2005, pp. 20–26).

While Columbia spotted frogs can show strong site fidelity, individuals are capable of travelling relatively large distances if adequate habitat is available (Bull 2005, pp. 13–15; Reaser and Pilliod 2005, p. 561). Radio telemetry and mark-recapture studies of Columbia spotted frogs have shown movement up to 6 km (3.7 mi) or more for breeding, overwintering, foraging, or predator avoidance (Engle 2000b, p. 34; Bull and Hayes 2001, pp. 120–122; Pilliod *et al*. 2002, pp. 1855–1859; Bull 2005, pp. 13–16; Funk *et al*. 2005a, p. 14; C. Mellison 2012, unpublished data). Columbia spotted frogs have also been documented moving under ice-covered habitat during winter months further emphasizing the importance of connected habitat (Bull and Hayes 2002, p. 143; Hatch *et al*. 2002, p. 29). Movement usually occurs along shoreline habitat or riparian corridors; however, overland movement has been documented in higher elevation sites or after rain events in more xeric habitats (Pilliod *et al*. 2002, pp. 1859; Pilliod *et al*. 2015a, p. 18).

Adult Columbia spotted frogs feed day or night and are opportunistic feeders, consuming many types of insects, mollusks, and even other amphibians (Turner 1959, pp. 405–413; Miller 1978, pp. 243–248; Whitaker *et al*. 1983, pp. 149–153; Munger 2003, pp. 5–6; Bull 2005, pp. 16–19;

Reaser and Pilliod 2005, p. 561). Bull (2005, pp. 16–19) conducted a diet analysis of adult Columbia spotted frogs in northeastern Oregon where the most common insects consumed were beetles (21 percent), ants or wasps (21 percent), and flies (10 percent). Columbia spotted frog tadpoles are grazers, which consume algae and detritus (Reaser and Pilliod 2005, p. 560).

Current Range/Distribution—Nevada

Columbia spotted frogs in Nevada are found at elevations between 1,700 and 2,650 meters (m) (5,600 and 8,700 feet (ft)). Columbia spotted frog populations in Nevada are geographically separated into three populations: Jarbidge-Independence Range, Ruby Mountains, and Toiyabe Mountains (Figure 12). The Nevada Wildlife Action Plan defines these areas as the Northern Basin and Range (Jarbidge-Independence Range) and Central Basin and Range (Jarbidge-Independence Range, Ruby Mountains, and Toiyabe Mountains populations) Ecoregions (Nevada Department of Wildlife (NDOW) 2012a, p. 84–85). The largest of Nevada's three population areas is the Jarbidge-Independence Range in Elko and Eureka Counties (this population also extends into southern Owyhee and Twin Falls Counties, Idaho; Figure 12). This population area is formed by the headwaters of streams in two major hydrographic basins. The South Fork Owyhee River, Owyhee River, Bruneau River, and Salmon Falls Creek drainages flow north into the Snake River basin while the Marys River, North Fork Humboldt River, Maggie Creek, and Rock Creek drain into the interior Humboldt River basin (NDOW 2003a, pp. S7–S16). Columbia spotted frogs occur in the Ruby Mountains in tributaries to the South Fork Humboldt River, Elko County (Figure 12; NDOW 2003a, pp. S7–S16). In the Toiyabe Mountains, Nye County, Columbia spotted frogs are found in six drainages within the Reese River watershed and Cloverdale Creek (Figure 12; NDOW 2003b, p. S8). The Toiyabe Mountains population is geographically isolated from the Ruby Mountains and Jarbidge-Independence Range populations by a large gap in suitable habitat and represents the southern-most extremity of the species' range. In 2013, Columbia spotted frogs were detected in the McDermitt Creek watershed west of the town of McDermitt, Humboldt County, Nevada (Figure 12). The current distribution includes 101 12-digit hydrologic units (HUCs; all references to HUCs in this document are at the 12-digit hydrologic unit level; USGS 2013, pp. 1-63) in northern and central Nevada (Figure 12).

Current Range/Distribution—Idaho

Both the Great Basin DPS and Northern DPS of Columbia spotted frogs are found in Idaho (Figure 1). Populations in southwestern Idaho are considered part of the Great Basin DPS. The current distribution of Columbia spotted frogs in southwestern Idaho includes 42 HUCs within tributaries of Salmon Falls Creek and the Owyhee and Bruneau Rivers in Twin Falls and Owyhee Counties and occur at elevations between 1,353–2,124 m (4,439–6,968 ft) (Figure 12; Munger *et al*. 1996, pp. 5, 66–69; La Fayette 2011, p. 12; Lohr 2012, p. 5). The Idaho Comprehensive Wildlife Conservation Strategy defines this area as the Columbia Plateau Ecoregion (Owyhee Uplands and Northwestern Basin and Range Ecosections; Idaho Department of Fish and Game (IDFG) 2005, pp. 1–13).

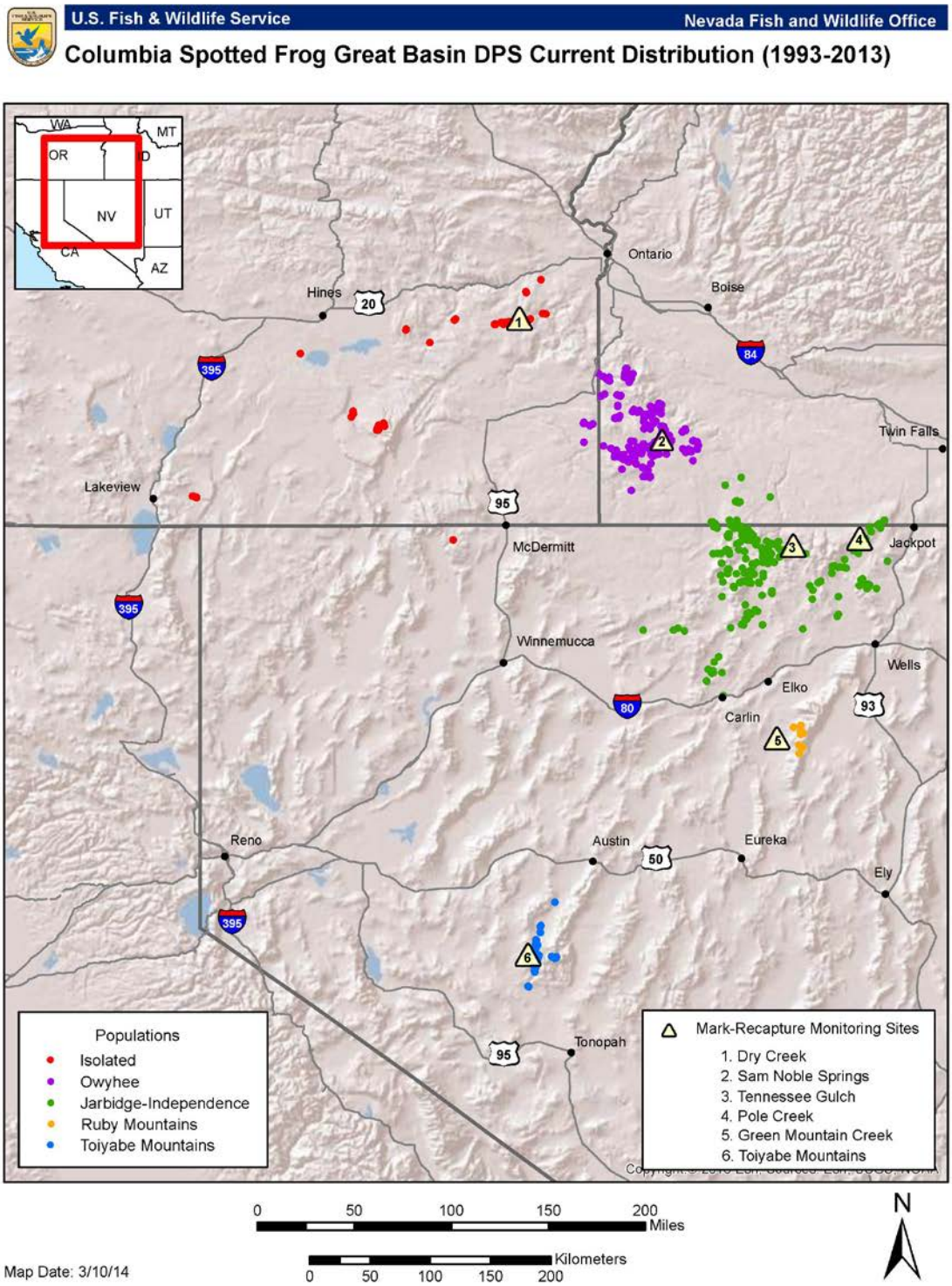


Figure 12. Current distribution of Columbia spotted frog populations within the Great Basin DPS. Currently occupied sites are those located from 1993 (year of Candidacy) to 2013. Also noted are locations of the mark-recapture monitoring sites.

Current Range/Distribution—Oregon

Both the Great Basin DPS and Northern DPS of Columbia spotted frogs are found in Oregon (Figures 1 and 2; Robertson and Funk 2012, p. 19–20). Populations east of Highway 395 and south of Highway 20 including the Owyhee and Steens Mountains in Lake, Harney, and Malheur Counties are part of the Great Basin DPS (Figure 2; Munger *et al*. 1998a, pp. 3–4; Smyth 2004, pp. 3–7; Funk *et al*. 2008, p. 202; Pearl *et al*. 2010, pp. 5–8; Robertson and Funk 2012, pp. 10–12, 19–20). The current range of the Great Basin DPS of Columbia spotted frogs in southeastern Oregon are found in 22 HUCs and occur at elevations between 1,097–2,247 m (3,599–7,372 ft). Isolated populations in southeastern Oregon occur in tributaries of the Donner und Blitzen (including Malheur Lake), Owyhee, and South Fork Malheur Rivers and a disjunct population in Parsnip Creek near Lakeview, Oregon. The Oregon Conservation Strategy defines this area as the Northern Basin and Range Ecoregion (Oregon Department of Fish and Wildlife (ODFW) 2006, pp. 204–221).

Rangewide Population Trends

Six long-term datasets (Dry Creek, Oregon; Sam Noble Springs, Idaho; Tennessee Gulch, Pole Creek, Green Mountain Creek, and Toiyabe Mountains, Nevada) were used to assess population trends of Columbia spotted frogs across the range of the Great Basin DPS (Figure 12; Pilliod *et al*. 2015b, pp. 1–50). In addition, two populations with long-term datasets from the Northern DPS (Little Rock Creek, Montana; Skyhigh Basin, Idaho) were used to compare areas which are believed to be relatively stable (Northern DPS) to areas which are thought to be declining (Great Basin DPS). Both recruitment (the number of adults added to the population) and adult survival (annual survival of adults) metrics were used to analyze the effects of year and drought-related weather covariates on population growth rates over a 9 to 16 year timeframe (Pilliod *et al*. 2015b, pp. 6–12). Results from Pilliod *et al*. (2015b, pp. 12–15) are discussed below.

Population growth rates from all eight populations (2 Northern DPS and 6 Great Basin DPS) indicate that four populations had positive growth rates (Skyhigh Basin, Dry Creek, Green Mountain Creek, and Toiyabe Mountains), and four populations were declining (Little Rock Creek, Sam Noble Springs, Tennessee Gulch, and Pole Creek). No evidence was found to indicate that the Great Basin DPS populations were declining as compared to the Northern DPS. Population growth rates were variable across years and by site. Several populations showed both positive and negative population growth rates depending on the year. Adult survival was relatively high (between 53 and 81 percent) at most sites (with the exception of Dry Creek) and, therefore, positive population growth rates were reliant on recruitment. Adult recruitment was more variable than adult survival (between 7–67 percent) with a general pattern of lower adult survival from low to high elevation sites, and alternatively, higher recruitment from low to high elevation sites. Weather-related covariates were also variable across sites and had different effects on both adult survival and recruitment. For example spring and summer precipitation positively influenced recruitment at Green Mountain and Skyhigh Basin while summer precipitation had a negative relationship on recruitment at Toiyabe Mountains. This complex interaction is a result of differences in latitude and elevation of the sites, different weather patterns across this rather large area, and different habitat types at each site. Pilliod *et al*.

(2015b, pp. 15–17) conclude that the asynchronous demographic rates of Columbia spotted frog populations found at these eight sites reduces the likelihood of all the populations declining at once, which increases the probability of persistence.

Population Estimates/Status–Nevada

Declines of Columbia spotted frog populations in Nevada have been recorded since 1962 when it was observed that in many Elko County localities where Columbia spotted frogs were once numerous, the species was nearly extirpated (Turner 1962, pp. 326–327). Extensive loss of habitat (particularly along mainstem rivers) had occurred from conversion of wetland habitats to irrigated pasture and from spring and stream dewatering by mining and irrigation practices. In addition, there were extensive impacts on riparian habitats due to historical intensive livestock grazing practices (Gruell and Swanson 2012, pp. 57–66). Researchers in Nevada have documented the loss of historically occupied sites, reduced numbers of individuals within local populations, and declines in the reproduction of local populations (Turner 1962, pp. 326–327; Hovingh 1990, p. 6; Reaser 1997a, pp. 30–33; Wente *et al*. 2005, p. 99).

Prior to 2003, lack of standardized and extensive monitoring prevented dependable determinations of frog population numbers or trends across Nevada. However, long-term standardized monitoring protocols have been implemented for both the Toiyabe Mountains and Northeastern populations (NDOW 2004b, pp. 1–25; 2009, pp. 1–21). Results from these efforts are provided below.

Within the Ruby Mountains, Jarbidge, and Mountain City Ranger Districts on the HTNF and the BLM Elko District in northeastern Nevada, there are approximately 212 HUCs. Of the 212 HUCs, 178 HUCs are associated with perennial water; the remaining 34 HUCs have little water and are not expected to have any frog habitat. From 2000 to present, the USFS and NDOW have conducted presence-absence surveys within 117 HUCs with perennial water. Upon completion of a HUC survey, the HUC is identified as either occupied (frogs detected), absent (no frogs detected and insufficient habitat), or unknown (no frogs detected, but more surveys needed). Of the 117 HUCs surveyed since 2000, Columbia spotted frogs have been detected in 71 (61 percent) (NDOW 2014, p. 16).

In 2004, the HTNF initiated an intensive mark-recapture survey at two sites, Green Mountain Creek, Ruby Mountains Ranger District; and Tennessee Gulch, Mountain City Ranger District (and added a third site in 2005, Pole Creek, Jarbidge Ranger District), as part of an effort to determine population estimates, mortality, juvenile-to-adult recruitment, movement, and habitat preference (Figure 12). A summary of findings is discussed below (Figure 13; Table 1; Van Horne 2013, pp. 1–17). Between 2004 and 2013, a total of 2,217 discrete adult frogs (total number marked plus total number of recaptures from previous years) were captured from all three sites. Between 2006 and 2013, the average number of adult frogs captured (mean = 43) at the Green Mountain Creek site was relatively stable and remained approximately double the numbers captured in 2004 and 2005; however, juvenile numbers have shown a more variable trend (Figure 13; Table 1; Van Horne 2013, pp. 4–7). Population growth has been positive at this site due to consistently high adult survival and high recruitment in some years (Pilliod *et al*.

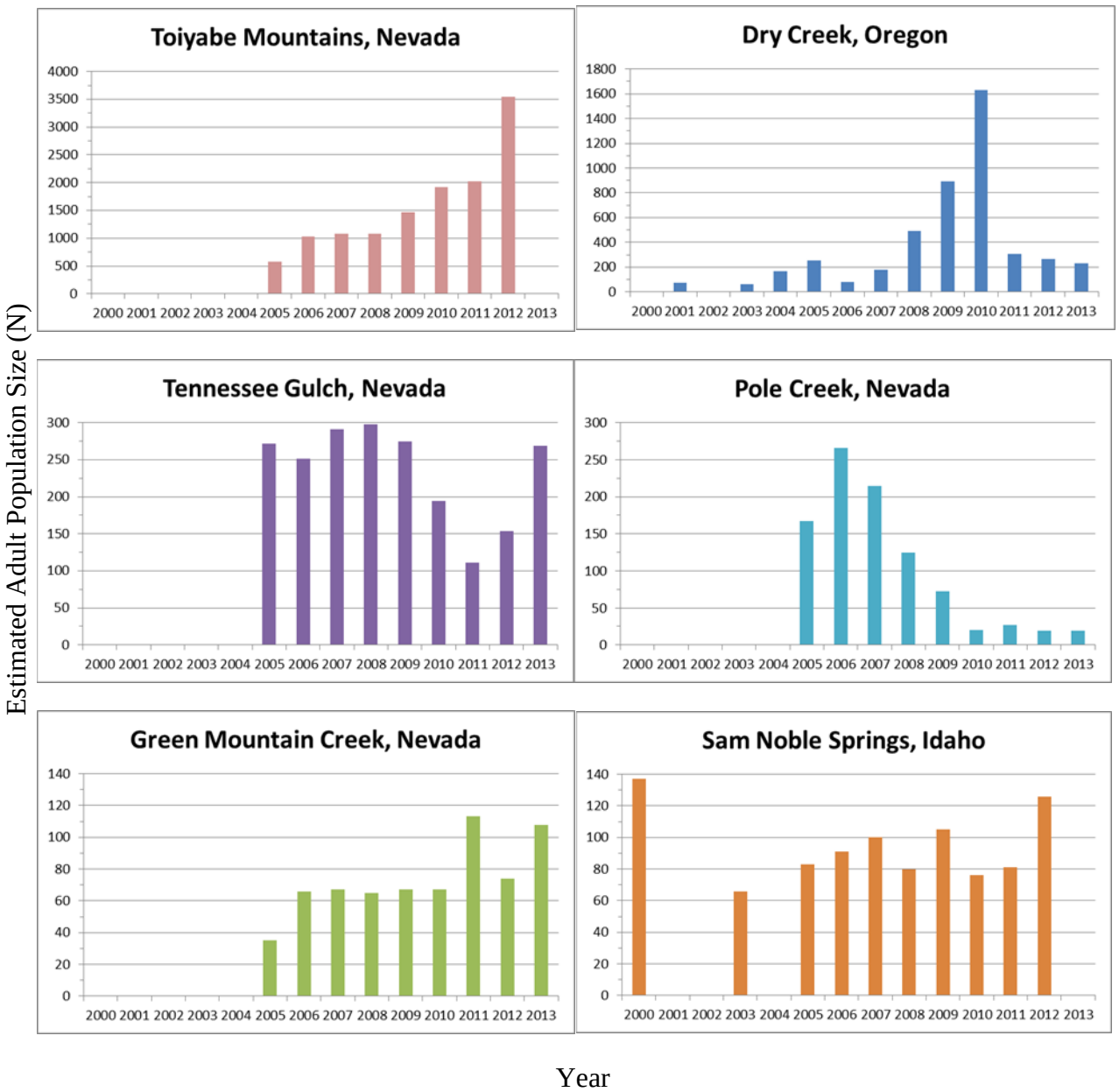


Figure 13. Adult population estimates of Columbia spotted frogs at the six long-term monitoring sites within the Great Basin DPS. Lincoln-Petersen methodology was used for population estimates at all sites except for the Toiyabe Mountains (Jolly-Seber) and Sam Noble Springs (program MARK). Note the different scales for the y-axis. Data sources include: Toiyabe Mountains (NDOW 2013b, unpublished data); Dry Creek (Meyer 2013, p. 14); Tennessee Gulch, Pole Creek, and Green Mountain Creek (Van Horne 2013, pp. 4–13); Sam Noble Springs (Lohr 2012, p. 12).

Table 1. Columbia spotted frog survey data for the Green Mountain (GM), Tennessee Gulch (TG), and Pole Creek (PC) sites in the Jarbidge-Independence Range and Ruby Mountains populations, Northeastern Nevada. Population estimates are based on Lincoln-Petersen methodology (Modified from Van Horne 2013, pp. 4–13).

		Year									
Site		**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
GM	Males	7	7	33	27	20	24	23	22	18	29
	Females	11	13	24	25	22	25	27	21	24	29
	Juveniles	32	65	5	21	43	32	47	40	13	41
	Population Estimate		35	66	67	65	67	67	113	74	108
TG	Males	20	73	64	56	56	46	34	15	23	55
	Females	21	66	75	119	146	107	59	44	54	65
	Juveniles	29	39	24	9	11	5	10	4	3	83
	Population Estimate		272	251	291	298	275	194	111	154	269
PC	Males		83	103	112	58	27	1	8	7	1
	Females		70	90	67	56	46	16	14	8	6
	Juveniles		72	5	3	0	0	0	3	0	0
	Population Estimate		167	266	215	125	72	20	27	19	19

2015b, p. 35). Adult numbers captured at Tennessee Gulch in 2013 was 120. Between 2005 and 2009 adult numbers were similar (mean = 161); however, between 2010 and 2012, the mean number of adults captured declined to 76. In addition, females outnumbered males in the population by 2 to 1, and juvenile numbers remained low for 6 years in a row before rebounding in 2013 (Figure 13; Table 1; Van Horne 2013, pp. 8–11). Adult survival has been very high; however, due to poor recruitment, population growth has been slightly negative at this site (Pilliod *et al*. 2015b, p. 35). The number of adult frogs captured at the Pole Creek site between 2005 and 2007 averaged 175 individuals; however, beginning in 2008 and continuing through 2013, the number of adults captured has declined sharply with only 7 adults captured in 2013 (Figure 13). Additionally, juvenile numbers remained low with a total of 11 captured between 2006 and 2013. Due to variable adult survival and poor recruitment, population growth has been negative at this site and is at risk of extirpation (Pilliod *et al*. 2015b, p. 35). This decline at the Pole Creek site is believed to be due to the declining amount of available habitat, which is due to reduced beaver (*Castor canadensis*) activity (Van Horne 2013, pp. 12–15).

To document population dynamics within the Toiyabe Mountains population, a large mark-recapture study using PIT tags was initiated in 2004 and has continued annually (Figures 7, 8, and 12). During this period, 6,435 frogs have been PIT tagged. Results from the 2013 monitoring are discussed below (Table 2; NDOW 2013b, unpublished data). In 2013, total discrete adult frog captures (total number marked plus total number of recaptures from previous years) decreased by 1,000 individuals (n = 1,597) compared to 2012 (n = 2,594); however, this

Table 2. Columbia spotted frog summary survey data from the Toiyabe Mountains population, central Nevada.

	Year									
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Adults Captured	403	308	417	669	624	913	1,106	1,166	2,594	1,597
Adults Recaptured	–	95	115	157	225	325	527	436	763	784
Juveniles	68	92	251	646	634	633	1,003	994	1,134	1,809
Egg Masses	38	17	83	17	59	56	131	360	429	255
Population Estimate[1]	–	582	1,023	1,075	1,077	1,465	1,921	2,027	3,549	–
Population Estimate[2]	595	544	635	920	803	1,114	1,619	–	–	–

[1] NDOW 2013b, unpublished data (Jolly-Seber); [2] Adams *et al*. 2013, p. 11 (program MARK).

number is the second highest since monitoring began. Total recaptures in 2013 (n = 784) were similar to 2012 (n = 763). The average number of juveniles captured between 2004 and 2009 was 387; however, between 2010 and 2013 the average increased substantially to 1,235. This is the single largest known population in the Great Basin and has shown positive growth every year with adult survival and consistent recruitment contributing equally to population growth (Pilliod *et al*. 2015b, p. 35). The average egg mass counts from 2004 to 2009 were 45; however, since 2010, egg mass counts have been 3 to 9 times higher (Table 2). Population estimates are made using the Jolly-Seber method and have ranged from a low of 582 adults in 2005 to a high of 3,549 adults in 2012 (Figure 13; Table 2; NDOW 2013b, unpublished data). Additionally, estimates of the adult population were made by USGS between 2004 and 2010 using the program MARK (Adams *et al*. 2013, pp. 1–12). Population estimates were generally lower using this method but showed similar trends (Table 2).

Population Estimates/Status—Idaho

Prior to their listing as a Candidate species in 1993, Columbia spotted frogs were found at seven locations in southwestern Idaho (Munger *et al*. 1996, p. 3). Since 1993, several more locations in southwestern Idaho have been documented (Figures 9 and 12). Extensive surveys (presence/not detected) began in 1995 and intensive surveys (mark-recapture and egg mass counts) at four sites began in 1997. In 2000, a monitoring protocol was established for extensive surveys of Columbia spotted frogs at 51 Element Occurrences (EO) in southwestern Idaho (Engle 2000a, p. 29). According to the protocol, a subset of EOs is surveyed every year on a 3-year rotation (approximately 15 EOs/year). From 2001 to 2006, Columbia spotted frogs occupied from 45 to 85 percent of surveyed EOs (Table 3). In 2007, the monitoring protocol shifted from presence/not detected surveys to occupancy estimation and modeling, and survey units were based on catchment basins (HUCs broken into smaller survey units) (Moser 2007, pp. 9–10). From 2007 to 2011, 58 to 85 percent of the catchment basins surveyed were occupied by Columbia spotted frogs (Table 3). Additionally, 39 different catchment basins located on private

Table 3. Columbia spotted frog percent occupancy of the Owyhee population in southwestern Idaho from 2001 to 2011.

Year	Percent Occupied
2001[a]	69
2002[b]	85
2003[c]	45
2004[d]	72
2005	Not surveyed
2006[e]	75
2007[f]	58
2008[g]	62
2009[h]	61
2010[i]	77
2011[j]	75

[a]Engle (2002, p. 35), [b]Lingo and Munger (2002, p. 27), [c]Lingo and Munger (2003, p. 54), [d]Blankenship and Munger (2005, p. 2), [e]Moser and Patton (2006, p. 2), [f]Moser (2007, p. 14), [g]Lohr and Moser (2008, p. 14), [h]Lohr and Haak (2009, p. 14), [i]Lohr and Haak (2010, p. 14), [j]Lohr (2011, p. 14).

lands in southwestern Idaho were surveyed from 2009 to 2012 (LaFayette 2009–2012, entire documents), and Columbia spotted frogs were detected in 32 (82 percent) (LaFayette 2009, pp. 6–17; 2010, p. 7; 2011, p. 13; 2012, p. 4).

Four sites, located in different catchment basins, have been intensively surveyed annually since 1997 (Lohr 2012, pp. 2–17). These sites are Sam Noble Springs, Circle Pond, Cottonwood Creek, and Stoneman Creek. Sam Noble Springs is a complex of nine man-made ponds excavated in wet meadows or at springheads managed by Idaho Department of Lands (Figures 9, 11; Lohr 2012, p. 6). Six of the oldest ponds are surrounded by a 104-acre grazing exclosure fence that was erected in 2003. Two of the other three ponds are partially fenced. Circle Pond is an impoundment that was originally created for livestock water and is fed by three springs (Munger 2003, p. 3). In 1997, a grazing exclosure fence was erected around the springs and pond. Cottonwood Creek is a slow-flowing, perennial stream with areas of pooled water. Stoneman Creek is a perennial stream that had an active beaver population prior to 1992 and again from 2001 to 2011.

Complete egg mass counts have been conducted at the four sites from 2000 to 2012 (Table 3). The number of egg masses at Stoneman Creek increased substantially with the reintroduction of beaver in 2001, which improved breeding habitat.

Mark-recapture surveys were conducted at Circle Pond and Stoneman Creek from 1997 to 2006, at Cottonwood Creek from 2000 to 2006, and at Sam Noble Springs from 1997 to 2012. Because of small sample sizes, population estimates were difficult to construct at Circle Pond,

Table 4. Total number of Columbia spotted frog egg masses observed at four sites within the Owyhee population in southwestern Idaho, 2000–2012 (Lohr 2012, pp. 9–10). Data for Sam Noble Springs represents the six original ponds within the grazing exclosure.

Egg Masses				
Year	Circle Pond	Cottonwood Creek	Stoneman Creek	Sam Noble Springs
2000	8	No survey	0	45
2001	Present	No survey	0	47
2002	2	8	1	34
2003	3	4	10	31
2004	0	8	29	13
2005	0	12	51	18
2006	1	11	120	25
2007	3	33	Present[a]	39
2008	3	6	93	57
2009	9	25	79	37
2010	1	11	167	33
2011	4	6	105	49
2012	4	22	25	52

[a] incomplete survey.

Cottonwood Creek, and Stoneman Creek and total captures were reported instead (Moser and Patton 2006, pp. 8-17). In contrast, at Sam Noble Springs, mark-recapture results were pooled for the six older ponds in the grazing exclosure leading to sample sizes large enough to use Program MARK. The resulting estimates ranged from a high of 137 adult frogs in 2000 to 66 adult frogs in 2003 (Figure 13). Population growth has been negative at Sam Noble Springs; however, it has been fairly stable since 2003 with consistent adult survival and variable recruitment (Pilliod *et al*. 2015b, p. 35).

Population Estimates/Status—Oregon

In southeastern Oregon, presence-absence surveys conducted in 1997 reconfirmed a population of Columbia spotted frogs in the Dry Creek drainage in Malheur County which had been previously documented in 1939 (Figures 11 and 12; Munger *et al*. 1998a, pp. 3–4, 12). Dry Creek was historically a tributary to the Owyhee River; however, it now flows into Owyhee Reservoir. Dry Creek is characterized by steep canyons, scour pools, and meandering stream reaches with boulders, cobbles, and sandy substrate (Figure 11; Meyer 2013, p. 2). Detailed population sampling using PIT tags has occurred in Dry Creek since 2001 (Table 5; Meyer 2013, pp. 1–30). During this period, 3,218 frogs were PIT tagged. Total discrete adult frog captures were substantially lower in 2013 (n = 29), 2012 (n = 56) and 2011 (n = 38) compared to 2010 (n = 197) and 2009 (n = 164) (Table 5; Meyer 2013, p. 14). Subadult frog counts were also fewer in 2013 (n = 127), 2012 (n = 158) and 2011 (n = 121) compared to 2010 (n = 1,086) and 2009 (n = 628) (Table 5; Meyer 2013, p. 14). Based on Lincoln-Petersen estimates, the total population size (N) has generally increased since 2001 (N = 74), with large increases detected in 2008 (N = 493), 2009 (N = 890), and 2010 (N = 1,632); however, in 2011 (N = 305), 2012 (N = 266), and

Table 5. Columbia spotted frog summary survey data from the Dry Creek population, southeastern Oregon (Meyer 2013, p. 14).

Year						
	2001	**2002**	**2003**	**2004**	**2005**	**2006**
Males	2	2	2	10	8	10
Females	9	9	9	26	18	22
Subadults	39	20	41	61	119	25
Population Estimate	74	–	62	168	255	80

Year							
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Males	11	21	69	97	22	34	11
Females	7	42	95	100	16	22	18
Subadults	108	317	628	1,086	121	158	127
Population Estimate	178	493	890	1,632	305	266	230

2013 (N = 230), a substantial decrease in the population occurred (Figure 13; Table 5; Meyer 2013, pp. 12– 14). Two large spring (March and May) flow events in 2011 coupled with recent drought conditions (2012–2013) are presumed to have caused this reduction in the population. Over the 13-year study period, only 301 individuals have been recaptured, indicating that annual survival rates of adults are low (Meyer 2013, p. 27). Despite this low adult survival, population growth has been increasing at this site due to very high recruitment levels (Pilliod *et al*. 2015b, pp. 14, 35).

Presence-absence monitoring has occurred in the Steens Mountain area, Harney County, in which small isolated populations of Columbia spotted frogs have been located (Smyth 2004, pp. 3–7). Between 2000 and 2003, the USGS compared regional distributions of amphibians with occurrence patterns suggested in historical (prior to 1999 in this study) data (Wente *et al*. 2005, pp. 95–99). Visual encounter surveys were used to determine presence-absence of Columbia spotted frogs on public lands in eastern Oregon and northern Nevada. Based on occupancy models, the USGS estimated that Columbia spotted frogs occupied 53 percent of the 30 historical sites in the area surveyed (Wente *et al*. 2005, p. 99). Between 2000 and 2003, 6 of 16 sites proximal to historical sites were occupied (Wente *et al*. 2005, p. 99). Additionally, 187 sites in southeastern Oregon were randomly selected for presence-absence surveys of which only 3 sites were occupied; however, variability in occupancy between the 3 years was problematic due to drought, variable historical records, and inherent biases in detecting declines using revisitation studies (Wente *et al*. 2005, pp. 99–106). More recently, USGS crews sampled 42 historical (prior to 2000 in this study) locations in southeastern Oregon (both Northern and Great Basin DPS) and found Columbia spotted frogs at nearly 60 percent of the target sites or in nearby habitat (Pearl *et al*. 2010, pp. 2–9). The authors caution interpretation of the results because the survey was conducted in one year (2009), sites were only visited once, many of the historical records contained just a few adult frogs, and many of the historical records contained poor location data (Pearl *et al*. 2010, pp. 7–8). Malheur National Wildlife Refuge biologists have also found more Columbia spotted frogs throughout the refuge than was previously thought (F. Healy, 2015, pers. comm.)

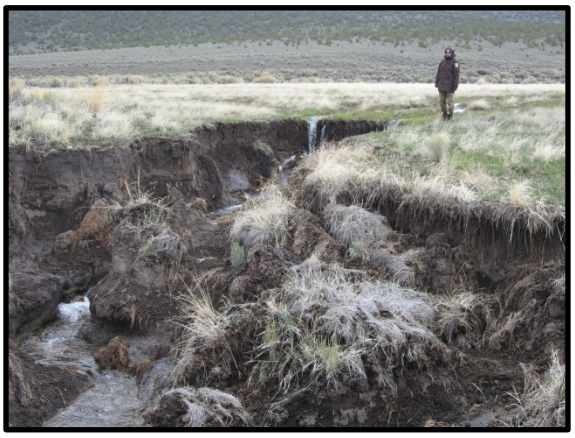
In summary, monitoring efforts of varying intensities are being implemented throughout the range of the Columbia spotted frog in Idaho, Nevada, and Oregon. Extensive surveys and monitoring since 1993 have revealed that Columbia spotted frog populations are much more widespread than what was previously known (and at the time of Candidacy). While some sites and HUCs are no longer occupied, Columbia spotted frogs are well distributed as compared to the known historical distribution throughout southwestern Idaho and northeastern Nevada with isolated and disjunct populations in southeastern Oregon and central Nevada (Figure 12). Population estimates are available for six intensively surveyed sites across three states—population growth at three sites are positive and three sites are declining (Pilliod *et al.* 2015b, pp. 15, 35). Population genetic analyses have been conducted in Oregon and Idaho and have revealed genetic signals indicative of small isolated populations (Robertson and Funk 2011, pp. 5–9, 13; Robertson and Funk 2012, pp. 5–12).

Chapter 2

In this Chapter, information presented will focus on both natural and human induced historical events which likely influenced and continue to influence the distribution and abundance of Columbia spotted frogs. We will use information from the species' past to explain how the species' resources evolved to their present state of availability and condition.

Phylogeography and Historical Anthropogenic Stressors

Numerous phylogeographic studies have demonstrated the influence of historical geologic, climate, and environmental events on speciation and species distributions including Columbia spotted frogs (*e.g*., Dumas 1966, pp. 71–73; Remington 1968 pp. 322–383, Green *et al*. 1996, pp. 374–388; Bos and Sites 2001, pp. 1499–1511; Swenson and Howard 2005 pp. 581–590; Funk *et al*. 2008, pp. 198–205; Zeisset and Beebee 2008, pp. 109–112). Important historical events that have influenced species distributions in the western United States include: (1) the uplift of the Cascade and Sierra Mountain Ranges during the Pliocene (2–5 million years ago (mya)), which caused much drier conditions in the Columbia Plateau and Great Basin Regions; (2) Pleistocene glaciation cycles beginning 1–2 mya and continuing until 18–20,000 years before present (ybp) also influenced the distribution of organisms; and (3) evidence of wetter conditions in the Great Basin, until approximately 10–12 thousand ybp when the last high pluvial lake levels occurred, and the subsequent drier conditions since that time, explain much of the Great Basin aquatic community composition and distribution (Hubbs and Miller 1946, pp. 21–29; Dumas 1966, pp. 71–73; Swenson and Howard 2005 pp. 581–590; Zeisset and Beebee 2008, pp. 109–112; Houston *et al*. 2011, pp. 163–173; NDOW 2012a, pp. 16–18). Additionally, more contemporary climate impacts (last 150 years) and anthropogenic influences in the region (*e.g.*, beaver trapping, grazing, agriculture, mining, and nonnative species introductions) have likely influenced Columbia spotted frog distribution and abundance (Miller and Alcorn 1945, pp. 173–193; Sada and Vinyard 2002, pp. 277–287; IPCC 2007, pp. 31, 38; Gruell and Swanson 2012, pp. 57–66; Morris and Rowe 2014, pp. 1146–1150). Robertson and Funk (2011, pp. 5, 9; 2012, pp. 4, 8) provide genetic evidence of bottleneck events for Columbia spotted frog populations in southeastern Oregon and southwestern Idaho which correspond to contemporary (100 ybp) events described below.



Figures 14–15. Examples of active erosional processes occurring in Indian Valley, Toiyabe Mountains population in central Nevada.

Habitat modification and destruction has been implicated in the majority of global amphibian declines (Bishop *et al*. 2003, pp. 209–210; Young *et al*. 2004, pp. 31–32; Bradford 2005, pp. 919, 921–922; Vredenburg and Wake 2007, p. 5; Wells 2007, pp. 817–825; Chanson *et al*. 2008, pp. 39–42). Columbia spotted frog habitat degradation and fragmentation is a combined result of topography, climate change, and past and some current land use influences from agricultural development, heavy livestock grazing, water development (*e.g.*, diversions, dams), nonnative fish stocking, beaver management, and mining activities (Miller and Alcorn 1945, pp. 173–193; Sada and Vinyard 2002, p. 280; Gruell and Swanson 2012, pp.57–66; Gibson and Olden 2014, pp. 394–395; Morris and Rowe 2014, pp. 1146–1150). Historical livestock grazing practices within the Great Basin caused substantial damage to rangelands, meadows, and riparian areas (Gruell and Swanson 2012, pp.57–66; Morris and Rowe 2014, pp. 1146–1148). Small upland streams and meadows found throughout the central Great Basin, including occupied habitat within the Toiyabe Mountains population in Nevada, are inherently unstable and have been prone to erosional processes such as incision (downcutting of streams) (Germanoski and Miller 2004, p. 117). Historical land use activities in these sensitive areas have initiated or accelerated the incision process, which has changed the hydrologic function of meadow systems (Figures 14–15; Jewett *et al*. 2004, pp. 152–155). These changes in the hydrology of meadows, mainly the lowering of the water table, can cause the vegetation communities to shift from wet meadow communities (*Carex* sp.) to dry upland plant communities (*Artemisia* sp.) (Chambers *et al*. 2004a, pp. 201–205). Natural fluctuations in environmental conditions (*e.g.*, drought) tend to magnify the detrimental effects of land use activities, just as the land use activities may compound the detrimental effects of natural environmental events (Boone *et al*. 2003, pp. 138–142).

Over the past 120 years, most rivers and streams have been dammed and diverted for irrigation, flood control, or power generation while many springs and smaller streams have been modified for livestock and agriculture (Sada and Vinyard 2002, p. 278). Within the Great Basin, cold water spring habitats provide a stable, permanent source of water for frog breeding, feeding, shelter, and winter refugia (IDFG *et al*. 1995, p. 9; Patla and Peterson 1997, pp. 16–17; Munger 2003, p.13). Analyzing 10 different factors that influence the abundance and distribution of

aquatic taxa in the Great Basin, Sada and Vinyard (2002, p. 280) found that anthropogenic water development (springs and stream diversions) was the most important factor affecting aquatic biota. Turner (1962, p. 327) noted intensive water utilization in the Reese River, which contributed to low stream flows and subsequent declines in Columbia spotted frogs in Nevada. Reduced streamflows below diversions can alter the biotic composition, structure, and function of aquatic and riparian ecosystems (Richter *et al.* 1996, p. 1164; Poff *et al*. 1997, p. 769; Poff and Zimmerman 2010, p. 198). Loss of this permanent source of water in semi-arid ecosystems can also lead to the loss of associated riparian habitats and wetlands used by Columbia spotted frogs.

Widespread removal of beaver from trapping throughout the Great Basin in the 19th century (Clements 1991, pp. 277–278; Gibson and Olden 2014, pp. 394–395) likely impacted and contributed to Columbia spotted frog habitat fragmentation. The reduction of beaver populations has been noted as an important feature in the reduction of suitable habitat for Columbia spotted frogs (Reaser 1997a, p. 39; NDOW 2012a, p. S–64; ODFW 2006, p. 288). Beaver are important in the creation of ponded, slow-moving water that functions as habitat for all life stages of Columbia spotted frogs (*e.g*., reproduction, larval development, overwinter) and create wet meadows that provide foraging habitat and protective vegetation cover (Naiman *et al*. 1988, pp. 754–761; Amish 2006, p. 9; Cunningham *et al*. 2007, pp. 2520–2523; Stevens *et al*. 2007, pp. 6–11; Arkle and Pilliod 2015, pp. 16–17; Pollock *et al*. 2014, pp. 282–289). Additionally, when beavers create a series of ponds they increase: (1) the quantity and quality of Columbia spotted frog habitat, (2) hydroperiod, and (3) connectivity between other sites across different watersheds (Arkle and Pilliod 2015, pp. 16–17). In southwestern Montana (Northern DPS), Amish (2006, pp. 28–32) found significantly higher amounts of lentic habitat and breeding sites for Columbia spotted frogs in watersheds containing beaver than watersheds without beaver. Within the Great Basin, beaver ponds were significantly more likely to be occupied than any other habitat type with beaver ponds constituting 57 percent of all occupied habitat (Arkle and Pilliod 2015, p. 11). Not only can beavers create ponded habitat, but their ability to restore degraded stream systems by reducing channel incision rates and increasing aggradation rates (streambed material accumulates faster than it is exported) is becoming recognized as an important restoration technique (Gibson and Olden 2014, pp. 399–401; Pollack *et al*. 2014, pp. 284–286). There is a growing body of evidence linking the positive habitat influence of beaver to the presence of Columbia spotted frogs in the Great Basin DPS.

Changes in occurrence

Phylogeography and historical anthropogenic influences on the habitat and distribution of Columbia spotted frogs in the Great Basin were described above. Now we will examine information from historical biological surveys to compare changes in occurrence. Comparing the historical and current distributions of a species like Columbia spotted frogs is challenging due to many factors including, but not limited to, incomplete historical surveys, few historical records, imprecise site locality information, typically few individuals at a site, and the transient nature of frog habitat associated with beaver ponds. To address some of these challenges, a watershed occupancy approach using HUCs was used to assess the status of the Great Basin DPS Columbia spotted frogs (based on the National Hydrography Dataset (NHD); see *http://nhd.usgs.gov* for more information). Sites occupied prior to 1993 are termed historical

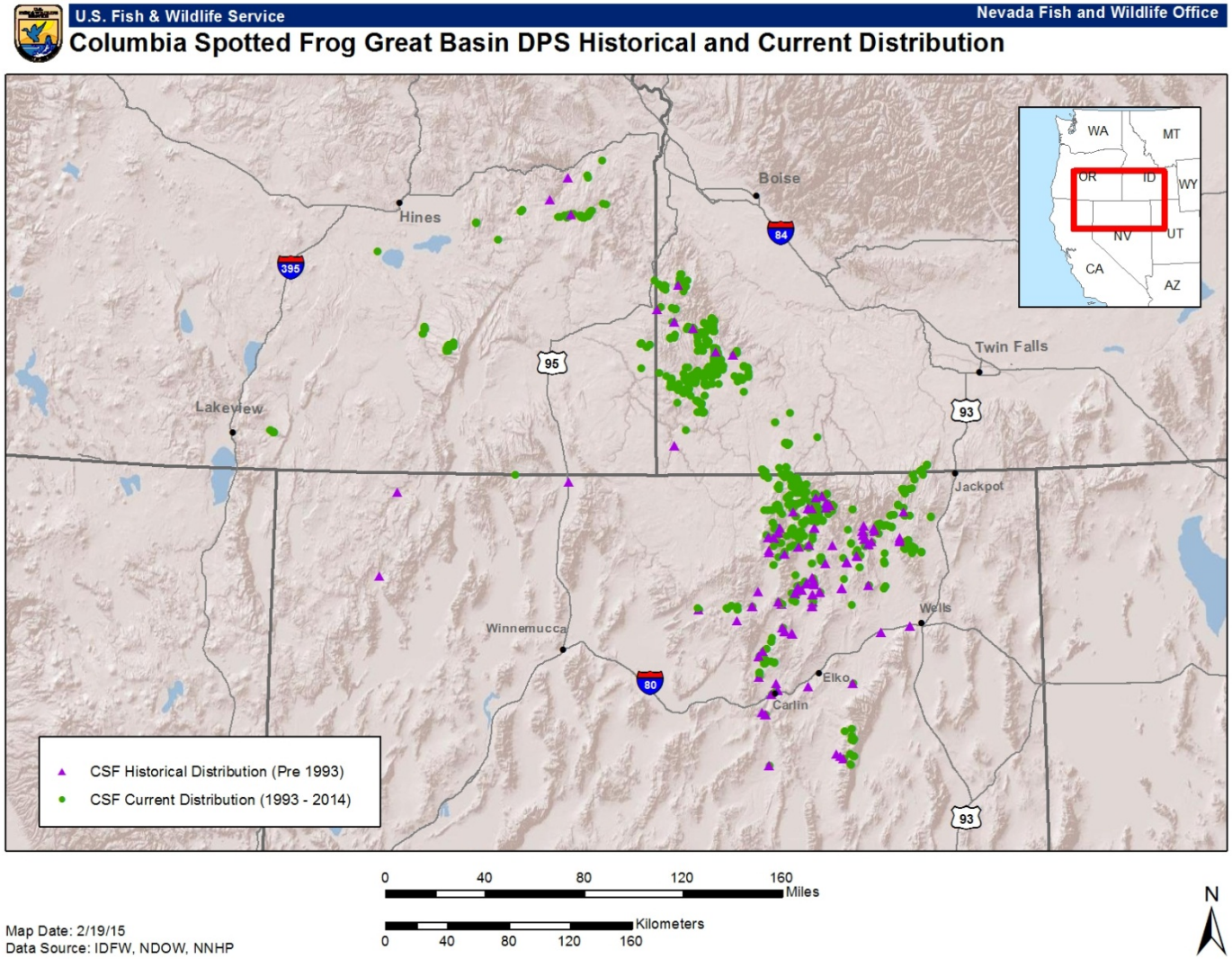


Figure 16. Current (1993–2014) and historical (pre-1993) Columbia spotted frog sites in southeastern Oregon, southwestern Idaho, and northern Nevada.

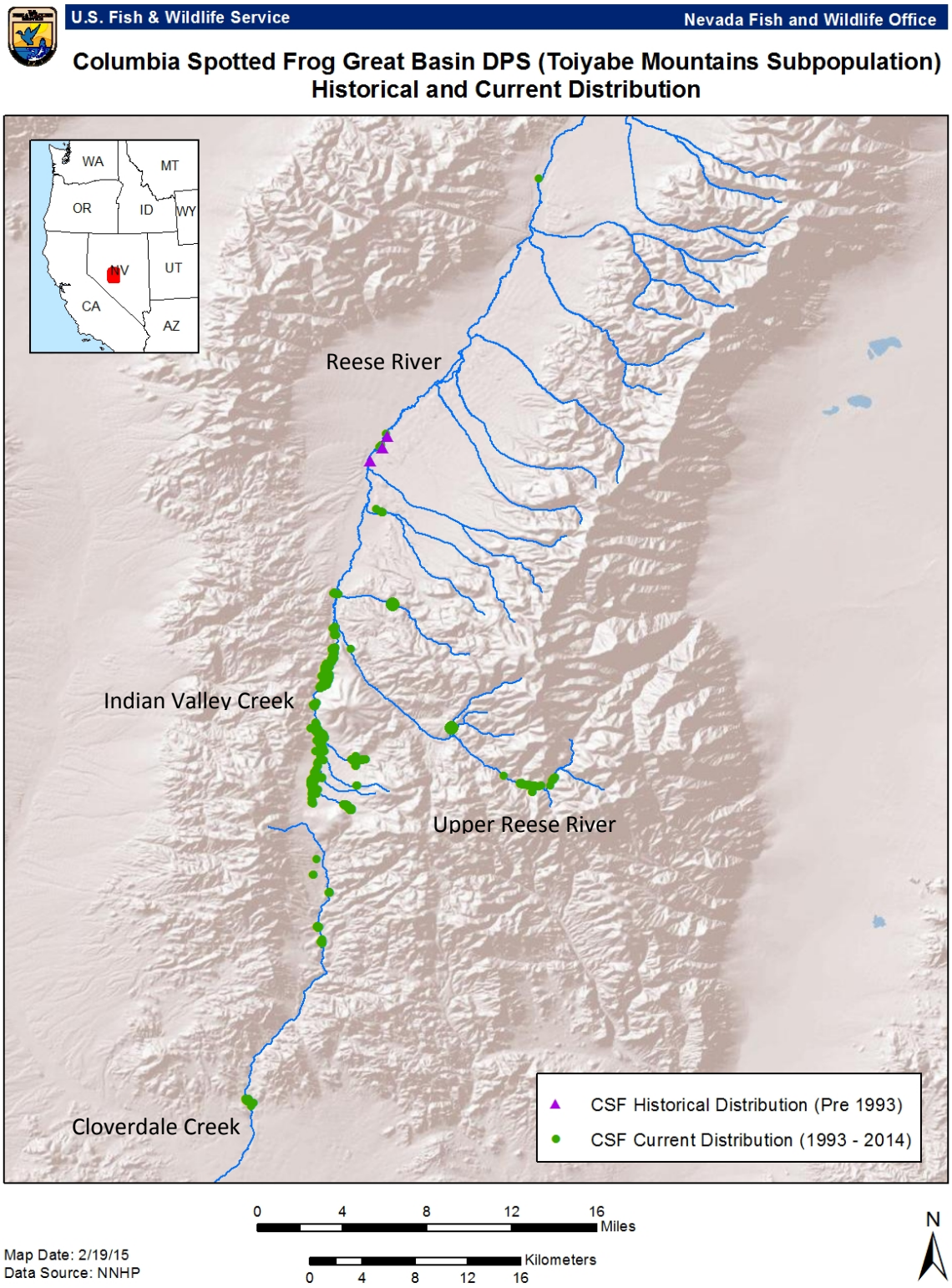


Figure 17. Current (1993–2014) and historical (pre-1993) Columbia spotted frog sites in the Toiyabe Mountains, central Nevada.

sites (prior to Candidacy) while sites detected from 1993 to 2014 are termed current sites. A HUC is considered occupied if it has at least one occupied site within its boundary. Prior to 1993, there were 66 known occupied HUCs within the Great Basin DPS (Oregon 3, Idaho 7, Nevada 56). Between 1993 and 2014, Columbia spotted frogs have been detected in 165 HUCs (Oregon 22, Idaho 42, Nevada 101; Figures 16–17). In Oregon, one historical HUC is known to still be occupied and the other two are thought to be extirpated based on recent surveys. In Idaho, of the seven HUCs known to exist prior to 1993, five were occupied on at least one occasion between 1995 and 2008, one is of unknown occupancy, and one (at the confluence of the Little Owyhee River and South Fork Owyhee River) may be extirpated. Of the 56 historical HUCs in Nevada, 16 have no known current occupancy. Of those 16 HUCs, 9 have a low likelihood of current occupancy due to presence of nonnative aquatic species, high anthropogenic disturbance, or no known contemporary habitat. The remaining seven HUCs have high quality habitat but have not been surveyed recently. There are unconfirmed reports of Columbia spotted frogs in the northeastern portion of California along the eastside of the Warner Mountains; however, there have been no recent surveys in this area and up to date field guides do not mention Columbia spotted frogs in California (Stebbins and McGinnis 2012, pp. 186–215). This information warrants further investigation.

Columbia spotted frogs were likely more widespread than historical surveys portray. Another way to analyze the differences between the past and current distribution of organisms is through climate modeling. Pilliod *et al*. (2015a, pp. 6–9) used a climate suitability model for Columbia spotted frogs to assess changes in the amount of suitable habitat between three time frames: (1) 1901–1930 (past), (2) 1981–2010 (recent), and (3) 2071–2100 (future). Future climate projections will be discussed in the climate change section of this document. Current climate data and Columbia spotted frog distributional information can be used to predict the area with suitable climate that may have been available for Columbia spotted frogs in the past assuming that the past climate-habitat requirements for Columbia spotted frogs are the same as they are today and they had access to these habitats (Pilliod *et al*. (2015a, p. 8). The authors used a minimum climate suitability value of 0.20 (minimum suitability that could support occupancy) which accounted for greater than 95 percent of all known current breeding locations (R. Arkle 2015 pers. comm.). Assuming this climate suitability value, Pilliod *et al*. (2015a, pp. 12, 32, 34; R. Arkle 2015, pers. comm.) found a 49 percent decline in suitable climate for Columbia spotted frog within the Great Basin between past and recent climates indicating a range restriction across the Great Basin.

Changes in genetic diversity

Many species have suffered bottlenecks or long time-periods at small population sizes which can be measured using tests of genetic diversity (Frankham *et al*. 2004, pp. 13–20). Comparison of historical and current rates of genetic variation may indicate how rapidly and severely populations have declined (Frankham *et al*. 2004, pp. 12–30). Genetic diversity can help buffer a species from short-term environmental fluctuations and provide resilience in a species' response to longer-term changes (Frankham 2005, pp. 135–136). Robertson and Funk (2011, pp. 1–23; 2012, pp. 1–20) used microsatellite markers to test for allelic richness and diversity as well as population declines using genetic bottleneck tests at 15 sites throughout southwestern Idaho (9 sites) and southeastern Oregon (6 sites). Results indicate that: (1) the average number of alleles

per locus was low, which is consistent with an overall reduction in allelic richness and diversity across all 15 sites, and (2) three of nine sites in southwestern Idaho and five of six sites in southeastern Oregon show evidence of a loss in allelic diversity indicating a recent bottleneck occurring within the last 80 years (Robertson and Funk 2011, p. 5; Robertson and Funk 2012, p. 4). This timeframe is correlated with high anthropogenic stressors on aquatic environments within the Great Basin such as agricultural development, intensive livestock grazing, water development (*e.g.*, diversions, dams), nonnative fish stocking, beaver management, and mining activities discussed above. These genetic analyses have not occurred for populations in Nevada.

Chapter 3

Species viability, or the ability to survive over the long term, is related to the ability to withstand disturbances of varying magnitude and duration (resiliency), the species ability to withstand catastrophic population and species-level events (redundancy), and the ability to adapt to changing environmental conditions (representation). The viability of species is also dependent on the likelihood of new or continued stressors now and in the future that act to reduce a species redundancy, representation, and resiliency. In this chapter we summarize information on the current distribution, population size, and genetic evaluation of Columbia spotted frog populations.

Resiliency

For the Columbia spotted frogs in the Great Basin DPS, our sense of how resilient they are comes from demographic metrics such as birth versus death rates, and population size. As mentioned earlier, six long-term datasets were used to assess population trends of Columbia spotted frogs across the range of the Great Basin DPS (Figure 12; Pilliod *et al*. 2015b, pp. 7–12). Both recruitment (the number of adults added to the population) and adult survival (annual survival of adults) metrics were used to analyze the effects of year and four different weather-related covariates on population growth rates over a 9 to 16 year timeframe (Pilliod *et al*. 2015b, pp. 7–12). Results from Pilliod *et al*. (2015b, pp. 15, 35) indicate that three populations had positive growth rates (Dry Creek, Green Mountain Creek, and Toiyabe Mountains) and three populations were declining (Sam Noble Springs, Tennessee Gulch, and Pole Creek). Population growth rates were variable across years and by site. Several populations showed both positive and negative population growth rates depending on the year. Additionally, weather related influences were highly variable depending on year and site. This complex interaction is a result of differences in latitude and elevation of the sites, different weather patterns across this rather large area, and different habitat types at each site. Pilliod *et al*. (2015b, pp. 15–16) conclude that the asynchronous demographic rates of Columbia spotted frog populations found at these six sites reduces the likelihood of all the populations declining at once, which increases the probability of persistence.

Adult population estimates range from the tens to the thousands of adults at the six long-term sites (Figure 13; Tables 1, 2, and 5). However, most occupied sites contain few adults, usually in the single digits or tens, indicating that the majority of occupied sites are small (Munger *et al*. 1998b, pp. 323–324; Smyth 2004, pp. 3–7; NDOW 2007, p. 5; Pearl *et al*. 2010, p. 5). While estimates of effective population size for populations in southeastern Oregon and southwestern

Idaho are small (N_e 7 to 25), they are within the range of other effective population sizes of Columbia spotted frogs in the Northern DPS (N_e 9 to 65), as well as several other ranid species in the Pacific Northwest (N_e 5 to 54) (Phillipsen *et al*. 2011, pp. 2936–2939, 2943–2945). Completely isolated populations in southeastern Oregon are the most vulnerable to extirpation due to their isolation and small effective population sizes (Figure 15; Robertson and Funk 2012, p. 7–8, 11). Estimates of effective population size have not been conducted for populations in Nevada.

Redundancy

For Columbia spotted frogs in the Great Basin DPS, redundancy is based on the duplication and distribution of resilient populations across its range. The distribution of Columbia spotted frogs in the Great Basin is limited due to the xeric nature of the region. Pilliod *et al*. (2015a, pp. 12, 32, 34) used a climate suitability model to estimate that suitable climate for Columbia spotted frogs declined 49 percent between the 1901 to 1930 (past) and 1981 to 2010 (recent) timeperiods. Despite a reduction in suitable climate, the species appears to be well distributed throughout its known historical range (Figures 12, 15–16). However, as mentioned above, most occupied sites contain few adults, usually in the single digits or tens, indicating that the majority of occupied sites are small (Munger *et al*. 1998b, pp. 323–324; Smyth 2004, pp. 3–7; NDOW 2007, p. 5; Pearl *et al*. 2010, p. 5). Two large clusters of populations exist in the Owyhee Mountains of southwestern Idaho and in the Jarbidge-Independence Mountain ranges in northeastern Nevada along with disjunct populations occurring in the Ruby Mountains in northeastern Nevada, Toiyabe Mountains of central Nevada, Steens Mountain in southeastern Oregon, and other isolated populations scattered across northern Nevada and southeastern Oregon (Figure 12). Pilliod *et al*. (2015b, pp. 15–19) found evidence to support redundancy throughout the Great Basin DPS due to the large latitudinal distribution, a wide elevational gradient, and a variety of occupied habitats. Columbia spotted frogs are well distributed throughout southwestern Idaho and northeastern Nevada with isolated and disjunct populations in southeastern Oregon and central Nevada (Figure 12). Between 1993 and 2014, Columbia spotted frogs have been detected in 165 HUCs across the Great Basin (Oregon 22, Idaho 42, Nevada 101; Figures 15–16). Within these 165 HUCs, breeding has been detected at 145 individual sites (there may be multiple sites within a HUC) (Pilliod *et al*. 2015a, pp. 6–7). Any future catastrophic event or action that extirpates a population in one area would not result in the extinction of the Great Basin DPS (Pilliod *et al*. 2015b, pp. 15–19). Reductions in the species range could occur if populations are extirpated due to the isolated nature of many populations.

Representation

For the Columbia spotted frogs in the Great Basin DPS, representation is based on the breadth of genetic diversity within and among populations and the ecological diversity of populations across the species range. The trailing edge of a species range often has small isolated populations which have low levels of within population genetic diversity due to the effects of isolation; however, genetic diversity between populations is typically high due to little or no genetic exchange between populations (Hampe and Petit 2005, p. 462). The isolated nature of the current distribution and small population sizes is reflected in several genetic studies. Funk *et al*. (2008, p. 205; Figure 1) showed that the Great Basin DPS is highly divergent from the

Northern and Utah DPSs. Additionally, within the Great Basin DPS, two distinct clades are apparent, the southeastern Oregon and southwestern Idaho/Nevada populations, indicating very isolated populations particularly in southeastern Oregon (Funk *et al*. 2008, p. 205). However, results from recent genetic studies indicate that populations in southeastern Oregon and southwestern Idaho: (1) are isolated from each other, (2) are relatively small (small effective populations), (3) have low genetic variation, (4) have either historical or more contemporary bottleneck signatures (at least for several of them), and (5) are highly differentiated from other Columbia spotted frog populations (Robertson and Funk 2011, pp. 5–9; Robertson and Funk 2012, pp. 5–8). Additionally, within the Owyhee population, Robertson and Funk (2011, pp. 8, 13, 19) found three clusters of genetically distinct populations, which generally corresponded to watershed boundaries and topographic features. While formal population viability analyses have not been performed for these populations, the results suggest that these populations have reduced representation which could result in negative impacts on population viability and persistence (Robertson and Funk 2011, p. 9; Robertson and Funk 2012, p. 8). These genetic analyses have not occurred for populations in Nevada which contains the largest proportion of frogs.

Columbia spotted frogs are adapted to the variable and harsh conditions of the Great Basin. As such, they are tolerant of variation in water quality and quantity typical of Great Basin aquatic environments. Columbia spotted frogs are relatively long-lived and capable of rapid reproduction and population expansion (*e.g*., Tables 2, 4, and 5); and therefore, they are expected to be tolerant of short-term drought conditions and other short-term alterations to their aquatic environment (McCaffery *et al*. 2012, p. 983). While Columbia spotted frogs can show strong site fidelity, individuals are capable of travelling relatively large distances (i.*e.*, 6 km (3.7 mi)) if adequate habitat is available (Engle 2000b, p. 34; Bull 2005, pp. 13–15; Reaser and Pilliod 2005, p. 561; C. Mellison 2012, unpublished data). Movement usually occurs along shoreline habitat or riparian corridors. This life history strategy presumably provided a high level of resiliency historically for populations to be able to withstand disturbances of high magnitude and duration through migration and recolonization. The species' ability to withstand environmental disturbances has been reduced due to habitat fragmentation from past and current anthropogenic influences in the Great Basin (*e.g.*, beaver trapping, heavy grazing, agriculture, and nonnative species introductions).

Pilliod *et al*. (2015a, pp. 10–12) used a measure of genetic distance (F_{ST} values) presented in previous genetic studies (Robertson and Funk 2011, pp. 1–23; Robertson and Funk 2012, pp. 1–23) and associated it with a measure of habitat connectivity represented as resistance distance (*e.g.*, high values of resistance indicate low connectivity). Connectivity and F_{ST} values were generally well correlated with increasing genetic distance (higher F_{ST} values) as levels of resistance increased indicating low levels of connectivity and high levels of isolation, particularly between clades, but also within nested clades (Pilliod *et al*. 2015a, pp. 14–15, 38). Even when well-connected habitat exists, other factors (*e.g*., predators) may prevent populations from inter-breeding (Pilliod *et al*. 2015a, pp. 14, 18). In general, isolated populations are vulnerable to extirpation through demographic stochasticity (random fluctuations in birth and death rates); environmental stochasticity (random variation in environmental attributes) and catastrophes; loss of genetic heterozygosity (genetic diversity) and rare alleles (inherited forms of a genetic trait); and human disturbance (Hedrick and Kalinowski 2000, pp. 140–142; Lande 2002, pp. 18–35; Reed and Frankham 2003, pp. 233–234; Frankham 2005, pp. 135–136;

Robertson and Funk 2011, pp. 5–9; Robertson and Funk 2012, pp. 5–8). To our knowledge, no population of Columbia spotted frogs have been extirpated due to demographic risk alone; instead, it is a factor that can make a population more vulnerable to extirpation from other factors (Frankham *et al*. 2004, p. 86). Although the literature and current genetic evaluations predict that isolated populations are more vulnerable to extirpation, we are unable to evaluate this prediction in Columbia spotted frogs because we lack complete knowledge of their historical distribution within the Great Basin DPS (Wente *et al*. 2005, pp. 99–106; Pearl *et al*. 2010, pp. 2–9). Much of our knowledge about the current distribution of the species is from contemporary monitoring.

In summary, Columbia spotted frogs in the Great Basin DPS are well distributed across their known historical range; however, most occupied sites harbor relatively few numbers of adult frogs and many populations are isolated from each other. The isolated nature of the current distribution and small population sizes is reflected in several genetic studies. The current condition of Columbia spotted frogs in the Great Basin DPS is due to a combination of historical geologic, climatic, and environmental events discussed previously and more recent anthropogenic influences which are discussed below.

Chapter 4

In this chapter we evaluate the past, current, and potential future factors that are affecting what Columbia spotted frogs need for long-term viability. It should be noted that current and potential future effects, along with current distribution and abundance, determine viability and, therefore, vulnerability to extinction. Information about historic causes and effects is included to assist interpretation of historic trends and to inform our assessment of the future responses by Columbia spotted frogs to ongoing and future causes of vulnerability to extinction.

Habitat Modification, Destruction or Curtailment of Habitat or Range

Habitat Fragmentation

Fragmentation of habitat may be one of the most significant factors affecting Columbia spotted frog conservation and long-term population persistence (Semlitsch 2002, pp. 620–623; Green 2003, pp. 340–341; Opdam and Wascher 2004, pp. 285–297; Funk *et al*. 2005a, pp. 14–15; Tait 2007, p. 26; Robertson and Funk 2011, pp. 5–9; Robertson and Funk 2012, pp. 5–8). Within the Great Basin, habitat fragmentation was negatively associated to both occupancy and persistence of Columbia spotted frogs (Arkle and Pilliod 2015, pp. 11, 32). As mentioned previously, aquatic habitat in the Great Basin is naturally scarce with less than 6 percent of the area within the Great Basin currently having suitable climate and permanent water for Columbia spotted frogs (Arkle and Pilliod 2015, p. 9). Those areas with high habitat connectivity accounted for 69 percent of all detections of Columbia spotted frogs indicating the importance of permanent waterbodies which are hydrologically connected (Arkle and Pilliod 2015, pp. 12, 34). Even though habitat may be physically connected, populations of Columbia spotted frogs may still be functionally isolated due to other mechanisms. Studies in Idaho indicate that Columbia spotted frogs exhibit breeding site fidelity (Pilliod *et al*. 2002, pp. 1853–1859; Engle and Munger 2003, pp. 9–10). Habitat fragmentation can impede seasonal movement of frogs from hibernation

ponds to breeding ponds, which can lead to reduced genetic diversity, local population declines, or extirpation (Engle and Munger 2003, pp. 12–13; Funk *et al*. 2005a, p. 15; Funk *et al*. 2005b, p. 494; Robertson and Funk 2011, pp. 5–9; Robertson and Funk 2012, pp. 5–8; Pilliod *et al*. 2015a, p. 19). While Columbia spotted frogs show strong site fidelity, individuals are capable of travelling relatively large distances of 6 km (3.7 mi) if adequate habitat is available (Engle 200b, p. 34; Funk *et al*. 2005a, p. 2; C. Mellison 2012, unpublished data). Local populations will become increasingly isolated if movement corridors become more fragmented (Bull and Hayes 2001, pp. 120–122; Pilliod *et al*. 2002, pp. 1853–1859; Engle and Munger 2003, pp. 12–13; Munger 2003, pp. 4–9; Funk *et al*. 2005a, p. 15; Funk *et al*. 2005b, p. 494; Semlitsch 2008, pp. 260–265). Riparian vegetation and surface water along movement corridors provide relief from high temperatures and arid environmental conditions typical of this region, as well as protection from predators. Loss of riparian vegetation or surface water and the presence of nonnative species can pose a significant impact to frogs moving from one area to another. Likewise, fragmentation and loss of habitat can prevent frogs from colonizing suitable sites elsewhere (Gibbs 2000, pp. 316–317; Semlitsch 2002, pp. 621–623; Storfer 2003, pp. 154–156; Funk *et al*. 2005b, p. 494; Pringle 2006, pp. 243–246). Many occupied Columbia spotted frog sites are isolated and fragmented from each other which increases the risk of extirpation for these populations (Arkle and Pilliod 2015, pp. 11–12, 32; Pilliod *et al*. 2015a, pp. 17–19).

Habitat Modification

Habitat modification and destruction have been implicated in the majority of amphibian declines wordwide (Bishop *et al*. 2003, pp. 209–210; Young *et al*. 2004, pp. 31–32; Bradford 2005, pp. 919, 921–922; Vredenburg and Wake 2007, p. 5; Wells 2007, pp. 817–825; Chanson *et al*. 2008, pp. 39–42). Isolated populations of amphibians, as seen throughout the range of Columbia spotted frogs in the Great Basin, are particularly susceptible to habitat modification (Noss *et al*. 2006, p. 230; Tait 2007, p. 26). Columbia spotted frog habitat degradation and destruction are a combined result of topography, climate change, and past and some current land use influences from spring development, beaver management, heavy livestock grazing, mining activities, and nonnative fish stocking which are discussed below.

Spring Development

Cold water spring habitats within the Great Basin provide a stable, permanent source of water for frog breeding, feeding, shelter, and winter refugia (IDFG *et al*. 1995, p. 9; Patla and Peterson 1997, pp. 16–17; Munger 2003, p. 13). Sada and Vinyard (2002, p. 280) found that anthropogenic spring development was the most important factor affecting spring-associated taxa, including Columbia spotted frogs. Most spring developments affect natural springflow through the installation of a pipe or box to fully capture the water source and direct water to another location such as a livestock watering trough. Loss or reduction of this permanent source of water in semi-arid ecosystems can also lead to the loss of associated riparian habitats and wetlands used by Columbia spotted frogs (Arkle and Pilliod 2015, pp. 15, 29, 32). Developed spring pools could be functioning as attractive nuisances for frogs, concentrating them into isolated groups, increasing the risk of disease and predation (Noss *et al*. 2006, p. 223). Many of the springs and streams in southwestern Idaho, eastern Oregon, and Nevada have been developed or diverted for anthropogenic reasons which further fragments available habitat (Sada and

Vinyard 2002, p. 283). In contrast, some springs developed into ponds for watering livestock appear to provide persistent high quality breeding and rearing sites in southwestern Idaho (La Fayette 2011, p. 19). Similarly, in northeastern Nevada, stock ponds are associated with 10 percent of known occupied sites (J. Petersen 2014, pers. comm.). While spring development has occurred throughout the Great Basin, the best available scientific and commercial information regarding the status of Columbia spotted frog habitat as it relates to spring development is unknown.

Beaver Management

The importance of beaver to the creation and maintenance of Columbia spotted frog habitat is discussed in Chapter 2 (Arkle and Pilliod 2014, pp. 11, 16, 28–29, 32). Trapping throughout the Great Basin in the 19th century nearly extirpated beavers (Clements 1991, pp. 277–278; Gibson and Olden 2014, pp. 394–395) and likely reduced the amount of high quality habitat for Columbia spotted frogs. Beaver trapping continues today throughout the occupied areas of the Great Basin, albeit at much lower levels. For example, the number of beavers trapped statewide in Oregon has steadily declined from an estimated 15,000 in 1951 to 3,200 during the 2010–2011 season with 85 percent of the harvest occurring on the west side of the Cascade Mountains which is outside the range of Columbia spotted frogs (Hiller 2011, pp. 7–10). In Nevada, the annual statewide beaver harvest over the past 40 years has averaged 914 animals (NDOW 2014, p. A-5). Nevada Department of Wildlife reported the 2013–2014 statewide beaver harvest at 699 animals which is 1 percent of the estimated beaver population in Nevada (NDOW 2014, pp. 3839, A-6). Thirty six percent of the 2013–2014 harvest occurred in northeastern Nevada counties where the majority of Columbia spotted frogs in Nevada exist (NDOW 2014, p. A-6). A recent IDFG report documented 3,543 beaver were harvested statewide during the 2012–2013 season, 65 (1.8 percent of the harvest) of which were trapped in Owyhee County (IDFG 2014a, pp. 11, 13–14). This report did not include historical annual levels of harvest. It should be noted that reported harvest numbers in all three states are reliant on end of season questionnaires sent to licensed trappers and do not include beavers killed for nuisance reasons; therefore, the reported numbers should be considered minimum harvest levels. Harvest location is reported at the county level; therefore, site specific information on the impacts of beaver harvest on Columbia spotted frogs is not available. Each state regulates the harvest of beaver through limits, trapping methods, and seasons. Beaver trapping is open from November 1 to March 31 in southwestern Idaho, and there is no bag limit (IDFG 2014b, p. 38). While trapping is allowed in Owyhee County, IDFG continues to investigate and encourage beaver release sites in this area (IDFG 2014a, p. 5). Oregon allows harvest of beavers in Lake, Harney, and Malheur Counties with a season from November 15 to March 15, and no bag limit (ODFW 2014, p. 4); however, the Oregon Conservation Strategy encourages allowing beaver to contribute to wetland creation and maintenance when compatible with existing land uses (ODFW 2006, pp. 288, 301). In Nevada, beaver trapping is allowed statewide from October 1 through April 30 and there is no bag limit (NDOW 2012d, p. 1). The Nevada Wildlife Action Plan emphasizes the importance of beaver to the presence of Columbia spotted frog (NDOW 2012a, p. S-64).

It is widely recognized that beaver populations in North America have been rebounding from near extirpation and occupy the majority of its historical range; however, densities may be substantially lower today compared to pre-trapping levels in the 19th century (Naiman *et al*.

1988, p. 753; Pollack *et al*. 2003, pp. 213–214; Gibson and Olden 2014, p. 394). Across the range of the Great Basin DPS, beaver harvest levels do not seem to be having population level impacts to beavers; however, local influences to Columbia spotted frog populations can occur if beaver leave an area or are removed. For example, Stoneman Creek (Owyhee population) had a population of beavers which were killed in the early 1990s. Over the next 10 years the frog population decreased as the ponded habitat the beavers created reverted back to lotic habitat (Lingo and Munger 2003, pp. 4–9). Beaver were reintroduced in 2001 and the Columbia spotted frog population responded to the ponded habitat and increased substantially; however, after the beaver moved upstream onto private land in 2010, the ponded habitat once again reverted back to lotic habitat, and the Columbia spotted frog population decreased (Lohr 2012, pp. 9, 13–14).

In summary, historical trapping nearly extirpated beaver from the Great Basin; however, beaver populations have rebounded and occupy the majority of its historical range but at lower densities. Harvest of beaver continues throughout the Great Basin but based on the best available scientific and commercial information does not seem to be impacting the beaver population as a whole within the Great Basin; however, there is little information on the impacts of harvest at the local watershed level to analyze impacts at this finer scale. There is a growing body of evidence linking the positive habitat influence of beaver to the presence of Columbia spotted frogs in the Great Basin DPS (Arkle and Pilliod 2015, pp. 16–17). The ability of beavers to restore degraded stream systems and the resulting habitat modification from their dams which keeps water on the landscape longer is becoming recognized as an important restoration technique (Arkle and Pilliod 2015, pp. 16–17; Gibson and Olden 2014, pp. 399–401; Pollack *et al*. 2014, pp. 284–286).

Livestock Grazing

Livestock grazing occurs throughout the range of Columbia spotted frogs and heavy utilization from livestock has been cited as detrimental to Columbia spotted frog habitat (Munger *et al*. 1996, p. 9; Reaser 1997a, pp. 37–38; Engle 2002, pp. 44–55; Service 2006, pp. 4–5; Arkle and Pilliod 2015, pp. 12, 16, 30, 33). Though direct effects of livestock grazing on Columbia spotted frog distribution and populations are not well documented, the effects of heavy grazing on riparian areas are well known (Kauffman *et al*. 1983a, pp. 684–685; 1983b, pp. 686–689; Kauffman and Krueger 1984, pp. 432–434; Schulz and Leininger 1990, pp. 297–299; Belsky *et al*. 1999, pp. 425–428). Livestock grazing can affect riparian areas by changing, reducing, or eliminating vegetation (Schulz and Leininger 1990, pp. 297–299; Green and Kauffman 1995, pp. 308–313), and by the actual loss of riparian areas through channel widening (Overton *et al*. 1994, pp. 5–7), stream channel degradation, or lowering of the water table (Chaney *et al.* 1990, p. 10). Effects to stream and riparian habitat include reduction of shade and cover and resultant increases in water temperature, changes in stream morphology, and the addition of sediment due to bank degradation and off-site soil erosion (Belsky *et al*. 1999, pp. 425–428).

Bull and Hayes (2000, pp. 292–294) found no impacts of cattle grazing on the reproductive success of Columbia spotted frogs in ponds in northeastern Oregon; however, there was high variability in their results. Grazing intensity and timing was not evaluated in this study. In addition, Adams *et al*. (2009, pp. 135–137) found no significant short-term effects of cattle exclosures on the number of Columbia spotted frog egg masses, larval survival, size of

metamorphs, or water quality measurements. Moreover, nutrient levels often associated with negative impacts to amphibians, were very low to non-detectable (Adams *et al*. 2009, pp. 136–137). In contrast, Gray *et al*. (2007, pp. 99–100) found higher levels of *Ranavirus* (an emerging pathogen implicated in many amphibian declines) in green frogs (*Lithobates* (formerly *Rana*) *clamitans*) sampled from ponds accessed by cattle. Howard and Munger (2003, p. 10) found lower survival of Columbia spotted frog larvae in their high livestock waste treatment; however, the high waste treatment larvae that survived had higher growth rates. Schmutzer *et al*. (2008, pp. 2617–2619) found significantly larger green frog, bullfrog (*L. catesbeianus*), and pickerel frog (*L. palustris*) larvae in ponds with cattle grazing; however, larval abundance for all three species was significantly higher in ponds with no cattle grazing. Additionally, water quality measurements including turbidity, specific conductivity, and dissolved oxygen, were significantly higher in ponds with grazing (Schmutzer *et al*. 2008, pp. 2618–2619). Capture probabilities of post-metamorphic green frogs were significantly higher in ungrazed ponds versus grazed ponds; however, the opposite was found for American toads (*Anaxyrus* (formerly *Bufo*) *americanus*) indicating species-specific impacts to amphibians from cattle grazing (Burton *et al*. 2009, pp. 272–273). Wading in streams by livestock during breeding can be assumed to induce mortality on Columbia spotted frog eggs and pre-emergent tadpoles (Ross *et al*. 1999, p. 163; Peterson *et al*. 2010, pp. 958–966). In a behavioral study, Shovlain *et al*. (2005, pp. 10–12) found that Oregon spotted frogs increased their use of grazing exclosures compared to areas under heavy grazing pressure while no preferences were found between exclosures and areas under a light grazing regime. Additionally, Jansen and Healey (2003, pp. 211–218) found that amphibian species diversity declined and habitat condition decreased with increasing grazing intensity along a river in southeastern Australia. Recently, Arkle and Pilliod (2015, pp. 12, 16, 30, 33) concluded that livestock grazing impacts were negatively related to Columbia spotted frog occupancy within the Great Basin DPS. In Oregon, 71 percent of all detections were in ungrazed areas, in Idaho 77 percent of all detections were in sites categorized as ungrazed or lightly grazed, and in Nevada, 86 percent of all detections occurred in sites with low or moderate grazing impacts (Arkle and Pilliod 2015, p. 33). In their study, Arkle and Pilliod (2015, pp. 12, 16, 30, 33) found that heavy livestock utilization of emergent vegetation, which was found to be very important in Columbia spotted frog occupancy, is the mechanism in which livestock impact Columbia spotted frogs. Recent studies have reported that changes in the timing and duration of livestock grazing and incorporating rest-rotation grazing strategies are resulting in improved riparian habitat conditions and water quality in some occupied Columbia spotted frog habitat in northern Nevada (Booth *et al*. 2012, pp. 515–518; Dalldorf *et al*. 2013, pp. 38–41; Kozlowski *et al*. 2013, pp. 37–60). The resultant increase in willow cover due to improved grazing strategies has allowed beaver to recolonize these areas which has slowed run-off, improved stream channel stability, improved water quality, increased water retention, and created a more permanent hydroperiod (Booth *et al*. 2012, p. 517; Kozlowski *et al*. 2013, pp. 8–9). The best available scientific information does not indicate that light to moderate grazing is impacting the Columbia spotted frog; however, heavy grazing has been shown to negatively impact streams, ponds, and riparian habitat and is a stressor to Columbia spotted frogs. There is uncertainty regarding the magnitude of this stressor as we lack data that informs where heavy grazing overlaps with habitats occupied by Columbia spotted frog. While livestock grazing occurs in the vicinity of nearly all populations, the status of Columbia spotted frog habitat as it relates to heavy livestock use is unknown.

Mining

The effects of mining on Great Basin Columbia spotted frogs and their habitat have not been specifically studied, but the adverse effects of mining activities on water quality and quantity, other wildlife species, and amphibians in particular have been addressed in professional scientific forums (Nelson *et al*. 1991, pp. 425–458; Ripley *et al*. 1996, pp. 49–111; Lefcort *et al*. 1998, pp. 449–452; Burkhart *et al*. 2003, pp. 111–128; Unrine *et al*. 2004, pp. 2966–2969; Bridges and Semlitsch 2005, pp. 89–92). Mining can contribute toxic substances into waterways, alter stream morphology, and dewater streams completely (Nelson *et al*. 1991, pp. 429–446; Service 2008, pp. 30–33). Up until 2001, Nevada had the second-highest level of atmospheric mercury releases in the nation (Miller 2004, p. 1). According to Toxic Release Inventory data from the Environmental Protection Agency (USEPA), major precious metal mining facilities in Nevada released between 5,443.1 and 5,896.7 kilograms (12,000 and 13,000 pounds) of mercury directly into the atmosphere from 1998 to 2001; however, mercury emissions have declined sharply since 2001 (USEPA 2013). Despite these reduced emissions, a recent advisory was issued by the Nevada State Health Division (NSHD) that recommends limiting human consumption of fish from six northern Nevada waters due to elevated methylmercury levels (NSHD 2007, pp. 1–2). In 2008, the Service published an assessment of trace-metal exposure to aquatic biota from historical mine sites in the western Great Basin (Service 2008, pp. 1–59). The study looked at five different streams across the western Great Basin with various levels of mining impacts (Service 2008, p. 11). The Service found low pH and increased concentrations of certain trace-metals in some streams which pose a significant impact to aquatic biota, increased concentrations of trace-metals in stream sediment, and bioaccumulation of trace-metals in macroinvertebrates and fish (Service 2008, pp. 30–33).

Historical mining practices have had lasting impacts on watersheds. In Idaho, Jordan Creek, (Owyhee population) was dredged for gold during the late 1800's and early 1900's (La Fayette 2011, p. 27). Dredging is a type of placer mining which extracts ore from alluvial deposits and can cause substantial damage to aquatic habitats (Nelson 1991, pp. 427–428). Evidence of this past mining activity and impacts (*i.e.*, stream channel alteration, dredge material) to Jordan Creek are still evident today (La Fayette 2011, pp. 26–27). Furthermore, high levels of mercury are still present in the water and stream sediments (USEPA 2011, pp. 19, 22). In southeastern Oregon, the Grassy Mountain Project (gold mine) is associated with a known occupied site for Columbia spotted frog; however, it is unknown how this project will impact this population (Calico 2012, pp. 1–3, 41).

In November 2006, a perched aquifer in the headwaters of the North Fork Humboldt River began to drain due to deep core drilling during mineral exploration at the Big Springs Mine (HydroGeo 2008, p. 62). Sammy Creek, a tributary to the North Fork Humboldt River, and portions of the North Fork Humboldt River have gone dry annually since 2007 due to the drained aquifer (HydroGeo 2008, p. 50; HydroGeo 2012, pp. 8–14). In addition to a decrease in the amount of water in the North Fork Humboldt River, water quality has also been negatively impacted with elevated levels of several constituents including arsenic and sulfate being recorded (HydroGeo 2012, pp. 22–45). Columbia spotted frogs have historically (prior to the drainage event) been found within this impacted stream reach (USFS 2004, p. 10); however, individuals were only located downstream of the impacted reach in 2010, and the population level impacts are largely

unknown (A. Jenne 2010, pers. comm.). Mining is an overall low impact to Columbia spotted frogs on a rangewide basis; however, it is locally important in several watersheds as mentioned above.

Summary of Habitat Modification, Destruction or Curtailment of Habitat or Range

In summary, Columbia spotted frogs in the Great Basin have been impacted primarily by the effects of past habitat destruction and/or modification, which caused increased habitat fragmentation and isolation. Heavy use by livestock has been shown to be detrimental to Columbia spotted frog habitat. While livestock grazing occurs throughout the Great Basin, there is uncertainty regarding livestock grazing effects from a lack of monitoring data (Veblen *et al*. 2011, pp. 24–28, 39). Development of springs for livestock and agricultural purposes has occurred throughout the Great Basin; however, the status of Columbia spotted frog habitat as it relates to spring development is unknown. Mining has been shown to have local impacts to populations but has a relatively low influence on a rangewide basis. Beaver management can influence Columbia spotted frogs if trapping occurs in areas which are occupied by Columbia spotted frogs. Beaver harvest is monitored by the states at the county level; therefore, the impact from trapping is difficult to evaluate. Modification and destruction of Columbia spotted frog habitat from historical and current anthropogenic disturbances have contributed to the current fragmented and isolated nature (and subsequent genetic character) of Columbia spotted frog populations in the Great Basin.

Disease or Predation

<u>Predation</u>

Predation has been documented on all life stages of Columbia spotted frogs by native predators including: reptiles (*e.g*., garter snake (*Thamnophis* sp.), fish (*e.g*., redband trout (*Oncorhynchus mykiss gairdneri*), birds (*e.g*., Clark's nutcracker (*Nucifraga columbiana*), mammals (*e.g*., coyote (*Canis latrans*), and aquatic insects (*e.g*., predacious diving beetles (Coleoptera) (Reaser and Pilliod 2005, pp. 561–562). However, none of these has been implicated as a driver of population dynamics, and we expect that such predation events do not generally have population-level impacts except where so few individuals remain that such predation is associated with loss of a population (Bradford 1991, pp 174–177; Jennings 1996, p. 938; Bradford 2005, p. 917).

The impact of nonnative invasive species on native species, communities, and ecosystems has been severe (Sakai *et al*. 2001, pp. 305–332). The introductions of nonnative salmonid (*Oncorhynchus*, *Salmo*, and *Salvelinus*) and centrarchid (*Micropterus*) species for recreational fishing have negatively affected amphibian species, including Columbia spotted frogs, throughout the United States (Turner 1962, p. 327; Pilliod and Peterson 2001, pp. 326–331; Bradford 2005, pp. 919–924; Tait 2007, pp. 32–33; Vredenburg and Wake 2007, pp. 5–6; Murphy *et al*. 2010; pp. 3640–3643; Paoletti *et al*. 2011, pp. 164–167). The effects of predation are difficult to document, particularly in stream systems. However, significant negative effects of predation on frog populations in lentic systems have been documented (Knapp and Matthews 2000, pp. 433–435; Pilliod and Peterson 2001, pp. 326–331; Kats and Ferrer 2003, pp. 99–108; Dunham *et al*. 2004, pp. 19–20; Bradford 2005, pp. 919–924; Knapp 2005, pp. 270–275; Pearl *et*

al. 2010, pp. 49–50). In the western United States, Lomnicky *et al*. (2007, p. 1086) found that 52 percent of stream lengths surveyed contained nonnative vertebrates. They also found that the most common nonnative vertebrates were brook trout (*Salvelinus fontinalis*) (17 percent of all nonnative vertebrates present), brown trout (*Salmo trutta*) (16 percent), and rainbow trout (*Oncorhynchus mykiss*) (14 percent) (Lomnicky *et al*. 2007, p. 1086). Using the same dataset, Whittier and Peck (2008, p. 1889) analyzed the surface area occupied by nonnative vertebrates and found that 75 percent of the waters sampled were occupied by nonnatives. They also found there is a greater likelihood of finding nonnative vertebrates in larger streams (Whittier and Peck 2008, p. 1889). When surface area is considered, the most common nonnative vertebrates are rainbow trout, carp (*Cyprinus carpio*), brown trout, and smallmouth bass (*Micropterus dolomieu*) (Whittier and Peck 2008, p. 1890). Smallmouth bass are known to occur throughout the mainstem Owyhee River watershed (including the North and South Forks) in Oregon and Idaho and the mainstem Humboldt River in Nevada. Turner (1962, p. 327) documented the presence of bass and bullfrogs at suitable Columbia spotted frog habitat in Nevada and surmised that they are a stressor as no Columbia spotted frogs were found at these locations. Predation by nonnative fish species within the historical range of Columbia spotted frogs, particularly along the mainstem river systems and reservoirs, further fragments populations making it difficult to recolonize habitat or exchange genetic material.

The American bullfrog, a ranid species native to much of central and eastern North America, now occurs within the range of Columbia spotted frog in the Great Basin (Casper and Hendricks 2005, pp. 540–541). Bullfrogs are known to compete with and prey on other frog species and they are important vectors for spreading many types of diseases and parasites to healthy populations of native amphibians (Moyle 1973, pp. 19–21; Pearl *et al*. 2004, pp. 16–18; Casper and Hendricks 2005, pp. 543–544; Johnson and Lunde 2005, p. 130; Monello *et al*. 2006, p. 406; Tait 2007, pp. 32–33). Within the Great Basin DPS, bullfrogs are known to occur in watersheds in south-central Oregon and northeastern Nevada that are occupied by Columbia spotted frogs (BLM 2011, p. 18; Tippery and Jones 2011, pp. 13–14; NDOW 2012e, unpubl. data). Sympatric bullfrog populations have not been observed in the Owyhee population in Idaho. Arkle and Pilliod (2015, p. 13) found that bullfrogs within the Great Basin occupied generally warmer sites in lower elevation mainstem rivers compared to Columbia spotted frogs; however, there was some overlap between the two species. Additionally, Arkle and Pilliod (2015, p. 13) examined 8 historically occupied sites in Nevada, which are now occupied by bullfrogs, and found that 7 sites are no longer occupied by Columbia spotted frogs; however, within the same watersheds but in areas upstream of bullfrog occupied habitat, Columbia spotted frogs still persist. Bullfrogs rarely co-occur with Columbia spotted frogs, but whether this is an artifact of competitive exclusion or predation is unknown at this time.

We conclude that nonnative species negatively impact Columbia spotted frogs rangewide because: (1) nonnative species have had documented negative effects on Columbia spotted frog populations; (2) nonnative species occur throughout the majority of unoccupied historical habitat; and (3) nonnative species continue to be stocked and/or managed for within historical Columbia spotted frog habitat (particularly in reservoirs and mainstem rivers). However, based on the best available scientific and commercial information, there is uncertainty regarding the magnitude of this stressor as we lack a complete dataset that informs where nonnative predators overlap with habitats occupied by Columbia spotted frog.

Chytridiomycosis

Although a diversity of microbial species is naturally associated with amphibians, it is generally accepted that they are rarely pathogenic to amphibians except under stressful environmental conditions. Amphibian chytridiomycosis is a panzootic fungal disease, caused by the pathogenic fungus *Batrachochytrium dendrobatidis* (*Bd*), which has been associated with amphibian declines in the United States and globally (Daszak *et al*. 2003, pp. 143–148; Blaustein *et al*. 2005, pp. 1464–1465; Briggs *et al*. 2005, pp. 3156–3158; Ouellet *et al*. 2005, pp. 1433–1438; Rachowicz *et al*. 2006, pp. 1676–1682; Pounds *et al*. 2006, pp. 161–167; Pearl *et al*. 2007b, pp. 146–148; Vredenburg and Wake 2007, p. 6). Clinical signs of chytridiomyciosis and diagnosis are described by Daszak *et al*. (1999, p. 737) and include abnormal posture, lethargy, and loss of righting reflex. Gross lesions, which are usually not apparent, consist of abnormal epidermal sloughing and ulceration; hemorrhages in the skin, muscle, or eye. Chytridiomyciosis can be identified in some species of frogs by examining the oral discs of tadpoles which may be abnormally formed or lacking pigment (Fellers *et al*. 2001, pp. 946–947). Not all individual amphibians that test positive for *Bd* develop chytridiomycosis.

Columbia spotted frogs at sites in Alberta, Canada, northeastern Oregon, northern Idaho, and Wyoming (Northern DPS) have tested positive for *Bd* (Bull 2006, pp. 3–4; Engle 2006, p. 16; Pearl *et al*. 2007b, pp. 146–148; Adams *et al*. 2010, pp. 294–298; Russell *et al*. 2010, pp. 226–227; Stevens *et al*. 2012, p. 5; Estes-Zumpf *et al*. 2014, p. 17). *Bd* has also been found in the Wasatch Mountains, Utah (Utah DPS) (Semon *et al*. 2005, pp. 11–12; Wilson *et al*. 2005, pp. 2–3). Within the Great Basin, *Bd* was confirmed in Columbia spotted frogs at the Circle Pond site, Idaho, in 2001 (Engle 2002, pp. 15–19) and in Oregon at the Dry Creek site (Engle 2006, p. 16). *Bd* has not been detected anywhere else within the Owyhee population. In 2011, *Bd* was detected at the Tennessee Gulch site in northeastern Nevada (Figures 12 and 13; Hanson and Glenn 2011, pp. 5–6, 9–11). In addition, *Bd* has been found in three bullfrog populations in Nevada. Along the Owyhee River in northern Elko County, one population of Columbia spotted frogs (which have not been tested) co-occur with *Bd*-infected bullfrogs (D. Green 2006, pers. comm.); while a second *Bd*-infected bullfrog population is located near Beatty, Nevada, which is approximately 225 km (140 mi) to the south of the Toiyabe Mountains population (USGS 2005, p. 1). Forrest *et al*. (2013, p. 77) documented *Bd* positive bullfrogs in Dixie Valley, approximately 120 km (75 mi) to the northwest of the Toiyabe Mountains population.

Bd has not been associated with large die-offs of Columbia spotted frogs, which have plagued other amphibian species (Rachowicz *et al*. 2006, pp. 1676–1682; Adams *et* a*l*. 2010, p. 300). Some evidence suggests that Columbia spotted frogs produce antimicrobial peptides in their skin, which may inhibit *Bd* infection (Rollins-Smith *et al*. 2002, pp. 473–476; Rollins-Smith *et al*. 2005, pp. 137–142; Rollins-Smith 2009, pp.1594–1595); however, further research of how *Bd* affects Columbia spotted frogs may be needed (Russell *et al*. 2010, pp. 228–229). Based on the best available scientific and commercial information, *Bd* is not known to be negatively impacting Columbia spotted frog populations within the Great Basin.

Ranavirus

Iridoviruses of the genus *Ranavirus* were first recognized in amphibians in the 1960s and have contributed to mass mortality events worldwide (Gray *et al*. 2009, p. 244). Between 1996 and 2005 within the United States, the majority of amphibian mortality events reported have been linked to ranaviruses (Green *et al*. 2002, p. 331; Muths *et al*. 2006, pp. 13–914). Clinical signs of ranavirus infection and disease diagnosis are described by Miller *et al*. (2011, pp. 2355–2357) and may include erratic swimming, buoyancy problems, lethargy, swelling, redness on legs and ventrum, and red blotching on internal organs.

Two mass mortality events of Columbia spotted frogs in northern Idaho (Northern DPS) were attributed to *Ranavirus* in 2009 (Russell 2011, pp. 223–225). It should be noted that this mass mortality event did not eradicate this population and more recent sampling has not detected *Ranavirus* at this site (C. Goldberg 2014, 2015, pers. comm.). Another Columbia spotted frog mortality event in 2002 within Yellowstone National Park (Northern DPS) was attributed to chytrid and *Ranavirus* with *Ranavirus* being the ultimate cause of death (Patla and Peterson 2004, pp. 15, 52–53). *Ranavirus* has not been detected in Columbia spotted frogs in the Great Basin. Based on the best available scientific and commercial information, ranaviruses are not known to be impacting Columbia spotted frog populations within the Great Basin.

Malformations

Malformations found in amphibian populations can be caused by several different factors including pesticides, high ultraviolet-B (UV-B) radiation exposure, and parasites and pathogens (Carey *et al*. 2003, pp. 194–197; Ankley *et al*. 2004, pp. 9–13; Johnson and Lunde 2005, pp. 125–138; Sutherland 2005, pp. 109–123). Pesticides and UV-B radiation are discussed further below. The larvae of the trematode *Ribeiroia ondatrae* has been associated with higher than normal levels of malformations in populations of several species of amphibians, including Columbia spotted frogs (Johnson *et al*. 2002, pp. 155–162); however, there is high variability in resistance to infection among amphibian species (Johnson and Hartson 2009, pp. 194–198). Malformed frogs have higher mortality rates than non-malformed individuals and mortality can be caused directly through infection or indirectly through reduced fitness and predation (Johnson and Lunde 2005, p. 136). The life cycle of *R. ondatrae* includes three hosts: snails of the genus *Planorbella*, amphibians or fish, and finally a bird or mammal (Johnson and Lunde 2005, p. 126). In a study covering five western states, the presence and abundance of *Planorbella* snails was the only variable related to the presence and abundance of *R. ondatrae* (Johnson *et al*. 2002, pp. 160–161). *Planorbella* snails were associated more closely with wetlands of human origin and higher orthophosphate levels (Johnson *et al*. 2002, pp. 160–161; Johnson and Lunde 2005, pp. 133–135; Johnson *et al*. 2007, pp. 15781–15784) indicating that stock ponds could be acting as a source for *Planorbella* snails. High prevalence of malformed Columbia spotted frogs outside the Great Basin DPS have been documented (Johnson *et al*. 2002, pp. 157–159; Roberts and Dickinson 2012, 810–813); however, within the Great Basin, there has been no evidence of above background level malformations (typically less than 5 percent of the population) reported at any of the long-term monitoring sites. Increased levels of malformations may be an expanding stressor to Columbia spotted frogs as *Planorbella* snail species are being recorded at sites beyond their previously known ranges (Johnson *et al*. 2002, p. 161). Based on the best available

scientific and commercial information, amphibian malformations are not known to be impacting Columbia spotted frog populations within the Great Basin.

Summary for Disease or Predation

In summary, nonnative fish (*i.e.*, salmonids or bass) and amphibian (bullfrog) predators occur within the range of Columbia spotted frogs. These predators can eliminate or reduce populations or restrict movement of individuals, thus, increasing fragmentation and inhibiting metapopulation dynamics; therefore, predation by nonnative fish and amphibians is negatively impacting Columbia spotted frogs in the Great Basin. Nonnative fish and amphibians can also be vectors for parasites and pathogens (*e.g.*, chytrid fungus), which may increase susceptibility of individuals or populations to disease outbreaks or deformities leading to increased mortality rates. However, population-level effects of both pathogens and parasites have yet to be documented within the Great Basin; therefore, we conclude that disease is not negatively affecting Columbia spotted frogs in the Great Basin at this time but may in the future.

Other Natural or Manmade Factors

Climate Change

Our analyses of the effects of climate change include consideration of ongoing and projected changes in climate. The terms "climate" and "climate change" are defined by the Intergovernmental Panel on Climate Change (IPCC). The term "climate" refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2013a, p. 1450). The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (*e.g.*, temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2013a, p. 1450).

Scientific measurements spanning several decades demonstrate that changes in climate are occurring, and that the rate of change has been faster since the 1950s. Warming trends due to climate change seen over the past 50 years in the United States are predicted to continue to increase (Field *et al*. 2007, pp. 626–627); however, the magnitude varies spatially across the continent, is most pronounced during spring and winter months, and has affected daily minimum temperatures more than daily maximum temperatures (Field *et al*. 2007, p. 620). Results of scientific analyses presented by the IPCC show that most of the observed increase in global average temperature since the mid-20th century cannot be explained by natural variability in climate, and is "very likely" (defined by the IPCC as 90 percent or higher probability) due to the observed increase in greenhouse gas (GHG) concentrations in the atmosphere as a result of human activities, particularly carbon dioxide emissions from use of fossil fuels (Solomon *et al*. 2007, pp. 21–35; Serreze 2010, pp. 11–13; IPCC 2013b, pp. 11–12 and figures SPM.4 and SPM.5; National Climate Assessment and Development Advisory Committee (NCADAC) 2013, pp. 28–31). Further confirmation of the role of GHGs comes from analyses by Huber and Knutti (2011, p. 4), who concluded it is extremely likely that approximately 75 percent of global warming since 1950 has been caused by human activities.

Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of GHG emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions (Meehl *et al*. 2007, pp. 747-845; Ganguly *et al*. 2009, pp. 11555, 15558; Prinn *et al*. 2011, pp. 527, 529). All combinations of models and emissions scenarios yield very similar projections of increases in the most common measure of climate change, average global surface temperature (commonly known as global warming), until about 2030. Although projections of the magnitude and rate of warming differ after about 2030, the overall trajectory of all the projections is one of increased global warming through the end of this century, even for the projections based on scenarios that assume that GHG emissions will stabilize or decline. Thus, there is strong scientific support for projections that warming will continue through the 21st century, and that the magnitude and rate of change will be influenced substantially by the extent of GHG emissions (Meehl *et al*. 2007, pp. 760–764, 797–811; Ganguly *et al*. 2009, pp. 15555–15558; Prinn *et al*. 2011, pp. 527, 529; IPCC 2013b, pp. 19–23).

Other effects of climate change include, but are not limited to, changes in types of precipitation (Knowles *et al*. 2006, p. 4557; Seager *et al*. 2007, pp. 1181–1184), earlier spring run-off (Stewart *et al*. 2005, p. 1152), longer and more intense wildfire seasons (Brown *et al*. 2004, pp. 375–385; Westerling *et al*. 2006, pp. 941–942; Bachelet *et al*. 2007, pp. 16–17), and more frequent extreme weather events (Diffenbaugh *et al*. 2005, pp. 15775–15777; Rosenzweig *et al*. 2007, p. 109; Kunkel *et al*. 2009, pp. 6207–6214). Climate change is predicted to have several effects on cold water habitat including: (1) increased water temperature; (2) decreased stream flow; (3) change in the hydrograph; and (4) increased frequency and severity of extreme events such as drought and wildfire (see below) (Stewart *et al*. 2005, pp. 1140–1154; Ficke *et al*. 2007, pp. 583–593; Bates *et al*. 2008, pp. 102–106; Webb *et al*. 2008, pp. 909–911; Kaushal *et al*. 2010, pp. 462–466). These changes in climate and subsequent effects can be attributed to the combined effects of greenhouse gases, sulphate aerosols, and natural external forcing (Karoly *et al*. 2003, p. 1203; Barnett *et al*. 2008, p. 1082; Serreze 2010, pp. 11–13; NCADAC 2013, pp. 28–31).

The IPCC states that of all ecosystems, freshwater ecosystems will have the highest proportion of species threatened with extinction due to climate change (Settele *et al.* 2014, pp. 312–314). Species with narrow temperature tolerances and cold-water species (*e.g.*, amphibians) will likely experience the greatest effects from climate change, and it is anticipated that populations located at the margins of the species' hydrologic and geographic distributions will be affected first (Bates *et al*. 2008, p. 104; Haak *et al*. 2010, pp. 534–535). Researchers in Italy have documented amphibian declines and have associated these declines with decreases in water availability and increases in temperature associated with climate change (D'Amen and Bombi 2009, pp. 3063–3066). Even in relatively pristine areas (*e.g.*, Yellowstone National Park), biologists are documenting amphibian declines and are linking these declines to long-term, large-scale climatic trends (McMenamin *et al*. 2008, pp. 16988–16990). In contrast, McCaffery and Maxell (2010, pp. 8645–8647) found that decreasing winter severity associated with warmer drier winters increased the population viability of Columbia spotted frogs in a high elevation wilderness area in Idaho (Northern DPS). The authors documented the more time an individual spent overwintering, due to more severe winters, resulted in a higher probability the habitat became hypoxic and the subsequent shorter summer resulted in less time feeding which reduced fat

reserves, both of which reduced population growth in these high elevation populations (McCaffery and Maxell 2010, p. 8646).

Past climate scenarios have shaped Great Basin ecosystems (Hubbs and Miller 1946, pp. 21–29; Tausch *et al*. 2004, pp. 24–40). Great Basin ecosystems and their associated riparian areas are expected to be highly sensitive to any future changes in climate (Sala *et al*. 2000, pp. 1772–1773; Fleishman *et al*. 2004, pp. 248–251; Field *et al*. 2007, pp. 627–630; NDOW 2012a, pp. 45–46). Ecological consequences of climate change to amphibians may include changes in population dynamics, timing of reproduction, changing geographic range, and broader community and ecosystem level changes (Hansen *et al*. 2001, pp. 766–773; McCarty 2001, pp. 321–325; Carey and Alexander 2003, pp. 116–118; Inkley *et al*. 2004, p. 9; Corn 2005, pp. 61–62; Parmesan 2006, pp. 637–669; Rahel and Olden 2008, pp. 522–531; Blaustein *et al*. 2010, pp. 285–300; Lawler *et al*. 2010, pp. 46–48). Amphibians are sensitive to changes in precipitation and temperature which may increase the risk of extinction for this group of organisms (Boone *et al*. 2003, pp. 131–136; Corn 2005, pp. 59–64; Noss *et al*. 2006, p. 236; Pounds *et al*. 2007, pp. 19–20; Vredenburg and Wake 2007, pp. 6–7; Blaustein *et al*. 2010, pp. 285–300; Pilliod *et al*. 2015a, p. 5). Additionally, rising stream temperatures may allow nonnative species to expand their current ranges into Columbia spotted frog occupied habitat (Rahel *et al*. 2008, pp. 553–554; Sharma and Jackson 2008, pp. 474–479; Lawrence *et al*. 2012, pp. 1935–1943; Arkle and Pilliod 2015, pp. 13, 17).

The impacts to Columbia spotted frogs and their habitat from climate change are not known with certainty. Predicted outcomes of climate change imply that negative impacts may occur through increased stream temperatures, decreased stream flow, changes in the hydrograph, and increased frequency of extreme events (Stewart *et al*. 2005, pp. 1140–1154; Ficke *et al*. 2007, pp. 583–593; Bates *et al*. 2008, pp. 102–106; Webb *et al*. 2008, pp. 909–911; Kaushal *et al*. 2010, pp. 462–466; Arkle and Pilliod 2015, p. 17; Pilliod *et al*. 2015a, pp. 12–20). Pilliod *et al*. (2015a, pp. 1–20) used a climate suitability model for Columbia spotted frogs to predict changes in suitable climate between three time frames: (1) 1901–1930 (past), (2) 1981–2010 (recent), and (3) 2071–2100 (future). Suitable climate for Columbia spotted frogs in the Great Basin is predicted to decrease between the recent and future time frames anywhere from 77 to 97 percent depending on the emission scenario (Pilliod *et al*. 2015a, p. 12, 32, 34; R. Arkle 2015, pers. comm.). This reduction in suitable climate is primarily due to reduced perennial water availability, increased temperature, and a slight reduction in precipitation; however, this precipitation is more likely to fall as rain than snow during the winter further reducing water availability during the subsequent summer months (Pilliod *et al*. 2015a, pp. 12–20).

Changes in the timing and magnitude of surface runoff are predicted to occur in the Great Basin. Future predictions of surface runoff during the spring months is expected to be reduced substantially as compared to recent time periods due to warmer temperatures and more precipitation falling as rain instead of snow (Pilliod *et al*. 2015a, pp. 12–20). Predicted winter and spring warming causes an increased fraction of winter precipitation to come as rain, resulting in a reduced snowpack, an earlier snowmelt, decreased spring runoff, and reduced summer streamflows (Stewart *et al*. 2005, pp. 1140–1144; Knowles *et al*. 2006, pp. 4548–4550; Pilliod *et al*. 2015a, pp. 12–20). Reductions in streamflow are predicted to have a negative impact on Columbia spotted frog populations because of the fragmented nature of populations, the small

size of most populations, and the close association of recruitment and survival to the amount of water available (Arkle and Pilliod 2015, pp. 11, 17; Pilliod *et al*. 2015a, pp. 13–20). Degraded aquatic systems exhibit greatly reduced resiliency to accommodate natural disturbances such as floods, fire, and drought, thereby exacerbating the effects of those events, which may further reduce the persistence of these populations (Wilcox *et al*. 2006, pp. 860–862). These degraded conditions, combined with variability in Columbia spotted frog numbers, place greater importance on the quantity and quality of the habitat needed for survival and recovery of Columbia spotted frogs. These impacts associated with climate change will likely intensify the stressors to Columbia spotted frogs previously described.

Drought

Drought has been an important natural disturbance in the western United States since the early Holocene (Cook *et al*. 2004, p. 1017; Mensing *et al*. 2008, pp. 80–84; Woodhouse *et al*. 2010, pp. 21283–21287). Cook *et al*. (2004, p. 1016) report the percentage of the western United States in drought conditions has gradually increased over the last century and that the current drought rivals the drought conditions in the 1930s; however, these more recent droughts (*i.e.,* in the last century) are not as severe compared to conditions found 700–1,100 ybp in terms of duration and severity. These historical drought conditions likely negatively impacted Columbia spotted frog populations throughout their range. Due to dispersal abilities, metapopulation dynamics, and unimpaired connected habitat in which they evolved, Columbia spotted frogs were able to persist and repopulate areas when conditions became favorable, despite these severe recurring drought conditions (Lake 2003, pp. 1166–1167; Wilcox *et al*. 2006, p. 859). In 1962, Turner (1962, p. 327) documented that a reoccurring drought during the previous 4–6 years had caused many of the streams to dry and found locating Columbia spotted frogs difficult. In a rangewide study of long-term trends of Columbia spotted frogs, drought had a strong negative effect on population growth, most notably at sites smaller than 0.15 ha (Hossack *et al*. 2013a, pp.1415–1417). Drought conditions which result in a reduction in permanent hydroperiods will have a negative impact on population growth, occupancy, and the persistence of Columbia spotted frogs in the Great Basin (Hossack *et al*. 2013a, pp.1415–1417; Arkle and Pilliod 2015, pp. 15, 17, 34; Pilliod and Scherer 2015, pp. 17–18; Pilliod *et al*. 2015a, p. 18). Summer drought conditions are predicted to intensify through the end of the century which may negatively impact Columbia spotted frogs, particularly occupied sites which are small (Cayan *et al*. 2010, pp. 21272–21275; Hossack *et al*. 2013a, pp.1415–1417; NCADAC 2013, pp. 113, 133–134, 700–701, 737–739). Increasing stream temperatures combined with decreases in streamflow are predicted to work together to further negatively affect coldwater species such as Columbia spotted frogs in the Great Basin (Arismendi *et al*. 2013, pp. 64–69). Since many populations are now fragmented and isolated, recolonization after extirpation or input of genetic material from other populations cannot occur naturally. With more frequent and severe droughts likely accompanying climate change, we conclude that effects of drought could impact Columbia spotted frogs throughout the Great Basin DPS where suitable habitat is not available or conservation measures are not being implemented.

Wildfire

Wildfire has been one of the dominant factors shaping ecosystems for millennia (Miller and Rose 1999, pp. 555–558). Fire regimes in the Great Basin differ by the three main vegetation types: sagebrush shrublands, desert shrublands, and pinyon-juniper woodlands. Prior to European settlement, fire regimes in sagebrush shrublands of the Great Basin have been characterized as a combination of mixed-severity and stand-replacing fires with return intervals ranging anywhere from 10 to 70 years (Rice *et al*. 2008, p. 154). Desert shrubland vegetation types are characterized by infrequent, stand-replacement fires with fire return intervals between 35 years to several centuries (Rice *et al*. 2008, p. 155). Pinyon-juniper woodlands are characterized as a mixed fire regime; however, fire histories in pinyon-juniper woodlands are difficult to reconstruct (Paysen *et al*. 2000, p. 130). Return intervals in pinyon-juniper woodlands range from 10 to over 300 years depending on site productivity and plant community structure (Rice *et al*. 2008, p. 162). Fire regimes in the Great Basin have become more frequent due to wildfire exclusion, historical grazing practices, and the introduction of invasive nonnative plant species (Rice *et al*. 2008, p. 141). More frequent fires favor the establishment of nonnative plants (*e.g.*, *Bromus tectorum* (cheatgrass)), which results in the loss of sagebrush and other native plant species (Rice *et al*. 2008, p. 154).

Riparian areas are also subject to fires; however, return intervals and fire regimes may be different than the adjacent uplands. The scant information available on fire in riparian areas indicates that return intervals and fire regime type depend on the width of the riparian area and the fuel type adjacent to the riparian area (Dwire and Kauffman 2003, pp. 62–63; Pettit and Naiman 2007, pp. 675–677). Fire return intervals and fire intensity in smaller riparian areas are more similar to the adjacent upland areas while larger riparian areas tend to have longer return intervals and lower fire intensity (Dwire and Kauffman 2003, pp. 62–63; Pettit and Naiman 2007, pp. 675–677). Streamside vegetation has adapted to disturbance which contributes to the relatively rapid recovery of riparian habitat following fire; however, recovery rates depend on the condition of the riparian area prior to the fire, fire severity, post-fire flooding, and post-fire management (Miller 2000, pp. 16–22; Bond and Midgley 2003, pp. S103–S112; Dwire and Kauffman 2003, pp. 67–71; Pettit and Naiman 2007, pp. 680–682; Halofsky and Hibbs 2009, pp. 1355–1358; Jackson and Sullivan 2009, pp. 27–31).

Changing climate has affected summer temperatures and the timing of spring snowmelt, which have contributed to increasing the length of the wildfire season, wildfire frequency, and the size of wildfires (McKenzie *et al*. 2004, pp. 893–897; Westerling *et al*. 2006, p. 941). Westerling *et al*. (2006, p. 942) conclude that there are robust statistical associations between wildfire and climate in the western United States and that increased fire activity over recent decades reflects responses to climate change.

Direct mortality of amphibians due to fire is thought to be rare and of minor importance to most populations (Russell *et al*. 1999, pp. 374–379; Smith 2000, pp. 20, 29–30; Pilliod *et al*. 2003, pp. 165–175; Hossack and Corn 2007, pp. 1406–1409); however, few studies have documented fire effects to aquatic amphibians in the western United States (Bury 2004, pp. 970–973; Hossack and Pilliod 2011, pp. 133–139; Hossack *et al*. 2013b, pp. 223–226). Hossack *et al*. (2013b, pp 223–226) found that occupancy of Columbia spotted frog populations in Glacier National Park

(Northern DPS) decreased by 25 percent or more but only after an initial 6 years post-fire of no measurable negative impact and greater than 50 percent of the surrounding forest burned. Most negative effects to aquatic species after wildfire are due to the immediate loss or alteration of habitat and indirect effects such as post-fire hydrologic events (Gresswell 1999, pp. 199–211; Benda *et al*. 2003, pp. 107–117; Miller *et al*. 2003, pp. 121–136; Wondzell and King 2003, pp. 75–84; Dunham *et al*. 2007, pp. 340–344; Hossack and Pilliod 2011, pp. 131–133). In addition, fire suppression activities, including construction of fire lines, back burning, application of water from pumps or aerial drops, and use of fire retardants and suppressant foams, could negatively affect amphibians (Little and Calfee 2002, p. 3; Backer *et al*. 2004, pp. 937–944).

Although Columbia spotted frogs evolved in a fire-prone environment, increases in wildfire frequency and severity due to increased fuel loads, exotic species, and effects from climate change (Westerling *et al*. 2006, p. 941) have increased the impacts due to wildfire. Current wildfires are may be having a larger impact to Columbia spotted frogs because of existing habitat loss and the current fragmented and isolated state of occupied habitat. We are not aware of any studies documenting negative impacts of wildfires to Columbia spotted frog populations in the Great Basin DPS (however, see Hossack *et al*. 2013b, pp 223–226; Northern DPS), despite recent fires occurring within occupied habitat. The best available scientific information does not indicate wildfire is currently a stressor to Columbia spotted frogs in the Great Basin; however, this impact should be investigated further since wildfire has been shown to have detrimental effects in other parts of its range.

UV-B Radiation

Increases in UV-B radiation from depletion of stratospheric ozone have been suggested as a possible stressor to amphibian populations (Blaustein *et al*. 1997, pp. 13735–13736; Adams *et al*. 2005, pp. 493–498; Blaustein and Belden 2005, pp. 87–88; Bancroft *et al*. 2008, pp. 990–993). UV-B mainly decreases egg survivorship and increases deformities in developing metamorphs (Blaustein *et al*. 1997, pp. 13735–13736). Columbia spotted frogs are a species that could be susceptible to increases in UV-B radiation because they are a basking species and lay their eggs in shallow water. However, Blaustein *et al*. (1999, pp. 1102–1104) found that Columbia spotted frogs in the embryonic stage were resistant to UV-B because of high levels of photolyase (a photoreactivating enzyme) and Adams *et al*. (2005, p. 497) found ambiguous results on the effects of UV-B on Columbia spotted frogs. UV-B radiation may also be limiting bullfrog expansion into higher elevation sites which are occupied by Columbia spotted frogs (Garcia *et al*. 2015, pp. 241–243). Based on the best available scientific and commercial information, UV-B radiation is not known to be a stressor to Columbia spotted frogs; however, Adams *et al*. (2005, p. 497) suggests that the relationship should be investigated further.

Pesticides

Amphibians are sensitive to chemical contaminants due to their habitat requirements (terrestrial and aquatic), complex life history, and their unique anatomy and physiology (Burkhart *et al*. 2003, pp. 111–112). Chemicals are the third most implicated factor in amphibian declines in the United States (Bradford 2005, p. 919). Evidence of direct mortality of amphibians is relatively sparse due to the low concentrations of individual chemicals in the environment; however,

sublethal impacts, such as decreased growth, changes in behavior, reduced fitness, or increased susceptibility to predation, may lead to population declines (Bridges and Semlitsch 2005, p. 89). Additionally, complex mixtures of various chemicals have been shown to be more toxic than individual chemicals acting alone (Burkhart *et al*. 2003, pp. 112–115; Relyea 2009, pp. 367–374).

Use of pesticides for control of grasshoppers (*Melanoplus* sp.) and crickets (*Anabrus simplex*), as well as use of herbicides to treat weeds and other vegetation, may affect some populations of Columbia spotted frogs in the Great Basin, particularly on private property. Grasshopper and cricket control programs on Federal lands require buffers around aquatic habitat to minimize or eliminate any impacts to aquatic organisms (U.S. Department of Agriculture 2013a, pp. 73–76). While we have no evidence to suggest frogs have been directly affected in the past, we do know substantial amounts of pesticides (*e.g.*, carbaryl), herbicides (*e.g*., Tordon®), and other chemicals are being used in proximity to occupied sites in Oregon, Nevada, and Idaho (Pearl *et al*. 2010, pp. 94–96; U.S. Department of Agriculture 2013a, pp. 1–87; 2013b, pp. 1–70; 2013c, pp. 1–70; 2013d, pp. 1–57). Based on the best available scientific and commercial information pesticide use is not known to be a stressor to Columbia spotted frogs; however, due to the application of chemicals known to cause negative impacts to amphibians being applied near occupied habitat and the potential for chemicals to travel large distances once airborne (Smalling *et al*. 2013, pp. 2028–2032), this potential impact should be investigated further.

Summary for Other Natural or Manmade Factors

In summary, climate change has and is expected to continue to affect Great Basin ecosystems; however, predictions are difficult to make and the impacts to Columbia spotted frog populations are not well documented (Fleishman *et al*. 2004, pp. 248–251; Botkin *et al*. 2007, pp. 227–234; Field *et al*. 2007, pp. 627–630). Corn (2005, pp. 59–64) describes many negative consequences of a changing climate to amphibian species and predicts that impacts from climate change may be the greatest challenge to conserving amphibians in the future. The current state of small fragmented populations of Columbia spotted frogs in the Great Basin DPS indicates populations are more vulnerable to extirpation due to loss of habitat from predicted climate related impacts (Corn 2005, pp. 59–64; Wilcox *et al*. 2006, pp. 857–862; Pilliod *et al*. 2015a, p. 19). Protecting or improving Columbia spotted frogs and their habitat so that they can adapt to expected changes in climate may be the most important conservation action (Chambers *et al*. 2004b, pp. 266–268; Seavy *et al*. 2009, pp. 331–333). Overall, we found that climate change research forecasts a drying pattern and a subsequent reduction in suitable habitat with additional isolation of populations, there is uncertainty about how these changes will play out at the population level and the future timeframe under which this will happen. While research has shown that current weather patterns are not influencing Columbia spotted frogs similarly across the Great Basin DPS, this pattern could change if these climate influences become more synchronous, or the frequency, duration, and severity of extreme events such as drought increases across the Great Basin (Pilliod *et al*. 2015b , pp. 15–19).

Multiple Stressors

Many of the stressors discussed above do not act alone. Multiple stressors can alter the effects of other stressors or act synergistically to affect individuals and populations (IPCC 2002, p. 22; Boone *et al*. 2003, pp. 138–143; Westerman *et al*. 2003, pp. 90–91; Opdam and Wascher 2004, pp. 285–297; Boone *et al*. 2007, pp. 293–297; Vredenburg and Wake 2007, p. 7; Lawler *et al*. 2010, p. 47; Reeves *et al*. 2010, pp. 432–435; Miller *et al*. 2011, pp. 2360–2361; Arkle and Pilliod 2015, p. 17). For example, Kiesecker and Blaustein (1995, pp. 11050–11051) describe how UV-B acts with a pathogen to increase embryonic mortality above levels shown with either factor alone. Interactions between current land uses and changing climate conditions are expected to cause shifts in populations, communities, and ecosystems (Hansen *et al*. 2001, p. 767), which may make certain species more vulnerable to extinction (IPCC 2002, p. 22). Additionally, chemicals may exist in the environment at sub-lethal levels; however, UV light may increase the toxicity of these chemicals or changing climate may increase an individual's susceptibility to infection, disease, or predation (Boone *et al*. 2003, pp. 138–142; Burkhart *et al*. 2003, pp. 116–120; Davidson *et al*. 2007, p. 1773; Bancroft *et al*. 2008, pp. 990–993; Rohr *et al*. 2008, pp. 1235–1237; Relyea 2009, pp. 367–374; Miller *et al*. 2011, pp. 2360–2361; Hooper *et al*. 2013, pp. 32–44; Rohr and Palmer 2013, pp. 745-747). The best available scientific information does not indicate that multiple stressors are currently a stressor to Columbia spotted frogs; however, multiple stressors are known to cause negative impacts to amphibians; therefore, this potential impact should be investigated further (Boone *et al*. 2007, pp. 297–300; Hof *et al*. 2011, pp. 516–519; Buck *et al*. 2012, pp. 68–70).

Chapter 5

Conservation Measures Implemented

In Nevada, 10-year conservation agreements (each known as a Conservation Agreement and Strategy, or CAS) were signed in September 2003 for the Toiyabe Mountains and Northeast populations (NDOW 2003a, pp. 1–43; 2003b, pp. 1–55). Federal, State, and local agencies signed the CAS's and all signatories have participated in conservation of Columbia spotted frogs. The purpose of the CAS's is to coordinate monitoring and expedite implementation of conservation measures to address stressors to the species through collaborative efforts among numerous agencies to ensure long-term survival of Columbia spotted frogs in Nevada. At the end of 2012, 15 percent of the identified tasks listed in the Northeast Nevada CAS had been completed and an additional 80 percent of the tasks had been initiated at some level (NDOW 2012b, p. 4). At the end of 2012, 29 percent of the identified tasks listed in the Toiyabe Mountains CAS had been completed and an additional 64 percent of the tasks had been initiated at some level (NDOW 2012c, unpublished data). It should be noted that most tasks in the CAS's are ongoing throughout the life of the agreement. Due to the success of the CAS's in managing and conserving Columbia spotted frogs in Nevada, a revised 10-year agreement (2015–2024) was signed in February 2015.

In 2003, adequate habitat was identified as a limiting factor in the CAS for the Toiyabe Mountains population, and in 2004, a habitat enhancement project was completed which included the construction or augmentation of 22 ponds in Indian Valley Creek (NDOW 2004a,

pp. 4–6). An additional 14 ponds were constructed near Indian Valley Creek in 2009 along with plug and pond restoration techniques within Indian Valley Creek to arrest headcutting within the meadows. All ponds created in 2004 and 2009 have documented occupancy and 77 percent have documented breeding activity (either egg masses or tadpoles observed). The plug and pond stream restoration stabilized the headcuts and changed 500 meters (0.31 mi) of ephemeral stream habitat into perennial habitat with documented occupancy and breeding activity (Humboldt-Toiyabe National Forest, unpublished data).

In Idaho, a Candidate Conservation Agreement with Assurances (CCAA) was completed in 2006 for the Columbia spotted frog population at Sam Noble Springs (Service 2006, pp. 1–45). The purpose of the CCAA is to implement conservation measures at Sam Noble Springs on 640 acres of state land to improve breeding, foraging, dispersal, hibernating habitat, and migration corridors for Columbia spotted frogs while allowing continued livestock use of the property. These conservation measures include: (1) erecting a grazing exclosure fence around a 104-acre portion of occupied Columbia spotted frog habitat, (2) reducing the number of AUMs by 43 percent outside of the grazing exclosure, (3) constructing additional ponds for breeding habitat outside of the grazing exlosure, and (4) improving the quality of habitat inside the grazing exclosure by refurbishing ponds, as needed. In addition, a draft Conservation Strategy has been written which provides information regarding conservation issues, management actions, and priorities intended to provide a framework for voluntary participation in collaborative conservation efforts in Idaho (IDFG 2010, pp. 1–11).

On other private lands within Owyhee County, Idaho, 41 ponds were constructed or enhanced on private land in 2010 and 2011, to increase breeding habitat and connectivity between existing populations (Service 2010, pp. 4–5; 2011a, pp. 1–14; 2011b, pp. 1–12). Since construction, breeding and/or Columbia spotted frog presence has been documented at 37 percent of the ponds with limited surveys.

Boise State University has conducted several research projects in Idaho related to Columbia spotted frogs including the reintroduction of beaver for Columbia spotted frog habitat restoration (Munger and Lingo 2003, pp. 1–6). Removal of beaver in 1992 and the subsequent deterioration of the associated beaver dam on Stoneman Creek in southwestern Idaho is believed to be directly related to the decline of a spotted frog population there (Lingo and Munger 2003, pp. 3–6; Munger and Oelrich 2006, pp. 5–8). Intensive surveying of Stoneman Creek documented only one adult Columbia spotted frog in 2000 (Engle 2000a, p. 4). Since beaver reintroduction in 2001, annual egg mass numbers have increased substantially (0 egg masses in 2000 to 167 in 2010; Lohr and Haak 2010, p. 13). In a study looking at long-term trends of Columbia spotted frogs across its entire range using egg mass data, sites with restoration specifically for Columbia spotted frogs had higher growth rates compared to sites without restoration indicating effective management options for conserving Columbia spotted frogs (Hossack *et al*. 2013a, pp. 1415, 1418).

The Malheur National Wildlife Refuge (MNWR) recently completed a Comprehensive Conservation Plan which includes numerous activities aimed at improving aquatic health on the refuge (Service 2013, pp. 1–773). The Comprehensive Conservation Plan defines 14 goals for the MNWR, six of which will directly benefit Columbia spotted frogs. These six goals include

(Goal 1) enhance aquatic health and habitat conditions essential to the conservation of the flora and fauna that depend on Malheur Lake and associated waterbodies; (Goal 2) protect, maintain, and rehabilitate riverine and riparian habitats to conditions essential for the conservation of native fish and wildlife species; (Goal 3) protect, maintain, and rehabilitate riparian habitats to conditions essential for the conservation of wildlife species; (Goal 4) enhance, protect, and/or maintain primary habitats essential to the conservation of a diversity of aquatic and terrestrial wildlife species; (Goal 5) enhance and maintain rare and unique habitats; and (Goal 13) gather scientific information (surveys, research, and assessments) to support adaptive management decisions (Service 2013, pp. 2-24–2-42; 2-61–2-65). Implementation of Goal 13 has already resulted in an increase in known occupied habitat on the MNWR (F. Healy 2015 pers. comm.).

To minimize the effects of livestock grazing on Columbia spotted frog habitat, many grazing allotment closures and grazing exclosure projects have been implemented throughout the frog's range including on Cloverdale Creek and Indian Valley Creek (Toiyabe Mountains population), Dry Creek in southeastern Oregon, and Circle Pond, Sam Noble Springs, and Stoneman Creek (Owyhee population), as well as study sites in northeastern Oregon (Northern DPS; Bull 2005, pp. 2, 35–36). Additionally, conservation grazing practices, particularly the timing and duration of grazing, have led to improved riparian and stream habitat conditions in several northern Nevada streams which have occupied Columbia spotted frog habitat (Booth *et al*. 2012, pp. 515–518; Dalldorf *et al*. 2013, pp. 38–41; Kozlowski *et al*. 2013, pp. 37–60). Effectiveness monitoring of these projects is vital in determining the impacts of grazing on Columbia spotted frogs in these areas and the validity of these management actions in protecting and enhancing Columbia spotted frog habitat. Active monitoring, research, and habitat improvement projects are occurring or are planned throughout the range of the Great Basin DPS of Columbia spotted frogs, which are increasing our knowledge of life history characteristics, population fluctuations, effectiveness of habitat improvement projects, genetics, and stressors to the species (Hossack *et al*. 2013a, pp. 1415, 1418; Arkle and Pilliod 2015, pp. 1–19; Pilliod and Scherer 2015, pp. 1–22; Pilliod *et al*. 2015a, pp. 1–20; Pilliod *et al*. 2015b, pp. 1–19).

State Protections

Columbia spotted frogs are classified as a protected amphibian by the State of Nevada under Nevada Administrative Code (NAC) 503.075(2)(a). Per NAC 503.090(1) there is no open season on those species of amphibian classified as protected. Per NAC 503.093 a person shall not hunt or take any wildlife which is classified as protected, or possess any part thereof, without first obtaining the appropriate license, permit or written authorization from the NDOW. NAC 503.094 authorizes issuance of permits for the take and possession of any species of wildlife for strictly scientific or educational purposes (NAC 2012, pp. 14–16).

All native amphibians are considered protected nongame species in Idaho (Idaho Administration Procedures Act (IDAPA) 2012, p. 7–8). No open seasons are set for protected nongame species and collection of these species is subject to IDFG issuance of a scientific collection permit except that up to four native amphibians and reptiles of a given species can be captured alive, held in captivity, killed, or possessed at any one time by holders of a valid Idaho hunting license (IDAPA 2012b, p. 4).

Columbia spotted frogs are on the nongame protected wildlife list for the State of Oregon which makes it unlawful for any person to hunt, trap, pursue, kill, take, catch, angle for, or have in possession, either dead or alive, whole or in part (Oregon Administrative Rules 2012, pp. 8–9). Moreover, they are listed as "critical" on Oregon's sensitive species list which is used as an early warning system and encourages voluntary actions to improve the status of species on the list (ODFW 2008, pp. 1, 11). Critical species are defined as species that are imperiled with extirpation from a specific geographic area of the state because of small population sizes, habitat loss or degradation, and/or immediate threats. Critical species may decline to a point of qualifying for threatened or endangered status if conservation actions are not taken (ODFW 2008, p. 2). All three States include Columbia spotted frogs in their State Wildlife Action Plans as a species of conservation concern or of conservation priority which highlights threats and conservation needs of the species (IDFG 2005, p. 71; NDOW 2012a, p. 76; ODFW 2006, p. 337).

Promising management options are available to maintain or improve Columbia spotted frog resiliency throughout the Great Basin. Improved grazing management (*e.g.*, reduced stocking rates, reduced utilization levels, rest rotation practices), particularly within riparian habitats, can lead to improved riparian and stream habitat conditions (Booth *et al*. 2012, pp. 515–518; Dalldorf *et al*. 2013, pp. 38–41; Kozlowski *et al*. 2013, pp. 37–60). Creating ponded habitat has also improved numerous occupied sites throughout the Great Basin as well as other parts of the species range (Hossack *et al*. 2013a, pp. 1415–1418; Pilliod and Scherer 2015, pp. 20–21). Beaver are important in the creation of small pools with slow-moving water that function as habitat for frog reproduction and create wet meadows that provide foraging habitat and protective vegetation cover (Naiman *et al*. 1988, pp. 754–761; Amish 2006, p. 9; Cunningham *et al*. 2007, pp. 2520–2523; Stevens *et al*. 2007, pp. 6–11; Gibson and Olden 2014, pp. 399–405; Pollack *et al*. 2014, pp. 279–289). There is a growing body of evidence linking the positive habitat influence of beaver to the presence of Columbia spotted frogs in the Great Basin DPS (Amish 2006, pp. 29–35; Arkle and Pilliod 2015, pp. 16–17; Pilliod *et al*. 2015a, pp. 17–19). Beaver management by the states will be important in the long-term survival of Columbia spotted frogs.

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GLOSSARY

Anthropogenic- caused or resulting from the influence of humans on the environment.

Catastrophic event- a rare destructive natural event or episode involving many populations and occurring suddenly.

Clade- a monophyletic group (derived from the same ancestral taxon) of taxa sharing closer common ancestry with one another than with members of any other clade.

Climate- prevailing mean weather conditions and their variability for a given area over a long period of time.

Climate change- a change in one or more measures of climate that persists over time, whether caused by natural variability, human activity, or both.

Demographic stochasticity- the variability of population growth rates arising from related random events such as birth rates, death rates, sex ratio, and dispersal, which, may increase the risk of extirpation in small populations.

Drought- a prolonged period of abnormally low precipitation.

Effective population size (N_e)- the average number of individuals in a population which are assumed to contribute genes equally to the succeeding generation.

Environmental stochasticity- the variation in birth and death rates from one season to the next in response to weather, disease, competition, predation, or other factors external to the population.

Ephemeral stream- a stream which flows only after rain or snowmelt and has no baseflow component.

Extinction- the process of completely ceasing to exist rangewide.

Extirpation- the loss of a population or a species from a particular geographic region.

F_{ST}- a standard measure of genetic divergence at individual loci. Values are used to estimate the amount of allele frequency divergence between demes (mating groups). Lower values of F_{ST} indicate less genetic divergence.

Habitat fragmentation- the disruption or alteration of extensive habitats into isolated and smaller patches. This can be caused by natural phenomena or by anthropogenic disturbances.

Hydrologic Unit- An identified area of surface drainage within the United States system for cataloging drainage areas, which was developed in the mid-1970s under the sponsorship of the Water Resources Council and includes drainage-basin boundaries, codes, and names. The drainage areas are delineated to nest in a multilevel, hierarchical arrangement. The hydrologic unit hierarchical system has four levels and is the theoretical basis for further subdivisions that form the Watershed Boundary Dataset fifth and sixth levels. A hydrologic unit can accept surface water directly from upstream drainage areas and indirectly from associated surface areas, such as remnant areas, noncontributing areas, and diversions, to form a drainage area with single or multiple outlet points (USGS 2013).

Hydrologic Unit Code- The numerical identifier of a specific hydrologic unit or drainage area consisting of a two-digit sequence for each specific level within the delineation hierarchy (USGS 2013).

Hydroperiod- the time period, or length of time, an area is inundated with water.

Hypoxic- a deficiency of oxygen reaching the tissues of the body.

Intermittent stream- a stream which ceases to flow during dry periods. The flow may occur when the water table is seasonally high but the flow dissipates over time as the water table drops below a certain threshold.

Lentic- applied to a freshwater habitat characteristic by calm or standing water (*e.g.*, lakes, ponds, wetland).

Lotic- applied to a freshwater habitat characteristic by running water (*e.g.*, springs, streams, rivers).

Perennial stream- a stream which has flow year round.

Redundancy- the ability of a species to survive catastrophic events, usually through sustaining a number of viable populations distributed over a larger landscape.

Representation- the ability of a species to adapt to changing environmental conditions, accomplished by having sufficient genetic or ecological diversity.

Resiliency- the ability of a species to withstand stochastic events, often determined by the size and health of existing populations.

Viability- the ability to survive, grow, and reproduce normally.

Xeric- a dry, as opposed to a wet (hydric) or intermediate (mesic) environment. Having very little moisture; tolerating or adapted to dry conditions.